R&S®FSW-K95
802.11ad Measurements
User Manual

1177.5962.02 — 01

Test & Measurement

User Manual

ROHDE&SCHWARZ

This manual applies to the following R&S®FSW models with firmware version 2.30 and higher:

- R&S®FSW8 (1312.8000K08)
- R&S®FSW13 (1312.8000K13)
- R&S®FSW26 (1312.8000K26)
- R&S®FSW43 (1312.8000K43)
- R&S®FSW50 (1312.8000K50)
- R&S®FSW67 (1312.8000K67)
- R&S®FSW85 (1312.8000K85)

The following firmware options are described:

- R&S FSW-K95 802.11ad measurements (1313.1639.02)

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The following abbreviations are used throughout this manual: R&S®FSW is abbreviated as R&S FSW.

Contents

1 Preface

1.1 About this Manual

This R&S FSW 802.11ad application User Manual provides all the information **specific to the application**. All general instrument functions and settings common to all applications and operating modes are described in the main R&S FSW User Manual.

The main focus in this manual is on the measurement results and the tasks required to obtain them. The following topics are included:

- chapter 2, "Welcome to the R&S FSW 802.11ad application", on page 9
  Introduction to and getting familiar with the application
- chapter 3, "Measurements and Result Displays", on page 13
  Details on supported measurements and their result types
- chapter 4, "Measurement Basics", on page 32
  Background information on basic terms and principles in the context of the measurement
- chapter 5, "Configuration", on page 44 and chapter 6, "Analysis", on page 87
  A concise description of all functions and settings available to configure measurements and analyze results with their corresponding remote control command
- chapter 7, "I/Q Data Import and Export", on page 95
  Description of general functions to import and export raw I/Q (measurement) data
- chapter 8, "How to Perform Measurements in the R&S FSW 802.11ad application", on page 100
  The basic procedure to perform each measurement and step-by-step instructions for more complex tasks or alternative methods
- chapter 9, "Remote Commands for IEEE 802.11ad Measurements", on page 103
  Remote commands required to configure and perform IEEE 802.11ad measurements in a remote environment, sorted by tasks
  (Commands required to set up the environment or to perform common tasks on the instrument are provided in the main R&S FSW User Manual)
  Programming examples demonstrate the use of many commands and can usually be executed directly for test purposes
- chapter A, "Annex", on page 211
  Reference material
- **List of remote commands**
  Alphahabetical list of all remote commands described in the manual
- **Index**

1.2 Documentation Overview

The user documentation for the R&S FSW consists of the following parts:

- Printed Getting Started manual
- Online Help system on the instrument
- Documentation DVD with:
  - Getting Started
  - User Manuals for base unit and firmware applications
  - Service Manual
  - Release Notes
  - Data sheet and product brochures

Online Help

The Online Help is embedded in the instrument's firmware. It offers quick, context-sensitive access to the complete information needed for operation and programming. Online help is available using the ? icon on the toolbar of the R&S FSW.

Web Help

The web help provides online access to the complete information on operating the R&S FSW and all available options, without downloading. The content of the web help corresponds to the user manuals for the latest product version. The web help is available from the R&S FSW product page at http://www.rohde-schwarz.com/product/FSW.html > Downloads > Web Help.

Getting Started

This manual is delivered with the instrument in printed form and in PDF format on the DVD. It provides the information needed to set up and start working with the instrument. Basic operations and handling are described. Safety information is also included.

The Getting Started manual in various languages is also available for download from the Rohde & Schwarz website, on the R&S FSW product page at http://www.rohde-schwarz.com/product/FSW.html.

User Manuals

User manuals are provided for the base unit and each additional (firmware) application.

The user manuals are available in PDF format - in printable form - on the Documentation DVD delivered with the instrument. In the user manuals, all instrument functions are described in detail. Furthermore, they provide a complete description of the remote control commands with programming examples.

The user manual for the base unit provides basic information on operating the R&S FSW in general, and the Spectrum application in particular. Furthermore, the software functions that enhance the basic functionality for various applications are described here. An introduction to remote control is provided, as well as information on maintenance, instrument interfaces and troubleshooting.

In the individual application manuals, the specific instrument functions of the application are described in detail. For additional information on default settings and parameters, refer to the data sheets. Basic information on operating the R&S FSW is not included in the application manuals.

All user manuals are also available for download from the Rohde & Schwarz website, on the R&S FSW product page at http://www.rohde-schwarz.com/product/FSW.html.

Service Manual

This manual is available in PDF format on the Documentation DVD delivered with the instrument. It describes how to check compliance with rated specifications, instrument function, repair, troubleshooting and fault elimination. It contains all information required for repairing the R&S FSW by replacing modules.

Release Notes

The release notes describe the installation of the firmware, new and modified functions, eliminated problems, and last minute changes to the documentation. The corresponding firmware version is indicated on the title page of the release notes.

The most recent release notes are also available for download from the Rohde & Schwarz website, on the R&S FSW product page at http://www.rohde-schwarz.com/product/FSW.html > Downloads > Firmware.

Application Notes

Application notes, application cards, white papers and educational notes are further publications that provide more comprehensive descriptions and background information. The latest versions are available for download from the Rohde & Schwarz website, at www.rohde-schwarz.com/appnote/.

1.3 Conventions Used in the Documentation

1.3.1 Typographical Conventions

The following text markers are used throughout this documentation:

Convention	Description
"Graphical user interface elements"	All names of graphical user interface elements on the screen, such as dialog boxes, menus, options, buttons, and softkeys are enclosed by quotation marks.
KEYS	Key names are written in capital letters.
`File names, commands, program code`	File names, commands, coding samples and screen output are distinguished by their font.
Input	Input to be entered by the user is displayed in italics.
Links	Links that you can click are displayed in blue font.
"References"	References to other parts of the documentation are enclosed by quotation marks.

1.3.2 Conventions for Procedure Descriptions

When describing how to operate the instrument, several alternative methods may be available to perform the same task. In this case, the procedure using the touchscreen is described. Any elements that can be activated by touching can also be clicked using an additionally connected mouse. The alternative procedure using the keys on the instrument or the on-screen keyboard is only described if it deviates from the standard operating procedures.

The term "select" may refer to any of the described methods, i.e. using a finger on the touchscreen, a mouse pointer in the display, or a key on the instrument or on a keyboard.

1.3.3 Notes on Screenshots

When describing the functions of the product, we use sample screenshots. These screenshots are meant to illustrate as much as possible of the provided functions and possible interdependencies between parameters.

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 Welcome to the R&S FSW 802.11ad application

The R&S FSW 802.11ad application extends the functionality of the R&S FSW to enable accurate and reproducible Tx measurements of a IEEE 802.11ad device under test (DUT) in accordance with the IEEE standard 802.11ad.

The R&S FSW 802.11ad application features:

- Support for data rates of up to 7 Gbit/s
- Use of the 60 GHz unlicensed band
  - Provides global availability
  - Avoids the overcrowded 2.4 GHz and 5 GHz bands
  - Uses short wavelengths (5 mm at 60 GHz), making compact and affordable antennas or antenna arrays possible
- Backward compatibility with the IEEE 802.11 universe:
  Seamless use of IEEE 802.11a,b,g,n across both bands 2.4 GHz and 5 GHz, plus 11ad in the 60 GHz range -> "triband" devices

Typical applications for IEEE 802.11ad are:

- Wireless Display
- Distribution of HDTV content (e.g. in residential living rooms)
- Wireless PC connection to transmit huge files quickly
- Automatic sync applications (e.g. uploading images from a camera to a PC, "kiosk" applications)

Due to the use of a 2 GHz bandwidth, the R&S FSW 802.11ad application requires the optional 2 GHz bandwidth extension (R&S FSW-B2000) to analyze IEEE 802.11ad signals.

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

Functions that are not discussed in this manual are the same as in the Spectrum application and are described in the R&S FSW User Manual. The latest version is available for download at the product homepage

http://www2.rohde-schwarz.com/product/FSW.html.

Installation

You can find detailed installation instructions in the R&S FSW Getting Started manual or in the Release Notes.

2.1 Starting the R&S FSW 802.11ad application

The IEEE 802.11ad measurements require a special application on the R&S FSW.

Furthermore, the optional 2 GHz bandwidth extension (R&S FSW-B2000) must be installed and active in order to analyze IEEE 802.11ad signals.

To activate the R&S FSW 802.11ad application

1. Select the MODE key.

   A dialog box opens that contains all operating modes and applications currently available on your R&S FSW.

2. Select the "IEEE 802.11ad" item.

   The R&S FSW opens a new measurement channel for the R&S FSW 802.11ad application.

The measurement is started immediately with the default settings. It can be configured in the IEEE 802.11ad "Overview" dialog box, which is displayed when you select the "Overview" softkey from any menu (see chapter 5.2.1, "Configuration Overview", on page 45).

Multiple Measurement Channels and Sequencer Function

When you activate an application, a new measurement channel is created which determines the measurement settings for that application. The same application can be activated with different measurement settings by creating several channels for the same application.

The number of channels that can be configured at the same time depends on the available memory on the instrument.

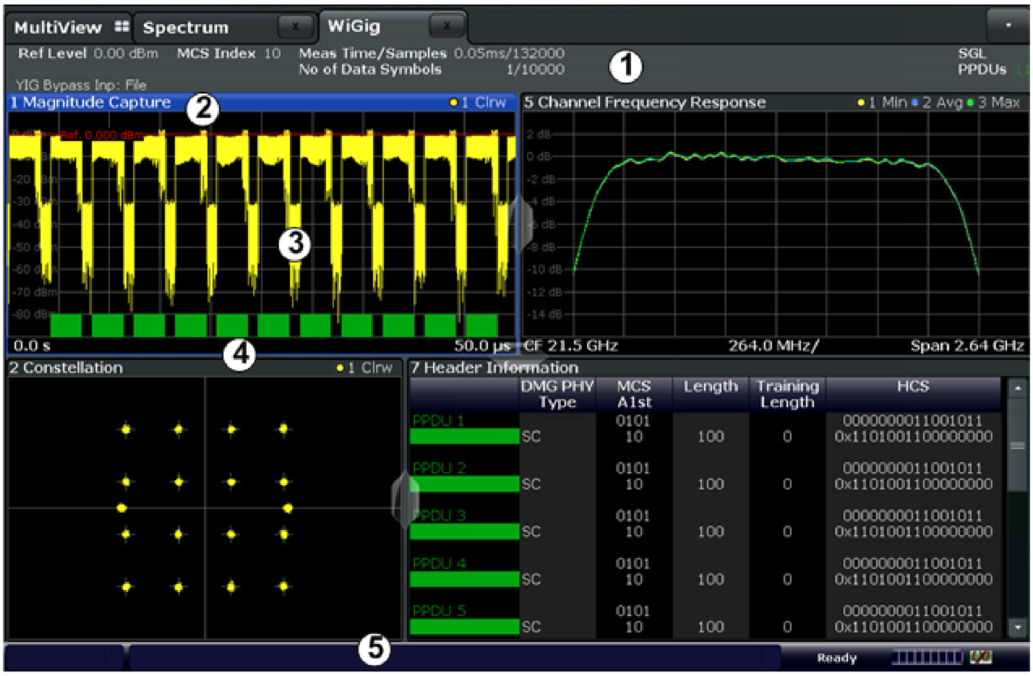
Only one measurement can be performed at any time, namely the one in the currently active channel. However, in order to perform the configured measurements consecutively, a Sequencer function is provided.

If activated, the measurements configured in the currently active channels are performed one after the other in the order of the tabs. The currently active measurement is indicated by a symbol in the tab label. The result displays of the individual channels are updated in the tabs (including the "MultiView") as the measurements are performed. Sequential operation itself is independant of the currently *displayed* tab.

For details on the Sequencer function see the R&S FSW User Manual.

2.2 Understanding the Display Information

The following figure shows a measurement diagram during analyzer operation. All information areas are labeled. They are explained in more detail in the following sections.



1 = Channel bar for firmware and measurement settings
2 = Window title bar with diagram-specific (trace) information
3 = Diagram area with marker information
4 = Diagram footer with diagram-specific information, depending on result display
5 = Instrument status bar with error messages, progress bar and date/time display

Channel bar information

In the R&S FSW 802.11ad application, the R&S FSW shows the following settings:

Table 2-1: Information displayed in the channel bar in the R&S FSW 802.11ad application

Label	Description
Ref Level	Reference level
Att	Mechanical and electronic RF attenuation
MCS Index	The MCS Index used for the analysis of the signal; Depending on the demodulation settings, this value is either detected automatically from the signal or the user settings are applied.
Freq	Center frequency for the RF signal
Meas time / Samples	Duration of signal capture and number of samples captured
No. of Data Symbols	The minimum and maximum number of data symbols that a PPDU may have if it is to be considered in results analysis.

Label	Description
SGL	The sweep is set to single sweep mode.
PPDUs	Number of analyzed PPDUs for statistical evaluation

In addition, the channel bar also displays information on instrument settings that affect the measurement results even though this is not immediately apparent from the display of the measured values (e.g. transducer or trigger settings). This information is displayed only when applicable for the current measurement. For details see the R&S FSW Getting Started manual.

Window title bar information

For each diagram, the header provides the following information:

Fig. 2-1: Window title bar information in the R&S FSW 802.11ad application

1 = Window number
2 = Window type
3 = Trace color
4 = Trace number
6 = Trace mode

Diagram footer information

The diagram footer (beneath the diagram) contains the start and stop values for the displayed x-axis range.

Status bar information

Global instrument settings, the instrument status and any irregularities are indicated in the status bar beneath the diagram. Furthermore, the progress of the current operation is displayed in the status bar. Click on a displayed warning or error message to obtain more details (see also .

3 Measurements and Result Displays

The R&S FSW 802.11ad application provides several different measurements in order to determine the parameters described by the IEEE 802.11ad specifications.

3.1 IEEE 802.11ad Modulation Accuracy Measurement

Access: "Overview" > "Select Measurement" > "Modulation Accuracy"

or: MEAS > "Select Measurement" > "Modulation Accuracy"

The default IEEE 802.11ad Modulation Accuracy measurement captures I/Q data from the RF Input of the FSW with a bandwidth up to 2 GHz. This I/Q data is used by the R&S FSW 802.11ad application to demodulate broadband signals and determine various characteristic signal parameters such as modulation accuracy, channel frequency response and power.

Other IEEE 802.11ad specific measurements such as Spectrum Emission Mask can also be performed by sweeping over the desired frequency range using a filter with a smaller measurement bandwidth. The advantage of using a smaller bandwidth is an increased signal-to-noise-ratio (see chapter 3.2, "SEM Measurements", on page 28).

3.1.1 Modulation Accuracy Parameters

The default IEEE 802.11ad Modulation Accuracy measurement captures I/Q data from the RF input of the R&S FSW and determines the following I/Q parameters in a single capture.

Table 3-1: IEEE 802.11ad Result Summary parameters

Parameter	**Description** **Remote command to query result**
Modulation Accuracy Parameters	
EVM All [dB]	EVM over all symbols in PPDUS to analyze in capture buffer `FETCh:EVM:ALL:AVERage?` on page 188
EVM Data Symbols [dB]	EVM over data symbols in PPDUS to analyze in capture buffer `FETCh:EVM:DATA:AVERage?` on page 188
EVM Pilot Symbols [dB]	EVM over pilot symbols in PPDUS to analyze in capture buffer `FETCh:EVM:PILot:AVERage?` on page 188

Parameter	Description Remote command to query result
I/Q Offset [dB]	Transmitter center frequency leakage relative to the total Tx channel power (see chapter 3.1.1.1, "I/Q Offset", on page 15) FETCh:IQOFfset:AVERage? on page 189
Gain Imbalance [%/dB]	Amplification of the quadrature phase component of the signal relative to the amplification of the in-phase component (see chapter 3.1.1.2, "Gain Imbalance", on page 15) FETCh:GIMBalance:AVERage? on page 189
Quadrature Error [°]	Deviation of the quadrature phase angle from the ideal 90° (see chapter 3.1.1.3, "Quadrature Offset", on page 16). FETCh:QUADerror:AVERage? on page 189
Center Frequency Error [Hz]	Frequency error between the signal and the current center frequency of the R&S FSW FETCh:CFERror:AVERage? on page 188
Symbol Clock Error [ppm]	Clock error between the signal and the sample clock of the R&S FSW in parts per million (ppm), i.e. the symbol timing error FETCh:SYMBolerror:AVERage? on page 190
Rise Time [s]	The time required for the PPDU to transition from the base to the top level. This is the difference between the time at which the PPDU exceeds the lower 10 % and upper 90 % thresholds. FETCh:RTIMe:AVERage? on page 189
Fall Time [s]	The time required for the PPDU to transition from the top to the base level. This is the difference between the time at which the PPDU drops below the upper 90 % and lower 10 %thresholds. FETCh:FTIMe:AVERage? on page 189
Time Skew [s]	A constant time difference between the I and Q data, for example due to different cable lengths FETCh:TSKew:AVERage? on page 190
Power Parameters	
Time Domain Power [dBm]	Power of the captured signal vs time FETCh:TDPower:AVERage? on page 190
Crest factor [dB]	The ratio of the peak power to the mean power of the signal (also called Peak to Average Power Ratio, PAPR). FETCh:CFACtor:AVERage? on page 188

The R&S FSW 802.11ad application also performs statistical evaluation over several PPDUs and displays the following results:

Table 3-2: Calculated summary results

Result type	Description
Min	Minimum value in current capture buffer
Average	Average value in current capture buffer
Max	Maximum value in current capture buffer

3.1.1.1 I/Q Offset

An I/Q offset indicates a carrier offset with fixed amplitude. This results in a constant shift of the I/Q axes. The offset is normalized by the mean symbol power and displayed in dB.

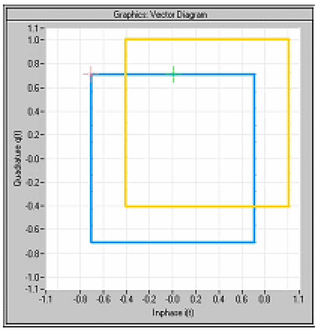


Fig. 3-1: I/Q offset in a vector diagram

3.1.1.2 Gain Imbalance

An ideal I/Q modulator amplifies the I and Q signal path by exactly the same degree. The imbalance corresponds to the difference in amplification of the I and Q channel and therefore to the difference in amplitude of the signal components. In the vector diagram, the length of the I vector changes relative to the length of the Q vector.

The result is displayed in dB and %, where 1 dB offset corresponds to roughly 12 % difference between the I and Q gain, according to the following equation:

$Imbalance\ [dB] = 20log\ (|\ Gain_Q\ |/|\ Gain_I\ |)$

Positive values mean that the Q vector is amplified more than the I vector by the corresponding percentage. For example using the figures mentioned above:

0.98 ≈ 20*log10(1.12/1)

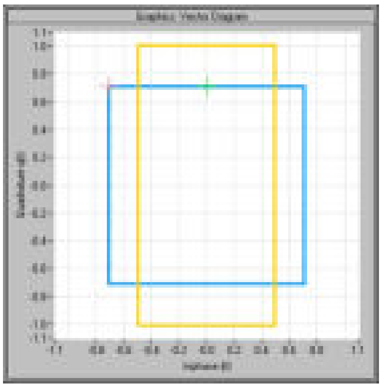


Fig. 3-2: Positive gain imbalance

Negative values mean that the I vector is amplified more than the Q vector by the corresponding percentage. For example using the figures mentioned above:

-0.98 ≈ 20*log10(1/1.12)

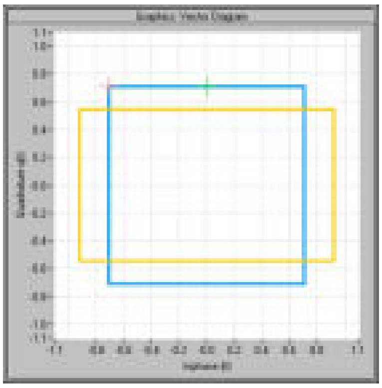


Fig. 3-3: Negative gain imbalance

3.1.1.3 Quadrature Offset

An ideal I/Q modulator sets the phase angle between the I and Q path mixer to exactly 90 degrees. With a quadrature offset, the phase angle deviates from the ideal 90 degrees, the amplitudes of both components are of the same size. In the vector diagram, the quadrature offset causes the coordinate system to shift.

A positive quadrature offset means a phase angle greater than 90 degrees:

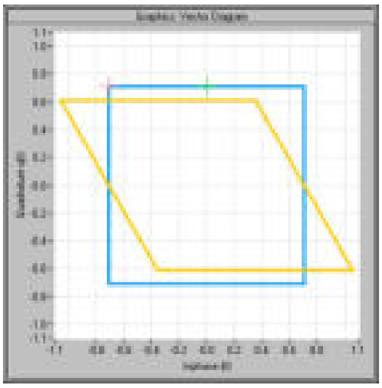


Fig. 3-4: Positive quadrature offset

A negative quadrature offset means a phase angle less than 90 degrees:

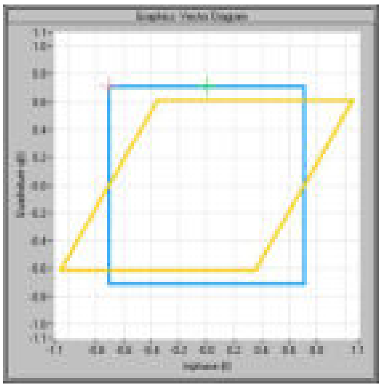


Fig. 3-5: Negative quadrature offset

3.1.1.4 EVM Measurement

The PPDU EVM (direct) method evaluates the root mean square EVM over one PPDU. That is the square root of the averaged error power normalized by the averaged reference power:

$$EVM = \sqrt{\frac{\sum_{n=0}^{N-1} \left| x_{meas}(n) - x_{ref}(n) \right|^2}{\sum_{n=0}^{N-1} \left| x_{ref}(n) \right|^2}} = \sqrt{\frac{\sum_{n=0}^{N-1} \left| e(n) \right|^2}{\sum_{n=0}^{N-1} \left| x_{ref}(n) \right|^2}}$$

Before calculation of the EVM, tracking errors in the measured signal are compensated for if specified by the user. In the ideal reference signal, the tracking errors are always compensated for. Tracking errors include phase (center frequency error + common phase error), timing (sampling frequency error) and gain errors. quadrature offset and gain imbalance errors, however, are not corrected.

The PPDU EVM is not part of the IEEE standard and no limit check is specified. Nevertheless, this commonly used EVM calculation can provide some insight in modulation quality and enables comparisons to other modulation standards.

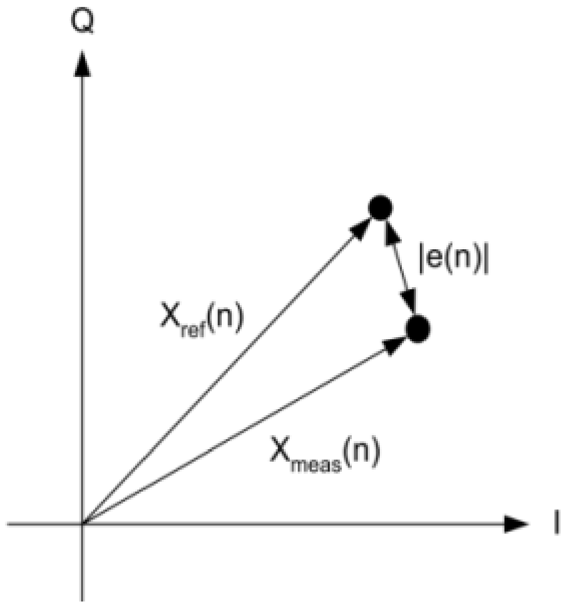


Fig. 3-6: I/Q diagram for EVM calculation

3.1.2 Evaluation Methods for IEEE 802.11ad Modulation Accuracy Measurements

Access: "Overview" > "Display Config"

or: MEAS > "Display Config"

The R&S FSW 802.11ad application provides various different methods to evaluate the captured signal without having to start a new measurement or sweep. Which results are displayed depends on the selected meaurement and evaluation.

The selected evaluation method not only affects the result display in a window, but also the results of the trace data query in remote control (see `TRACe<n>[:DATA]?` on page 192).

All evaluations available for the selected IEEE 802.11ad measurement are displayed in SmartGrid mode.

For details on working with the SmartGrid see the R&S FSW Getting Started manual.

The IEEE 802.11ad measurements provide the following evaluation methods:

Bitstream

This result display shows a data stream for all analyzed PPDUs of the currently captured I/Q data as indicated in the "Magnitude Capture" display. The bitstream is derived from the constellation diagram points using the 'constellation bit encoding' from the corresponding IEEE 802.11ad standard.

Different result displays are available for the bitstream of either the header or the payload data, and depending on whether the bits are decoded (using the IEEE 802.11ad specific LDPC decoder) or shown as raw data.

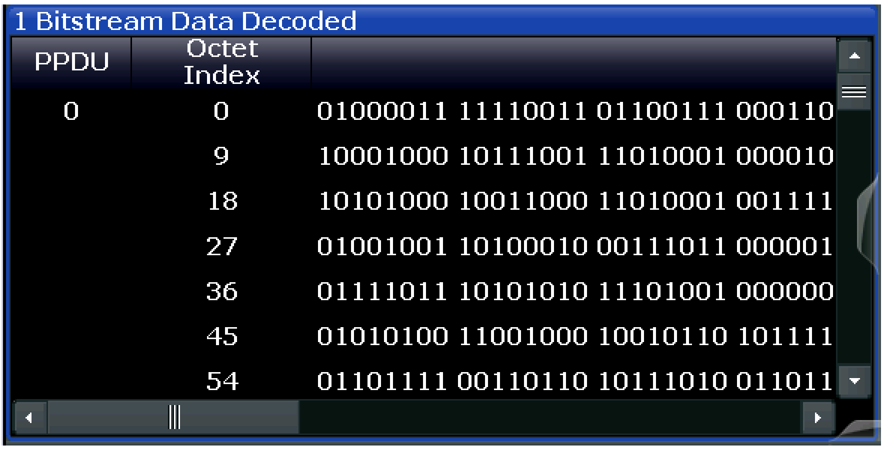


Fig. 3-7: Bitstream result display

Note that the raw and the decoded bitstreams only differ from each other when bit errors have occurred.

The PPDU number refers to the number in the capture buffer. The symbol index refers to the position relative to the analyzed PPDU start. The bitstream shows one value per symbol for each PPDU.

Remote command:

`LAY:ADD? '1',RIGH, DBST`
`LAY:ADD? '1',RIGH, DDBS`
`LAY:ADD? '1',RIGH, HBST`
`LAY:ADD? '1',RIGH, HDBS`

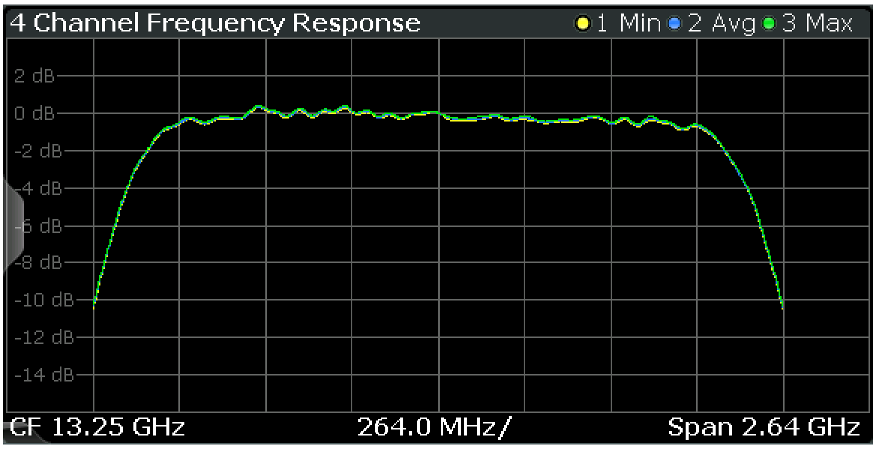
See `LAYout:ADD[:WINDow]?` on page 157

Querying results:

`TRACe<n>[:DATA]?`, see chapter 9.10.4.1, "Bitstream", on page 195

Channel Frequency Response

The Channel frequency response trace shows the amplitude of the channel transfer function vs frequency.



The numeric trace results for this evaluation method are described in chapter 9.10.4.11, "Channel Frequency Response", on page 198.

Remote command:

`LAY:ADD? '1',RIGH, CFR`, see `LAYout:ADD[:WINDow]?` on page 157

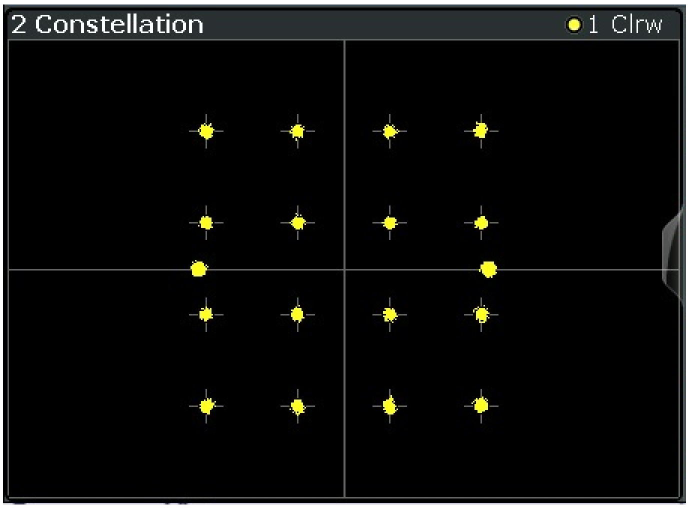
Querying results:

`TRACe<n>[:DATA]?`, see chapter 9.10.4.11, "Channel Frequency Response", on page 198

Constellation

This result display shows the in-phase and quadrature phase results for all payload symbols and all carriers for the analyzed PPDUs of the current capture buffer. The Tracking/Channel Estimation according to the user settings is applied.

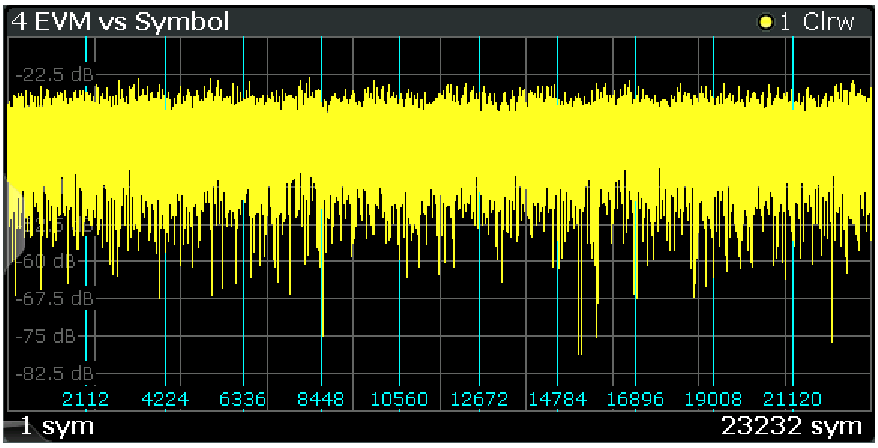
The inphase results (I) are displayed on the x-axis, the quadrature phase (Q) results on the y-axis.



The numeric trace results for this evaluation method are described in chapter 9.10.4.2, "Constellation", on page 195.

Remote command:
`LAY:ADD? '1',RIGH, CONS`, see `LAYout:ADD[:WINDow]?` on page 157
Querying results:
`TRACe<n>[:DATA]?`, see chapter 9.10.4.2, "Constellation", on page 195

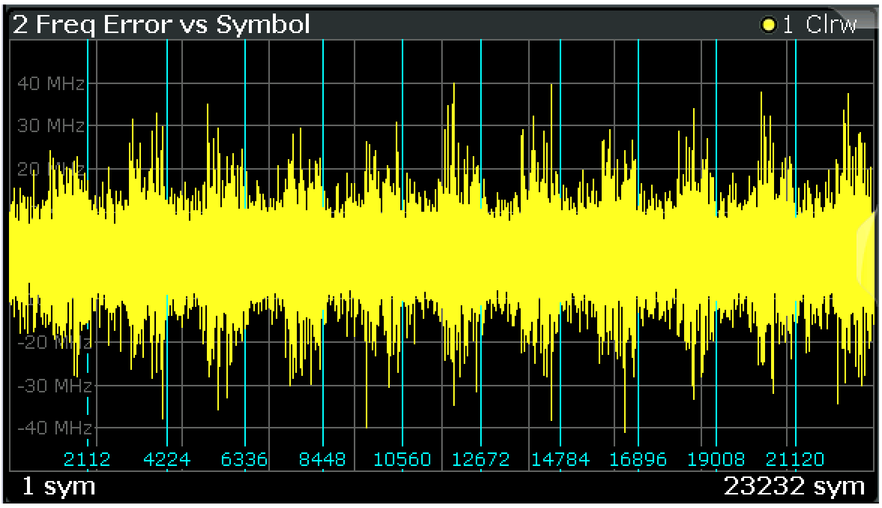
EVM vs Symbol
This result display shows all EVM values per symbol over the number of analyzed PPDUs as defined by the "Evaluation Range" settings (see "PPDU to Analyze / Index of Specific PPDU" on page 87). The Tracking/Channel Estimation according to the user settings is applied (see chapter 5.2.5, "Tracking", on page 78).



Vertical lines indicate the start of the next PPDU. The numbers at the bottom of the lines indicate the corresponding symbol positions.

Remote command:
`LAY:ADD? '1',RIGH, EVSY`, see `LAYout:ADD[:WINDow]?` on page 157
Querying results:
`TRACe<n>[:DATA]?`, see chapter 9.10.4.3, "EVM vs Symbol", on page 196

Freq. Error vs Symbol
Displays the frequency error values per (analyzed) symbol in the PPDU.



Vertical lines indicate the start of the next PPDU. The numbers at the bottom of the lines indicate the corresponding symbol positions.

Remote command:
`LAY:ADD? '1',RIGH,FEVS`, see `LAYout:ADD[:WINDow]?` on page 157
or:
Querying results:
`TRACe<n>[:DATA]?`, see chapter 9.10.4.4, "Frequency Error vs Symbol", on page 196

Header information
Displays information that has been decoded from the headers of the PPDUs. The header contains information on the modulation used for transmission.

3 Header Information

	DMG PHY Type	MCS A1st	Length	Training Length	HCS
PPDU 1	SC	1000 1	2345	0	1111000100110100 0x0010110010001111
PPDU 2	SC	0100 2	2000	0	1111000001011000 0x0001101000001111
PPDU 3	SC	1100 3	4000	0	0100011110100110 0x0110010111100010
PPDU 4	SC	0010 4	8000	0	0100100010010001 0x1000100100010010
PPDU 5	SC	1010 5	16000	0	1011100110110110 [illegible]

The header information is provided as a decoded bit sequence and, where appropriate, also in human-readable form, beneath the bit sequence for each PPDU.

Table 3-3: Results for Header Info result display

Parameter	Description
MCS	Modulation and Coding Scheme (MCS) index of the PPDU as defined in IEEE Std 802.11-2012 section "21.2.2 TXVECTOR and RXVECTOR parameters" (lower value: human-readable value)
DMG PHY Type	single carrier (SC) or control PHY (OFDM currently not supported); see "Types of PHYs" on page 33
Length	Length of the PPDU in symbols
Training Length	Length of the optional beam forming training field; see "Beamforming" on page 34
HCS	Header check sum (CRC) (lower value: human-readable value)

The numeric trace results for this evaluation method are described in chapter 9.10.4.5, "Header Info", on page 197.

Remote command:
`LAY:ADD? '1',RIGH,HEAD`, see `LAYout:ADD[:WINDow]?` on page 157
Querying results:
`TRACe<n>[:DATA]?`, see chapter 9.10.4.5, "Header Info", on page 197

Magnitude Capture
The Magnitude Capture Buffer display shows the magnitude vs time for the complete range of captured data for the last sweep. Green bars at the bottom of the Magnitude Capture Buffer display indicate the positions of the analyzed PPDUs. A single green bar may indicate the the evaluation range is limited to a single PPDU (see "PPDU to Analyze / Index of Specific PPDU" on page 87).

The trigger position is indicated by a vertical red line, if it lies within the displayed x-axis span.

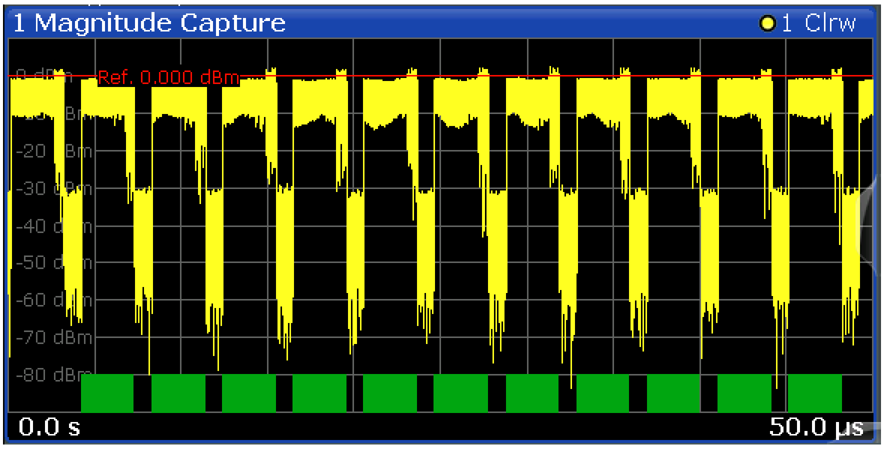


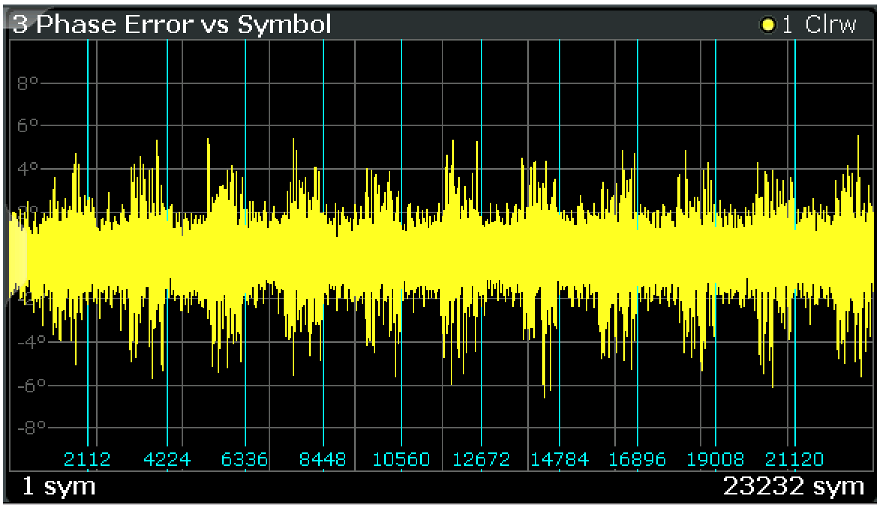
Fig. 3-8: Magnitude capture display for single PPDU evaluation

Remote command:
`LAY:ADD? '1',RIGH, MCAP`, see `LAYout:ADD[:WINDow]?` on page 157
Querying results:
`TRACe<n>[:DATA]?`, see chapter 9.10.4.6, "Magnitude Capture", on page 197

Phase Error vs Symbol

Displays the phase error values in degrees or radians per symbol. The phase error is calculated as the difference between the ideal reference signal and the measured signal (with any active compensation applied). Thus, this result display shows the remaining phase error that has not been compensated for by phase tracking.

Tip: The Phase Tracking vs Symbol result display shows the actual compensation values that were applied by the R&S FSW 802.11ad application.



Vertical lines indicate the start of the next PPDU. The numbers at the bottom of the lines indicate the corresponding symbol positions.

Remote command:
`LAY:ADD? '1',RIGH,PEVS`, see `LAYout:ADD[:WINDow]?` on page 157
Querying results:
`TRACe<n>[:DATA]?`, see chapter 9.10.4.7, "Phase Error vs Symbol", on page 197

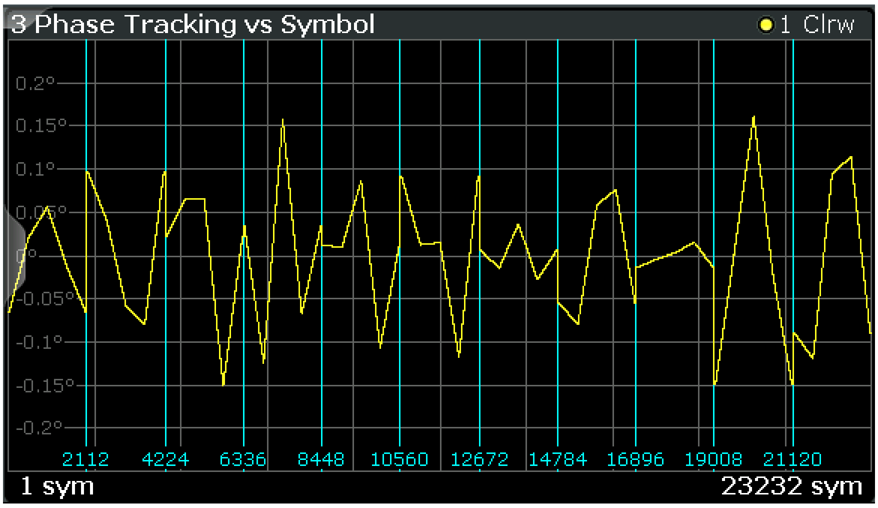
Phase Tracking vs Symbol

Shows the average compensated phase drift in degrees or radians vs symbol for phase tracking (see "Phase, level and timing tracking" on page 34). Thus, you can see which compensation has been applied by the R&S FSW 802.11ad application.

Since phase tracking is performed based on data symbol blocks (=512 symbols), it represents the low-frequency part of the Phase Error vs Symbol, if phase tracking is off.

Tip: The Phase Error vs Symbol result display shows the remaining phase error *after* compensation has been applied.

Note that this result display is also available if Phase Tracking is not active.

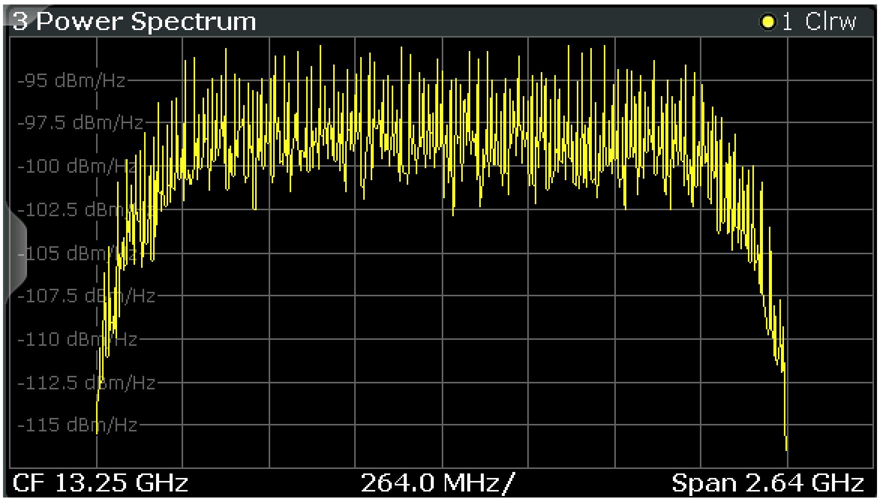


Vertical lines indicate the start of the next PPDU. The numbers at the bottom of the lines indicate the corresponding symbol positions.

Remote command:
`LAY:ADD? '1',RIGH,PTVS`, see `LAYout:ADD[:WINDow]?` on page 157
Querying results:
`TRACe<n>[:DATA]?`, see chapter 9.10.4.8, "Phase Tracking vs. Symbol", on page 197

Power Spectrum

This result display shows the power vs frequency values obtained from an FFT. The FFT is performed over the complete data in the current capture buffer, without any correction or compensation.



The numeric trace results for this evaluation method are described in chapter 9.10.4.9, "Power Spectrum", on page 197.

Remote command:
`LAY:ADD? '1',RIGH, PSP`, see `LAYout:ADD[:WINDow]?` on page 157
Querying results:
`TRACe<n>[:DATA]?`, see chapter 9.10.4.9, "Power Spectrum", on page 197

PvT Full PPDU
Displays the minimum, average and maximum power vs time traces for all PPDUs.

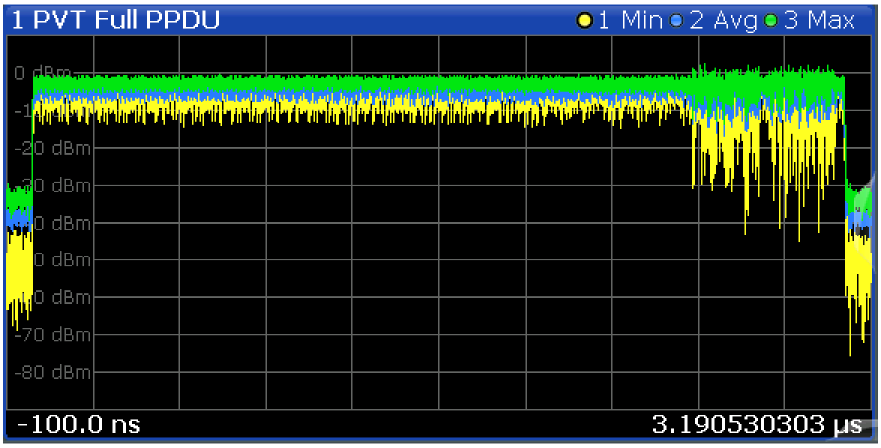


Fig. 3-9: PvT Full PPDU result display

Remote command:
`LAY:ADD:WIND '2',RIGH,PFPP` see `LAYout:ADD[:WINDow]?` on page 157
Querying results:
`TRACe<n>[:DATA]?`, see chapter 9.10.4.10, "Power vs Time (PVT)", on page 197

PvT Rising Edge
Displays the minimum, average and maximum power vs time traces for the rising edge of all PPDUs.

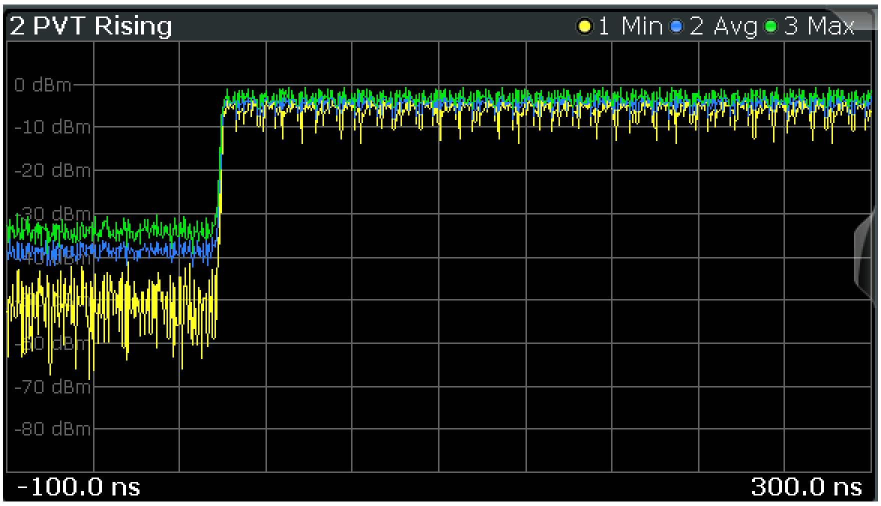


Fig. 3-10: PvT Rising Edge result display

Remote command:
`LAY:ADD:WIND '2',RIGH,PRIS` see `LAYout:ADD[:WINDow]?` on page 157
Querying results:
`TRACe<n>[:DATA]?`, see chapter 9.10.4.10, "Power vs Time (PVT)", on page 197

PvT Falling Edge
Displays the minimum, average and maximum power vs time traces for the falling edge of all PPDUs.

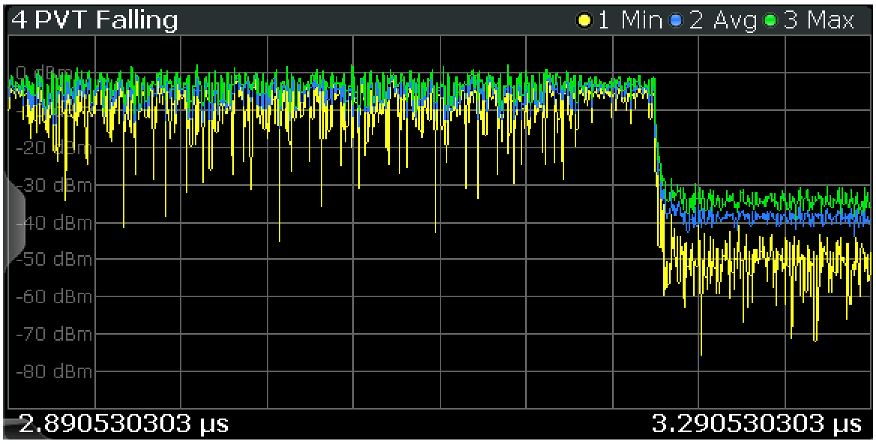


Fig. 3-11: PvT Falling Edge result display

Remote command:
`LAY:ADD:WIND '2',RIGH,PFAL` see `LAYout:ADD[:WINDow]?` on page 157
Querying results:
`TRACe<n>[:DATA]?`, see chapter 9.10.4.10, "Power vs Time (PVT)", on page 197

Result Summary
The result summary provides measurement results based on the complete captured signal.

3 Result Summary

PPDUs	Min	Average	Max
EVM All [dB]	-33.544	-33.451	-33.346
EVM Data Symbols [dB]	-33.467	-33.318	-33.193
EVM Pilot Symbols [dB]	-33.869	-33.706	-33.568
IQ Offset [dB]	-49.079	-47.109	-45.970
Gain Imbalance [dB]	-0.001	-0.000	0.001
Quadrature Error [°]	-0.063	-0.052	-0.041
Center Freq Error [Hz]	24.674	303.389	1171.958
Symbol Clock Error [ppm]	-82.448	-83.182	-83.690
Rise Time [s]	---	---	---
Fall Time [s]	---	---	---
Time Skew [s]	---	---	---
Time Domain Power [dBm]	-4.028	-4.024	-4.019
Crest Factor [dB]	5.699	5.917	6.274
Header BER	0	0	0
Payload BER	0	0	0

Fig. 3-12: Result summary

Note: You can configure which results are displayed (see chapter 5.2.8.1, "Table Configuration", on page 80). However, the results are always calculated, regardless of their visibility.

For details on the individual results and the summarized values see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Remote command:
`LAY:ADD? '1',RIGH, RSGL`, see `LAYout:ADD[:WINDow]?` on page 157
Querying results:
`FETCh:BURSt:ALL?` on page 187

3.2 SEM Measurements

Access: "Overview" > "Select Measurement" > "SEM"

or: MEAS > "Select Measurement" > "SEM"

In addition to the default IEEE 802.11ad Modulation Accuracy measurement, which captures I/Q data from the RF Input of the FSW with a bandwidth up to 2 GHz, the R&S FSW 802.11ad application also provides an SEM measurement. The SEM measurement sweeps over the desired frequency range using a filter with a smaller measurement bandwidth. The advantage of using a smaller bandwidth is an increased signal-to-noise-ratio

The SEM measurement provided by the R&S FSW 802.11ad application is identical to the corresponding measurements in the base unit, but it is pre-configured according to the requirements of the IEEE 802.11ad standard.

If you require any other frequency sweep measurements, use the Spectrum application.

For details on frequency sweep measurements see the R&S FSW User Manual.

The Spectrum Emission Mask (SEM) measurement determines the power of the IEEE 802.11ad signal in defined offsets from the carrier and compares the power values with a spectral mask specified by the IEEE 802.11ad specifications. The limits depend on the selected bandclass. Thus, the performance of the DUT can be tested and the emissions and their distance to the limit be identified.

The IEEE 802.11ad standard does not distinguish between spurious and spectral emissions.

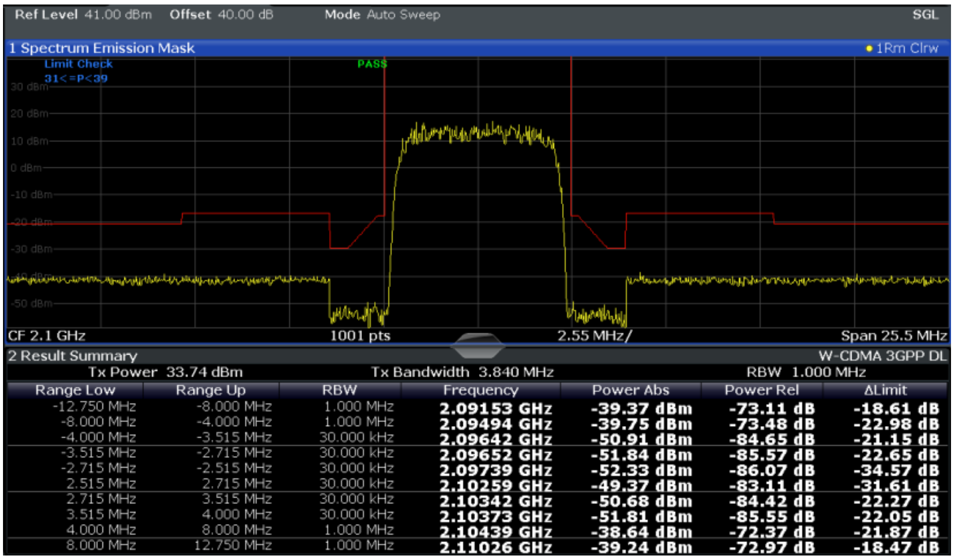


Fig. 3-13: SEM measurement results

Remote commands:

`[SENSe:]SWEep:MODE` on page 114

Querying results:

`CALCulate<n>:LIMit<k>:FAIL?` on page 190

`TRAC:DATA? LIST`, see `TRACe<n>[:DATA]?` on page 192

Evaluation methods

The evaluation methods for SEM measurements in the R&S FSW 802.11ad application are identical to those in the R&S FSW base unit (Spectrum application).

Diagram

Displays a basic level vs. frequency or level vs. time diagram of the measured data to evaluate the results graphically. This is the default evaluation method. Which data is displayed in the diagram depends on the "Trace" settings. Scaling for the y-axis can be configured.

Remote command:

`LAY:ADD? '1',RIGH, DIAG`, see `LAYout:ADD[:WINDow]?` on page 157

Result Summary

Result summaries provide the results of specific measurement functions in a table for numerical evaluation. The contents of the result summary vary depending on the selected measurement function. See the description of the individual measurement functions for details.

2 Result Summary

Channel	Bandwidth	Offset	Power	
TX1 (Ref)	1.229 MHz		-0.86 dBm	
Tx Total			-0.86 dBm	
Channel	**Bandwidth**	**Offset**	**Lower**	**Upper**
Adj	30.000 kHz	750.000 kHz	-79.59 dB	-80.34 dB
Alt1	30.000 kHz	1.980 MHz	-85.04 dB	-83.85 dB

Tip: To navigate within long result summary tables, simply scroll through the entries with your finger on the touchscreen.

Remote command:

`LAY:ADD? '1',RIGH, RSUM`, see `LAYout:ADD[:WINDow]?` on page 157

Marker Table

Displays a table with the current marker values for the active markers.

4 Marker Table

Wnd	Type	Ref	Trc	X-value	Y-value
1	M1		1	13.25 GHz	-200.0 dBm
1	D2	M1	1	-600.0 kHz	0.0 dB
1	D3	M1	1	600.0 kHz	0.0 dB
1	D4	M1	1	-2.0 MHz	0.0 dB

Tip: To navigate within long marker tables, simply scroll through the entries with your finger on the touchscreen.

Remote command:

`LAY:ADD? '1',RIGH, MTAB`, see `LAYout:ADD[:WINDow]?` on page 157

Results:

`CALCulate<n>:MARKer<m>:X` on page 174

`CALCulate<n>:MARKer<m>:Y?` on page 199

Marker Peak List

The marker peak list determines the frequencies and levels of peaks in the spectrum or time domain. How many peaks are displayed can be defined, as well as the sort order. In addition, the detected peaks can be indicated in the diagram. The peak list can also be exported to a file for analysis in an external application.

2 Marker Peak List

No	Stimulus	Response
1	64.400000 MHz	-30.352 dBm
2	128.400000 MHz	-51.896 dBm
3	192.300000 MHz	-40.227 dBm
4	257.200000 MHz	-60.699 dBm
5	320.200000 MHz	-44.273 dBm
6	384.100000 MHz	-53.494 dBm
7	448.100000 MHz	-47.460 dBm
8	513.000000 MHz	-55.603 dBm

Tip: To navigate within long marker peak lists, simply scroll through the entries with your finger on the touchscreen.

Remote command:

`LAY:ADD? '1',RIGH, PEAK`, see `LAYout:ADD[:WINDow]?` on page 157

Results:

`CALCulate<n>:MARKer<m>:X` on page 174

`CALCulate<n>:MARKer<m>:Y?` on page 199

4 Measurement Basics

Some background knowledge on basic terms and principles used in IEEE 802.11ad measurements is provided here for a better understanding of the required configuration settings.

Additional background information is available in the Rohde & Schwarz White Paper: 1MA220: 802.11ad - WLAN at 60 GHz A Technology Introduction

4.1 Characteristics of the IEEE 802.11ad Standard

The popular wireless transmission standard WLAN (IEEE 802.11) has been amended and updated regularly since it was first published in order to accomodate for constant demands of transmitting higher data rates and larger bandwidths. Multimedia data streams, for example, require very high throughput over large periods of time.

To meet this need, the Wireless Gigabit Alliance (WiGig) has developed a specification for wireless transmission of data in the 60 GHz band at speeds in the multi-Gigabit range.

Thus, the 11ad physical layer was added as an amendment to the existing WLAN standard, in chapter 21 of the 802.11-2012 standard [1]. It is called "**Directional Multi-Gigabit (DMG) PHY**" (or short: *PHY*).

Used bandwidths

The outstanding new feature of the IEEE 802.11ad standard is the use of the 60 GHz band; however, in order to maintain compatibility with existing WLAN devices, the 2.4 GHz and 5 GHz ranges defined by the IEEE 802.11a, b, g, and n standards are also supported.

In the range around 60 GHz, an unlicensed frequency band is available everywhere in the world. This range permits higher channel bandwidths for greater throughput. Another advantage is the small wavelengths (approx. 5 mm). These make it possible to use compact and competitive antennas or antenna arrays (e.g. for beamforming).

On the down side, this band has a very high free field attenuation and oxygen (O2) absorption. However, because the transmission typically takes place within a limited range of under 10 m (the typical living room), the high degree of attenuation can also be seen as an advantage. Interference from adjacent transmissions is very unlikely. The transmission is very difficult to intercept, making it even more secure. Finally, beamforming can be used to focus the power to the receiver.

Even when the IEEE 802.11ad transmission takes place in the open ISM band, interference of other applications must be minimized. Thus, a spectrum mask is defined by the standard, which must be adhered to during transmission. Therefore, an SEM measurement is provided by the R&S FSW 802.11ad application.

Types of PHYs

In principle, four different types of DMG PHYs are available using different package structures and modulation modes. They make it possible to fulfill differing requirements, such as high throughput or robustness.

Table 4-1: PHY types and modulation modes

PHY type	MCS	Data rate	Modulation	Usage
Control PHY	0	27.5 Mbps	DBPSK	Control messages for connection and monitoring, small data rates, but must be very robust
Single carrier (SC) PHY	1 to 12	385-4620 Mbps	BPSK QPSK 16QAM	Robust data transmission of large data rates
Low power SC PHY	25 to 31	626-2053 Mbps	BPSK QPSK	Transmission using battery-operated devices
OFDM PHY	13 to 24	693-6756 Mbps	SQPSK QPSK 16QAM 64QAM	Very high data rates, strong power supply (Currently not supported by R&S FSW 802.11ad application)

All DMG PHYs use the same package structure, but they differ in how the individual fields are defined as well as in the coding and modulation that is used.

Package structure

The general structure of a package in the IEEE 802.11ad physical layer consists of the following common parts:

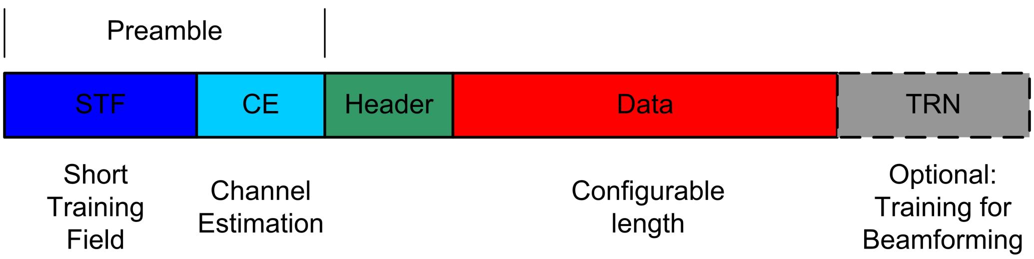


Fig. 4-1: General package structure in IEEE 802.11ad

- **Preamble**
  The preamble consists of the **short training field** (STF) and the **channel estimation** (CE) field. It is required in every package. It supports the receiver during automatic gain control (AGC), when recognizing the package and in estimating the frequency offset, and it displays the type of displays the type of PHY that is used (SC or OFDM). The receiver can also use the known CE field to estimate the channel.
- **Header**

The header is different for every PHY and contains additional important information for the receiver, such as the modulation mode (MCS), the length of the data field or a checksum.

- **Data**
  This part is used to transmit the actual data with different modulations (MCS). The length of the field varies (number of bytes/octets).
- TRN
  This field is optional and can be appended to all packages. It includes beamforming information (see "Beamforming" on page 34)

Golay sequences

In radiocommunications, training sequences are used for channel estimation. Predefined sequences that are already known to the receiver are transmitted over the channel and evaluated by the receiver in order to estimate the channel. Complementary Golay sequences are perfectly suited to this task.

The individual fields in the IEEE 802.11ad signal packages (e.g. the preamble) are made up of Golay sequences. Each sequence consists of bipolar symbols (±1). They are constructed mathematically in order to achieve specific autocorrelation characteristics. Each consists of a complementary pair (a and b). An additional index contains the length of the sequence. For example, G_a128 and G_b128 represent a complementary sequence with a length of 128. In addition, four specific G_x128 are then logically combined into G_u512 or G_v512.

The single carrier physical layers (SC, low power SC and control) nominally use a bandwidth of 1760 MHz, while the OFDM physical layer uses 1830.47 MHz.

Beamforming

Transmission in the 60 GHz range is subject to greater free-space loss than in the 2.4 or 5 GHz range. The channel conditions can change dramatically during a connection (for example, someone moves between a BluRay player and a projector during a 3DHD connection). Both can be managed in realtime by using beamforming. Because the antenna size in the 60 GHz band is very compact, small and competitive antenna arrays can be used. IEEE 802.11ad supports beamforming in realtime. During the beam refinement process, training sequences for beamforming are sent between the transmitter and receiver and evaluated. The best antenna weightings for each situation can then be set.

Beamforming training sequences can be appended to all PHY packages (control, SC, low-power SC and OFDM) for this purpose. The package type and training length are set accordingly in the corresponding header.

Phase, level and timing tracking

Golay sequences are also used as guard intervals, which are inserted after each 512 symbols (see figure 4-2). These guard intervals are used for phase tracking, that is: compensating the estimated phase error. The values that have been compensated by the R&S FSW 802.11ad application based on this phase estimation are displayed in the "Phase Tracking vs Symbol" on page 25 result display. After the phase tracking and other compensation (for example for level or time) has been applied, further results such as the EVM are calculated.

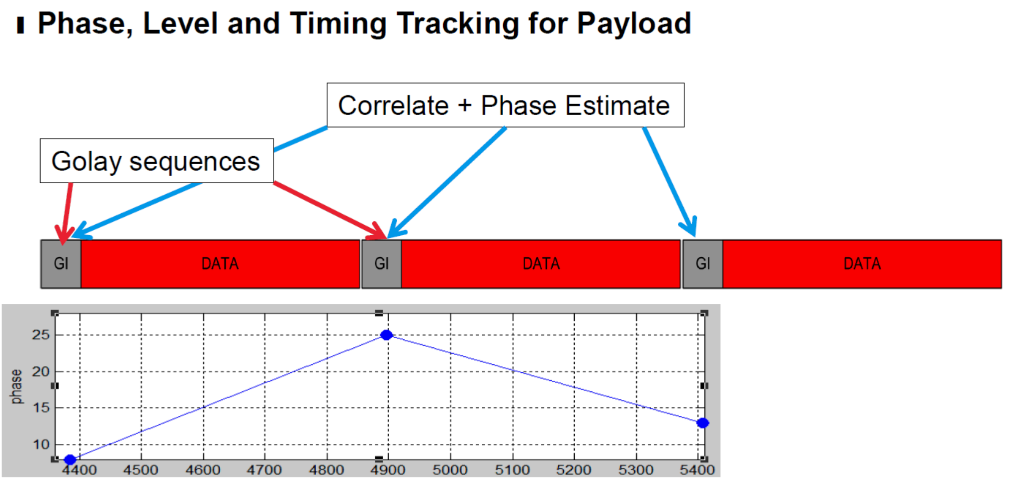


Fig. 4-2: Phase tracking using guard intervals and golay sequences

4.2 Measurement Setup

In order to perform a IEEE 802.11ad measurement with the R&S FSW 802.11ad application, the following setup is required:

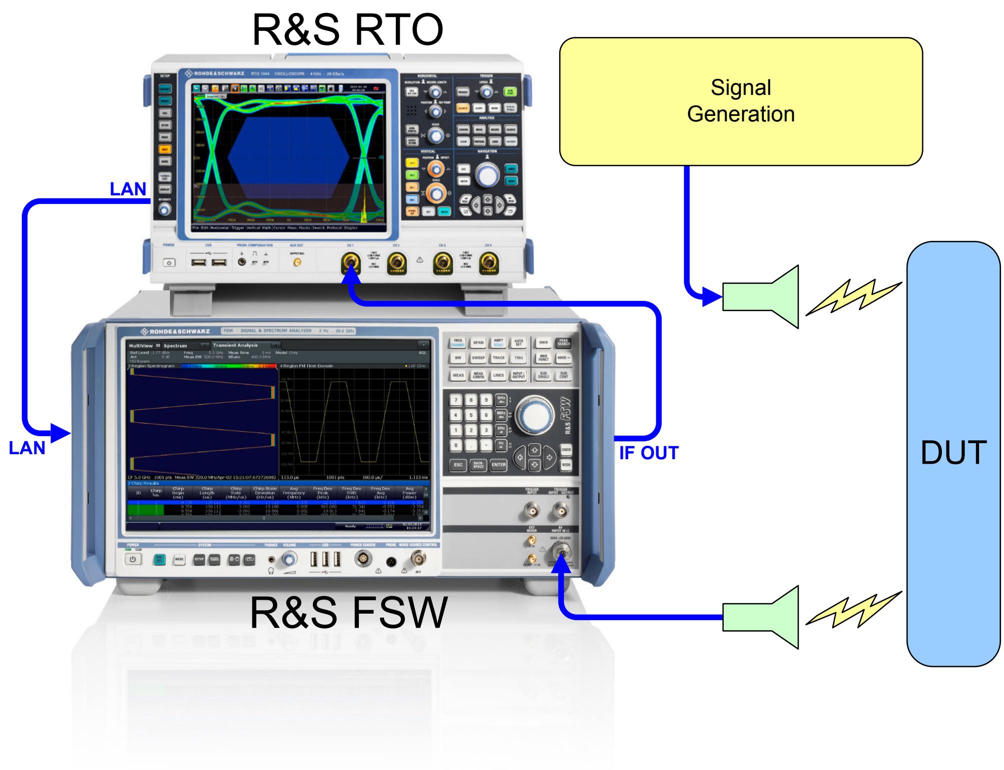


Fig. 4-3: Measurement setup for a IEEE 802.11ad measurement with the R&S FSW

In addition to the R&S FSW and the R&S FSW 802.11ad application, an R&S oscilloscope is required with which the 2 GHz bandwidth can be measured.

For details on setting up the R&S oscilloscope and the 2 GHz bandwidth extension (R&S FSW-B2000), see the R&S FSW I/Q Analyzer and I/Q Input User Manual and the oscilloscope documentation.

4.3 Receiving Data Input and Providing Data Output

The R&S FSW can analyze signals from different input sources and provide various types of output (such as noise or trigger signals).

4.3.1 RF Input Protection

The RF input connector of the R&S FSW must be protected against signal levels that exceed the ranges specified in the data sheet. Therefore, the R&S FSW is equipped with an overload protection mechanism. This mechanism becomes active as soon as the power at the input mixer exceeds the specified limit. It ensures that the connection between RF input and input mixer is cut off.

When the overload protection is activated, an error message is displayed in the status bar ("INPUT OVLD"), and a message box informs you that the RF Input was disconnected. Furthermore, a status bit (bit 3) in the `STAT:QUES:POW` status register is set. In this case you must decrease the level at the RF input connector and then close the message box. Then measurement is possible again. Reactivating the RF input is also possible via the remote command `INPut:ATTenuation:PROTection:RESet`.

4.3.2 Basics on Input from I/Q Data Files

The I/Q data to be evaluated in a particular R&S FSW application can not only be captured by the application itself, it can also be loaded from a file, provided it has the correct format. The file is then used as the input source for the application.

For example, you can capture I/Q data using the I/Q Analyzer application, store it to a file, and then analyze the signal parameters for that data later using the Pulse application (if available).

The I/Q data must be stored in a format with the file extension `.iq.tar`. For a detailed description see chapter A.2, "I/Q Data File Format (iq-tar)", on page 211.

As opposed to importing data from an I/Q data file using the import functions provided by some R&S FSW applications (e.g. the I/Q Analyzer or the R&S FSW VSA application), the data is not only stored temporarily in the capture buffer, where it overwrites the current measurement data and is in turn overwritten by a new measurement. Instead, the stored I/Q data remains available as input for any number of subsequent measurements. Furthermore, the (temporary) data import requires the current measurement settings in the current application to match the settings that were applied when the measurement results were stored (possibly in a different application). When the data is used as an input source, however, the data acquisition settings in the current application (attenuation, center frequency, measurement bandwidth, sample rate) can be ignored. As a result, these settings cannot be changed in the current application. Only the measurement time can be decreased, in order to perform measurements on an extract of the available data (from the beginning of the file) only.

When using input from an I/Q data file, the RUN SINGLE function starts a single measurement (i.e. analysis) of the stored I/Q data, while the RUN CONT function repeatedly analyzes the same data from the file.

Sample iq.tar files

If you have the optional R&S FSW VSA application (R&S FSW-K70), some sample `iq.tar` files are provided in the `C:/R_S/Instr/user/vsa/DemoSignals` directory on the R&S FSW.

Pre-trigger and post-trigger samples

In applications that use pre-triggers or post-triggers, if no pre-trigger or post-trigger samples are specified in the I/Q data file, or too few trigger samples are provided to satisfy the requirements of the application, the missing pre- or post-trigger values are filled up with zeros. Superfluous samples in the file are dropped, if necessary. For pre-trigger samples, values are filled up or omitted at the beginning of the capture buffer, for post-trigger samples, values are filled up or omitted at the end of the capture buffer.

4.3.3 Input from Noise Sources

The R&S FSW provides a connector (NOISE SOURCE CONTROL) with a voltage supply for an external noise source. By switching the supply voltage for an external noise source on or off in the firmware, you can activate or deactive the device as required.

External noise sources are useful when you are measuring power levels that fall below the noise floor of the R&S FSW itself, for example when measuring the noise level of an amplifier.

In this case, you can first connect an external noise source (whose noise power level is known in advance) to the R&S FSW and measure the total noise power. From this value you can determine the noise power of the R&S FSW. Then when you measure the power level of the actual DUT, you can deduct the known noise level from the total power to obtain the power level of the DUT.

The noise source is controlled in the "Output" settings, see "Noise Source" on page 65

4.3.4 Receiving and Providing Trigger Signals

Using one of the TRIGGER INPUT / OUTPUT connectors of the R&S FSW, the R&S FSW can use a signal from an external device as a trigger to capture data. Alternatively, the internal trigger signal used by the R&S FSW can be output for use by other connected devices. Using the same trigger on several devices is useful to synchronize the transmitted and received signals within a measurement.

For details on the connectors see the R&S FSW "Getting Started" manual.

External trigger as input

If the trigger signal for the R&S FSW is provided by an external device, the trigger signal source must be connected to the R&S FSW and the trigger source must be defined as "External" for the R&S FSW.

Trigger output

The R&S FSW can provide output to another device either to pass on the internal trigger signal, or to indicate that the R&S FSW itself is ready to trigger.

The trigger signal can be output by the R&S FSW automatically, or manually by the user. If it is provided automatically, a high signal is output when the R&S FSW has triggered due to a measurement start ("Device Triggered"), or when the R&S FSW is ready to receive a trigger signal after a measurement start ("Trigger Armed").

Manual triggering

If the trigger output signal is initiated manually, the length and level (high/low) of the trigger pulse is also user-definable. Note, however, that the trigger pulse level is always opposite to the constant signal level defined by the output "Level" setting, e.g. for "Level = High", a constant high signal is output to the connector until the "Send Trigger" button is selected. Then, a low pulse is provided.

Providing trigger signals as output is described in detail in the R&S FSW User Manual.

4.4 Preparing the R&S FSW for the Expected Input Signal - Frontend Parameters

On the R&S FSW, the input data can only be processed optimally if the hardware settings match the signal characteristics as closely as possible. On the other hand, the hardware must be protected from powers or frequencies that exceed the allowed limits. Therefore, you must set the hardware so that it is optimally prepared for the expected input signal, without being overloaded. You do this using the *frontend* parameters. Consider the following recommendations:

Reference level

Adapt the R&S FSW's hardware to the expected maximum signal level by setting the "Reference Level" to this maximum. Compensate for any external attenuation or gain by defining a "Reference Level" offset.

Attenuation

To optimize the signal-to-noise ratio of the measurement for high signal levels and to protect the R&S FSW from hardware damage, provide for a high attenuation. Use AC coupling for DC input voltage.

Amplification

To optimize the signal-to-noise ratio of the measurement for low signal levels, the signal level in the R&S FSW should be as high as possible but without introducing compression, clipping, or overload. Provide for early amplification by the preamplifier and a low attenuation.

Impedance

In the R&S FSW 802.11ad application, the impedance is fixed to 50 Ω and cannot be changed.

4.5 Triggered Measurements

In a basic measurement with default settings, the measurement is started immediately. However, sometimes you want the measurement to start only when a specific condition is fulfilled, for example a signal level is exceeded, or in certain time intervals. For these cases you can define a trigger for the measurement. In FFT sweep mode, the trigger defines when the data acquisition starts for the FFT conversion.

An "Offset" can be defined to delay the measurement after the trigger event, or to include data before the actual trigger event in time domain measurements (pre-trigger offset).

For complex tasks, advanced trigger settings are available:

- Hysteresis to avoid unwanted trigger events caused by noise
- Holdoff to define exactly which trigger event will cause the trigger in a jittering signal

4.5.1 Trigger Offset

An offset can be defined to delay the measurement after the trigger event, or to include data before the actual trigger event in time domain measurements (pre-trigger offset). Pre-trigger offsets are possible because the R&S FSW captures data continuously in the time domain, even before the trigger occurs.

See "Trigger Offset" on page 76.

4.5.2 Trigger Hysteresis

Setting a hysteresis for the trigger helps avoid unwanted trigger events caused by noise, for example. The hysteresis is a threshold to the trigger level that the signal must fall below on a rising slope or rise above on a falling slope before another trigger event occurs.

Example:

In the following example, the second possible trigger event is ignored as the signal does not exceed the hysteresis (threshold) before it reaches the trigger level again on the rising edge. On the falling edge, however, two trigger events occur as the signal exceeds the hysteresis before it falls to the trigger level the second time.

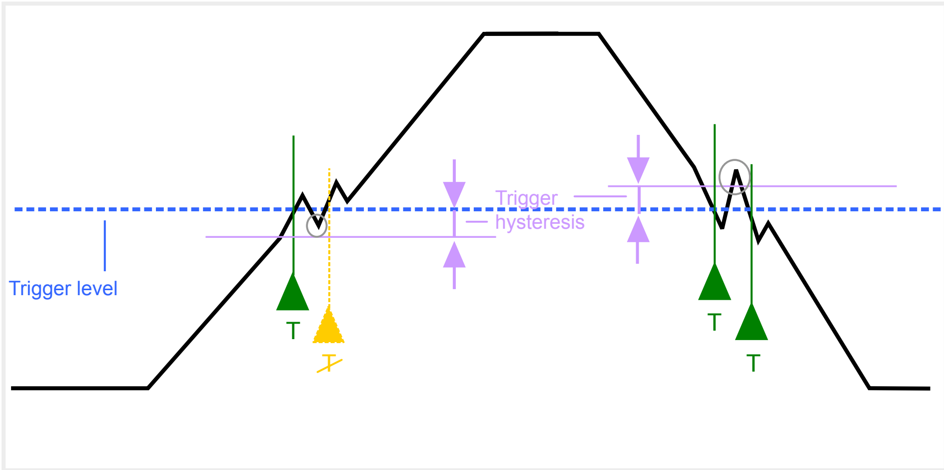


Fig. 4-4: Effects of the trigger hysteresis

See "Hysteresis" on page 76

4.5.3 Trigger Drop-Out Time

If a modulated signal is instable and produces occassional "drop-outs" during a burst, you can define a minimum duration that the input signal must stay below the trigger level before triggering again. This is called the "drop-out" time. Defining a dropout time helps you stabilize triggering when the analyzer is triggering on undesired events.

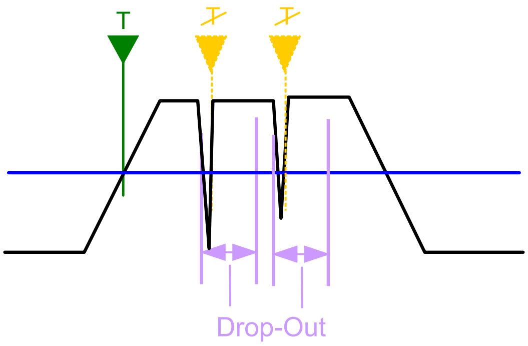


Fig. 4-5: Effect of the trigger drop-out time

See "Drop-Out Time" on page 76.

Drop-out times for falling edge triggers

If a trigger is set to a falling edge ("Slope" = "Falling", see "Slope" on page 76) the measurement is to start when the power level falls below a certain level. This is useful, for example, to trigger at the end of a burst, similar to triggering on the rising edge for the beginning of a burst.

If a drop-out time is defined, the power level must remain below the trigger level at least for the duration of the drop-out time (as defined above). However, if a drop-out time is defined that is longer than the pulse width, this condition cannot be met before the final pulse, so a trigger event will not occur until the pulsed signal is over!

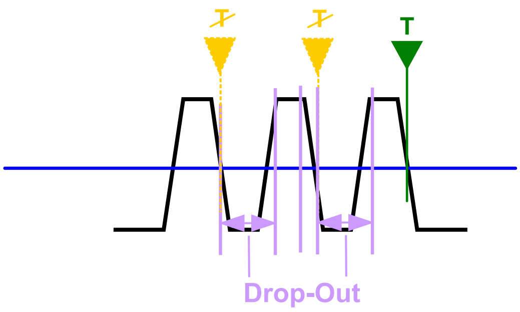


Fig. 4-6: Trigger drop-out time for falling edge trigger

For gated measurements, a combination of a falling edge trigger and a drop-out time is generally not allowed.

4.5.4 Trigger Holdoff

The trigger holdoff defines a waiting period before the next trigger after the current one will be recognized.

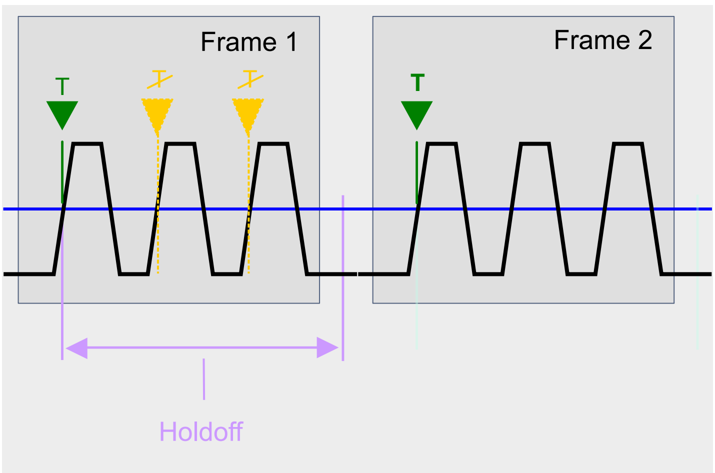


Fig. 4-7: Effect of the trigger holdoff

See "Trigger Holdoff" on page 76.

4.6 Max. Sample Rate and Bandwidth with Activated I/Q Bandwidth Extension Option B2000

The bandwidth extension option R&S FSW-B2000 provides measurement bandwidths up to 2 GHz.

Sample rate	Maximum I/Q bandwidth
10 kHz to 10 GHz	proportional up to maximum 2 GHz

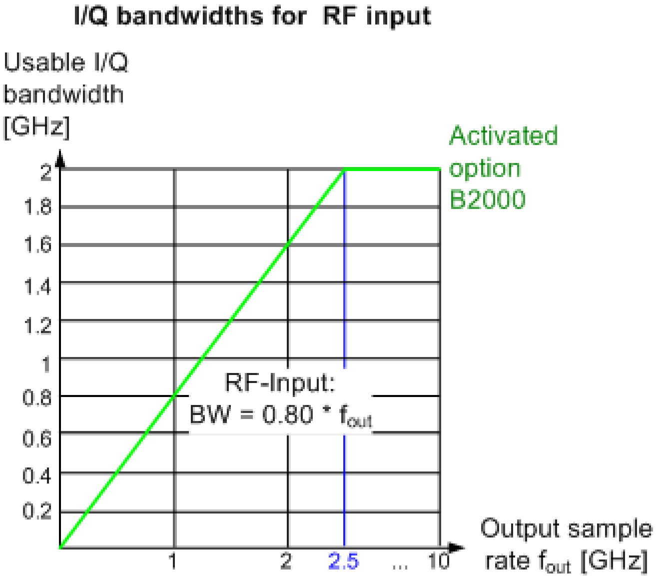


Fig. 4-8: Relationship between maximum usable I/Q bandwidth and output sample rate for active R&S FSW-B2000

5 Configuration

Access: MODE > "802.11ad"

IEEE 802.11ad measurements require a special application on the R&S FSW.

The default IEEE 802.11ad Modulation Accuracy measurement captures the I/Q data from the IEEE 802.11ad Modulation Accuracy measurement signal and determines various characteristic signal parameters such as the modulation accuracy, channel frequency response, and power gain in just one measurement (see chapter 3.1, "IEEE 802.11ad Modulation Accuracy Measurement", on page 13)

Other parameters specified in the IEEE 802.11ad standard must be determined in separate measurements (see chapter 3.2, "SEM Measurements", on page 28).

The settings required to configure each of these measurements are described here.

5.1 Display Configuration

Access: "Overview" > "Display Config"

or: MEAS CONFIG > "Display Config"

The measurement results can be displayed using various evaluation methods. All evaluation methods available for the R&S FSW 802.11ad application are displayed in the evaluation bar in SmartGrid mode.

Drag one or more evaluations to the display area and configure the layout as required.

Up to 16 evaluation methods can be displayed simultaneously in separate windows. The IEEE 802.11ad evaluation methods are described in chapter 3.1.2, "Evaluation Methods for IEEE 802.11ad Modulation Accuracy Measurements", on page 18.

To close the SmartGrid mode and restore the previous softkey menu select the "Close" icon in the righthand corner of the toolbar, or press any key.

For details on working with the SmartGrid see the R&S FSW Getting Started manual.

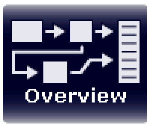
5.2 IEEE 802.11ad Modulation Accuracy Measurement

Access: "Overview" > "Select Measurement" > "Modulation Accuracy"

or: MEAS > "Select Measurement" > "Modulation Accuracy"

When you activate the R&S FSW 802.11ad application, an I/Q measurement of the input signal is started automatically with the default configuration. The "IEEE 802.11ad" menu is displayed and provides access to the most important configuration functions.

The "Span", "Bandwidth", "Lines", and "Marker Functions" menus are not available for IEEE 802.11ad Modulation Accuracy measurements.



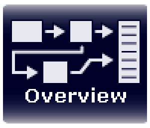
Multiple access paths to functionality

The easiest way to configure a measurement channel is via the "Overview" dialog box, which is displayed when you select the "Overview" softkey from any IEEE 802.11ad menu.

Alternatively, you can access the individual dialog boxes via softkeys from the corresponding menus, or via tools in the toolbars, if available.

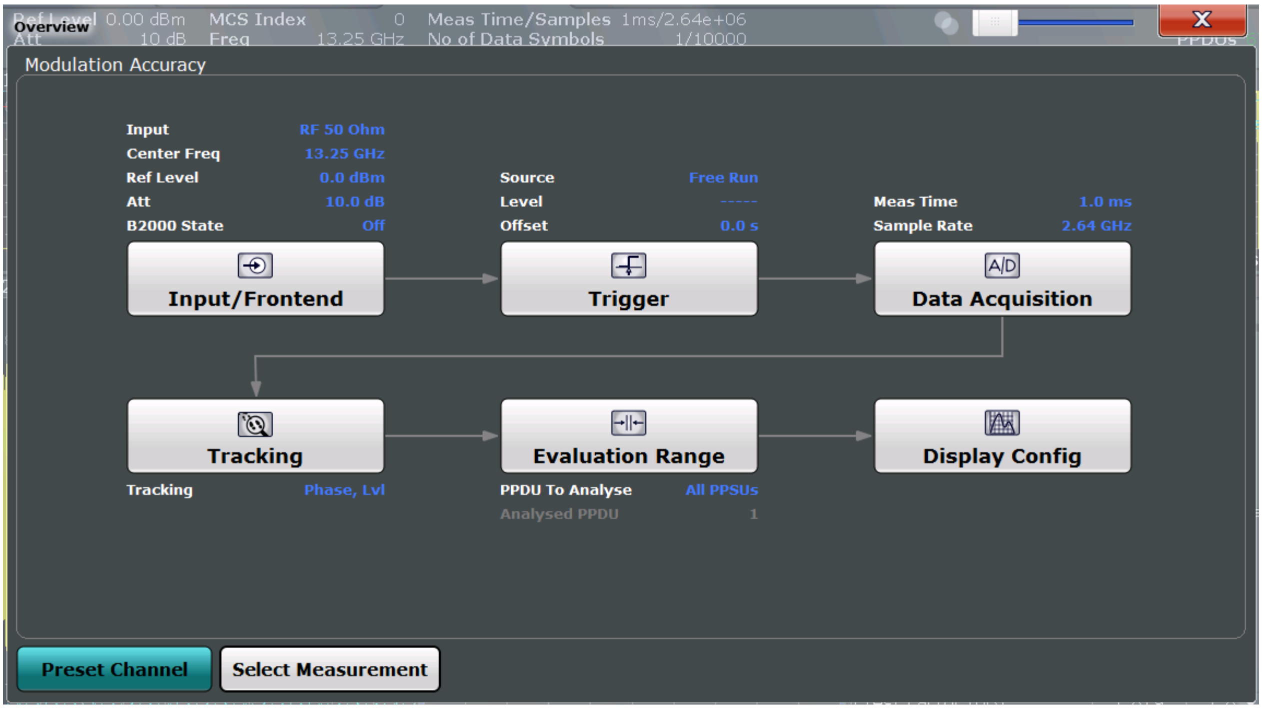
In this documentation, only the most convenient method of accessing the dialog boxes is indicated - usually via the "Overview".

5.2.1 Configuration Overview



Access: all menus

Throughout the measurement channel configuration, an overview of the most important currently defined settings is provided in the "Overview".



The "Overview" not only shows the main measurement settings, it also provides quick access to the main settings dialog boxes. The indicated signal flow shows which parameters affect which processing stage in the measurement. Thus, you can easily configure an entire measurement channel from input over processing to output and analysis by stepping through the dialog boxes as indicated in the "Overview".

The available settings and functions in the "Overview" vary depending on the currently selected measurement. For SEM measurements see chapter 3.2, "SEM Measurements", on page 28.

For the IEEE 802.11ad Modulation Accuracy measurement, the "Overview" provides quick access to the following configuration dialog boxes (listed in the recommended order of processing):

1. "Select Measurement"
   See "Select Measurement" on page 47
2. "Input/ Frontend"
   See chapter 5.2.2, "Input, Output and Frontend Settings", on page 47
3. "Data Acquisition"
   See chapter 5.2.3, "Data Acquisition", on page 71
4. "Tracking"
   See chapter 5.2.5, "Tracking", on page 78
5. "Evaluation Range"
   See chapter 6.1, "Evaluation Range", on page 87

6. "Display Configuration"
   See chapter 5.1, "Display Configuration", on page 44

To configure settings

► Select any button in the "Overview" to open the corresponding dialog box.

Preset Channel

Select the "Preset Channel" button in the lower lefthand corner of the "Overview" to restore all measurement settings **in the current channel** to their default values.

Note that the PRESET key restores the entire instrument to its default values and thus closes **all measurement channels** on the R&S FSW (except for the default Spectrum application channel)!

Remote command:
`SYSTem:PRESet:CHANnel[:EXECute]` on page 113

Select Measurement

Selects a measurement to be performed.

See chapter 3, "Measurements and Result Displays", on page 13.

Specifics for

The measurement channel may contain several windows for different results. Thus, the settings indicated in the "Overview" and configured in the dialog boxes vary depending on the selected window.

Select an active window from the "Specifics for" selection list that is displayed in the "Overview" and in all window-specific configuration dialog boxes.

The "Overview" and dialog boxes are updated to indicate the settings for the selected window.

5.2.2 Input, Output and Frontend Settings

Access: "Overview" ≥ "Input/Frontend"

or: INPUT/OUTPUT

The R&S FSW can analyze signals from different input sources and provide various types of output (such as noise or trigger signals).

Importing and Exporting I/Q Data

The I/Q data to be analyzed for IEEE 802.11ad can not only be measured by the R&S FSW 802.11ad application itself, it can also be imported to the application, provided it has the correct format. Furthermore, the analyzed I/Q data from the R&S FSW 802.11ad application can be exported for further analysis in external applications.

See chapter 7.1, "Import/Export Functions", on page 95.

Frequency, amplitude and y-axis scaling settings represent the "frontend" of the measurement setup.

For more information on the use and effects of these settings, see chapter 4.4, "Preparing the R&S FSW for the Expected Input Signal - Frontend Parameters", on page 39.

5.2.2.1 Input Source Settings

Access: "Overview" ≥ "Input/Frontend" > "Input Source Config"

or: INPUT/OUTPUT > "Input Source Config"

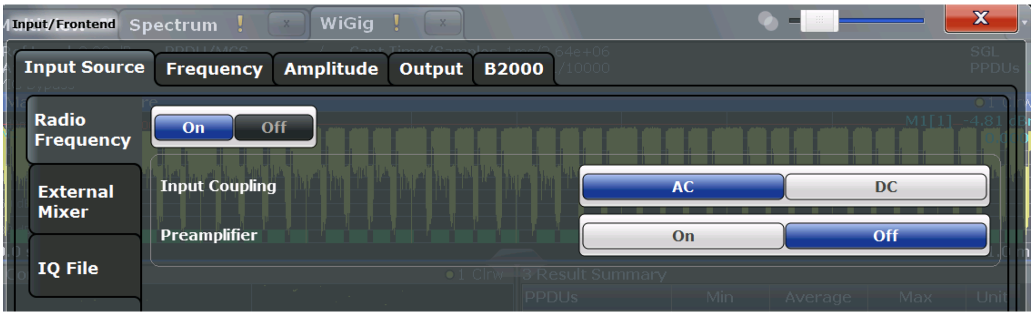
The input source determines which data the R&S FSW will analyze.

Radio Frequency Input

Access: "Overview" ≥ "Input/Frontend" > "Input Source Config"> "Radio Frequency"

or: INPUT/OUTPUT > "Input Source Config" > "Input Source" > "Radio Frequency"

The default input source for the R&S FSW is "Radio Frequency", i.e. the signal at the RF INPUT connector of the R&S FSW. If no additional options are installed, this is the only available input source.



Radio Frequency State

Activates input from the RF INPUT connector.

Remote command:
`INPut:SELect` on page 115

Input Coupling

The RF input of the R&S FSW can be coupled by alternating current (AC) or direct current (DC).

AC coupling blocks any DC voltage from the input signal. This is the default setting to prevent damage to the instrument. Very low frequencies in the input signal may be distorted.

However, some specifications require DC coupling. In this case, you must protect the instrument from damaging DC input voltages manually. For details, refer to the data sheet.

Remote command:
`INPut:COUPling` on page 115

Preamplifier

If the (optional) Preamplifier hardware is installed, a preamplifier can be activated for the RF input signal.

You can use a preamplifier to analyze signals from DUTs with low input power.

For R&S FSW26 or higher models, the input signal is amplified by 30 dB if the preamplifier is activated.

For R&S FSW8 or 13 models, the following settings are available:

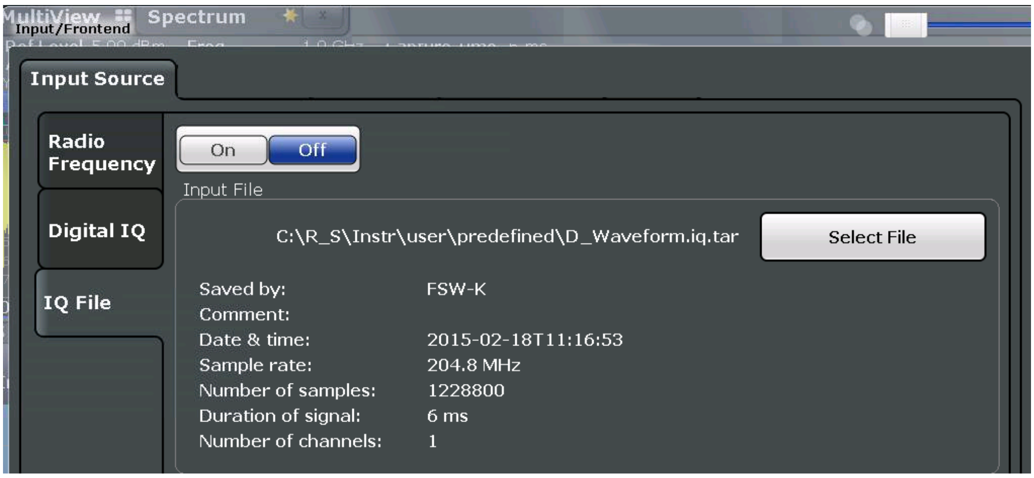
"Off"	Deactivates the preamplifier.
"15 dB"	The RF input signal is amplified by about 15 dB.
"30 dB"	The RF input signal is amplified by about 30 dB.

Remote command:
`INPut:GAIN:STATe` on page 141
`INPut:GAIN[:VALue]` on page 140

Settings for Input from I/Q Data Files

Access: "Overview" > "Input/Frontend" > "Input Source" > "IQ file"

or: INPUT/OUTPUT > "Input Source Config" > "Input Source" > "IQ file"



For details see chapter 4.3.2, "Basics on Input from I/Q Data Files", on page 37.

I/Q Input File State
Activates input from the selected I/Q input file.

If enabled, the application performs measurements on the data from this file. Thus, most measurement settings related to data acquisition (attenuation, center frequency, measurement bandwidth, sample rate) cannot be changed. The measurement time can only be decreased, in order to perform measurements on an extract of the available data only.

Note: Even when the file input is deactivated, the input file remains selected and can be activated again quickly by changing the state.

Remote command:
`INPut:SELect` on page 115

Select I/Q Data File
Opens a file selection dialog box to select an input file that contains I/Q data.

Note that the I/Q data must have a specific format (`.iq.tar`) as described in chapter A.2, "I/Q Data File Format (iq-tar)", on page 211.

The default storage location for I/Q data files is `C:\R_S\Instr\user\`.

Remote command:
`INPut:FILE:PATH` on page 116

External Mixer Settings

Access: "Overview" > "Input/Frontend" > "Input Source" > "External Mixer"

or: INPUT/OUTPUT > "Input Source Config" > "Input Source" > "External Mixer"

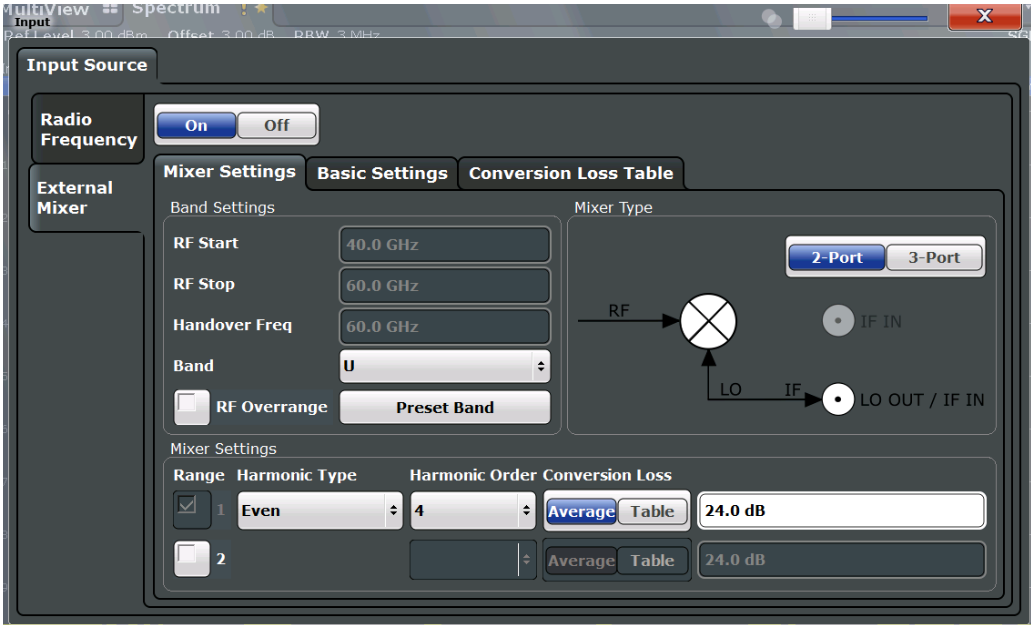
If installed, the optional external mixer can be configured from the R&S FSW 802.11ad application.

Mixer Settings

Access: "Overview" > "Input/Frontend" > "Input Source" > "External Mixer" > "Mixer Settings"

or: INPUT/OUTPUT > "Input Source Config" > "Input Source" > "External Mixer" > "Mixer Settings"

In this tab you configure the band and specific mixer settings.



External Mixer State

Activates or deactivates the external mixer for input. If activated, "ExtMix" is indicated in the channel bar of the application, together with the used band (see "Band" on page 52).

Remote command:

`[SENSe:]MIXer[:STATe]` on page 117

RF Start / RF Stop

Displays the start and stop frequency of the selected band (read-only).

The frequency range for the user-defined band is defined via the harmonics configuration (see "Range 1/2" on page 52).

For details on available frequency ranges see table 9-4.

Remote command:

`[SENSe:]MIXer:FREQuency:STARt?` on page 119

`[SENSe:]MIXer:FREQuency:STOP?` on page 119

Handover Freq.
Defines the frequency at which the mixer switches from one range to the next (if two different ranges are selected). The handover frequency can be selected freely within the overlapping frequency range.

Remote command:
`[SENSe:]MIXer:FREQuency:HANDover` on page 119

Band
Defines the waveguide band or user-defined band to be used by the mixer.

The start and stop frequencies of the selected band are displayed in the "RF Start" and "RF Stop" fields.

For a definition of the frequency range for the pre-defined bands, see table 9-4).

The mixer settings for the user-defined band can be selected freely. The frequency range for the user-defined band is defined via the harmonics configuration (see "Range 1/2" on page 52).

Remote command:
`[SENSe:]MIXer:HARMonic:BAND[:VALue]` on page 120

RF Overrange
If enabled, the frequency range is not restricted by the band limits ("RF Start" and "RF Stop"). In this case, the full LO range of the selected harmonics is used.

Remote command:
`[SENSe:]MIXer:RFOVerrange[:STATe]` on page 123

Preset Band
Restores the presettings for the selected band.

Note: changes to the band and mixer settings are maintained even after using the PRESET function. This function allows you to restore the original band settings.

Remote command:
`[SENSe:]MIXer:HARMonic:BAND:PRESet` on page 120

Mixer Type
The External Mixer option supports the following external mixer types:

"2 Port"	LO and IF data use the same port
"3 Port"	LO and IF data use separate ports

Remote command:
`[SENSe:]MIXer:PORTs` on page 123

Mixer Settings (Harmonics Configuration)
The harmonics configuration determines the frequency range for user-defined bands (see "Band" on page 52).

Range 1/2 ← Mixer Settings (Harmonics Configuration)
Enables the use of a second range based on another harmonic frequency of the mixer to cover the band's frequency range.

For each range you can define which harmonic to use and how the Conversion loss is handled.

Remote command:
[SENSe:]MIXer:HARMonic:HIGH:STATe on page 121

Harmonic Type ← Mixer Settings (Harmonics Configuration)
Defines if only even, only odd, or even and odd harmonics can be used for conversion. Depending on this selection, the order of harmonic to be used for conversion changes (see "Harmonic Order" on page 53). Which harmonics are supported depends on the mixer type.

Remote command:
[SENSe:]MIXer:HARMonic:TYPE on page 121

Harmonic Order ← Mixer Settings (Harmonics Configuration)
Defines which order of the harmonic of the LO frequencies is used to cover the frequency range.

By default, the lowest order of the specified harmonic type is selected that allows conversion of input signals in the whole band. If due to the LO frequency the conversion is not possible using one harmonic, the band is split.

For the band "USER", the order of harmonic is defined by the user. The order of harmonic can be between 2 and 61, the lowest usable frequency being 26.5 GHz.

Remote command:
[SENSe:]MIXer:HARMonic[:LOW] on page 121
[SENSe:]MIXer:HARMonic:HIGH[:VALue] on page 121

Conversion loss ← Mixer Settings (Harmonics Configuration)
Defines how the conversion loss is handled. The following methods are available:

"Average" Defines the average conversion loss for the entire range in dB.

"Table" Defines the conversion loss via the table selected from the list. Predefined conversion loss tables are often provided with the external mixer and can be imported to the R&S FSW. Alternatively, you can define your own conversion loss tables. Imported tables are checked for compatibility with the current settings before being assigned.
Conversion loss tables are configured and managed in the Conversion Loss Table tab.
For details on importing tables, see "Import Table" on page 57.

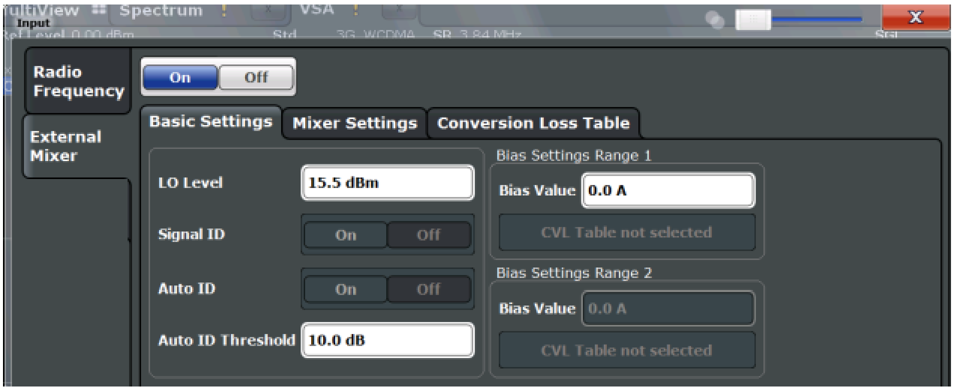
Remote command:
Average for range 1:
[SENSe:]MIXer:LOSS[:LOW] on page 122
Table for range 1:
[SENSe:]MIXer:LOSS:TABLe[:LOW] on page 122
Average for range 2:
[SENSe:]MIXer:LOSS:HIGH on page 122
Table for range 2:
[SENSe:]MIXer:LOSS:TABLe:HIGH on page 122

Basic Settings

Access: "Overview" > "Input/Frontend" > "Input Source" > "External Mixer" > "Basic Settings"

or: INPUT/OUTPUT > "Input Source Config" > "Input Source" > "External Mixer" > "Basic Settings"

The basic settings concern general use of an external mixer. They are only available if the External Mixer State is "On".



LO Level

Defines the LO level of the external mixer's LO port. Possible values are from 13.0 dBm to 17.0 dBm in 0.1 dB steps. Default value is 15.5 dB.

Remote command:
`[SENSe:]MIXer:LOPower` on page 117

Signal ID

Activates or deactivates visual signal identification. Two sweeps are performed alternately. Trace 1 shows the trace measured on the upper side band (USB) of the LO (the test sweep), trace 2 shows the trace measured on the lower side band (LSB), i.e. the reference sweep.

Note that automatic signal identification is only available for measurements that perform frequency sweeps (not in the VSA, the I/Q Analyzer, or the Real-Time application, for instance).

Mathematical functions with traces and trace copy cannot be used with the Signal ID function.

Remote command:
`[SENSe:]MIXer:SIGNal` on page 118

Auto ID

Activates or deactivates automatic signal identification.

Auto ID basically functions like Signal ID. However, the test and reference sweeps are converted into a single trace by a comparison of maximum peak values of each sweep point. The result of this comparison is displayed in trace 3 if "Signal ID" is active at the same time. If "Signal ID" is not active, the result can be displayed in any of the traces 1 to 3. Unwanted mixer products are suppressed in this calculated trace.

Note that automatic signal identification is only available for measurements that perform frequency sweeps (not in vector signal analysis or the I/Q Analyzer, for instance).

Remote command:

`[SENSe:]MIXer:SIGNal` on page 118

Auto ID Threshold

Defines the maximum permissible level difference between test sweep and reference sweep to be corrected during automatic comparison ("Auto ID" on page 55 function). The input range is between 0.1 dB and 100 dB. Values of about 10 dB (i.e. default setting) generally yield satisfactory results.

Remote command:

`[SENSe:]MIXer:THReshold` on page 118

Bias Settings

Define the bias current for each range, which is required to set the mixer to its optimum operating point. It corresponds to the short-circuit current. The bias current can range from -10 mA to 10 mA. The actual bias current is lower because of the forward voltage of the mixer diode(s).

The trace is adapted to the settings immediately so you can check the results. To store the bias setting in the currently selected conversion loss table, select the Write to <CVL table name> button.

Remote command:

`[SENSe:]MIXer:BIAS[:LOW]` on page 117

`[SENSe:]MIXer:BIAS:HIGH` on page 117

Write to <CVL table name> ← Bias Settings

Stores the bias setting in the currently selected "Conversion loss table" for the range (see "Managing Conversion Loss Tables" on page 55). If no conversion loss table is selected yet, this function is not available ("CVL Table not selected").

Remote command:

`[SENSe:]CORRection:CVL:BIAS` on page 124

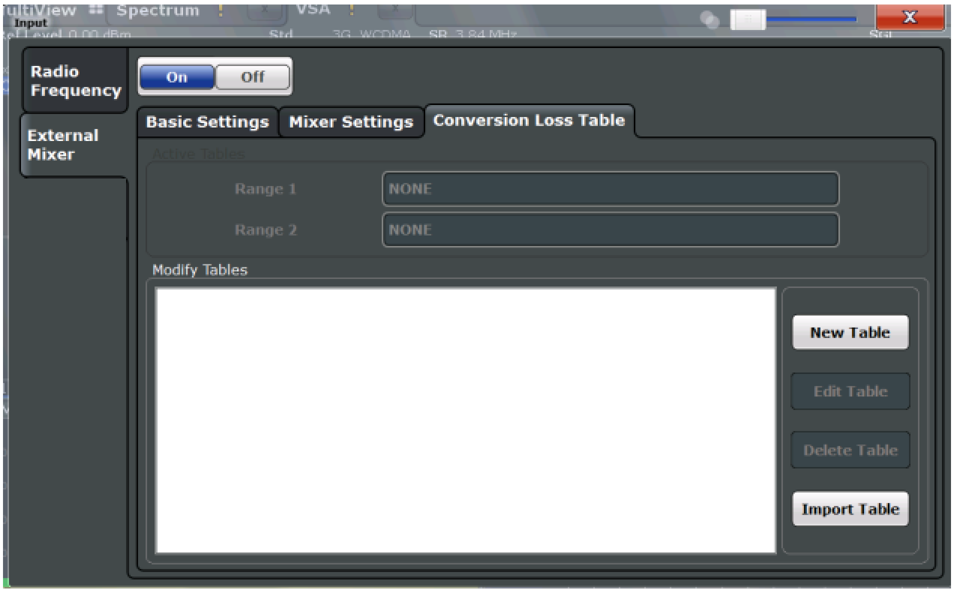
Managing Conversion Loss Tables

Access: "Overview" > "Input/Frontend" > "Input Source" > "External Mixer" > "Conversion Loss Table"

or: INPUT/OUTPUT > "Input Source Config" > "Input Source" > "External Mixer" > "Conversion Loss Table"

In this tab you configure and manage conversion loss tables. Conversion loss tables consist of value pairs that describe the correction values for conversion loss at certain frequencies. The correction values for frequencies between the reference points are obtained via interpolation.

The currently selected table for each range is displayed at the top of the dialog box. All conversion loss tables found in the instrument's `C:\r_s\instr\user\cvl\` directory are listed in the "Modify Tables" list.



New Table

Opens the "Edit Conversion loss table" dialog box to configure a new conversion loss table. For details on table configuration see "Creating and Editing Conversion Loss Tables" on page 57.

Remote command:
`[SENSe:]CORRection:CVL:SELect` on page 127

Edit Table

Opens the "Edit Conversion loss table" dialog box to edit the selected conversion loss table. For details on table configuration see "Creating and Editing Conversion Loss Tables" on page 57.

Note that only common conversion loss tables (in `.acl` files) can be edited. Special B2000 tables (in `b2g` files) can only be imported and deleted.

Remote command:
`[SENSe:]CORRection:CVL:SELect` on page 127

Delete Table

Deletes the currently selected conversion loss table after you confirm the action.

Remote command:
[SENSe:]CORRection:CVL:CLEAr on page 124

Import Table

Imports a stored conversion loss table from any directory and copies it to the instrument's C:\r_s\instr\user\cvl\ directory. It can then be assigned for use for a specific frequency range (see "Conversion loss" on page 53).

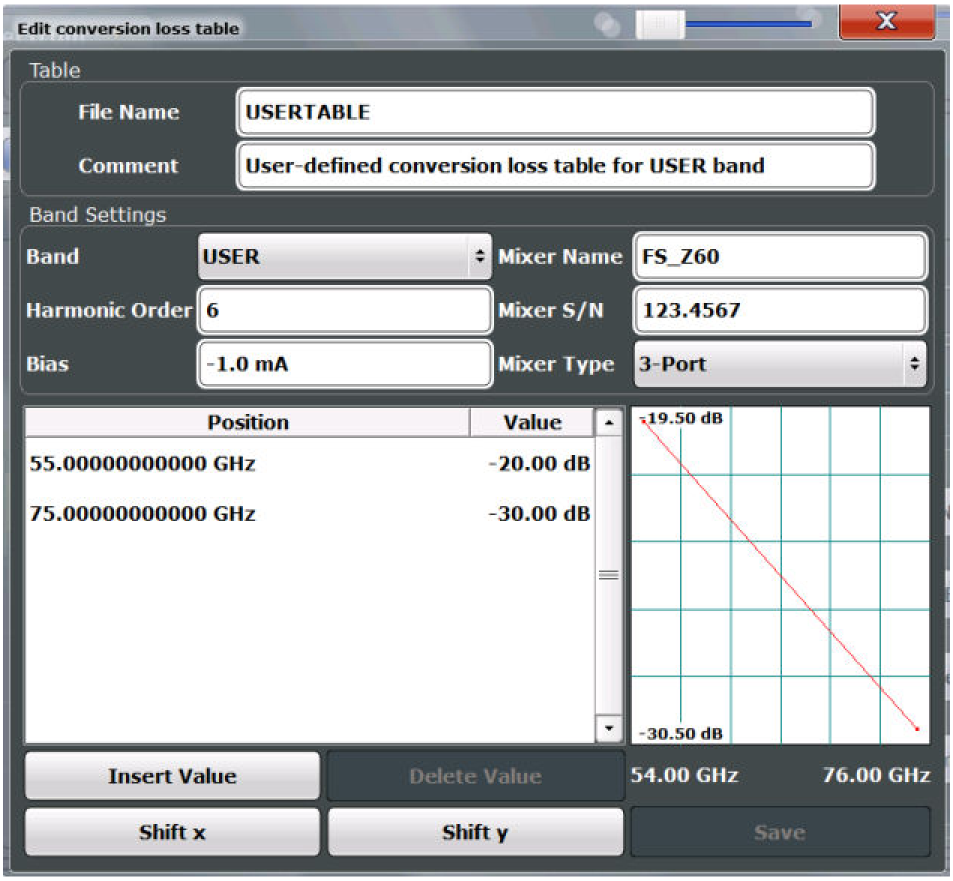
Creating and Editing Conversion Loss Tables

Access: "Overview" > "Input/Frontend" > "Input Source" > "External Mixer" > "Conversion Loss Table" > "New Table" / "Edit Table"

or: INPUT/OUTPUT > "Input Source Config" > "Input Source" > "External Mixer" > "Conversion Loss Table" > "New Table" / "Edit Table"

Conversion loss tables can be newly defined and edited.

A preview pane displays the current configuration of the conversion loss function as described by the position/value entries.



File Name

Defines the name under which the table is stored in the `C:\r_s\instr\user\cvl\` directory on the instrument. The name of the table is identical with the name of the file (without extension) in which the table is stored. This setting is mandatory. The `.ACL` extension is automatically appended during storage.

Remote command:
`[SENSe:]CORRection:CVL:SELect` on page 127

Comment

An optional comment that describes the conversion loss table. The comment can be freely defined by the user.

Remote command:
`[SENSe:]CORRection:CVL:COMMent` on page 125

Band

The waveguide or user-defined band for which the table is to be applied. This setting is checked against the current mixer setting before the table can be assigned to the range.

For a definition of the frequency range for the pre-defined bands, see table 9-4).

Remote command:
`[SENSe:]CORRection:CVL:BAND` on page 123

Harmonic Order

The harmonic order of the range for which the table is to be applied. This setting is checked against the current mixer setting before the table can be assigned to the range.

Remote command:
`[SENSe:]CORRection:CVL:HARMonic` on page 126

Bias

The bias current which is required to set the mixer to its optimum operating point. It corresponds to the short-circuit current. The bias current can range from -10 mA to 10 mA. The actual bias current is lower because of the forward voltage of the mixer diode(s).

Tip: You can also define the bias interactively while a preview of the trace with the changed setting is displayed, see "Bias Settings" on page 55.

Remote command:
`[SENSe:]CORRection:CVL:BIAS` on page 124

Mixer Name

Specifies the name of the external mixer for which the table is to be applied. This setting is checked against the current mixer setting before the table can be assigned to the range.

Remote command:
`[SENSe:]CORRection:CVL:MIXer` on page 126

Mixer S/N

Specifies the serial number of the external mixer for which the table is to be applied.

The specified number is checked against the currently connected mixer number before the table can be assigned to the range.

Remote command:
`[SENSe:]CORRection:CVL:SNUMber` on page 127

Mixer Type

Specifies whether the external mixer for which the table is to be applied is a two-port or three-port type. This setting is checked against the current mixer setting before the table can be assigned to the range.

Remote command:
`[SENSe:]CORRection:CVL:PORTs` on page 126

Position/Value

Each position/value pair defines the correction value for conversion loss for a specific frequency. The reference values must be entered in order of increasing frequencies. A maximum of 50 reference values can be entered. To enter a new value pair, select an empty space in the "Position/Value" table, or select the Insert Value button.

Correction values for frequencies between the reference values are obtained by interpolation. Linear interpolation is performed if the table contains only two values. If it contains more than two reference values, spline interpolation is carried out. Outside the frequency range covered by the table the conversion loss is assumed to be the same as that for the first and last reference value.

The current configuration of the conversion loss function as described by the position/value entries is displayed in the preview pane to the right of the table.

Remote command:
`[SENSe:]CORRection:CVL:DATA` on page 125

Insert Value
Inserts a new position/value entry in the table.

If the table is empty, a new entry at 0 Hz is inserted.

If entries already exist, a new entry is inserted above the selected entry. The position of the new entry is selected such that it divides the span to the previous entry in half.

Delete Value
Deletes the currently selected position/value entry.

Shift x
Shifts all positions in the table by a specific value. The value can be entered in the edit dialog box. The conversion loss function in the preview pane is shifted along the x-axis.

Shift y
Shifts all conversion loss values by a specific value. The value can be entered in the edit dialog box. The conversion loss function in the preview pane is shifted along the y-axis.

Save
The conversion loss table is stored under the specified name in the `C:\r_s\instr\user\cvl\` directory of the instrument.

Settings for 2 GHz Bandwidth Extension (R&S FSW-B2000)

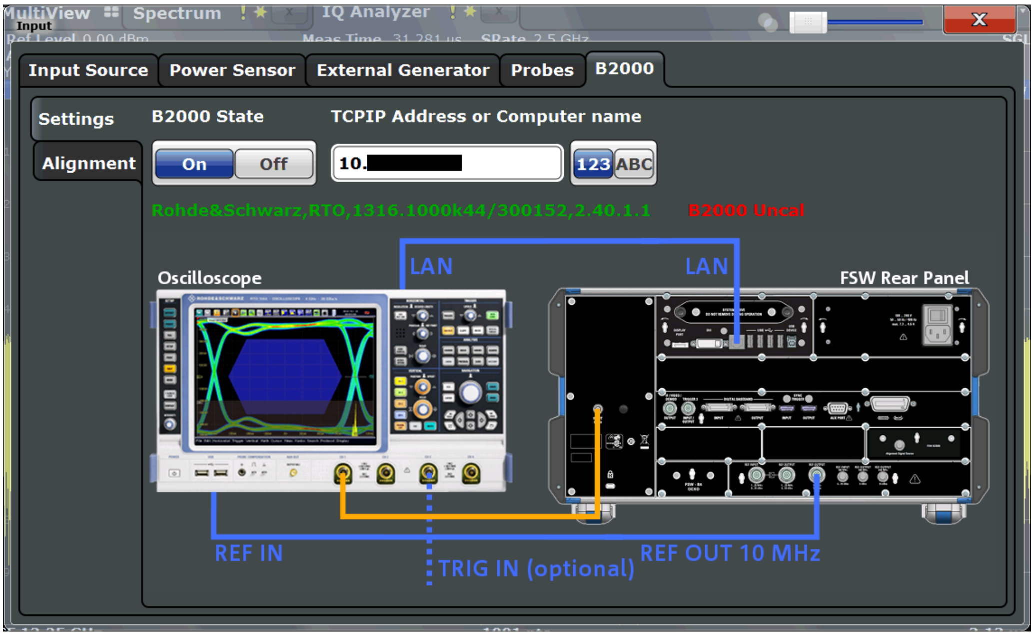
Access: INPUT/OUTPUT > "B2000 Config"

The R&S FSW 802.11ad application supports the optional 2 GHz bandwidth extension (R&S FSW-B2000), if installed.

The following settings are available for the optional 2 GHz bandwidth extension (R&S FSW-B2000).

General Settings

Access: INPUT/OUTPUT > "B2000 Config" > "Settings"



The required connections between the R&S FSW and the oscilloscope are illustrated in the dialog box.

B2000 State
Activates the optional 2 GHz bandwidth extension (R&S FSW-B2000).

Note: Manual operation on the connected oscilloscope, or remote operation other than by the R&S FSW, is not possible while the B2000 option is active.

Remote command:
`SYSTem:COMMunicate:RDEVice:OSCilloscope[:STATe]` on page 130

TCPIP Address or Computer name
When using the optional 2 GHz bandwidth extension (R&S FSW-B2000), the entire measurement via the IF OUT 2 GHZ connector and an oscilloscope, as well as both instruments, are controlled by the R&S FSW. Thus, the instruments must be connected via LAN, and the TCPIP address or computer name of the oscilloscope must be defined on the R&S FSW.

By default, the TCPIP address is expected. To enter the computer name, toggle the "123"/"ABC" button to "ABC".

As soon as a name or address is entered, the R&S FSW attempts to establish a connection to the oscilloscope. If it is detected, the oscilloscope's identity string is queried and displayed in the dialog box. The alignment status is also displayed (see "Alignment" on page 62).

Note: The IP address / computer name is maintained after a PRESET, and is transferred between applications.

Remote command:
`SYSTem:COMMunicate:RDEVice:OSCilloscope:TCPip` on page 132
`SYSTem:COMMunicate:RDEVice:OSCilloscope:IDN?` on page 131

Alignment

Access: INPUT/OUTPUT > "B2000 Config" > "Alignment"

An initial alignment of the output to the oscilloscope is required once after setup. It need only be repeated if a new oscilloscope is connected to the IF OUT 2 GHZ connector of the R&S FSW, or if a new firmware is installed on the oscilloscope.

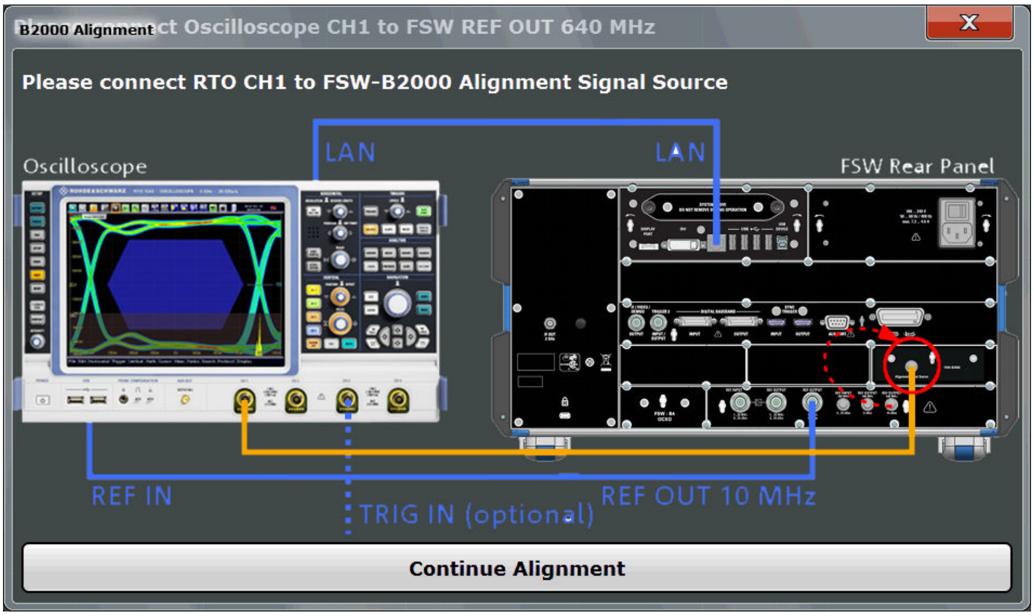
The required connections between the R&S FSW and the oscilloscope are illustrated in the dialog box.

Alignment consists of two steps. The first step requires a (temporary) connection from the REF OUTPUT 640 MHZ connector on the R&S FSW to the CH1 input on the oscilloscope.

To perform the alignment, select the "Alignment" button.

If necessary, in particular after the firmware on the oscilloscope has been updated, a self-alignment is performed on the oscilloscope before the actual B2000 alignment starts. This may take a few minutes.

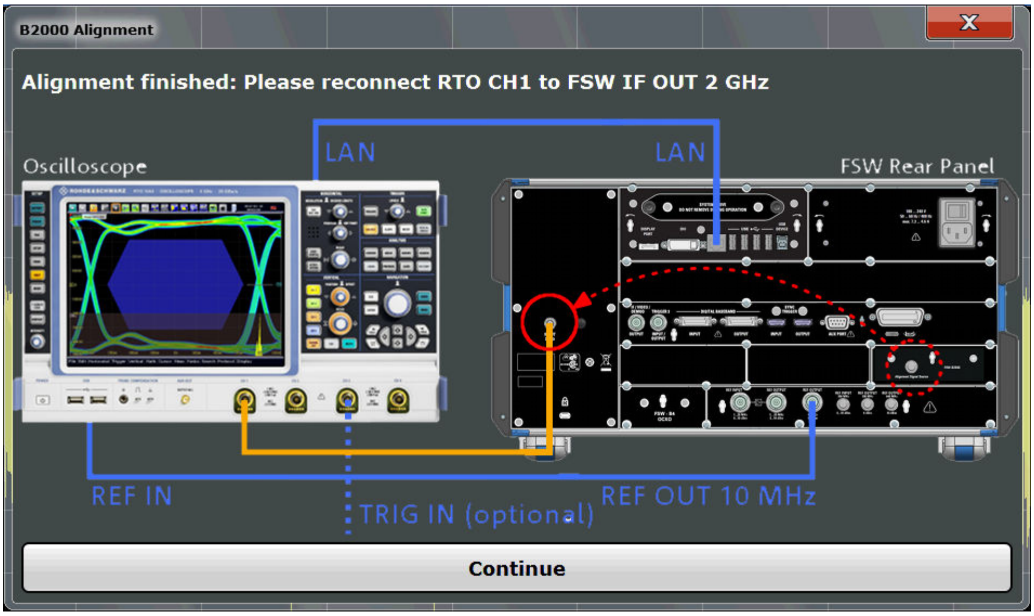
If the oscilloscope and the oscilloscope ADC are aligned successfully, a new dialog box is displayed.



For the second alignment step, the connector must be disconnected from the REF OUTPUT 640 MHZ connector and instead connected to the FSW B2000 ALIGNMENT SIGNAL SOURCE connector on the R&S FSW.

To continue the alignment, select the "Continue Alignment" button.

After the second alignment step has been completed successfully, a new dialog box is displayed.



In order to switch from alignment mode to measurement mode, move the cable from the FSW B2000 ALIGNMENT SIGNAL SOURCE back to the IF OUT 2 GHZ connector, so that it is then connected to the CH1 input on the oscilloscope.

If UNCAL is displayed, alignment was not yet performed (successfully).

If both alignment steps were performed successfully, the date of alignment is indicated.

Remote commands:

SYSTem:COMMunicate:RDEVice:OSCilloscope:ALIGnment:STEP[:STATe]? on page 131

SYSTem:COMMunicate:RDEVice:OSCilloscope:ALIGnment:DATE? on page 131

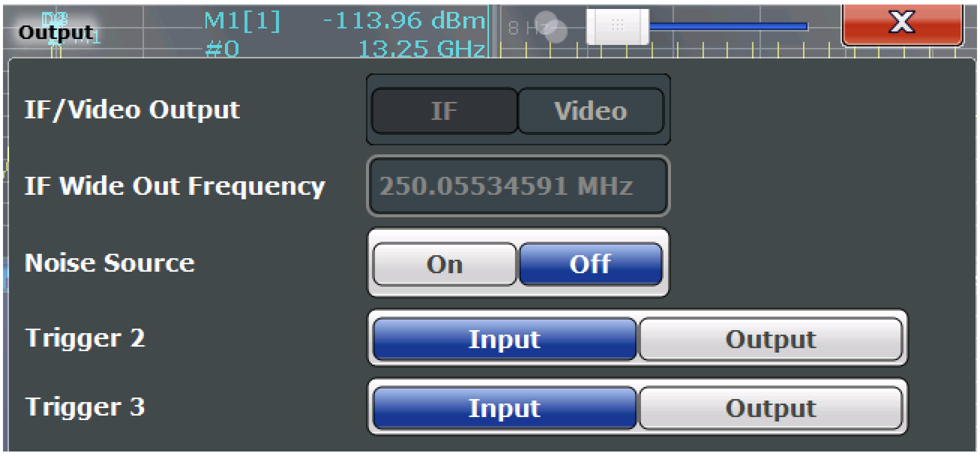
5.2.2.2 Output Settings

Access: INPUT/OUTPUT > "Output"

The R&S FSW can provide output to special connectors for other devices.

For details on connectors refer to the R&S FSW Getting Started manual, "Front / Rear Panel View" chapters.

How to provide trigger signals as output is described in detail in the R&S FSW User Manual.



IF/Video Output
Defines the type of signal available at the IF/VIDEO/DEMOD on the rear panel of the R&S FSW.

For restrictions and additional information see the R&S FSW I/Q Analyzer and I/Q Input User Manual.

"IF" The measured IF value is available at the IF/VIDEO/DEMOD output connector.
The frequency at which this value is available is defined in "IF (Wide) Out Frequency" on page 65.

"IF 2 GHz Out" The measured IF value is provided at the IF OUT 2 GHZ output connector, if available, at a frequency of 2 GHz.
If the optional 2 GHz bandwidth extension (R&S FSW-B2000) option is installed and active, this is the *only* option available for IF output. When the B2000 option is activated, the basic IF OUT 2 GHZ output is automatically deactivated. It is not reactivated when the B2000 option is switched off.
For details see the R&S FSW I/Q Analyzer and I/Q Input User Manual.

Remote command:
`OUTPut:IF[:SOURce]` on page 134

IF (Wide) Out Frequency
Defines or indicates the frequency at which the IF signal level is provided at the IF/VIDEO/DEMOD connector if IF/Video Output is set to "IF".

Note: The IF output frequency of the **IF WIDE OUTPUT** connector cannot be defined manually, but is determined automatically depending on the center frequency. It is indicated in this field when the IF WIDE OUTPUT connector is used. For details on the used frequencies see the data sheet.
The IF WIDE OUTPUT connector is used automatically instead of the IF/VIDEO/DEMOD connector if the bandwidth extension (hardware option R&S FSW-B160 / -U160) is activated (i.e. for bandwidths > 80 MHz).

Remote command:
`OUTPut:IF:IFFRequency` on page 134

Noise Source
Switches the supply voltage for an external noise source on or off.

External noise sources are useful when you are measuring power levels that fall below the noise floor of the R&S FSW itself, for example when measuring the noise level of a DUT.

Remote command:
`DIAGnostic:SERVice:NSOurce` on page 134

Trigger 2/3
Defines the usage of the variable TRIGGER INPUT/OUTPUT connectors, where:

"Trigger 2": TRIGGER INPUT/OUTPUT connector on the front panel

"Trigger 3": TRIGGER 3 INPUT/ OUTPUT connector on the rear panel

(Trigger 1 is INPUT only.)

Note: Providing trigger signals as output is described in detail in the R&S FSW User Manual.

"Input"	The signal at the connector is used as an external trigger source by the R&S FSW. Trigger input parameters are available in the "Trigger" dialog box.
"Output"	The R&S FSW sends a trigger signal to the output connector to be used by connected devices. Further trigger parameters are available for the connector.

Remote command:
`OUTPut:TRIGger<port>:LEVel` on page 147
`OUTPut:TRIGger<port>:DIRection` on page 147

Output Type ← Trigger 2/3
Type of signal to be sent to the output

"Device Triggered"	(Default) Sends a trigger when the R&S FSW triggers.
"Trigger Armed"	Sends a (high level) trigger when the R&S FSW is in "Ready for trigger" state. This state is indicated by a status bit in the `STATus:OPERation` register (bit 5), as well as by a low level signal at the AUX port (pin 9).
"User Defined"	Sends a trigger when user selects "Send Trigger" button. In this case, further parameters are available for the output signal.

Remote command:
`OUTPut:TRIGger<port>:OTYPe` on page 147

Level ← Output Type ← Trigger 2/3
Defines whether a constant high (1) or low (0) signal is sent to the output connector.

Remote command:
`OUTPut:TRIGger<port>:LEVel` on page 147

Pulse Length ← Output Type ← Trigger 2/3
Defines the length of the pulse sent as a trigger to the output connector.

Remote command:
`OUTPut:TRIGger<port>:PULSe:LENGth` on page 148

Send Trigger ← Output Type ← Trigger 2/3
Sends a user-defined trigger to the output connector immediately. Note that the trigger pulse level is always opposite to the constant signal level defined by the output "Level" setting, e.g. for "Level = High", a constant high signal is output to the connector until the "Send Trigger" button is selected. Then, a low pulse is sent.

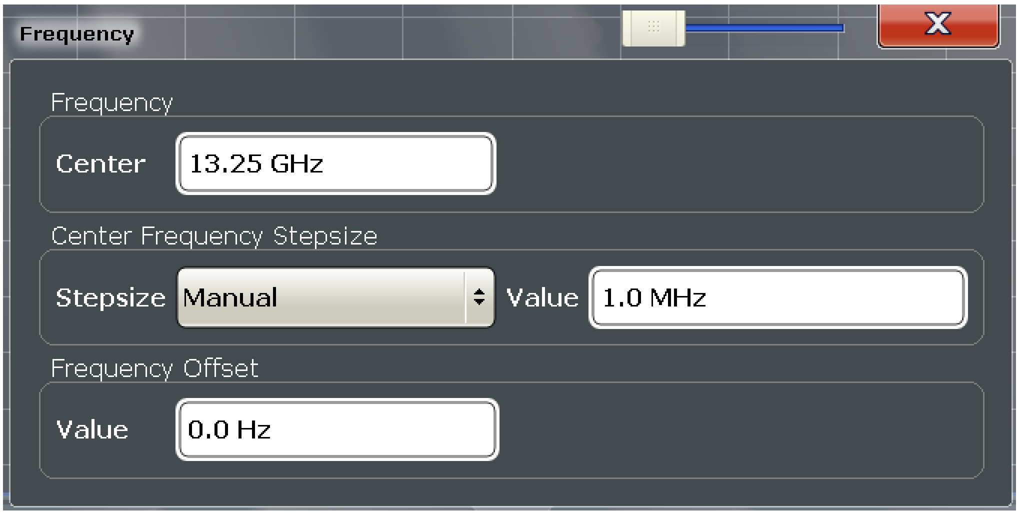
Which pulse level will be sent is indicated by a graphic on the button.

Remote command:
`OUTPut:TRIGger<port>:PULSe:IMMediate` on page 148

5.2.2.3 Frequency Settings

Access: "Overview" > "Input/Frontend" > "Frequency"

or: FREQ > "Frequency Config"



Center frequency

Defines the center frequency of the signal in Hertz.

Remote command:

`[SENSe:]FREQuency:CENTer` on page 135

Center Frequency Stepsize

Defines the step size by which the center frequency is increased or decreased using the arrow keys.

When you use the rotary knob the center frequency changes in steps of only 1/10 of the "Center Frequency Stepsize".

The step size can be coupled to another value or it can be manually set to a fixed value.

"= Center"	Sets the step size to the value of the center frequency. The used value is indicated in the "Value" field.
"Manual"	Defines a fixed step size for the center frequency. Enter the step size in the "Value" field.

Remote command:

`[SENSe:]FREQuency:CENTer:STEP` on page 136

Frequency Offset

Shifts the displayed frequency range along the x-axis by the defined offset.

This parameter has no effect on the instrument's hardware, or on the captured data or on data processing. It is simply a manipulation of the final results in which absolute frequency values are displayed. Thus, the x-axis of a spectrum display is shifted by a constant offset if it shows absolute frequencies, but not if it shows frequencies relative to the signal's center frequency.

A frequency offset can be used to correct the display of a signal that is slightly distorted by the measurement setup, for example.

The allowed values range from -100 GHz to 100 GHz. The default setting is 0 Hz.

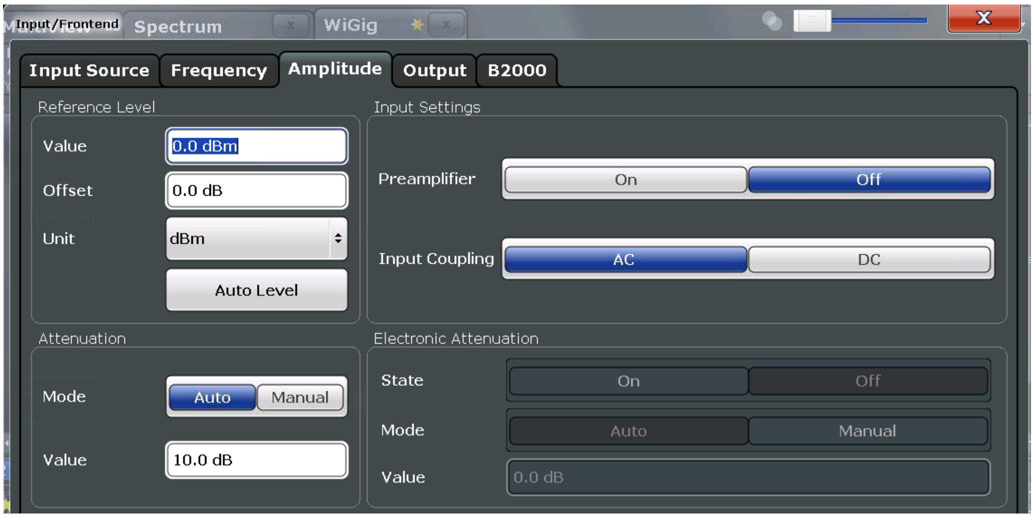
Remote command:
`[SENSe:]FREQuency:OFFSet` on page 136

5.2.2.4 Amplitude Settings

Access: "Overview" > "Input/Frontend" > "Amplitude"

or: AMPT > "Amplitude Config"

Amplitude settings determine how the R&S FSW must process or display the expected input power levels.



In the R&S FSW 802.11ad application, the impedance is fixed to 50 Ω and cannot be changed.

Reference Level

The reference level is also used to scale power diagrams; the reference level is then used as the maximum on the y-axis.

Since the hardware of the R&S FSW is adapted according to this value, it is recommended that you set the reference level close above the expected maximum signal level to ensure an optimum measurement (no compression, good signal-to-noise ratio).

Remote command:
`DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:RLEVel` on page 138

Shifting the Display (Offset) ← Reference Level
Defines an arithmetic level offset. This offset is added to the measured level. In some result displays, the scaling of the y-axis is changed accordingly.

Define an offset if the signal is attenuated or amplified before it is fed into the R&S FSW so the application shows correct power results. All displayed power level results will be shifted by this value.

The setting range is ±200 dB in 0.01 dB steps.

Note, however, that the *internal* reference level (used to adjust the hardware settings to the expected signal optimally) ignores any "Reference Level Offset". Thus, it is important to keep in mind the actual power level the R&S FSW must handle, and not to rely on the displayed reference level (internal reference level = displayed reference level - offset).

Remote command:
`DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:RLEVel:OFFSet` on page 138

Unit ← Reference Level
The R&S FSW measures the signal voltage at the RF input.

The following units are available and directly convertible:
- dBm
- dBmV
- dBμV
- dBμA
- dBpW
- Volt
- Ampere
- Watt

Remote command:
`CALCulate<n>:UNIT:POWer` on page 164

Setting the Reference Level Automatically (Auto Level) ← Reference Level
Automatically determines a reference level which ensures that no overload occurs at the R&S FSW for the current input data. At the same time, the internal attenuators and the preamplifier (for analog baseband input: the full scale level) are adjusted so the signal-to-noise ratio is optimized, while signal compression and clipping are minimized.

To determine the required reference level, a level measurement is performed on the R&S FSW.

If necessary, you can optimize the reference level further by manually decreasing the attenuation level to the lowest possible value before an overload occurs, then decreasing the reference level in the same way.

Remote command:
[SENSe:]ADJust:LEVel on page 153

RF Attenuation
Defines the attenuation applied to the RF input of the R&S FSW.

Attenuation Mode / Value ← RF Attenuation
The RF attenuation can be set automatically as a function of the selected reference level (Auto mode). This ensures that no overload occurs at the RF INPUT connector for the current reference level. It is the default setting.

By default and when electronic attenuation is not available, mechanical attenuation is applied.

In "Manual" mode, you can set the RF attenuation in 1 dB steps (down to 0 dB). Other entries are rounded to the next integer value. The range is specified in the data sheet. If the defined reference level cannot be set for the defined RF attenuation, the reference level is adjusted accordingly and the warning "Limit reached" is displayed.

NOTICE! Risk of hardware damage due to high power levels. When decreasing the attenuation manually, ensure that the power level does not exceed the maximum level allowed at the RF input, as an overload may lead to hardware damage.

Remote command:
INPut:ATTenuation on page 138
INPut:ATTenuation:AUTO on page 139

Using Electronic Attenuation
If the (optional) Electronic Attenuation hardware is installed on the R&S FSW, you can also activate an electronic attenuator.

In "Auto" mode, the settings are defined automatically; in "Manual" mode, you can define the mechanical and electronic attenuation separately.

Note: Electronic attenuation is not available for stop frequencies (or center frequencies in zero span) >13.6 GHz.
In "Auto" mode, RF attenuation is provided by the electronic attenuator as much as possible to reduce the amount of mechanical switching required. Mechanical attenuation may provide a better signal-to-noise ratio, however.

When you switch off electronic attenuation, the RF attenuation is automatically set to the same mode (auto/manual) as the electronic attenuation was set to. Thus, the RF attenuation may be set to automatic mode, and the full attenuation is provided by the mechanical attenuator, if possible.

Both the electronic and the mechanical attenuation can be varied in 1 dB steps. Other entries are rounded to the next lower integer value.

For the R&S FSW85, the mechanical attenuation can be varied only in 10 dB steps.

If the defined reference level cannot be set for the given attenuation, the reference level is adjusted accordingly and the warning "Limit reached" is displayed in the status bar.

Remote command:
INPut:EATT:STATe on page 140
INPut:EATT:AUTO on page 139
INPut:EATT on page 139

Input Settings
Some input settings affect the measured amplitude of the signal, as well.

The parameters "Input Coupling" and "Impedance" are identical to those in the "Input" settings.

See chapter 5.2.2.1, "Input Source Settings", on page 48.

Preamplifier ← Input Settings
If the (optional) Preamplifier hardware is installed, a preamplifier can be activated for the RF input signal.

You can use a preamplifier to analyze signals from DUTs with low input power.

For R&S FSW26 or higher models, the input signal is amplified by 30 dB if the preamplifier is activated.

For R&S FSW8 or 13 models, the following settings are available:

"Off"	Deactivates the preamplifier.
"15 dB"	The RF input signal is amplified by about 15 dB.
"30 dB"	The RF input signal is amplified by about 30 dB.

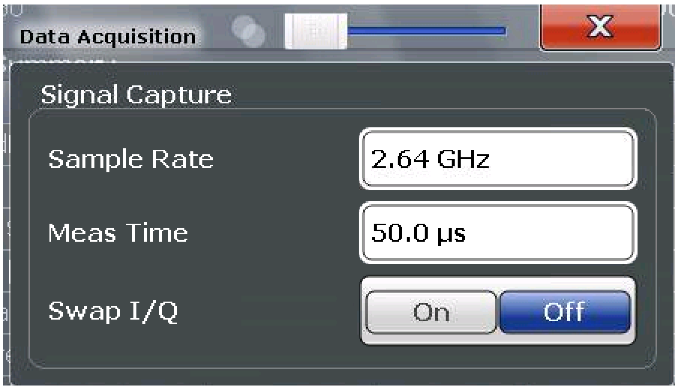
Remote command:
INPut:GAIN:STATe on page 141
INPut:GAIN[:VALue] on page 140

5.2.3 Data Acquisition

Access: "Overview" > "Data Acquisition"

or: MEAS CONFIG > "Data Acquisition"

You can define how much and how data is captured from the input signal.



Sample Rate

This is the sample rate the R&S FSW 802.11ad application expects the I/Q input data to have. For standard IEEE 802.11ad measurements, a sample rate of 2.64 MHz is used.

The R&S FSW 802.11ad application does not resample the data. To measure signals with a sample rate other than the standard 2.64 MHz for IEEE 802.11ad signals, change this setting.

Remote command:
`TRACe:IQ:SRATe` on page 142

Capture Time

Specifies the duration (and therefore the amount of data) to be captured in the capture buffer. If the capture time is too short, demodulation will fail.

Remote command:
`[SENSe:]SWEep:TIME` on page 142

Swap I/Q

Activates or deactivates the inverted I/Q modulation. If the I and Q parts of the signal from the DUT are interchanged, the R&S FSW can do the same to compensate for it.

On	I and Q signals are interchanged Inverted sideband, Q+j*I
Off	I and Q signals are not interchanged Normal sideband, I+j*Q

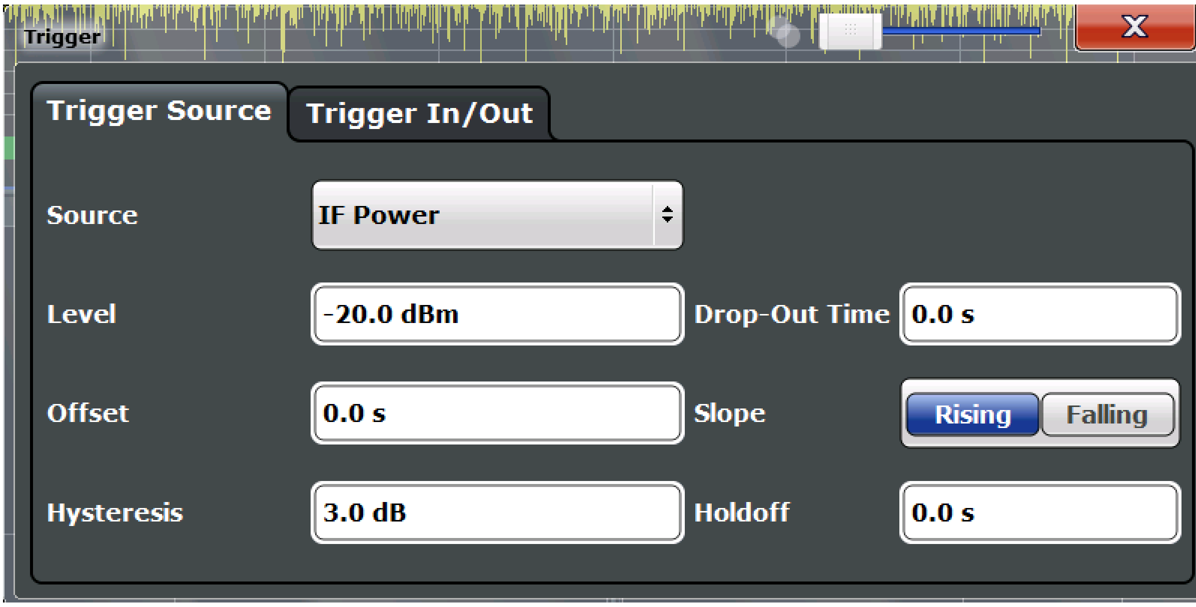
Remote command:
`[SENSe:]SWAPiq` on page 141

5.2.4 Trigger Settings

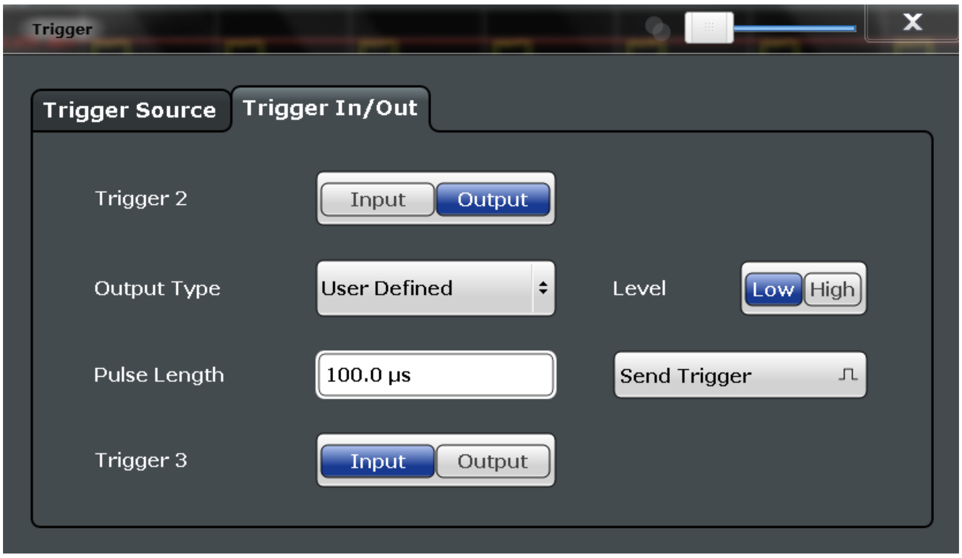
Access: "Overview" > "Trigger"

or: TRIG > "Trigger Config"

Trigger settings determine when the input signal is measured.



External triggers from one of the TRIGGER INPUT/OUTPUT connectors on the R&S FSW are configured in a separate tab of the dialog box.



For step-by-step instructions on configuring triggered measurements, see the main R&S FSW User Manual.

Trigger Source

The trigger settings define the beginning of a measurement.

Trigger Source ← Trigger Source

Defines the trigger source. If a trigger source other than "Free Run" is set, "TRG" is displayed in the channel bar and the trigger source is indicated.

Remote command:

`TRIGger[:SEQuence]:SOURce` on page 145

Free Run ← Trigger Source ← Trigger Source

No trigger source is considered. Data acquisition is started manually or automatically and continues until stopped explicitely.

Remote command:

`TRIG:SOUR IMM`, see `TRIGger[:SEQuence]:SOURce` on page 145

External Trigger 1/2/3 ← Trigger Source ← Trigger Source

Data acquisition starts when the TTL signal fed into the specified input connector meets or exceeds the specified trigger level.

(See "Trigger Level" on page 75).

Note: The "External Trigger 1" softkey automatically selects the trigger signal from the TRIGGER 1 INPUT connector on the front panel.

For details see the "Instrument Tour" chapter in the R&S FSW Getting Started manual.

"External Trigger 1"
Trigger signal from the TRIGGER 1 INPUT connector.

"External Trigger 2"
Trigger signal from the TRIGGER 2 INPUT / OUTPUT connector.

"External Trigger 3"
Trigger signal from the TRIGGER 3 INPUT/ OUTPUT connector on the rear panel.

Remote command:

`TRIG:SOUR EXT`, `TRIG:SOUR EXT2`

`TRIG:SOUR EXT3`

See `TRIGger[:SEQuence]:SOURce` on page 145

IF Power ← Trigger Source ← Trigger Source

The R&S FSW starts capturing data as soon as the trigger level is exceeded around the third intermediate frequency.

For frequency sweeps, the third IF represents the start frequency. The trigger bandwidth at the third IF depends on the RBW and sweep type.

For measurements on a fixed frequency (e.g. zero span or I/Q measurements), the third IF represents the center frequency.

This trigger source is only available for RF input.

The available trigger levels depend on the RF attenuation and preamplification. A reference level offset, if defined, is also considered.

For details on available trigger levels and trigger bandwidths see the data sheet.

Remote command:
`TRIG:SOUR IFP`, see `TRIGger[:SEQuence]:SOURce` on page 145

RF Power ← Trigger Source ← Trigger Source

Defines triggering of the measurement via signals which are outside the displayed measurement range.

For this purpose the instrument uses a level detector at the first intermediate frequency.

The input signal must be in the frequency range between 500 MHz and 8 GHz.

The resulting trigger level at the RF input depends on the RF attenuation and preamplification. For details on available trigger levels see the instrument's data sheet.

Note: If the input signal contains frequencies outside of this range (e.g. for fullspan measurements), the measurement may be aborted and a message indicating the allowed input frequencies is displayed in the status bar.

A "Trigger Offset", "Trigger Polarity" and "Trigger Holdoff" (to improve the trigger stability) can be defined for the RF trigger, but no "Hysteresis".

Remote command:
`TRIG:SOUR RFP`, see `TRIGger[:SEQuence]:SOURce` on page 145

I/Q Power ← Trigger Source ← Trigger Source

This trigger source is not available if the optional Digital Baseband Interface or optional Analog Baseband Interface is used for input. It is also not available for analysis bandwidths ≥ 160 MHz.

Triggers the measurement when the magnitude of the sampled I/Q data exceeds the trigger threshold.

Remote command:
`TRIG:SOUR IQP`, see `TRIGger[:SEQuence]:SOURce` on page 145

Trigger Level ← Trigger Source

Defines the trigger level for the specified trigger source.

For details on supported trigger levels, see the data sheet.

Remote command:
TRIGger[:SEQuence]:LEVel:IFPower on page 144
TRIGger[:SEQuence]:LEVel:IQPower on page 144
TRIGger[:SEQuence]:LEVel[:EXTernal<port>] on page 144
TRIGger[:SEQuence]:LEVel:RFPower on page 145

Drop-Out Time ← Trigger Source
Defines the time the input signal must stay below the trigger level before triggering again.

Remote command:
TRIGger[:SEQuence]:DTIMe on page 143

Trigger Offset ← Trigger Source
Defines the time offset between the trigger event and the start of the measurement.

offset > 0:	Start of the measurement is delayed
offset < 0:	Measurement starts earlier (pre-trigger)

Remote command:
TRIGger[:SEQuence]:HOLDoff[:TIME] on page 143

Hysteresis ← Trigger Source
Defines the distance in dB to the trigger level that the trigger source must exceed before a trigger event occurs. Settting a hysteresis avoids unwanted trigger events caused by noise oscillation around the trigger level.

This setting is only available for "IF Power" trigger sources. The range of the value is between 3 dB and 50 dB with a step width of 1 dB.

Remote command:
TRIGger[:SEQuence]:IFPower:HYSTeresis on page 143

Trigger Holdoff ← Trigger Source
Defines the minimum time (in seconds) that must pass between two trigger events. Trigger events that occur during the holdoff time are ignored.

Remote command:
TRIGger[:SEQuence]:IFPower:HOLDoff on page 143

Slope ← Trigger Source
For all trigger sources except time you can define whether triggering occurs when the signal rises to the trigger level or falls down to it.

Remote command:
TRIGger[:SEQuence]:SLOPe on page 145

Trigger 2/3
Defines the usage of the variable TRIGGER INPUT/OUTPUT connectors, where:

"Trigger 2": TRIGGER INPUT/OUTPUT connector on the front panel

"Trigger 3": TRIGGER 3 INPUT/ OUTPUT connector on the rear panel

(Trigger 1 is INPUT only.)

Note: Providing trigger signals as output is described in detail in the R&S FSW User Manual.

"Input"	The signal at the connector is used as an external trigger source by the R&S FSW. Trigger input parameters are available in the "Trigger" dialog box.
"Output"	The R&S FSW sends a trigger signal to the output connector to be used by connected devices. Further trigger parameters are available for the connector.

Remote command:
`OUTPut:TRIGger<port>:LEVel` on page 147
`OUTPut:TRIGger<port>:DIRection` on page 147

Output Type ← Trigger 2/3
Type of signal to be sent to the output

"Device Triggered"	(Default) Sends a trigger when the R&S FSW triggers.
"Trigger Armed"	Sends a (high level) trigger when the R&S FSW is in "Ready for trigger" state. This state is indicated by a status bit in the `STATus:OPERation` register (bit 5), as well as by a low level signal at the AUX port (pin 9).
"User Defined"	Sends a trigger when user selects "Send Trigger" button. In this case, further parameters are available for the output signal.

Remote command:
`OUTPut:TRIGger<port>:OTYPe` on page 147

Level ← Output Type ← Trigger 2/3
Defines whether a constant high (1) or low (0) signal is sent to the output connector.

Remote command:
`OUTPut:TRIGger<port>:LEVel` on page 147

Pulse Length ← Output Type ← Trigger 2/3
Defines the length of the pulse sent as a trigger to the output connector.

Remote command:
`OUTPut:TRIGger<port>:PULSe:LENGth` on page 148

Send Trigger ← Output Type ← Trigger 2/3
Sends a user-defined trigger to the output connector immediately. Note that the trigger pulse level is always opposite to the constant signal level defined by the output "Level" setting, e.g. for "Level = High", a constant high signal is output to the connector until the "Send Trigger" button is selected. Then, a low pulse is sent.

Which pulse level will be sent is indicated by a graphic on the button.

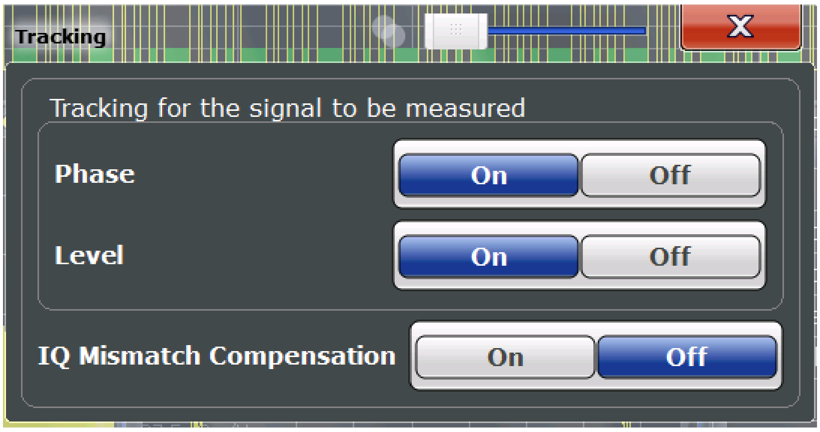
Remote command:
`OUTPut:TRIGger<port>:PULSe:IMMediate` on page 148

5.2.5 Tracking

Access: "Overview" > "Tracking"

or: MEAS CONFIG > "Tracking"

Tracking settings allow for compensation of some transmission effects in the signal (see "Phase, level and timing tracking" on page 34).



Phase Tracking

Activates or deactivates the compensation for phase drifts. If activated, the measurement results are compensated for phase drifts based on data symbol blocks (=512 symbols).

Tip: the phase drifts which will be used for compensation are displayed in the Phase Tracking vs Symbol result display.

Remote command:
`SENSe:TRACking:PHASe` on page 149

Level Error (Gain) Tracking

Activates or deactivates the compensation for level drifts within a single PPDU. If activated, the measurement results are compensated for level error on a per-symbol basis.

Remote command:
`SENSe:TRACking:LEVel` on page 149

I/Q Mismatch Compensation

Activates or deactivates the compensation for I/Q mismatch.

If activated, the measurement results are compensated for gain imbalance and quadrature offset.

Remote command:
`SENSe:TRACking:IQMComp` on page 149

5.2.6 Automatic Settings

Access: AUTO SET

Some settings can be adjusted by the R&S FSW automatically according to the current measurement settings and signal characteristics.

Setting the Reference Level Automatically (Auto Level)
Automatically determines a reference level which ensures that no overload occurs at the R&S FSW for the current input data. At the same time, the internal attenuators and the preamplifier (for analog baseband input: the full scale level) are adjusted so the signal-to-noise ratio is optimized, while signal compression and clipping are minimized.

To determine the required reference level, a level measurement is performed on the R&S FSW.

If necessary, you can optimize the reference level further by manually decreasing the attenuation level to the lowest possible value before an overload occurs, then decreasing the reference level in the same way.

Remote command:
`[SENSe:]ADJust:LEVel` on page 153

5.2.7 Sweep Settings

Access: SWEEP

The sweep settings define how the data is measured.

Continuous Sweep/RUN CONT
After triggering, starts the sweep and repeats it continuously until stopped. This is the default setting.

While the measurement is running, the "Continuous Sweep" softkey and the RUN CONT key are highlighted. The running measurement can be aborted by selecting the highlighted softkey or key again. The results are not deleted until a new measurement is started.

Note: Sequencer. Furthermore, the RUN CONT key controls the Sequencer, not individual sweeps. RUN CONT starts the Sequencer in continuous mode.

Remote command:
`INITiate<n>:CONTinuous` on page 169

Single Sweep/ RUN SINGLE
While the measurement is running, the "Single Sweep" softkey and the RUN SINGLE key are highlighted. The running measurement can be aborted by selecting the highlighted softkey or key again.

Note: Sequencer. Furthermore, the RUN SINGLE key controls the Sequencer, not individual sweeps. RUN SINGLE starts the Sequencer in single mode.
If the Sequencer is off, only the evaluation for the currently displayed measurement channel is updated.

Remote command:
`INITiate<n>[:IMMediate]` on page 169

Continue Single Sweep
After triggering, repeats the number of sweeps set in "Sweep Count", without deleting the trace of the last measurement.

While the measurement is running, the "Continue Single Sweep" softkey and the RUN SINGLE key are highlighted. The running measurement can be aborted by selecting the highlighted softkey or key again.

Capture Time
Specifies the duration (and therefore the amount of data) to be captured in the capture buffer. If the capture time is too short, demodulation will fail.

Remote command:
`[SENSe:]SWEep:TIME` on page 142

Sweep / Average Count
Defines the number of measurements to be performed in the single sweep mode. Values from 0 to 200000 are allowed. If the values 0 or 1 are set, one measurement is performed.

Remote command:
`[SENSe:]SWEep:COUNt` on page 182

5.2.8 Result Configuration

Access: "Overview" ≥ "Result Config"

or: MEAS CONFIG > "Result Config"

Some evaluation methods require or allow for additional settings to configure the result display. Note that the available settings depend on the selected window (see "Specifics for" on page 47).

5.2.8.1 Table Configuration

Access: "Overview" > "Result Config" > "Table Config"

or: MEAS CONFIG > "Result Config" > "Table Config"

During each measurement, a large number of statistical and characteristic values are determined. The Result Summary result display provides an overview of the parameters selected here.

You can configure which results are displayed in Result Summary displays (see "Result Summary" on page 27). However, the results are always *calculated*, regardless of their visibility on the screen.

Note that the "Result Configuration" dialog box is window-specific; table configuration settings are only available if a table display is selected.

Select the parameters to be included in the table. For a description of the individual parameters see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Remote command:

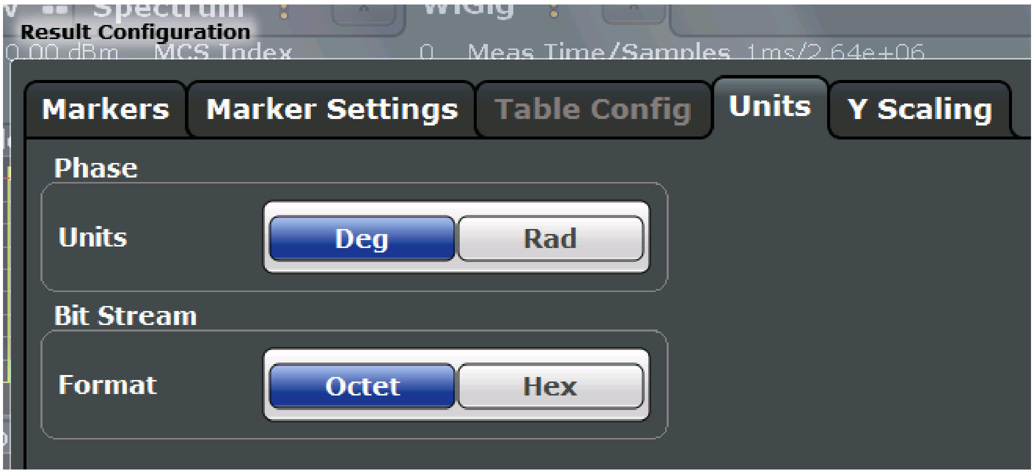
CALCulate<n>:TABLe:<GroupName>:<ParamName>, see chapter 9.7.3, "Selecting Items to Display in Result Summary", on page 163

5.2.8.2 Units

Access: "Overview" > "Result Config" > "Units"

or: MEAS CONFIG > "Result Config" > "Units"

The unit for phase display is configurable. This setting is described here.



Phase Unit
Defines the unit in which phases are displayed (degree or rad).

Remote command:
`UNIT:ANGLe` on page 164

Bitstream Format
Switches the format of the bitstream between octet and hexadecimal values.

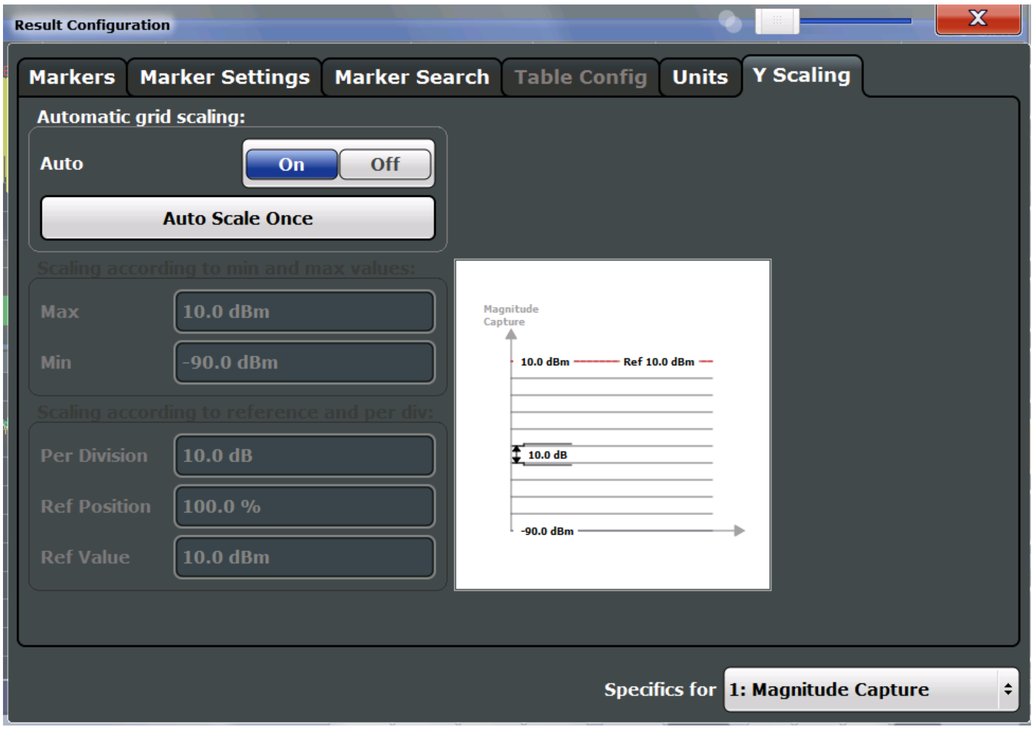
Remote command:
`FORMat:BSTReam` on page 167

5.2.8.3 Y-Scaling

Access: "Overview" > "Result Config" > "Y Scaling"

or: MEAS CONFIG > "Result Config" > "Y Scaling"

The scaling for the vertical axis in (most) graphical displays is highly configurable, using either absolute or relative values. These settings are described here.



Automatic Grid Scaling

The y-axis is scaled automatically according to the current measurement settings and results.

Remote command:

`DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:AUTO` on page 165

Auto Scale Once

Automatically determines the optimal range and reference level position to be displayed for the current measurement settings.

The display is only set once; it is not adapted further if the measurement settings are changed again.

Remote command:

`DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:AUTO` on page 165

Absolute Scaling (Min/Max Values)
Define the scaling using absolute minimum and maximum values.

Remote command:
DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:MAXimum on page 165
DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:MINimum on page 165

Relative Scaling (Reference/ per Division)
Define the scaling relative to a reference value, with a specified value range per division.

Per Division ← Relative Scaling (Reference/ per Division)
Defines the value range to be displayed per division of the diagram (1/10 of total range).

Note: The value defined per division refers to the default display of 10 divisions on the y-axis. If fewer divisions are displayed (e.g. because the window is reduced in height), the range per division is increased in order to display the same result range in the smaller window. In this case, the per division value does not correspond to the actual display.

Remote command:
DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:PDIVision on page 166

Ref Position ← Relative Scaling (Reference/ per Division)
Defines the position of the reference value in percent of the total y-axis range.

Remote command:
DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:RPOSition on page 166

Ref Value ← Relative Scaling (Reference/ per Division)
Defines the reference value to be displayed at the specified reference position.

Remote command:
DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:RVALue on page 166

5.3 SEM Measurements

Access: "Overview" > "Select Measurement"

or: MEAS > "Select Measurement"

When you activate a measurement channel in IEEE 802.11ad mode, an IQ measurement of the input signal is started automatically (see chapter 3.1, "IEEE 802.11ad Modulation Accuracy Measurement", on page 13). However, some parameters specified in the IEEE 802.11ad standard require a better signal-to-noise level or a smaller bandwidth filter than the default measurement on I/Q data provides and must be determined in separate measurements based on RF data (see chapter 3.2, "SEM Measurements", on page 28). In these measurements, demodulation is not performed.

The R&S FSW 802.11ad application uses the functionality of the R&S FSW base system (Spectrum application) to perform the IEEE 802.11ad SEM measurements. Some parameters are set automatically according to the IEEE 802.11ad standard the first time a measurement is selected (since the last PRESET operation). These parameters can be changed, but are not reset automatically the next time you re-enter the measurement. Refer to the description of each measurement type for details.

The main measurement configuration menus for the IEEE 802.11ad SEM measurements are identical to the Spectrum application.

For details refer to "Measurements" in the R&S FSW User Manual.

5.3.1 Spectrum Emission Mask

Access: "Overview" > "Select Measurement" > "SEM"

or: MEAS > "Select Measurement" > "SEM"

The Spectrum Emission Mask measurement shows the quality of the measured signal by comparing the power values in the frequency range near the carrier against a spectral mask that is defined by the IEEE 802.11ad specifications. Thus, the performance of the DUT can be tested and the emissions and their distance to the limit are identified.

Note that the IEEE 802.11ad standard does not distinguish between spurious and spectral emissions.

The Result Summary contains a peak list with the values for the largest spectral emissions including their frequency and power.

The R&S FSW 802.11ad application performs the SEM measurement as in the Spectrum application with the following settings:

Table 5-1: Predefined settings for IEEE 802.11ad SEM measurements

Setting	Default value
Number of ranges	7
Frequency Span	+/- 3.06 GHz
Fast SEM	OFF
Sweep time	1 ms to 1.88 ms (depending on range)
RBW	1 MHz
Power reference type	Peak Power
Tx Bandwidth	1.88 MHz
Number of power classes	1

For further details about the Spectrum Emission Mask measurements refer to "Spectrum Emission Mask Measurement" in the R&S FSW User Manual.

To restore adapted measurement parameters, the following parameters are saved on exiting and are restored on re-entering this measurement:

- Reference level and reference level offset
- Sweep time
- Span

The main measurement menus for the SEM measurements are identical to the Spectrum application.

Remote command:

SENS:SWE:MODE SEM

6 Analysis

After a IEEE 802.11ad measurement has been performed, you can analyze the results in various ways.

Analysis of SEM measurements

General result analysis settings concerning the trace, markers, lines etc. for RF measurements are identical to the analysis functions in the Spectrum application except for some special marker functions and spectrograms, which are not available in the R&S FSW 802.11ad application.

For details see the "Common Analysis and Display Functions" chapter in the R&S FSW User Manual.

The remote commands required to perform these tasks are described in chapter 9.9, "Analysis", on page 172.

6.1 Evaluation Range

Access: "Overview" > "Evaluation Range"

or: MEAS CONFIG > "Evaluation Range"

The evaluation range defines which objects the result displays are based on.

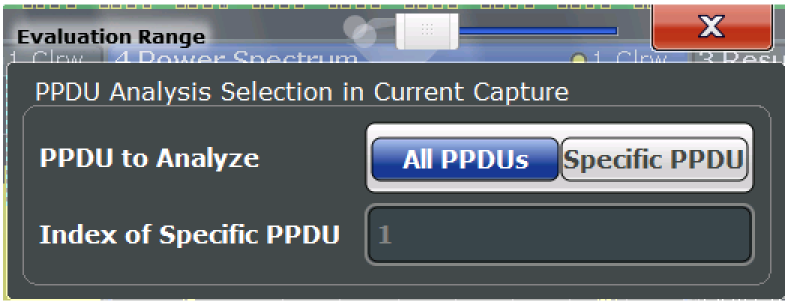


Fig. 6-1: Evaluation range settings

PPDU to Analyze / Index of Specific PPDU

If "All PPDUs" is enabled, the I/Q results are based on all PPDUs in the current capture buffer.

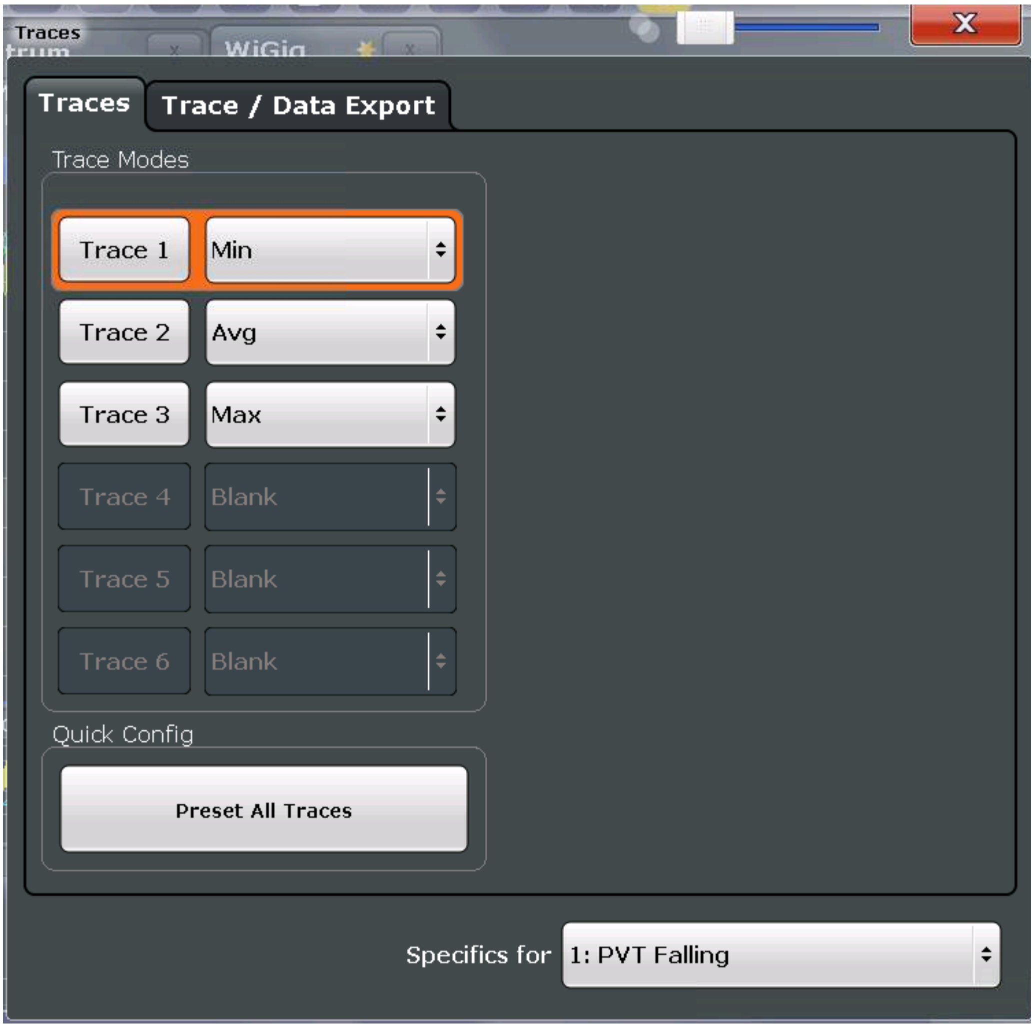
If "Specific PPDU" is enabled, the IEEE 802.11ad I/Q results are based on one individual PPDU only, namely the one with the specified index. The result displays are updated to show the results for the the new evaluation range. The selected PPDU is marked by a blue bar in PPDU-based results (see "Magnitude Capture" on page 23).

Note: Note that this setting is only applicable *after* a measurement has been performed. As soon as a new measurement is started, the evaluation range is reset to all PPDUs in the current capture buffer.

Remote command:
`[SENSe:]BURSt:SELect:STATe` on page 151
`[SENSe:]BURSt:SELect` on page 151

6.2 Trace Configuration

Access: TRACE > "Trace Config"



For the Power vs Time and Channel Frequency Response result displays, a maximum of three traces are available, for all other result displays in the R&S FSW 802.11ad application, only one trace is available. The trace modes cannot be changed.

Trace data can also be exported to an ASCII file for further analysis. For details see chapter 6.2.1, "Trace / Data Export Configuration", on page 89.

6.2.1 Trace / Data Export Configuration

Access: "Save" > "Export" > "(Trace) Export Config"

or: TRACE > "Trace Config" > "Trace/Data Export"

The standard data management functions (e.g. saving or loading instrument settings) that are available for all R&S FSW applications are not described here.

Export all Traces and all Table Results
Selects all displayed traces and result tables (e.g. Result Summary, marker table etc.) in the current application for export to an ASCII file.

Alternatively, you can select one specific trace only for export (see Trace to Export).

The results are output in the same order as they are displayed on the screen: window by window, trace by trace, and table row by table row.

Remote command:
`FORMat:DEXPort:TRACes` on page 202

Include Instrument Measurement Settings
Includes additional instrument and measurement settings in the header of the export file for result data.

Remote command:
`FORMat:DEXPort:HEADer` on page 202

Export all Traces for Selected Graph
Includes all traces for the currently selected graphical result display in the export file.

Remote command:
`FORMat:DEXPort:GRAPh` on page 202

Trace to Export
Defines an individual trace that will be exported to a file.

This setting is not available if Export all Traces and all Table Results is selected.

Decimal Separator
Defines the decimal separator for floating-point numerals for the data export files. Evaluation programs require different separators in different languages.

Remote command:
`FORMat:DEXPort:DSEParator` on page 202

Export Trace to ASCII File
Opens a file selection dialog box and saves the selected trace in ASCII format (**`.dat`**) to the specified file and directory.

The results are output in the same order as they are displayed on the screen: window by window, trace by trace, and table row by table row.

Note: Secure user mode.
In secure user mode, settings that are to be stored on the instrument are stored to volatile memory, which is restricted to 256 MB. Thus, a "Memory full" error may occur although the hard disk indicates that storage space is still available.

To store data permanently, select an external storage location such as a USB memory device.

For details see "Protecting Data Using the Secure User Mode" in the "Data Management" section of the R&S FSW User Manual.

Remote command:
`MMEMory:STORe<n>:TRACe` on page 203

6.3 Markers

Access: MKR

Markers help you analyze your measurement results by determining particular values in the diagram. Thus you can extract numeric values from a graphical display.

Markers are configured in the "Marker" dialog box which is displayed when you do one of the following:

6.3.1 Individual Marker Settings

Access: MKR > "Marker Config"

Up to 17 markers or delta markers can be activated for each window simultaneously.

Marker 1 / Marker 2 / Marker 3 / … Marker 16,/ Marker Norm/Delta
The "Marker X" softkey activates the corresponding marker and opens an edit dialog box to enter the marker position ("X-value"). Pressing the softkey again deactivates the selected marker.

Marker 1 is always the default reference marker for relative measurements. If activated, markers 2 to 16 are delta markers that refer to marker 1. These markers can be converted into markers with absolute value display using the "Marker Type" function.

Note: If normal marker 1 is the active marker, pressing the "Mkr Type" softkey switches on an additional delta marker 1.

Remote command:
`CALCulate<n>:MARKer<m>[:STATe]` on page 173
`CALCulate<n>:MARKer<m>:X` on page 174
`CALCulate<n>:MARKer<m>:Y?` on page 199
`CALCulate<n>:DELTamarker<m>[:STATe]` on page 175
`CALCulate<n>:DELTamarker<m>:X` on page 176
`CALCulate<n>:DELTamarker<m>:X:RELative?` on page 198
`CALCulate<n>:DELTamarker<m>:Y?` on page 199

Selected Marker
Marker name. The marker which is currently selected for editing is highlighted orange.

Remote command:
Marker selected via suffix <m> in remote commands.

Marker State
Activates or deactivates the marker in the diagram.

Remote command:
`CALCulate<n>:MARKer<m>[:STATe]` on page 173
`CALCulate<n>:DELTamarker<m>[:STATe]` on page 175

X-value
Defines the position of the marker on the x-axis.

Note: Setting markers in Parameter Trend Displays. In Parameter Trend displays, especially when the x-axis unit is not pulse number, positioning a marker by defining its x-axis value can be very difficult or unambiguous. Thus, markers can be positioned by defining the corresponding pulse number in the "Marker" edit field for all parameter trend displays, regardless of the displayed x-axis parameter. The "Marker" edit field is displayed when you select one of the "Marker" softkeys.

Remote command:
`CALCulate<n>:DELTamarker<m>:X` on page 176
`CALCulate<n>:MARKer<m>:X` on page 174

Marker Type
Toggles the marker type.

The type for marker 1 is always "Normal", the type for delta marker 1 is always "Delta". These types cannot be changed.

Note: If normal marker 1 is the active marker, switching the "Mkr Type" activates an additional delta marker 1. For any other marker, switching the marker type does not activate an additional marker, it only switches the type of the selected marker.

"Normal" A normal marker indicates the absolute value at the defined position in the diagram.

"Delta" A delta marker defines the value of the marker relative to the specified reference marker (marker 1 by default).

Remote command:
`CALCulate<n>:MARKer<m>[:STATe]` on page 173
`CALCulate<n>:DELTamarker<m>[:STATe]` on page 175

Reference Marker
Defines a marker as the reference marker which is used to determine relative analysis results (delta marker values).

If the reference marker is deactivated, the delta marker referring to it is also deactivated.

Remote command:
`CALCulate<n>:DELTamarker<m>:MREF` on page 175

Linking to Another Marker
Links the current marker to the marker selected from the list of active markers. If the x-axis value of the inital marker is changed, the linked marker follows on the same x-position. Linking is off by default.

Using this function you can set two markers on different traces to measure the difference (e.g. between a max hold trace and a min hold trace or between a measurement and a reference trace).

Remote command:
`CALCulate<n>:MARKer<m>:LINK:TO:MARKer<m>` on page 173
`CALCulate<n>:DELTamarker<m>:LINK:TO:MARKer<m>` on page 174
`CALCulate<n>:DELTamarker<m>:LINK` on page 174

Assigning the Marker to a Trace
The "Trace" setting assigns the selected marker to an active trace. The trace determines which value the marker shows at the marker position. If the marker was previously assigned to a different trace, the marker remains on the previous frequency or time, but indicates the value of the new trace.

If a trace is turned off, the assigned markers and marker functions are also deactivated.

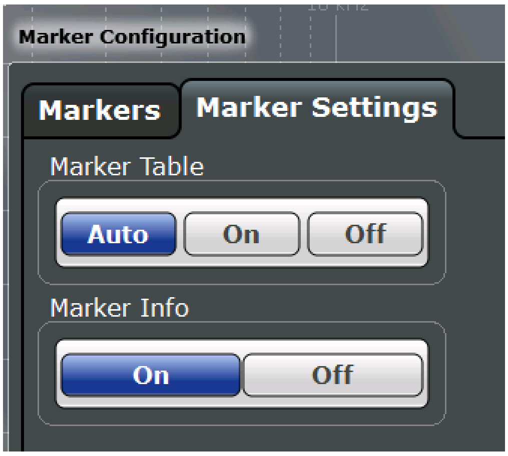
Remote command:
`CALCulate<n>:MARKer<m>:TRACe` on page 173

All Markers Off
Deactivates all markers in one step.

Remote command:
`CALCulate<n>:MARKer<m>:AOFF` on page 172

6.3.2 General Marker Settings

Access: MKR ->"Marker Config" > "Marker Settings"



Marker Table Display

Defines how the marker information is displayed.

"On"	Displays the marker information in a table in a separate area beneath the diagram.
"Off"	Displays the marker information within the diagram area.
"Auto"	(Default) Up to two markers are displayed in the diagram area. If more markers are active, the marker table is displayed automatically.

Remote command:

`DISPlay:MTABle` on page 176

7 I/Q Data Import and Export

Baseband signals mostly occur as so-called complex baseband signals, i.e. a signal representation that consists of two channels; the in phase (I) and the quadrature (Q) channel. Such signals are referred to as I/Q signals. The complete modulation information and even distortion that originates from the RF, IF or baseband domains can be analyzed in the I/Q baseband.

Importing and exporting I/Q signals is useful for various applications:

- Generating and saving I/Q signals in an RF or baseband signal generator or in external software tools to analyze them with the R&S FSW later
- Capturing and saving I/Q signals with an RF or baseband signal analyzer to analyze them with the R&S FSW or an external software tool later

For example, you can capture I/Q data using the I/Q Analyzer application, if available, and then analyze that data later using the R&S FSW 802.11ad application.

As opposed to storing trace data, which may be averaged or restricted to peak values, I/Q data is stored as it was captured, without further processing. The data is stored as complex values in 32-bit floating-point format. Multi-channel data is not supported. The I/Q data is stored in a format with the file extension `.iq.tar`.

For a detailed description see the R&S FSW I/Q Analyzer and I/Q Input User Manual.

7.1 Import/Export Functions

The following import and export functions are available via softkeys in the "Save/Recall" menu which is displayed when you select the "Save" or "Open" icon in the toolbar.

These functions are only available if no measurement is running.

In particular, if Continuous Sweep/RUN CONT is active, the import/export functions are not available.

These functions are maintained for compatibilty with other R&S FSW applications. However, it is recommended that you use the I/Q file input function in the "Input Source" settings, see "Settings for Input from I/Q Data Files" on page 49.

For a description of the other functions in the "Save/Recall" menu see the R&S FSW User Manual.

Import

Provides functions to import data.

Currently, only I/Q data can be imported, and only by applications that process I/Q data.

See the R&S FSW I/Q Analyzer User Manual for more information.

I/Q Import ← Import

Opens a file selection dialog box to select an import file that contains IQ data. This function is only available in single sweep mode and only in applications that process I/Q data, such as the I/Q Analyzer or optional applications.

Note that the I/Q data must have a specific format as described in the R&S FSW I/Q Analyzer and I/Q Input User Manual.

Remote command:
`MMEMory:LOAD:IQ:STATe` on page 200

Export

Opens a submenu to configure data export.

Export Trace to ASCII File ← Export

Opens a file selection dialog box and saves the selected trace in ASCII format (**`.dat`**) to the specified file and directory.

The results are output in the same order as they are displayed on the screen: window by window, trace by trace, and table row by table row.

Note: Secure user mode.
In secure user mode, settings that are to be stored on the instrument are stored to volatile memory, which is restricted to 256 MB. Thus, a "Memory full" error may occur although the hard disk indicates that storage space is still available.

To store data permanently, select an external storage location such as a USB memory device.

For details see "Protecting Data Using the Secure User Mode" in the "Data Management" section of the R&S FSW User Manual.

Remote command:
`MMEMory:STORe<n>:TRACe` on page 203

Trace Export Configuration ← Export

Opens the "Traces" dialog box to configure the trace and data export settings.

See chapter 6.2.1, "Trace / Data Export Configuration", on page 89.

I/Q Export ← Export

Opens a file selection dialog box to select an export file to which the IQ data will be stored. This function is only available in single sweep mode, and only in applications that process I/Q data, such as the I/Q Analyzer or optional applications.

Note: Secure user mode.
In secure user mode, settings that are to be stored on the instrument are stored to volatile memory, which is restricted to 256 MB. Thus, a "Memory full" error may occur although the hard disk indicates that storage space is still available.

To store data permanently, select an external storage location such as a USB memory device.

For details see "Protecting Data Using the Secure User Mode" in the "Data Management" section of the R&S FSW User Manual.

Remote command:
`MMEMory:STORe<n>:IQ:STATe` on page 201
`MMEMory:STORe<n>:IQ:COMMent` on page 200

7.2 How to Export and Import I/Q Data

I/Q data can only be exported in applications that process I/Q data, such as the I/Q Analyzer or optional applications.

Capturing and exporting I/Q data

1. Press the PRESET key.
2. Press the MODE key and select the R&S FSW 802.11ad application or any other application that supports I/Q data.
3. Configure the data acquisition.
4. Press the RUN SINGLE key to perform a single sweep measurement.
5. Select the "Save" icon in the toolbar.
6. Select the "I/Q Export" softkey.
7. In the file selection dialog box, select a storage location and enter a file name.
8. Select "Save".

   The captured data is stored to a file with the extension `.iq.tar`.

Using exported I/Q data as an input source

1. Press the MODE key and select the R&S FSW 802.11ad application.
2. If necessary, switch to single sweep mode by pressing the RUN SINGLE key.
3. Select the "Input/Frontend" button and switch to the "Input Source" > "IQ File" tab.
4. Select "Select File".
5. In the file selection dialog box, select the file that contains the exported I/Q data (`.iq.tar` extension).

6. Set the I/Q file state to "On".
7. Select the "Frequency" tab to define the input signal's center frequency.
8. Start a new measurement with the data from the file.
   - To perform a single sweep measurement, press the RUN SINGLE hardkey.
   - To perform a continuous sweep measurement, press the RUN CONT hardkey.

Importing I/Q data

1. Press the MODE key and select the "IQ Analyzer" or any other application that supports I/Q data.
2. If necessary, switch to single sweep mode by pressing the RUN SINGLE key.
3. Select the "Open" icon in the toolbar.
4. Select the "I/Q Import" softkey.
5. Select the storage location and the file name with the `.iq.tar` file extension.
6. Select "Open".

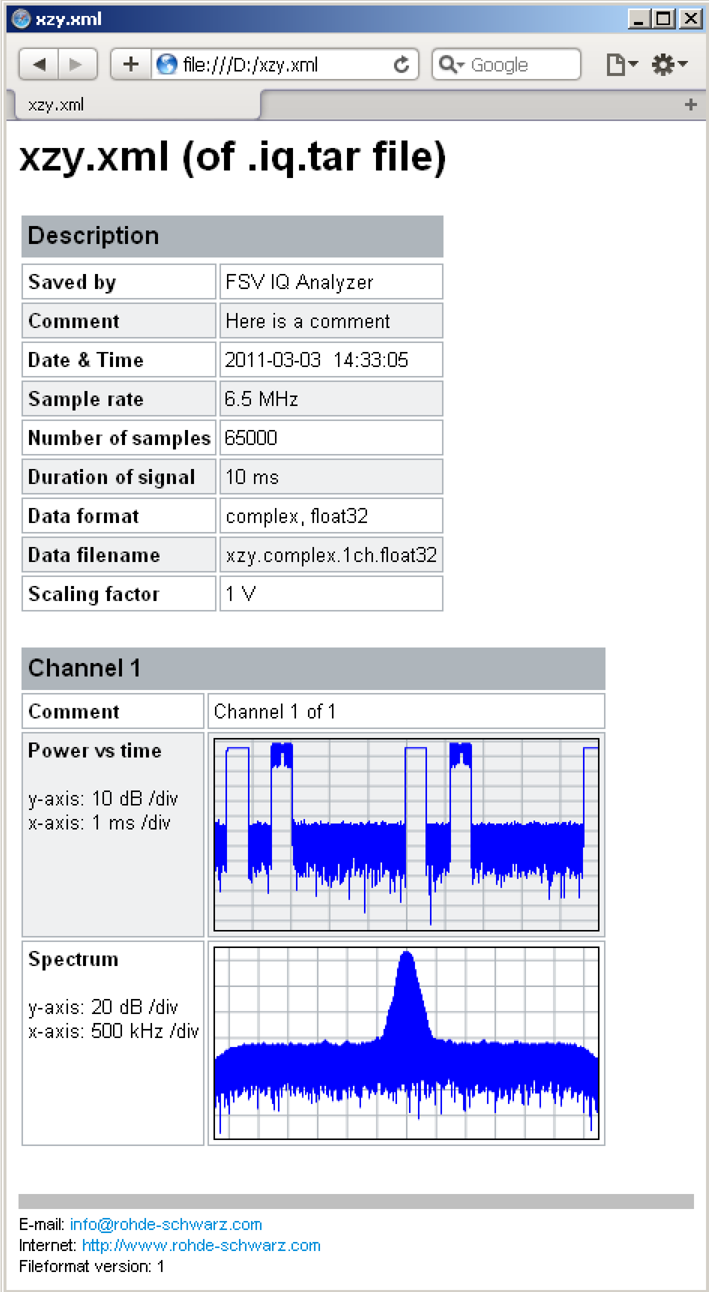
   The stored data is loaded from the file and displayed in the current application.

Previewing the I/Q data in a web browser

The `iq-tar` file format allows you to preview the I/Q data in a web browser.

1. Use an archive tool (e.g. WinZip® or PowerArchiver®) to unpack the `iq-tar` file into a folder.
2. Locate the folder using Windows Explorer.
3. Open your web browser.

4. Drag the I/Q parameter XML file, e.g. `example.xml`, into your web browser.



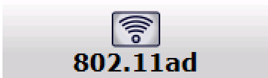
8 How to Perform Measurements in the R&S FSW 802.11ad application

The following step-by-step instructions demonstrate how to perform measurements in the R&S FSW 802.11ad application. The following tasks are described:

8.1 How to Determine Modulation Accuracy Parameters for IEEE 802.11ad Signals

1. Press the PRESET key.
2. Press the MODE key.

   A dialog box opens that contains all operating modes and applications currently available on your R&S FSW.
3. Select the "IEEE 802.11ad" item.

   The R&S FSW opens a new measurement channel for the R&S FSW 802.11ad application.
4. Select the "Overview" softkey to display the "Overview" for a IEEE 802.11ad measurement.
5. Activate the B2000 option:
   a) Select the "Input/Frontend" button and switch to the "B2000" tab.
   b) Set the "State" of the B2000 option to "On".
   c) If necessary, enter the IP address or computer name of the connected oscilloscope.
   d) Check the alignment status displayed under the IP address or computer name of the oscilloscope.

   If "UNCAL" or an error message is displayed, perform an alignment first as described in the R&S FSW I/Q Analyzer and I/Q Input User Manual.
   If the green alignment message is displayed, the R&S FSW is ready to perform a measurement.
6. Select the "Frequency" tab to define the input signal's center frequency.

7. Select the "Data Acquisition" button to define how much and which data to capture from the input signal.
8. Select the "Tracking" button to define which distortions will be compensated for.
9. Select the "Demod" button to provide information on the modulated signal and how the PPDUs detected in the capture buffer are to be demodulated.
10. Select the "Evaluation Range" button to define which data in the capture buffer you want to analyze.
11. Select the "Display Config" button and select the displays that are of interest to you (up to 16).
    Arrange them on the display to suit your preferences.
12. Exit the SmartGrid mode.
13. Start a new sweep with the defined settings.
    - To perform a single sweep measurement, press the RUN SINGLE hardkey.
    - To perform a continuous sweep measurement, press the RUN CONT hardkey.

    Measurement results are updated once the measurement has completed.

8.2 How to Determine the SEM for IEEE 802.11ad Signals

1. Press the MODE key and select the "IEEE 802.11ad" application.

   The R&S FSW opens a new measurement channel for the R&S FSW 802.11ad application. I/Q data acquisition is performed by default.
2. Select the required measurement:
   a) Press the MEAS key.
   b) In the "Select Measurement" dialog box, select the required measurement.

   The selected measurement is activated with the default settings for IEEE 802.11ad immediately.
3. Select the "Display Config" button and select the evaluation methods that are of interest to you.
   Arrange them on the display to suit your preferences.
4. Exit the SmartGrid mode and select the "Overview" softkey to display the "Overview" again.
5. Select the "Analysis" button in the "Overview" to make use of the advanced analysis functions in the result displays.
   - Configure a trace to display the average over a series of sweeps; if necessary, increase the "Sweep Count" in the "Sweep" settings.
   - Configure markers and delta markers to determine deviations and offsets within the evaluated signal.

- Use special marker functions to calculate noise or a peak list.
- Configure a limit check to detect excessive deviations.

6. Optionally, export the trace data of the graphical evaluation results to a file.
   a) In the "Traces" tab of the "Analysis" dialog box, switch to the "Trace Export" tab.
   b) Select "Export Trace to ASCII File".
   c) Define a file name and storage location and select "OK".

9 Remote Commands for IEEE 802.11ad Measurements

The following commands are required to perform measurements in the R&S FSW 802.11ad application in a remote environment.

It is assumed that the R&S FSW has already been set up for remote control in a network as described in the R&S FSW User Manual.

Note that basic tasks that are independant of the application are not described here. For a description of such tasks, see the R&S FSW User Manual.

In particular, this includes:

- Managing Settings and Results, i.e. storing and loading settings and result data
- Basic instrument configuration, e.g. checking the system configuration, customizing the screen layout, or configuring networks and remote operation
- Using the common status registers

After an introduction to SCPI commands, the following tasks specific to the R&S FSW 802.11ad application are described here:

9.1 Common Suffixes

For the description of the remote commands in the R&S FSW 802.11ad application, the following common suffixes are used:

Table 9-1: Common suffixes for IEEE 802.11ad measurements on I/Q data

Suffix	Value range	Description
<n>	1..16	Window
<k>	1..8	Limit

Suffix	Value range	Description
<t>	1	Trace
<m>	1..4	Marker

Table 9-2: Common suffixes for SEM measurements

Suffix	Value range	Description
<n>	1..16	Window
<t>	1..6	Trace
<m>	1..16	Marker
<ch>	1..18 (Tx channel) 1..11 (ALTernate or ADJacent channel)	Channel
<k>	1..8	Limit line

9.2 Introduction

Commands are program messages that a controller (e.g. a PC) sends to the instrument or software. They operate its functions ('setting commands' or 'events') and request information ('query commands'). Some commands can only be used in one way, others work in two ways (setting and query). If not indicated otherwise, the commands can be used for settings and queries.

The syntax of a SCPI command consists of a header and, in most cases, one or more parameters. To use a command as a query, you have to append a question mark after the last header element, even if the command contains a parameter.

A header contains one or more keywords, separated by a colon. Header and parameters are separated by a "white space" (ASCII code 0 to 9, 11 to 32 decimal, e.g. blank). If there is more than one parameter for a command, these are separated by a comma from one another.

Only the most important characteristics that you need to know when working with SCPI commands are described here. For a more complete description, refer to the User Manual of the R&S FSW.

Remote command examples

Note that some remote command examples mentioned in this general introduction may not be supported by this particular application.

9.2.1 Conventions used in Descriptions

Note the following conventions used in the remote command descriptions:

- **Command usage**

If not specified otherwise, commands can be used both for setting and for querying parameters.
If a command can be used for setting or querying only, or if it initiates an event, the usage is stated explicitely.

- **Parameter usage**
  If not specified otherwise, a parameter can be used to set a value and it is the result of a query.
  Parameters required only for setting are indicated as **Setting parameters**.
  Parameters required only to refine a query are indicated as **Query parameters**.
  Parameters that are only returned as the result of a query are indicated as **Return values**.
- **Conformity**
  Commands that are taken from the SCPI standard are indicated as **SCPI confirmed**. All commands used by the R&S FSW follow the SCPI syntax rules.
- **Asynchronous commands**
  A command which does not automatically finish executing before the next command starts executing (overlapping command) is indicated as an **Asynchronous command**.
- **Reset values (*RST)**
  Default parameter values that are used directly after resetting the instrument (`*RST` command) are indicated as ***RST** values, if available.
- **Default unit**
  This is the unit used for numeric values if no other unit is provided with the parameter.
- **Manual operation**
  If the result of a remote command can also be achieved in manual operation, a link to the description is inserted.

9.2.2 Long and Short Form

The keywords have a long and a short form. You can use either the long or the short form, but no other abbreviations of the keywords.

The short form is emphasized in upper case letters. Note however, that this emphasis only serves the purpose to distinguish the short from the long form in the manual. For the instrument, the case does not matter.

Example:

`SENSe:FREQuency:CENTer` is the same as `SENS:FREQ:CENT`.

9.2.3 Numeric Suffixes

Some keywords have a numeric suffix if the command can be applied to multiple instances of an object. In that case, the suffix selects a particular instance (e.g. a measurement window).

Numeric suffixes are indicated by angular brackets (<n>) next to the keyword.

If you don't quote a suffix for keywords that support one, a 1 is assumed.

Example:

`DISPlay[:WINDow<1...4>]:ZOOM:STATe` enables the zoom in a particular measurement window, selected by the suffix at `WINDow`.

`DISPlay:WINDow4:ZOOM:STATe ON` refers to window 4.

9.2.4 Optional Keywords

Some keywords are optional and are only part of the syntax because of SCPI compliance. You can include them in the header or not.

Note that if an optional keyword has a numeric suffix and you need to use the suffix, you have to include the optional keyword. Otherwise, the suffix of the missing keyword is assumed to be the value 1.

Optional keywords are emphasized with square brackets.

Example:

Without a numeric suffix in the optional keyword:

`[SENSe:]FREQuency:CENTer` is the same as `FREQuency:CENTer`

With a numeric suffix in the optional keyword:

`DISPlay[:WINDow<1...4>]:ZOOM:STATe`

`DISPlay:ZOOM:STATe ON` enables the zoom in window 1 (no suffix).

`DISPlay:WINDow4:ZOOM:STATe ON` enables the zoom in window 4.

9.2.5 Alternative Keywords

A vertical stroke indicates alternatives for a specific keyword. You can use both keywords to the same effect.

Example:

`[SENSe:]BANDwidth|BWIDth[:RESolution]`

In the short form without optional keywords, `BAND 1MHZ` would have the same effect as `BWID 1MHZ`.

9.2.6 SCPI Parameters

Many commands feature one or more parameters.

If a command supports more than one parameter, these are separated by a comma.

Example:

`LAYout:ADD:WINDow Spectrum,LEFT,MTABle`

Parameters may have different forms of values.

9.2.6.1 Numeric Values

Numeric values can be entered in any form, i.e. with sign, decimal point or exponent. In case of physical quantities, you can also add the unit. If the unit is missing, the command uses the basic unit.

Example:

with unit: `SENSe:FREQuency:CENTer 1GHZ`

without unit: `SENSe:FREQuency:CENTer 1E9` would also set a frequency of 1 GHz.

Values exceeding the resolution of the instrument are rounded up or down.

If the number you have entered is not supported (e.g. in case of discrete steps), the command returns an error.

Instead of a number, you can also set numeric values with a text parameter in special cases.

- MIN/MAX
  Defines the minimum or maximum numeric value that is supported.
- DEF
  Defines the default value.
- UP/DOWN
  Increases or decreases the numeric value by one step. The step size depends on the setting. In some cases you can customize the step size with a corresponding command.

Querying numeric values

When you query numeric values, the system returns a number. In case of physical quantities, it applies the basic unit (e.g. Hz in case of frequencies). The number of digits after the decimal point depends on the type of numeric value.

Example:

Setting: `SENSe:FREQuency:CENTer 1GHZ`

Query: `SENSe:FREQuency:CENTer?` would return `1E9`

In some cases, numeric values may be returned as text.

- INF/NINF
  Infinity or negative infinity. Represents the numeric values 9.9E37 or -9.9E37.
- NAN

Not a number. Represents the numeric value 9.91E37. NAN is returned in case of errors.

9.2.6.2 Boolean

Boolean parameters represent two states. The "ON" state (logically true) is represented by "ON" or a numeric value 1. The "OFF" state (logically untrue) is represented by "OFF" or the numeric value 0.

Querying boolean parameters

When you query boolean parameters, the system returns either the value 1 ("ON") or the value 0 ("OFF").

Example:

Setting: `DISPlay:WINDow:ZOOM:STATe ON`

Query: `DISPlay:WINDow:ZOOM:STATe?` would return `1`

9.2.6.3 Character Data

Character data follows the syntactic rules of keywords. You can enter text using a short or a long form. For more information see chapter 9.2.2, "Long and Short Form", on page 105.

Querying text parameters

When you query text parameters, the system returns its short form.

Example:

Setting: `SENSe:BANDwidth:RESolution:TYPE NORMal`

Query: `SENSe:BANDwidth:RESolution:TYPE?` would return `NORM`

9.2.6.4 Character Strings

Strings are alphanumeric characters. They have to be in straight quotation marks. You can use a single quotation mark (') or a double quotation mark (").

Example:

`INSTRument:DELete 'Spectrum'`

9.2.6.5 Block Data

Block data is a format which is suitable for the transmission of large amounts of data.

The ASCII character # introduces the data block. The next number indicates how many of the following digits describe the length of the data block. In the example the 4 following digits indicate the length to be 5168 bytes. The data bytes follow. During the transmission of these data bytes all end or other control signs are ignored until all bytes are transmitted. #0 specifies a data block of indefinite length. The use of the indefinite format requires a NL^END message to terminate the data block. This format is useful when the length of the transmission is not known or if speed or other considerations prevent segmentation of the data into blocks of definite length.

9.3 Activating IEEE 802.11ad measurements

IEEE 802.11ad measurements require a special application on the R&S FSW (R&S FSW-K91). The measurement is started immediately with the default settings.

These are basic R&S FSW commands, listed here for your convenience.

INSTrument:CREate:DUPLicate

This command duplicates the currently selected measurement channel, i.e creates a new measurement channel of the same type and with the identical measurement settings. The name of the new channel is the same as the copied channel, extended by a consecutive number (e.g. "IQAnalyzer" -> "IQAnalyzer2").

The channel to be duplicated must be selected first using the `INST:SEL` command.

Example:
```
INST:SEL 'IQAnalyzer'
INST:CRE:DUPL
```
Duplicates the channel named 'IQAnalyzer' and creates a new measurement channel named 'IQAnalyzer2'.

Usage: Event

INSTrument:CREate[:NEW] <ChannelType>, <ChannelName>

This command adds an additional measurement channel.

The number of measurement channels you can configure at the same time depends on available memory.

Parameters:

<ChannelType> Channel type of the new channel.
For a list of available channel types see `INSTrument:LIST?` on page 110.

<ChannelName> String containing the name of the channel. The channel name is displayed as the tab label for the measurement channel.
Note: If the specified name for a new channel already exists, the default name, extended by a sequential number, is used for the new channel (see INSTrument:LIST? on page 110).

Example: `INST:CRE IQ, 'IQAnalyzer2'`
Adds an additional I/Q Analyzer channel named "IQAnalyzer2".

INSTrument:CREate:REPLace <ChannelName1>,<ChannelType>,<ChannelName2>

This command replaces a measurement channel with another one.

Setting parameters:

<ChannelName1> String containing the name of the measurement channel you want to replace.

<ChannelType> Channel type of the new channel.
For a list of available channel types see INSTrument:LIST? on page 110.

<ChannelName2> String containing the name of the new channel.
Note: If the specified name for a new channel already exists, the default name, extended by a sequential number, is used for the new channel (see INSTrument:LIST? on page 110).

Example: `INST:CRE:REPL 'IQAnalyzer2',IQ,'IQAnalyzer'`
Replaces the channel named 'IQAnalyzer2' by a new measurement channel of type 'IQ Analyzer' named 'IQAnalyzer'.

Usage: Setting only

INSTrument:DELete <ChannelName>

This command deletes a measurement channel.

If you delete the last measurement channel, the default "Spectrum" channel is activated.

Parameters:

<ChannelName> String containing the name of the channel you want to delete.
A measurement channel must exist in order to be able delete it.

Example: `INST:DEL 'IQAnalyzer4'`
Deletes the channel with the name 'IQAnalyzer4'.

Usage: Event

INSTrument:LIST?

This command queries all active measurement channels. This is useful in order to obtain the names of the existing measurement channels, which are required in order to replace or delete the channels.

Return values:

<ChannelType>, <ChannelName>
For each channel, the command returns the channel type and channel name (see tables below).
Tip: to change the channel name, use the `INSTrument:REName` command.

Example:
`INST:LIST?`
Result for 3 measurement channels:
`'ADEM','Analog Demod','IQ','IQ Analyzer','IQ','IQ Analyzer2'`

Usage: Query only

Table 9-3: Available measurement channel types and default channel names in Signal and Spectrum Analyzer mode

Application	<ChannelType> Parameter	Default Channel Name*)
Spectrum	SANALYZER	Spectrum
I/Q Analyzer	IQ	IQ Analyzer
Pulse (R&S FSW-K6)	PULSE	Pulse
Analog Demodulation (R&S FSW-K7)	ADEM	Analog Demod
GSM (R&S FSW-K10)	GSM	GSM
Multi-Carrier Group Delay (R&S FSW-K17)	MCGD	MC Group Delay
Amplifier Measurements (R&S FSW-K18)	AMPLifier	Amplifier
Noise (R&S FSW-K30)	NOISE	Noise
Phase Noise (R&S FSW-K40)	PNOISE	Phase Noise
Transient Analysis (R&S FSW-K60)	TA	Transient Analysis
VSA (R&S FSW-K70)	DDEM	VSA
3GPP FDD BTS (R&S FSW-K72)	BWCD	3G FDD BTS
3GPP FDD UE (R&S FSW-K73)	MWCD	3G FDD UE
TD-SCDMA BTS (R&S FSW-K76)	BTDS	TD-SCDMA BTS
TD-SCDMA UE (R&S FSW-K77)	MTDS	TD-SCDMA UE
cdma2000 BTS (R&S FSW-K82)	BC2K	CDMA2000 BTS
cdma2000 MS (R&S FSW-K83)	MC2K	CDMA2000 MS
1xEV-DO BTS (R&S FSW-K84)	BDO	1xEV-DO BTS
1xEV-DO MS (R&S FSW-K85)	MDO	1xEV-DO MS
WLAN (R&S FSW-K91)	WLAN	WLAN
802.11ad (R&S FSW-K95)	WIGIG	802.11ad
LTE (R&S FSW-K10x)	LTE	LTE
*) the default channel name is also listed in the table. If the specified name for a new channel already exists, the default name, extended by a sequential number, is used for the new channel.		

Application	<ChannelType> Parameter	Default Channel Name*)
Real-Time Spectrum (R&S FSW-B160R/-K160RE)	RTIM	Real-Time Spectrum
DOCSIS 3.1 (R&S FSW-K192/193)	DOCSis	DOCSIS 3.1
*) the default channel name is also listed in the table. If the specified name for a new channel already exists, the default name, extended by a sequential number, is used for the new channel.		

INSTrument:REName <ChannelName1>, <ChannelName2>

This command renames a measurement channel.

Parameters:

<ChannelName1> String containing the name of the channel you want to rename.

<ChannelName2> String containing the new channel name.
Note that you can not assign an existing channel name to a new channel; this will cause an error.

Example: `INST:REN 'IQAnalyzer2','IQAnalyzer3'`
Renames the channel with the name 'IQAnalyzer2' to 'IQAnalyzer3'.

Usage: Setting only

INSTrument[:SELect] <ChannelType> | <ChannelName>

This command activates a new measurement channel with the defined channel type, or selects an existing measurement channel with the specified name.

See also `INSTrument:CREate[:NEW]` on page 109.

For a list of available channel types see `INSTrument:LIST?` on page 110.

Parameters:

<ChannelType> Channel type of the new channel.
For a list of available channel types see table 9-3.

WIGIG
802.11ad option, R&S FSW–K95

<ChannelName> String containing the name of the channel.

Example: `INST WIGIG`
Activates a measurement channel for the R&S FSW 802.11ad application.
`INST '802.11ad'`
Selects the measurement channel named '802.11ad' (for example before executing further commands for that channel).

SYSTem:PRESet:CHANnel[:EXECute]

This command restores the default instrument settings in the current channel.

Use `INST:SEL` to select the channel.

Example: `INST 'Spectrum2'`
Selects the channel for "Spectrum2".
`SYST:PRES:CHAN:EXEC`
Restores the factory default settings to the "Spectrum2" channel.

Usage: Event

Manual operation: See "Preset Channel" on page 47

9.4 Selecting a Measurement

The following commands are required to define the measurement type in a remote environment. The selected measurement must be started explicitely (see chapter 9.8, "Starting a Measurement", on page 167)!

For details on available measurements see chapter 3, "Measurements and Result Displays", on page 13.

The IEEE 802.11ad Modulation Accuracy measurement captures the I/Q data from the IEEE 802.11ad signal using a (nearly rectangular) filter with a relatively large bandwidth. This measurement is selected when the IEEE 802.11ad measurement channel is activated. The commands to select a different measurement or return to the IEEE 802.11ad Modulation Accuracy measurement are described here.

Note that the `CONF:BURS:<ResultType>:IMM` commands change the screen layout to display the Magnitude Capture buffer in window 1 at the top of the screen and the selected result type in window 2 below that. Any other active windows are closed.

Use the `LAYout` commands to change the display (see chapter 9.7, "Configuring the Result Display", on page 155).

9.4.1 Selecting the IEEE 802.11ad Modulation Accuracy Measurement

Any of the following commands can be used to return to the IEEE 802.11ad Modulation Accuracy measurement. Each of these results are automatically determined when the IEEE 802.11ad Modulation Accuracy measurement is performed.

9.4.2 Selecting a Common RF Measurement for IEEE 802.11ad Signals

The following commands are required to select a common RF measurement for IEEE 802.11ad signals in a remote environment.

For details on available measurements see chapter 3.2, "SEM Measurements", on page 28.

[SENSe:]SWEep:MODE <Mode>

Selects the measurement to be performed.

Parameters:

<Mode> AUTO | ESPectrum

AUTO
Standard IEEE 802.11ad I/Q measurement

ESPectrum
Spectrum emission mask measurement

*RST: AUTO

Example: `SENS:SWE:MODE ESP`

9.5 Configuring the IEEE 802.11ad Modulation Accuracy Measurement

The following commands are required to configure the IEEE 802.11ad Modulation Accuracy measurement described in chapter 3.1, "IEEE 802.11ad Modulation Accuracy Measurement", on page 13.

9.5.1 Configuring the Data Input and Output

9.5.1.1 RF Input

INPut:ATTenuation:PROTection:RESet

This command resets the attenuator and reconnects the RF input with the input mixer after an overload condition occured and the protection mechanism intervened.The error status bit (bit 3 in the `STAT:QUES:POW` status register) and the `INPUT OVLD` message in the status bar are cleared.

The command works only if the overload condition has been eliminated first.

Usage: Event

INPut:COUPling <CouplingType>

This command selects the coupling type of the RF input.

Parameters:

<CouplingType>

AC
AC coupling

DC
DC coupling

*RST: AC

Example: `INP:COUP DC`

Usage: SCPI confirmed

Manual operation: See "Input Coupling" on page 49

INPut:SELect <Source>

This command selects the signal source for measurements, i.e. it defines which connector is used to input data to the R&S FSW.

Parameters:

<Source>

RF
Radio Frequency ("RF INPUT" connector)

FIQ
I/Q data file (selected by `INPut:FILE:PATH` on page 116)
For details see chapter 4.3.2, "Basics on Input from I/Q Data Files", on page 37.

*RST: RF

Manual operation: See "Radio Frequency State" on page 48
See "I/Q Input File State" on page 50

9.5.1.2 Input from I/Q Data Files

The input for measurements can be provided from I/Q data files.The commands required to configure the use of such files are described here.

For details see chapter 4.3.2, "Basics on Input from I/Q Data Files", on page 37.

Useful commands for retrieving results described elsewhere:

- `INPut:SELect` on page 115

Remote commands exclusive to input from I/Q data files:

INPut:FILE:PATH <FileName>

This command selects the I/Q data file to be used as input for further measurements.

The I/Q data must have a specific format as described in chapter A.2, "I/Q Data File Format (iq-tar)", on page 211.

For details see chapter 4.3.2, "Basics on Input from I/Q Data Files", on page 37.

Parameters:

<FileName> String containing the path and name of the source file. The file extension is `*.iq.tar`.

Example: `INP:FILE:PATH 'C:\R_S\Instr\user\data.iq.tar'`
Uses I/Q data from the specified file as input.

Usage: Setting only

Manual operation: See "Select I/Q Data File" on page 50

9.5.1.3 Using External Mixers

The commands required to work with external mixers in a remote environment are described here. Note that these commands require the R&S FSW-B21 option to be installed and an external mixer to be connected to the front panel of the R&S FSW.

For details on working with external mixers see the R&S FSW User Manual.

Basic Settings

The basic settings concern general usage of an external mixer.

[SENSe:]MIXer[:STATe] <State>

Activates or deactivates the use of a connected external mixer as input for the measurement. This command is only available if the optional External Mixer is installed and an external mixer is connected.

Parameters:

<State> ON | OFF

*RST: OFF

Example: `MIX ON`

Manual operation: See "External Mixer State" on page 51

[SENSe:]MIXer:BIAS:HIGH <BiasSetting>

This command defines the bias current for the high (second) range.

This command is only available if the external mixer is active (see `[SENSe:]MIXer[:STATe]` on page 117).

Parameters:

<BiasSetting> *RST: 0.0 A

Default unit: A

Manual operation: See "Bias Settings" on page 55

[SENSe:]MIXer:BIAS[:LOW] <BiasSetting>

This command defines the bias current for the low (first) range.

This command is only available if the external mixer is active (see `[SENSe:]MIXer[:STATe]` on page 117).

Parameters:

<BiasSetting> *RST: 0.0 A

Default unit: A

Manual operation: See "Bias Settings" on page 55

[SENSe:]MIXer:LOPower <Level>

This command specifies the LO level of the external mixer's LO port.

Parameters:

<Level> numeric value

Range: 13.0 dBm to 17.0 dBm

Increment: 0.1 dB

*RST: 15.5 dBm

Example: `MIX:LOP 16.0dBm`

Manual operation: See "LO Level" on page 54

[SENSe:]MIXer:SIGNal <State>

This command specifies whether automatic signal detection is active or not.

Note that automatic signal identification is only available for measurements that perform frequency sweeps (not in vector signal analysis or the I/Q Analyzer, for instance).

Parameters:

<State> **OFF | ON | AUTO | ALL**

OFF
No automatic signal detection is active.

ON
Automatic signal detection (Signal ID) is active.

AUTO
Automatic signal detection (Auto ID) is active.

ALL
Both automatic signal detection functions (Signal ID+Auto ID) are active.

*RST: OFF

Manual operation: See "Signal ID" on page 54
See "Auto ID" on page 55

[SENSe:]MIXer:THReshold <Value>

This command defines the maximum permissible level difference between test sweep and reference sweep to be corrected during automatic comparison (see `[SENSe:]MIXer:SIGNal` on page 118).

Parameters:

<Value> <numeric value>

Range: 0.1 dB to 100 dB
*RST: 10 dB

Example: `MIX:PORT 3`

Manual operation: See "Auto ID Threshold" on page 55

Mixer Settings

The following commands are required to configure the band and specific mixer settings.

[SENSe:]MIXer:FREQuency:HANDover <Frequency>

This command defines the frequency at which the mixer switches from one range to the next (if two different ranges are selected). The handover frequency for each band can be selected freely within the overlapping frequency range.

This command is only available if the external mixer is active (see `[SENSe:]MIXer[:STATe]` on page 117).

Parameters:

<Frequency> numeric value

Example: `MIX ON`
Activates the external mixer.
`MIX:FREQ:HAND 78.0299GHz`
Sets the handover frequency to 78.0299 GHz.

Manual operation: See "Handover Freq." on page 52

[SENSe:]MIXer:FREQuency:STARt?

This command queries the frequency at which the external mixer band starts.

Example: `MIX:FREQ:STAR?`
Queries the start frequency of the band.

Usage: Query only

Manual operation: See "RF Start / RF Stop" on page 51

[SENSe:]MIXer:FREQuency:STOP?

This command queries the frequency at which the external mixer band stops.

Example: `MIX:FREQ:STOP?`
Queries the stop frequency of the band.

Usage: Query only

Manual operation: See "RF Start / RF Stop" on page 51

[SENSe:]MIXer:HARMonic:BAND:PRESet

This command restores the preset frequency ranges for the selected standard waveguide band.

Note: Changes to the band and mixer settings are maintained even after using the PRESET function. Use this command to restore the predefined band ranges.

Example: `MIX:HARM:BAND:PRES`
Presets the selected waveguide band.

Usage: Event

Manual operation: See "Preset Band" on page 52

[SENSe:]MIXer:HARMonic:BAND[:VALue] <Band>

This command selects the external mixer band. The query returns the currently selected band.

This command is only available if the external mixer is active (see `[SENSe:]MIXer[:STATe]` on page 117).

Parameters:

<Band> KA | Q | U | V | E | W | F | D | G | Y | J | USER
Standard waveguide band or user-defined band.

Manual operation: See "Band" on page 52

Table 9-4: Frequency ranges for pre-defined bands

Band	Frequency start [GHz]	Frequency stop [GHz]
KA (A) *)	26.5	40.0
Q	33.0	50.0
U	40.0	60.0
V	50.0	75.0
E	60.0	90.0
W	75.0	110.0
F	90.0	140.0
D	110.0	170.0
G	140.0	220.0
J	220.0	325.0
Y	325.0	500.0
USER	32.18 (default)	68.22 (default)
***)** The band formerly referred to as "A" is now named "KA".		

[SENSe:]MIXer:HARMonic:HIGH:STATe <State>

This command specifies whether a second (high) harmonic is to be used to cover the band's frequency range.

Parameters:

<State> ON | OFF

*RST: OFF

Example: `MIX:HARM:HIGH:STAT ON`

Manual operation: See "Range 1/2" on page 52

[SENSe:]MIXer:HARMonic:HIGH[:VALue] <HarmOrder>

This command specifies the harmonic order to be used for the high (second) range.

Parameters:

<HarmOrder numeric value

Range: 2 to 61 (USER band); for other bands: see band definition

Example: `MIX:HARM:HIGH 2`

Manual operation: See "Harmonic Order" on page 53

[SENSe:]MIXer:HARMonic:TYPE <OddEven>

This command specifies whether the harmonic order to be used should be odd, even, or both.

Which harmonics are supported depends on the mixer type.

Parameters:

<OddEven> **ODD | EVEN | EODD**

*RST: EVEN

Example: `MIX:HARM:TYPE ODD`

Manual operation: See "Harmonic Type" on page 53

[SENSe:]MIXer:HARMonic[:LOW] <HarmOrder>

This command specifies the harmonic order to be used for the low (first) range.

Parameters:

<HarmOrder> numeric value

Range: 2 to 61 (USER band); for other bands: see band definition

*RST: 2 (for band F)

Example: `MIX:HARM 3`

Manual operation: See "Harmonic Order" on page 53

[SENSe:]MIXer:LOSS:HIGH <Average>

This command defines the average conversion loss to be used for the entire high (second) range.

Parameters:

<Average> numeric value

Range: 0 to 100
*RST: 24.0 dB
Default unit: dB

Example: `MIX:LOSS:HIGH 20dB`

Manual operation: See "Conversion loss" on page 53

[SENSe:]MIXer:LOSS:TABLe:HIGH <FileName>

This command defines the file name of the conversion loss table to be used for the high (second) range.

Parameters:

<FileName> String containing the path and name of the file.

Example: `MIX:LOSS:TABL:HIGH 'MyCVLTable'`

Manual operation: See "Conversion loss" on page 53

[SENSe:]MIXer:LOSS:TABLe[:LOW] <FileName>

This command defines the file name of the conversion loss table to be used for the low (first) range.

Parameters:

<FileName> String containing the path and name of the file.

Example: `MIX:LOSS:TABL 'mix_1_4'`
Specifies the conversion loss table *mix_1_4*.

Manual operation: See "Conversion loss" on page 53

[SENSe:]MIXer:LOSS[:LOW] <Average>

This command defines the average conversion loss to be used for the entire low (first) range.

Parameters:

<Average> numeric value

Range: 0 to 100
*RST: 24.0 dB
Default unit: dB

Example: `MIX:LOSS 20dB`

Manual operation: See "Conversion loss" on page 53

[SENSe:]MIXer:PORTs <PortType>

This command specifies whether the mixer is a 2-port or 3-port type.

Parameters:

<PortType> **2 | 3**

*RST: 2

Example: `MIX:PORT 3`

Manual operation: See "Mixer Type" on page 52

[SENSe:]MIXer:RFOVerrange[:STATe] <State>

If enabled, the band limits are extended beyond "RF Start" and "RF Stop" due to the capabilities of the used harmonics.

Parameters:

<State> ON | OFF

*RST: OFF

Manual operation: See "RF Overrange" on page 52

Conversion Loss Table Settings

The following settings are required to configure and manage conversion loss tables.

[SENSe:]CORRection:CVL:BAND <Type>

This command defines the waveguide band for which the conversion loss table is to be used. This setting is checked against the current mixer setting before the table can be assigned to the range.

Before this command can be performed, the conversion loss table must be selected (see `[SENSe:]CORRection:CVL:SELect` on page 127).

This command is only available with option B21 (External Mixer) installed.

Parameters:

<Band> K | A | KA | Q | U | V | E | W | F | D | G | Y | J | USER

Standard waveguide band or user-defined band.
Note: The band formerly referred to as "A" is now named "KA"; the input parameter "A" is still available and refers to the same band as "KA".
For a definition of the frequency range for the pre-defined bands, see table 9-4).

*RST: F (90 GHz - 140 GHz)

Example: `CORR:CVL:SEL 'LOSS_TAB_4'`
Selects the conversion loss table.
`CORR:CVL:BAND KA`
Sets the band to KA (26.5 GHz - 40 GHz).

Manual operation: See "Band" on page 58

[SENSe:]CORRection:CVL:BIAS <BiasSetting>

This command defines the bias setting to be used with the conversion loss table.

Before this command can be performed, the conversion loss table must be selected (see `[SENSe:]CORRection:CVL:SELect` on page 127.

This command is only available with option B21 (External Mixer) installed.

Parameters:

<BiasSetting> numeric value

*RST: 0.0 A
Default unit: A

Example: `CORR:CVL:SEL 'LOSS_TAB_4'`
Selects the conversion loss table.
`CORR:CVL:BIAS 3A`

Manual operation: See "Write to <CVL table name>" on page 55
See "Bias" on page 59

[SENSe:]CORRection:CVL:CATAlog?

This command queries all available conversion loss tables saved in the `C:\r_s\instr\user\cvl\` directory on the instrument.

This command is only available with option B21 (External Mixer) installed.

Usage: Query only

[SENSe:]CORRection:CVL:CLEAr

This command deletes the selected conversion loss table. Before this command can be performed, the conversion loss table must be selected (see `[SENSe:]CORRection:CVL:SELect` on page 127).

This command is only available with option B21 (External Mixer) installed.

Example: `CORR:CVL:SEL 'LOSS_TAB_4'`
Selects the conversion loss table.
`CORR:CVL:CLE`

Usage: Event

Manual operation: See "Delete Table" on page 57

[SENSe:]CORRection:CVL:COMMent <Text>

This command defines a comment for the conversion loss table. Before this command can be performed, the conversion loss table must be selected (see `[SENSe:]CORRection:CVL:SELect` on page 127).

This command is only available with option B21 (External Mixer) installed.

Parameters:
<Text>

Example: `CORR:CVL:SEL 'LOSS_TAB_4'`
Selects the conversion loss table.
`CORR:CVL:COMM 'Conversion loss table for FS_Z60'`

Manual operation: See "Comment" on page 58

[SENSe:]CORRection:CVL:DATA <Freq>,<Level>

This command defines the reference values of the selected conversion loss tables. The values are entered as a set of frequency/level pairs. A maximum of 50 frequency/level pairs may be entered. Before this command can be performed, the conversion loss table must be selected (see `[SENSe:]CORRection:CVL:SELect` on page 127).

This command is only available with option B21 (External Mixer) installed.

Parameters:
<Freq> numeric value
The frequencies have to be sent in ascending order.

<Level>

Example: `CORR:CVL:SEL 'LOSS_TAB_4'`
Selects the conversion loss table.
`CORR:CVL:DATA 1MHZ,-30DB,2MHZ,-40DB`

Manual operation: See "Position/Value" on page 59

[SENSe:]CORRection:CVL:HARMonic <HarmOrder>

This command defines the harmonic order for which the conversion loss table is to be used. This setting is checked against the current mixer setting before the table can be assigned to the range.

Before this command can be performed, the conversion loss table must be selected (see `[SENSe:]CORRection:CVL:SELect` on page 127.

This command is only available with option B21 (External Mixer) installed.

Parameters:

<HarmOrder> numeric value

Range: 2 to 65

Example: `CORR:CVL:SEL 'LOSS_TAB_4'`
Selects the conversion loss table.
`CORR:CVL:HARM 3`

Manual operation: See "Harmonic Order" on page 58

[SENSe:]CORRection:CVL:MIXer <Type>

This command defines the mixer name in the conversion loss table. This setting is checked against the current mixer setting before the table can be assigned to the range.

Before this command can be performed, the conversion loss table must be selected (see `[SENSe:]CORRection:CVL:SELect` on page 127).

This command is only available with option B21 (External Mixer) installed.

Parameters:

<Type> string

Name of mixer with a maximum of 16 characters

Example: `CORR:CVL:SEL 'LOSS_TAB_4'`
Selects the conversion loss table.
`CORR:CVL:MIX 'FS_Z60'`

Manual operation: See "Mixer Name" on page 59

[SENSe:]CORRection:CVL:PORTs <PortNo>

This command defines the mixer type in the conversion loss table. This setting is checked against the current mixer setting before the table can be assigned to the range.

Before this command can be performed, the conversion loss table must be selected (see `[SENSe:]CORRection:CVL:SELect` on page 127).

This command is only available with option B21 (External Mixer) installed.

Parameters:
<PortType> 2 | 3
*RST: 2

Example: `CORR:CVL:SEL 'LOSS_TAB_4'`
Selects the conversion loss table.
`CORR:CVL:PORT 3`

Manual operation: See "Mixer Type" on page 59

[SENSe:]CORRection:CVL:SELect <FileName>

This command selects the conversion loss table with the specified file name. If <file_name> is not available, a new conversion loss table is created.

This command is only available with option B21 (External Mixer) installed.

Parameters:
<FileName> String containing the path and name of the file.

Example: `CORR:CVL:SEL 'LOSS_TAB_4'`

Manual operation: See "New Table" on page 56
See "Edit Table" on page 56
See "File Name" on page 58

[SENSe:]CORRection:CVL:SNUMber <SerialNo>

This command defines the serial number of the mixer for which the conversion loss table is to be used. This setting is checked against the current mixer setting before the table can be assigned to the range.

Before this command can be performed, the conversion loss table must be selected (see `[SENSe:]CORRection:CVL:SELect` on page 127).

This command is only available with option B21 (External Mixer) installed.

Parameters:
<SerialNo> Serial number with a maximum of 16 characters

Example: `CORR:CVL:SEL 'LOSS_TAB_4'`
Selects the conversion loss table.
`CORR:CVL:MIX '123.4567'`

Manual operation: See "Mixer S/N" on page 59

Programming Example: Working with an External Mixer

This example demonstrates how to work with an external mixer in a remote environment. It is performed in the Spectrum application in the default layout configuration. Note that without a real input signal and connected mixer, this measurement will not return useful results.

```
//--------------Preparing the instrument -----------
//Reset the instrument
```

```
*RST
//Activate the use of the connected external mixer.
SENS:MIX ON
//----------- Configuring basic mixer behavior -------------
//Set the LO level of the mixer's LO port to 15 dBm.
SENS:MIX:LOP 15dBm
//Set the bias current to -1 mA .
SENS:MIX:BIAS:LOW -1mA
//----------- Configuring the mixer and band settings -------------
//Use band "V" to full possible range extent for assigned harmonic (6).
SENS:MIX:HARM:BAND V
SENS:MIX:RFOV ON
//Query the possible range
SENS:MIX:FREQ:STAR?
//Result: 47480000000 (47.48 GHz)
SENS:MIX:FREQ:STOP?
//Result: 138020000000 (138.02 GHz)
//Use a 3-port mixer type
SENS:MIX:PORT 3
//Split the frequency range into two ranges;
//range 1 covers 47.48 GHz GHz to 80 GHz; harmonic 6, average conv. loss of 20 dB
//range 2 covers 80 GHz to 138.02 GHz; harmonic 8, average conv.loss of 30 dB
SENS:MIX:HARM:TYPE EVEN
SENS:MIX:HARM:HIGH:STAT ON
SENS:MIX:FREQ:HAND 80GHz
SENS:MIX:HARM:LOW 6
SENS:MIX:LOSS:LOW  20dB
SENS:MIX:HARM:HIGH 8
SENS:MIX:LOSS:HIGH 30dB
//--------- Activating automatic signal identification functions -----------
//Activate both automatic signal identification functions.
SENS:MIX:SIGN ALL
//Use auto ID threshold of 8 dB.
SENS:MIX:THR 8dB

//--------------Performing the Measurement-----
//Select single sweep mode.
INIT:CONT OFF
//Initiate a basic frequency sweep and wait until the sweep has finished.
INIT;*WAI
//---------------Retrieving Results-------------
//Return the trace data for the input signal without distortions
//(default screen configuration)
TRAC:DATA? TRACE3
```

Configuring a conversion loss table for a user-defined band

```
//--------------Preparing the instrument -----------
//Reset the instrument
```

```
*RST
//Activate the use of the connected external mixer.
SENS:MIX ON
//--------------Configuring a new conversion loss table --------------
//Define cvl table for range 1 of band as described in previous example
// (extended V band)
SENS:CORR:CVL:SEL 'UserTable'
SENS:CORR:CVL:COMM 'User-defined conversion loss table for USER band'
SENS:CORR:CVL:BAND USER
SENS:CORR:CVL:HARM 6
SENS:CORR:CVL:BIAS -1mA
SENS:CORR:CVL:MIX 'FS_Z60'
SENS:CORR:CVL:SNUM '123.4567'
SENS:CORR:CVL:PORT 3
//Conversion loss is linear from 55 GHz to 75 GHz
SENS:CORR:CVL:DATA 55GHZ,-20DB,75GHZ,-30DB
//----------- Configuring the mixer and band settings -------------
//Use user-defined band and assign new cvl table.
SENS:MIX:HARM:BAND USER
//Define band by two ranges;
//range 1 covers 47.48 GHz to 80 GHz; harmonic 6, cvl table 'UserTable'
//range 2 covers 80 GHz to 138.02 GHz; harmonic 8, average conv.loss of 30 dB
SENS:MIX:HARM:TYPE EVEN
SENS:MIX:HARM:HIGH:STAT ON
SENS:MIX:FREQ:HAND 80GHz
SENS:MIX:HARM:LOW 6
SENS:MIX:LOSS:TABL:LOW 'UserTable'
SENS:MIX:HARM:HIGH 8

SENS:MIX:LOSS:HIGH 30dB
//Query the possible range
SENS:MIX:FREQ:STAR?
//Result: 47480000000 (47.48 GHz)
SENS:MIX:FREQ:STOP?
//Result: 138020000000 (138.02 GHz)

//--------------Performing the Measurement-----
//Select single sweep mode.
INIT:CONT OFF
//Initiate a basic frequency sweep and wait until the sweep has finished.
INIT;*WAI
//---------------Retrieving Results-------------
//Return the trace data (default screen configuration)
TRAC:DATA? TRACe1
```

9.5.1.4 Configuring the 2 GHz Bandwidth Extension (R&S FSW-B2000)

The following commands are required to use the optional 2 GHz bandwidth extension (R&S FSW-B2000).

See also the command for configuring triggers while using the optional 2 GHz bandwidth extension (R&S FSW-B2000):

- `TRIGger[:SEQuence]:OSCilloscope:COUPling` on page 133

Remote commands exclusive to configuring the 2 GHz bandwidth extension:

EXPort:WAVeform:DISPlayoff <FastExport>

Enables or disables the display update on the oscilloscope during data acquisition with the **optional 2 GHz bandwidth extension (R&S FSW-B2000)**.

As soon as the R&S FSW-B2000 is activated (see "B2000 State" on page 61), the display on the oscilloscope is turned off to improve performance during data export. As soon as the R&S FSW closes the connection to the oscilloscope, the display is reactivated and the oscilloscope can be operated as usual. However, if the LAN connection is lost for any reason, the display of the oscilloscope remains deactivated. Use this command to re-activate it.

Parameters:

<FastExport> ON | OFF

ON: Disables the display update for maximum export speed.
OFF: Enables the display update. The export is slower.

*RST: ON

SYSTem:COMMunicate:RDEVice:OSCilloscope[:STATe] <State>

Activates the optional 2 GHz bandwidth extension (R&S FSW-B2000).

Note: Manual operation on the connected oscilloscope, or remote operation other than by the R&S FSW, is not possible while the B2000 option is active.

Parameters:

<State> ON | OFF | 1 | 0

ON | 1
Option is active.

OFF | 0
Option is disabled.

*RST: 0

Example: `SYST:COMM:RDEV:OSC ON`

Manual operation: See "B2000 State" on page 61

SYSTem:COMMunicate:RDEVice:OSCilloscope:ALIGnment:STEP[:STATe]?

Performs the alignment of the oscilloscope itself and the oscilloscope ADC for the optional 2 GHz bandwidth extension (R&S FSW-B2000). The correction data for the oscilloscope (including the connection cable between the R&S FSW and the oscilloscope) is recorded. As a result, the state of the alignment is returned.

Alignment is required only once after setup. If alignment was performed successfully, the alignment data is stored on the oscilloscope.

Thus, alignment need only be repeated if one of the following applies:
- A new oscilloscope is connected to the IF OUT 2 GHZ connector of the R&S FSW
- A new cable is used between the IF OUT 2 GHZ connector of the R&S FSW and the oscilloscope
- A new firmware is installed on the oscilloscope

Return values:
<State> Returns the state of the second alignment step.

ON | 1
Alignment was successful.

OFF | 0
Alignment was not yet performed (successfully).

Example:
```
SYST:COMM:RDEV:OSC:ALIG:STEP?
//Result: 1
```

Usage: Query only

SYSTem:COMMunicate:RDEVice:OSCilloscope:ALIGnment:DATE?

Returns the date of alignment of the IF OUT 2 GHZ to the oscilloscope for the optional 2 GHz bandwidth extension (R&S FSW-B2000).

Return values:
<Date> Returns the date of alignment.

Example:
```
SYST:COMM:RDEV:OSC:DATE?
//Result: 2014-02-28
```

Usage: Query only

SYSTem:COMMunicate:RDEVice:OSCilloscope:IDN?

Returns the identification string of the oscilloscope connected to the R&S FSW.

Return values:
<IDString>

Example: `SYST:COMM:RDEV:OSC:IDN?`
`//Result: Rohde&Schwarz,RTO,`
`1316.1000k14/200153,2.45.1.1`

Usage: Query only

Manual operation: See "TCPIP Address or Computer name" on page 61

SYSTem:COMMunicate:RDEVice:OSCilloscope:LEDState?

Returns the state of the LAN connection to the oscilloscope for the optional 2 GHz bandwidth extension (R&S FSW-B2000).

Return values:

<Color>

GREEN
Connection to the instrument has been established successfully.

GREY
Configuration state unknown, for example if you have not yet started transmission.

RED
Connection to the instrument could not be established.
Check the connection between the R&S FSW and the oscilloscope, and make sure the IP address of the oscilloscope has been defined (see `SYSTem:COMMunicate:RDEVice:OSCilloscope:TCPip` on page 132).

Example: `SYST:COMM:RDEV:OSC:LEDS?`
`//Result: 'GREEN'`

Usage: Query only

SYSTem:COMMunicate:RDEVice:OSCilloscope:TCPip <Address>

Defines the TCPIP address or computer name of the oscilloscope connected to the R&S FSW via LAN.

Note: The IP address is maintained after a PRESET, and is transferred between applications.

Parameters:

<Address> computer name or IP address

Example: `SYST:COMM:RDEV:OSC:TCP '192.0.2.0'`

Example: `SYST:COMM:RDEV:OSC:TCP 'FSW43-12345'`

Manual operation: See "TCPIP Address or Computer name" on page 61

SYSTem:COMMunicate:RDEVice:OSCilloscope:VDEVice?

Queries whether the connected instrument is supported by the 2 GHz bandwidth extension option(R&S FSW-B2000).

Return values:

<State>

ON | 1
Instrument is supported

OFF | 0
Instrument is not supported

Example: `SYST:COMM:RDEV:OSC:VDEV?`

Usage: Query only

SYSTem:COMMunicate:RDEVice:OSCilloscope:VFIRmware?

Queries whether the firmware on the connected oscilloscope is supported by the 2 GHz bandwidth extension (R&S FSW-B2000) option.

Return values:

<State>

ON | 1
Firmware is supported

OFF | 0
Firmware is not supported

Example: `SYST:COMM:RDEV:OSC:VFIR?`

Usage: Query only

TRIGger[:SEQuence]:OSCilloscope:COUPling <CoupType>

Configures the coupling of the external trigger to the oscilloscope.

Parameters:

<CoupType>

Coupling type

DC
Direct connection with 50 Ω termination, passes both DC and AC components of the trigger signal.

CDLimit
Direct connection with 1 MΩ termination, passes both DC and AC components of the trigger signal.

AC
Connection through capacitor, removes unwanted DC and very low-frequency components.

*RST: DC

9.5.1.5 Configuring the Outputs

Configuring trigger input/output is described in "Configuring the Trigger Output" on page 146.

DIAGnostic:SERVice:NSOurce <State>

This command turns the 28 V supply of the BNC connector labeled NOISE SOURCE CONTROL on the R&S FSW on and off.

Parameters:

<State> ON | OFF

*RST: OFF

Example: `DIAG:SERV:NSO ON`

Manual operation: See "Noise Source" on page 65

OUTPut:IF:IFFRequency <Frequency>

This command defines the frequency for the IF output of the R&S FSW. The IF frequency of the signal is converted accordingly.

This command is available in the time domain and if the IF/VIDEO/DEMOD output is configured for IF.

Parameters:

<Frequency> *RST: 50.0 MHz

Manual operation: See "IF (Wide) Out Frequency" on page 65

OUTPut:IF[:SOURce] <Source>

Defines the type of signal available at the IF/VIDEO/DEMOD or IF OUT 2 GHZ connector of the R&S FSW.

Parameters:

<Source>

IF
The measured IF value is available at the IF/VIDEO/DEMOD output connector.
The frequency at which the IF value is provided is defined using the `OUTPut:IF:IFFRequency` command.

IF2
The measured IF value is available at the IF OUT 2 GHZ output connector at a frequency of 2 GHz.
This setting is only available if the IF OUT 2 GHZ connector or the optional 2 GHz bandwidth extension (R&S FSW-B2000) is available.

VIDeo
The displayed video signal (i.e. the filtered and detected IF signal, 200mV) is available at the IF/VIDEO/DEMOD output connector.
This setting is required to provide demodulated audio frequencies at the output.

*RST: IF

Example:
`OUTP:IF VID`
Selects the video signal for the IF/VIDEO/DEMOD output connector.

Manual operation: See "IF/Video Output" on page 64

9.5.2 Frontend Configuration

The following commands configure frequency, amplitude and y-axis scaling settings, which represent the "frontend" of the measurement setup.

9.5.2.1 Frequency

[SENSe:]FREQuency:CENTer <Frequency>

This command defines the center frequency.

Parameters:

<Frequency> The allowed range and f_{max} is specified in the data sheet.

UP
Increases the center frequency by the step defined using the [SENSe:]FREQuency:CENTer:STEP command.

DOWN
Decreases the center frequency by the step defined using the [SENSe:]FREQuency:CENTer:STEP command.

*RST: fmax/2
Default unit: Hz

Example:
```
FREQ:CENT 100 MHz
FREQ:CENT:STEP 10 MHz
FREQ:CENT UP
```
Sets the center frequency to 110 MHz.

Usage: SCPI confirmed

Manual operation: See "Center frequency" on page 67

[SENSe:]FREQuency:CENTer:STEP <StepSize>

This command defines the center frequency step size.

Parameters:

<StepSize> f_{max} is specified in the data sheet.

Range: 1 to fMAX
*RST: 0.1 x span
Default unit: Hz

Example:
```
FREQ:CENT 100 MHz
FREQ:CENT:STEP 10 MHz
FREQ:CENT UP
```
Sets the center frequency to 110 MHz.

Manual operation: See "Center Frequency Stepsize" on page 67

[SENSe:]FREQuency:CENTer:STEP:AUTO <State>

This command couples or decouples the center frequency step size to the span.

Parameters:

<State> ON | OFF | 0 | 1

*RST: 1

Example:
```
FREQ:CENT:STEP:AUTO ON
```
Activates the coupling of the step size to the span.

[SENSe:]FREQuency:OFFSet <Offset>

This command defines a frequency offset.

If this value is not 0 Hz, the application assumes that the input signal was frequency shifted outside the application. All results of type "frequency" will be corrected for this shift numerically by the application.

Parameters:

<Offset>	Range:	-100 GHz to 100 GHz
	*RST:	0 Hz

Example: `FREQ:OFFS 1GHZ`

Usage: SCPI confirmed

Manual operation: See "Frequency Offset" on page 67

9.5.2.2 Amplitude Settings

The following commands are required to configure the amplitude settings in a remote environment.

Useful commands for amplitude settings described elsewhere:

- `INPut:COUPling` on page 115
- `[SENSe:]ADJust:LEVel` on page 153
- `CALCulate<n>:UNIT:POWer` on page 164

Remote commands exclusive to amplitude settings:

CONFigure:POWer:AUTO <Mode>

This command is used to switch on or off automatic power level detection.

Parameters for setting and query:

<Mode>

ON
Automatic power level detection is performed at the start of each measurement sweep, and the reference level is adapted accordingly.

OFF
The reference level must be defined manually (see `DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:RLEVel` on page 138)

ONCE
Automatic power level detection is performed once at the start of the next measurement sweep, and the reference level is adapted accordingly.

*RST: ON

DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:RLEVel <ReferenceLevel>

This command defines the reference level (for all traces, <t> is irrelevant).

Example: `DISP:TRAC:Y:RLEV -60dBm`

Usage: SCPI confirmed

Manual operation: See "Reference Level" on page 68

DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:RLEVel:OFFSet <Offset>

This command defines a reference level offset (for all traces, <t> is irrelevant).

Parameters:

<Offset>

Range: -200 dB to 200 dB
*RST: 0dB

Example: `DISP:TRAC:Y:RLEV:OFFS -10dB`

Manual operation: See "Shifting the Display (Offset)" on page 69

INPut:ATTenuation <Attenuation>

This command defines the total attenuation for RF input.

If you set the attenuation manually, it is no longer coupled to the reference level, but the reference level is coupled to the attenuation. Thus, if the current reference level is not compatible with an attenuation that has been set manually, the command also adjusts the reference level.

Parameters:

<Attenuation>

Range: see data sheet
Increment: 5 dB
*RST: 10 dB (AUTO is set to ON)

Example: `INP:ATT 30dB`
Defines a 30 dB attenuation and decouples the attenuation from the reference level.

Usage: SCPI confirmed

Manual operation: See "Attenuation Mode / Value" on page 70

INPut:ATTenuation:AUTO <State>

This command couples or decouples the attenuation to the reference level. Thus, when the reference level is changed, the R&S FSW determines the signal level for optimal internal data processing and sets the required attenuation accordingly.

Parameters:
<State> ON | OFF | 0 | 1
*RST: 1

Example: `INP:ATT:AUTO ON`
Couples the attenuation to the reference level.

Usage: SCPI confirmed

Manual operation: See "Attenuation Mode / Value" on page 70

INPut:EATT <Attenuation>

This command defines an electronic attenuation manually. Automatic mode must be switched off (`INP:EATT:AUTO OFF`, see `INPut:EATT:AUTO` on page 139).

If the current reference level is not compatible with an attenuation that has been set manually, the command also adjusts the reference level.

Parameters:
<Attenuation> attenuation in dB
Range: see data sheet
Increment: 1 dB
*RST: 0 dB (OFF)

Example:
```
INP:EATT:AUTO OFF
INP:EATT 10 dB
```

Manual operation: See "Using Electronic Attenuation" on page 70

INPut:EATT:AUTO <State>

This command turns automatic selection of the electronic attenuation on and off.

If on, electronic attenuation reduces the mechanical attenuation whenever possible.

Parameters:

<State> 1 | 0 | ON | OFF

1 | ON

0 | OFF

*RST: 1

Example: `INP:EATT:AUTO OFF`

Manual operation: See "Using Electronic Attenuation" on page 70

INPut:EATT:STATe <State>

This command turns the electronic attenuator on and off.

Parameters:

<State> 1 | 0 | ON | OFF

1 | ON

0 | OFF

*RST: 0

Example: `INP:EATT:STAT ON`
Switches the electronic attenuator into the signal path.

Manual operation: See "Using Electronic Attenuation" on page 70

INPut:GAIN[:VALue] <Gain>

This command selects the gain level if the preamplifier is activated (`INP:GAIN:STAT ON`, see `INPut:GAIN:STATe` on page 141).

The command requires the additional preamplifier hardware option.

Parameters:

<Gain> 15 dB | 30 dB

The availability of gain levels depends on the model of the R&S FSW.
R&S FSW8/13: 15dB and 30 dB
R&S FSW26 or higher: 30 dB
All other values are rounded to the nearest of these two.

*RST: OFF

Example: `INP:GAIN:VAL 30`
Switches on 30 dB preamplification.

Usage: SCPI confirmed

Manual operation: See "Preamplifier" on page 49

INPut:GAIN:STATe <State>

This command turns the preamplifier on and off. It requires the optional preamplifiier hardware.

Parameters:
<State> ON | OFF
*RST: OFF

Example: `INP:GAIN:STAT ON`
Switches on 30 dB preamplification.

Usage: SCPI confirmed

Manual operation: See "Preamplifier" on page 49

9.5.3 Signal Capturing

The following commands are required to configure how much and how data is captured from the input signal.

9.5.3.1 General Capture Settings

[SENSe:]SWAPiq <State>

This command defines whether or not the recorded I/Q pairs should be swapped (I<->Q) before being processed. Swapping I and Q inverts the sideband.

This is useful if the DUT interchanged the I and Q parts of the signal; then the R&S FSW can do the same to compensate for it.

Parameters:
<State>
ON
I and Q signals are interchanged
Inverted sideband, Q+j*I

OFF
I and Q signals are not interchanged
Normal sideband, I+j*Q

*RST: OFF

Manual operation: See "Swap I/Q" on page 72

[SENSe:]SWEep:TIME <Time>

This command defines the measurement time.

Parameters:

<Time> refer to data sheet

*RST: depends on current settings (determined automatically)

Example: `SWE:TIME 10s`

Usage: SCPI confirmed

Manual operation: See "Capture Time" on page 72

TRACe:IQ:SRATe <SampleRate>

Parameters:

<SampleRate> For standard IEEE 802.11ad signals, a sample rate of 2.64 GHz is used (requires the optional 2 GHz bandwidth extension R&S FSW-B2000).
The valid sample rates are described in chapter 4.6, "Max. Sample Rate and Bandwidth with Activated I/Q Bandwidth Extension Option B2000", on page 43.

Default unit: HZ

Manual operation: See "Sample Rate" on page 72

9.5.3.2 Configuring Triggered Measurements

The following commands are required to configure a triggered measurement in a remote environment. The tasks for manual operation are described in chapter 5.2.4, "Trigger Settings", on page 72.

The `*OPC` command should be used after commands that retrieve data so that subsequent commands to change the selected trigger source are held off until after the sweep is completed and the data has been returned.

Configuring the Triggering Conditions

The following commands are required to configure a triggered measurement.

TRIGger[:SEQuence]:DTIMe <DropoutTime>

Defines the time the input signal must stay below the trigger level before a trigger is detected again.

Parameters:

<DropoutTime> Dropout time of the trigger.

Range: 0 s to 10.0 s
*RST: 0 s

Manual operation: See "Drop-Out Time" on page 76

TRIGger[:SEQuence]:HOLDoff[:TIME] <Offset>

Defines the time offset between the trigger event and the start of the measurement.

Parameters:

<Offset> *RST: 0 s

Example: `TRIG:HOLD 500us`

Manual operation: See "Trigger Offset" on page 76

TRIGger[:SEQuence]:IFPower:HOLDoff <Period>

This command defines the holding time before the next trigger event.

Note that this command can be used for **any trigger source**, not just IF Power (despite the legacy keyword).

Parameters:

<Period> Range: 0 s to 10 s
*RST: 0 s

Example: `TRIG:SOUR EXT`
Sets an external trigger source.
`TRIG:IFP:HOLD 200 ns`
Sets the holding time to 200 ns.

Manual operation: See "Trigger Holdoff" on page 76

TRIGger[:SEQuence]:IFPower:HYSTeresis <Hysteresis>

This command defines the trigger hysteresis, which is only available for "IF Power" trigger sources.

Parameters:

<Hysteresis> Range: 3 dB to 50 dB
*RST: 3 dB

Example: `TRIG:SOUR IFP`
Sets the IF power trigger source.
`TRIG:IFP:HYST 10DB`
Sets the hysteresis limit value.

Manual operation: See "Hysteresis" on page 76

TRIGger[:SEQuence]:LEVel[:EXTernal<port>] <TriggerLevel>

This command defines the level the external signal must exceed to cause a trigger event.

Suffix:

<port> Selects the trigger port.
1 = trigger port 1 (TRIGGER INPUT connector on front panel)
2 = trigger port 2 (TRIGGER INPUT/OUTPUT connector on front panel)
3 = trigger port 3 (TRIGGER3 INPUT/OUTPUT connector on rear panel)

Parameters:

<TriggerLevel> Range: 0.5 V to 3.5 V
*RST: 1.4 V

Example: `TRIG:LEV 2V`

Manual operation: See "Trigger Level" on page 75

TRIGger[:SEQuence]:LEVel:IFPower <TriggerLevel>

This command defines the power level at the third intermediate frequency that must be exceeded to cause a trigger event. Note that any RF attenuation or preamplification is considered when the trigger level is analyzed. If defined, a reference level offset is also considered.

Parameters:

<TriggerLevel> For details on available trigger levels and trigger bandwidths see the data sheet.
*RST: -10 dBm

Example: `TRIG:LEV:IFP -30DBM`

Manual operation: See "Trigger Level" on page 75

TRIGger[:SEQuence]:LEVel:IQPower <TriggerLevel>

This command defines the magnitude the I/Q data must exceed to cause a trigger event. Note that any RF attenuation or preamplification is considered when the trigger level is analyzed.

Parameters:

<TriggerLevel> Range: -130 dBm to 30 dBm
*RST: -20 dBm

Example: `TRIG:LEV:IQP -30DBM`

Manual operation: See "Trigger Level" on page 75

TRIGger[:SEQuence]:LEVel:RFPower <TriggerLevel>

This command defines the power level the RF input must exceed to cause a trigger event. Note that any RF attenuation or preamplification is considered when the trigger level is analyzed. If defined, a reference level offset is also considered.

The input signal must be between 500 MHz and 8 GHz.

Parameters:

<TriggerLevel> For details on available trigger levels and trigger bandwidths see the data sheet.
*RST: -20 dBm

Example: `TRIG:LEV:RFP -30dBm`

Manual operation: See "Trigger Level" on page 75

TRIGger[:SEQuence]:SLOPe <Type>

Parameters:

<Type> POSitive | NEGative

POSitive
Triggers when the signal rises to the trigger level (rising edge).

NEGative
Triggers when the signal drops to the trigger level (falling edge).

*RST: POSitive

Example: `TRIG:SLOP NEG`

Manual operation: See "Slope" on page 76

TRIGger[:SEQuence]:SOURce <Source>

This command selects the trigger source.

Note on external triggers:

If a measurement is configured to wait for an external trigger signal in a remote control program, remote control is blocked until the trigger is received and the program can continue. Make sure this situation is avoided in your remote control programs.

Parameters:

<Source>

IMMediate
Free Run

EXTernal
Trigger signal from the TRIGGER INPUT connector.

EXT2
Trigger signal from the TRIGGER INPUT/OUTPUT connector.
Note: Connector must be configured for "Input".

EXT3
Trigger signal from the TRIGGER 3 INPUT/ OUTPUT connector.
Note: Connector must be configured for "Input".

RFPower
First intermediate frequency

IFPower
Second intermediate frequency

IQPower
Magnitude of sampled I/Q data
For applications that process I/Q data, such as the I/Q Analyzer or optional applications.

*RST: IMMediate

Example:

`TRIG:SOUR EXT`
Selects the external trigger input as source of the trigger signal

Manual operation:

See "Trigger Source" on page 74
See "Free Run" on page 74
See "External Trigger 1/2/3" on page 74
See "IF Power" on page 75
See "RF Power" on page 75
See "I/Q Power" on page 75

TRIGger[:SEQuence]:TIME:RINTerval <Interval>

This command defines the repetition interval for the time trigger.

Parameters:

<Interval> 2.0 ms to 5000

Range: 2 ms to 5000 s
*RST: 1.0 s

Example:

`TRIG:SOUR TIME`
Selects the time trigger input for triggering.
`TRIG:TIME:RINT 50`
The measurement starts every 50 s.

Configuring the Trigger Output

The following commands are required to send the trigger signal to one of the variable TRIGGER INPUT/OUTPUT connectors on the R&S FSW.

OUTPut:TRIGger<port>:DIRection <Direction>

This command selects the trigger direction for trigger ports that serve as an input as well as an output.

Suffix:

<port> Selects the used trigger port.
2 = trigger port 2 (front panel)
3 = trigger port 3 (rear panel)

Parameters:

<Direction> **INPut**
Port works as an input.

OUTPut
Port works as an output.

*RST: INPut

Manual operation: See "Trigger 2/3" on page 65

OUTPut:TRIGger<port>:LEVel <Level>

This command defines the level of the signal generated at the trigger output.

This command works only if you have selected a user defined output with `OUTPut:TRIGger<port>:OTYPe`.

Suffix:

<port> Selects the trigger port to which the output is sent.
2 = trigger port 2 (front)
3 = trigger port 3 (rear)

Parameters:

<Level> **HIGH**
TTL signal.

LOW
0 V

*RST: LOW

Manual operation: See "Trigger 2/3" on page 65
See "Level" on page 66

OUTPut:TRIGger<port>:OTYPe <OutputType>

This command selects the type of signal generated at the trigger output.

Suffix:

<port> Selects the trigger port to which the output is sent.
2 = trigger port 2 (front)
3 = trigger port 3 (rear)

Parameters:

<OutputType> **DEVice**
Sends a trigger signal when the R&S FSW has triggered internally.

TARMed
Sends a trigger signal when the trigger is armed and ready for an external trigger event.

UDEFined
Sends a user defined trigger signal. For more information see `OUTPut:TRIGger<port>:LEVel`.

*RST: DEVice

Manual operation: See "Output Type" on page 66

OUTPut:TRIGger<port>:PULSe:IMMediate

This command generates a pulse at the trigger output.

Suffix:

<port> Selects the trigger port to which the output is sent.
2 = trigger port 2 (front)
3 = trigger port 3 (rear)

Usage: Event

Manual operation: See "Send Trigger" on page 66

OUTPut:TRIGger<port>:PULSe:LENGth <Length>

This command defines the length of the pulse generated at the trigger output.

Suffix:

<port> Selects the trigger port to which the output is sent.
2 = trigger port 2 (front)
3 = trigger port 3 (rear)

Parameters:

<Length> Pulse length in seconds.

Manual operation: See "Pulse Length" on page 66

9.5.4 Tracking

SENSe:TRACking:IQMComp <State>

Activates or deactivates the compensation for I/Q mismatch (gain imbalance, quadrature offset, I/Q skew, see chapter 3.1.1.1, "I/Q Offset", on page 15).

Parameters:

<State> ON | OFF

ON
Compensation for gain imbalance, quadrature offset, and I/Q skew impairments is applied.

OFF
Compensation is not applied; this setting is required for measurements strictly according to the IEEE 802.11ad standard

*RST: OFF

Manual operation: See "I/Q Mismatch Compensation" on page 78

SENSe:TRACking:LEVel <State>

Activates or deactivates the compensation for level variations within a single PPDU. If activated, the measurement results are compensated for level error on a per-symbol basis.

Parameters:

<State> ON | OFF

*RST: OFF

Example: `SENS:TRAC:LEV ON`

Manual operation: See "Level Error (Gain) Tracking" on page 78

SENSe:TRACking:PHASe <State>

Activates or deactivates the compensation for phase drifts. If activated, the measurement results are compensated for phase drifts on a per-symbol basis.

Parameters:

<State> ON | OFF | 0 | 1

*RST: 1

Example: `SENS:TRAC:PHAS ON`

Manual operation: See "Phase Tracking" on page 78

SENSe:TRACking:TIME <State>

Activates or deactivates the compensation for timing drift. If activated, the measurement results are compensated for timing error on a per-symbol basis.

Parameters:

<State>	ON | OFF | 0 | 1
	*RST: 0

Example: `SENS:TRAC:TIME ON`

[SENSe] (see also SENSe: commands!)

9.5.5 Evaluation Range

The evaluation range defines which data is evaluated in the result display.

Note that, as opposed to manual operation, the PPDUs to be analyzed can be defined either by the number of data symbols, the number of data bytes, or the measurement duration.

[SENSe:]BURSt:COUNt <Value>

If the statistic count is enabled (see `[SENSe:]BURSt:COUNt:STATe` on page 150), the specified number of PPDUs is taken into consideration for the statistical evaluation (maximally the number of PPDUs detected in the current capture buffer).

If disabled, all detected PPDUs in the current capture buffer are considered.

Parameters:

<Value>	*RST: 1

Example:

```
SENS:BURS:COUN:STAT ON
SENS:BURS:COUN 10
```

[SENSe:]BURSt:COUNt:STATe <State>

If the statistic count is enabled, the specified number of PPDUs is taken into consideration for the statistical evaluation (maximally the number of PPDUs detected in the current capture buffer).

If disabled, all detected PPDUs in the current capture buffer are considered.

Parameters:

<State> ON | OFF

*RST: OFF

Example:

```
SENS:BURS:COUN:STAT ON
SENS:BURS:COUN 10
```

[SENSe:]BURSt:SELect <Value>

If single PPDU analysis is enabled (see [SENSe:]BURSt:SELect:STATe on page 151), the IEEE 802.11ad I/Q results are based on the specified PPDU.

If disabled, all detected PPDUs in the current capture buffer are evaluated.

Parameters:

<Value> *RST: 1

Example:

```
SENS:BURS:SEL:STAT ON
SENS:BURS:SEL 2
```

Results are based on the PPDU number 2 only.

Manual operation: See "PPDU to Analyze / Index of Specific PPDU" on page 87

[SENSe:]BURSt:SELect:STATe <State>

Defines the evaluation basis for result displays.

Note that this setting is only applicable *after* a measurement has been performed.

Parameters:

<State> ON | OFF | 0 | 1

OFF | 0
All detected PPDUs in the current capture buffer are evaluated.

ON | 1
The IEEE 802.11ad I/Q results are based on one individual PPDU only, namely the defined using [SENSe:]BURSt:SELect on page 151. As soon as a new measurement is started, the evaluation range is reset to all PPDUs in the current capture buffer.

*RST: 0

Example:

```
SENS:BURS:SEL:STAT ON
SENS:BURS:SEL 2
```

Results are based on the PPDU number 2 only.

Manual operation: See "PPDU to Analyze / Index of Specific PPDU" on page 87

[SENSe:]DEMod:FORMat:BANalyze:SYMBols:EQUal <State>

If **enabled**, only PPDUs with a **specific** number of symbols are considered for measurement analysis.

If **disabled**, only PPDUs whose length is within a specified **range** are considered.

The number of symbols is specified by the [SENSe:]DEMod:FORMat:BANalyze:SYMBols:MIN command.

A **range** of data symbols is defined as a minimum and maximum number of symbols the payload may contain (see [SENSe:]DEMod:FORMat:BANalyze:SYMBols:MAX on page 152 and [SENSe:]DEMod:FORMat:BANalyze:SYMBols:MIN on page 152).

Parameters:

<State>	ON | OFF	
	*RST:	OFF

[SENSe:]DEMod:FORMat:BANalyze:SYMBols:MAX <NumDataSymbols>

If the [SENSe:]DEMod:FORMat:BANalyze:SYMBols:EQUal command is set to **false**, this command specifies the maximum number of payload symbols allowed for a PPDU to take part in measurement analysis.

The number of payload symbols is defined as the uncoded bits including service and tail bits.

If the [SENSe:]DEMod:FORMat:BANalyze:SYMBols:EQUal command has been set to **true**, then this command has no effect.

Parameters:

<NumDataSymbols>	*RST:	64

[SENSe:]DEMod:FORMat:BANalyze:SYMBols:MIN <NumDataSymbols>

If the [SENSe:]DEMod:FORMat:BANalyze:SYMBols:EQUal command has been set to **true**, then this command specifies the exact number of payload symbols a PPDU must have to take part in measurement analysis.

If the [SENSe:]DEMod:FORMat:BANalyze:SYMBols:EQUal command is set to **false**, this command specifies the minimum number of payload symbols required for a PPDU to take part in measurement analysis.

The number of payload symbols is defined as the uncoded bits including service and tail bits.

Parameters:

<NumDataSymbols>	*RST:	1

Example:

```
SENS:DEM:FORM:BAN:SYMB:EQU ON
SENS:DEMO:FORM:BANA:SYMB:MIN
```

9.5.6 Automatic Settings

Remote commands exclusive to automatic configuration:

[SENSe:]ADJust:LEVel

This command initiates a single (internal) measurement that evaluates and sets the ideal reference level for the current input data and measurement settings. This ensures that the settings of the RF attenuation and the reference level are optimally adjusted to the signal level without overloading the R&S FSW or limiting the dynamic range by an S/N ratio that is too small.

Example: `ADJ:LEV`

Usage: Event

Manual operation: See "Setting the Reference Level Automatically (Auto Level)" on page 69

9.6 Configuring SEM Measurements on IEEE 802.11ad Signals

The R&S FSW 802.11ad application uses the functionality of the R&S FSW base system (Spectrum application, see the R&S FSW User Manual) to perform the IEEE 802.11ad SEM measurements. The R&S FSW 802.11ad application automatically sets the parameters to predefined settings as described in chapter 5.3, "SEM Measurements", on page 84.

The IEEE 802.11ad RF measurements must be activated for a measurement channel in the R&S FSW 802.11ad application, see chapter 9.3, "Activating IEEE 802.11ad measurements", on page 109.

For details on configuring these RF measurements in a remote environment, see the Remote Commands chapter of the R&S FSW User Manual.

Remote commands exclusive to SEM measurements in the R&S FSW 802.11ad application:

MMEMory:LOAD:SEM:STATe <1>, <Filename>

This command loads a spectrum emission mask setup from an xml file.

Note that this command is maintained for compatibility reasons only. Use the `SENS:ESP:PRES` command for new remote control programs.

See the R&S FSW User Manual, "Remote commands for SEM measurements" chapter.

Parameters:
<1>

<Filename> string

Path and name of the `.xml` file that contains the SEM setup information.

Example:
```
MMEM:LOAD:SEM:STAT 1,
'..\sem_std\WLAN\802_11a\802_11a_10MHz_5GHz_band.XML'
```

[SENSe:]POWer:SEM <Type>

This command sets the Spectrum Emission Mask (SEM) measurement type.

Parameters:
<Type> IEEE | ETSI | User

User
Settings and limits are configured via a user-defined XML file.
Load the file using `MMEMory:LOAD:SEM:STATe` on page 153.

IEEE
Settings and limits are as specified in the IEEE Std 802.11n™-2009 Figure 20-17—Transmit spectral mask for 20 MHz transmission. For other IEEE standards see the parameter values in the table below.
After a query, `IEEE` is returned for all IEEE standards.

ETSI
Settings and limits are as specified in the ETSI standard.

*RST: IEEE

Example:
```
POW:SEM ETSI
```

Table 9-5: Supported IEEE standards

Manual operation	The spectrum emission mask measurement is performed according to the standard	Parameter value
IEEE 802.11n-2009 20M@2.4G	IEEE Std 802.11n™-2009 Figure 20-17—Transmit spectral mask for 20 MHz transmission	IEEE or 'IEEE_2009_20_2_4'
IEEE 802.11n-2009 40M@2.4G	IEEE Std 802.11n™-2009 Figure 20-18—Transmit spectral mask for a 40 MHz channel	'IEEE_2009_40_2_4'
IEEE 802.11n-2009 20M@5G	IEEE Std 802.11n™-2009 Figure 20-17—Transmit spectral mask for 20 MHz transmission	'IEEE_2009_20_5'
IEEE 802.11n-2009 40M@5G	IEEE Std 802.11n™-2009 Figure 20-18—Transmit spectral mask for a 40 MHz channel	'IEEE_2009_40_5'

Manual operation	The spectrum emission mask measurement is performed according to the standard	Parameter value
IEEE 802.11mb/D08 20M@2.4G	IEEE Std 802.11n™-2009 Figure 20-17—Transmit spectral mask for 20 MHz transmission IEEE Draft P802.11-REVmb™/D8.0, March 2011 Figure 19-17—Transmit spectral mask for 20 MHz transmission in the 2.4 GHz band	'IEEE_D08_20_2_4'
IEEE 802.11mb/D08 40M@2.4G	IEEE Std 802.11n™-2009 Figure 20-18—Transmit spectral mask for a 40 MHz channel IEEE Draft P802.11-REVmb™/D8.0, March 2011 Figure 19-18—Transmit spectral mask for a 40 MHz channel in the 2.4 GHz band	'IEEE_D08_40_2_4'
IEEE 802.11mb/D08 20M@5G	IEEE Draft P802.11-REVmb™/D8.0, March 2011 Figure 19-19—Transmit spectral mask for 20 MHz transmission in the 5 GHz band	'IEEE_D08_20_5'
IEEE 802.11mb/D08 40M@5G	IEEE Draft P802.11-REVmb™/D8.0, March 2011 Figure 19-20—Transmit spectral mask for a 40 MHz channel in the 5 GHz band	'IEEE_D08_40_5'
IEEE 802.11ac/D1.1 20M@5G	IEEE P802.11ac™/D1.1, August 2011 Figure 22-17—Transmit spectral mask for a 20 MHz channel	'IEEE_AC_D1_1_20_5'
IEEE 802.11ac/D1.1 40M@5G	IEEE P802.11ac™/D1.1, August 2011 Figure 22-18—Transmit spectral mask for a 40 MHz channel	'IEEE_AC_D1_1_40_5'
IEEE 802.11ac/D1.1 80M@5G	IEEE P802.11ac™/D1.1, August 2011 Figure 22-19—Transmit spectral mask for a 80 MHz channel	'IEEE_AC_D1_1_80_5'

[SENSe:]POWer:SEM:CLASs <Index>

This command sets the Spectrum Emission Mask (SEM) power class index. The index represents the power classes to be applied. The index is directly related to the entries displayed in the power class drop down combo box, within the SEM settings configuration page.

Parameters:
<Index> *RST: 0

9.7 Configuring the Result Display

The following commands are required to configure the screen display in a remote environment. The corresponding tasks for manual operation are described in chapter 5.1, "Display Configuration", on page 44.

The suffix <n> in the following remote commands represents the window (1..16) in the currently selected measurement channel.

9.7.1 General Window Commands

The following commands are required to configure general window layout, independent of the application.

Note that the suffix <n> always refers to the window *in the currently selected measurement channel* (see `INSTrument[:SELect]` on page 112).

DISPlay:FORMat <Format>

This command determines which tab is displayed.

Parameters:

<Format>

SPLit
Displays the MultiView tab with an overview of all active channels

SINGle
Displays the measurement channel that was previously focused.

*RST: SING

Example: `DISP:FORM SPL`

DISPlay[:WINDow<n>]:SIZE <Size>

This command maximizes the size of the selected result display window *temporarily*. To change the size of several windows on the screen permanently, use the `LAY:SPL` command (see `LAYout:SPLitter` on page 160).

Parameters:

<Size>

LARGe
Maximizes the selected window to full screen.
Other windows are still active in the background.

SMALl
Reduces the size of the selected window to its original size.
If more than one measurement window was displayed originally, these are visible again.

*RST: SMALl

Example: DISP:WIND2:LARG

9.7.2 Working with Windows in the Display

The following commands are required to change the evaluation type and rearrange the screen layout for a measurement channel as you do using the SmartGrid in manual operation. Since the available evaluation types depend on the selected application, some parameters for the following commands also depend on the selected measurement channel.

LAYout:ADD[:WINDow]? <WindowName>,<Direction>,<WindowType>

This command adds a window to the display in the active measurement channel.

This command is always used as a query so that you immediately obtain the name of the new window as a result.

To replace an existing window, use the `LAYout:REPLace[:WINDow]` command.

Parameters:

<WindowName> String containing the name of the existing window the new window is inserted next to.
By default, the name of a window is the same as its index. To determine the name and index of all active windows, use the `LAYout:CATalog[:WINDow]?` query.

<Direction> LEFT | RIGHt | ABOVe | BELow
Direction the new window is added relative to the existing window.

<WindowType> text value
Type of result display (evaluation method) you want to add.
See the table below for available parameter values.

Return values:

<NewWindowName> When adding a new window, the command returns its name (by default the same as its number) as a result.

Example: `LAY:ADD? '1',LEFT,MTAB`
Result:
`'2'`
Adds a new window named '2' with a marker table to the left of window 1.

Usage: Query only

Manual operation: See "Bitstream" on page 19
See "Channel Frequency Response" on page 20
See "Constellation" on page 20
See "EVM vs Symbol" on page 21
See "Freq. Error vs Symbol" on page 21
See "Header information" on page 22
See "Magnitude Capture" on page 23
See "Phase Error vs Symbol" on page 24
See "Phase Tracking vs Symbol" on page 25
See "Power Spectrum" on page 25
See "PvT Full PPDU" on page 26
See "PvT Rising Edge" on page 26
See "PvT Falling Edge" on page 27
See "Result Summary" on page 27
See "Diagram" on page 30
See "Result Summary" on page 30
See "Marker Table" on page 30
See "Marker Peak List" on page 30

Table 9-6: <WindowType> parameter values for 802.11ad application

Parameter value	Window type
Window types for I/Q data	
CFR	Channel Frequency Response
CONStellation	Constellation
DBSTream	Data Bitstream (raw)
DDBStream	Data Bitstream (decoded)
EVSYmbol	EVM vs Symbol
FEVSymbol	Frequency Error vs. Symbol
HBSTream	Header Bitstream (raw)
HDBStream	Header Bitstream (decoded)
HEADer	Header Info
MCAPture	Magnitude Capture
PEVSymbol	Phase Error vs. Symbol
PTVSymbol	Phase Tracking vs. Symbol
PFALling	PvT Falling Edge
PFPPdu	PvT Full PPDU

Parameter value	Window type
PRISing	PvT Rising Edge
PSPectrum	Power Spectrum
RSGLobal	Result Summary
Window types for RF data	
DIAGram	Diagram
MTABle	Marker table
PEAKlist	Marker peak list
RSUMmary	Result summary

LAYout:CATalog[:WINDow]?

This command queries the name and index of all active windows in the active measurement channel from top left to bottom right. The result is a comma-separated list of values for each window, with the syntax:

<WindowName_1>,<WindowIndex_1>..<WindowName_n>,<WindowIndex_n>

Return values:

<WindowName> string

Name of the window.
In the default state, the name of the window is its index.

<WindowIndex> **numeric value**
Index of the window.

Example: `LAY:CAT?`
Result:
`'2',2,'1',1`
Two windows are displayed, named '2' (at the top or left), and '1' (at the bottom or right).

Usage: Query only

LAYout:IDENtify[:WINDow]? <WindowName>

This command queries the **index** of a particular display window in the active measurement channel.

Note: to query the **name** of a particular window, use the `LAYout:WINDow<n>:IDENtify?` query.

Query parameters:

<WindowName> String containing the name of a window.

Return values:

<WindowIndex> Index number of the window.

Example: `LAY:WIND:IDEN? '2'`
Queries the index of the result display named '2'.
Response:
`2`

Usage: Query only

LAYout:REMove[:WINDow] <WindowName>

This command removes a window from the display in the active measurement channel.

Parameters:

<WindowName> String containing the name of the window.
In the default state, the name of the window is its index.

Example: `LAY:REM '2'`
Removes the result display in the window named '2'.

Usage: Event

LAYout:REPLace[:WINDow] <WindowName>,<WindowType>

This command replaces the window type (for example from "Diagram" to "Result Summary") of an already existing window in the active measurement channel while keeping its position, index and window name.

To add a new window, use the `LAYout:ADD[:WINDow]?` command.

Parameters:

<WindowName> String containing the name of the existing window.
By default, the name of a window is the same as its index. To determine the name and index of all active windows in the active measurement channel, use the `LAYout:CATalog[:WINDow]?` query.

<WindowType> Type of result display you want to use in the existing window.
See `LAYout:ADD[:WINDow]?` on page 157 for a list of available window types.

Example: `LAY:REPL:WIND '1',MTAB`
Replaces the result display in window 1 with a marker table.

LAYout:SPLitter <Index1>,<Index2>,<Position>

This command changes the position of a splitter and thus controls the size of the windows on each side of the splitter.

Compared to the `DISPlay[:WINDow<n>]:SIZE` on page 156 command, the `LAYout:SPLitter` changes the size of all windows to either side of the splitter permanently, it does not just maximize a single window temporarily.

Note that windows must have a certain minimum size. If the position you define conflicts with the minimum size of any of the affected windows, the command will not work, but does not return an error.

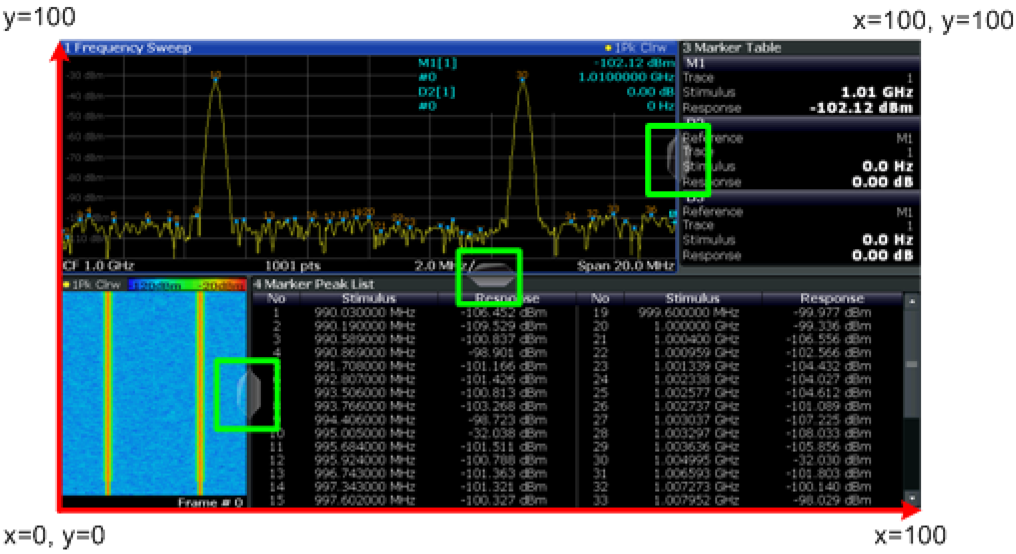


Fig. 9-1: SmartGrid coordinates for remote control of the splitters

Parameters:

<Index1> The index of one window the splitter controls.

<Index2> The index of a window on the other side of the splitter.

<Position> New vertical or horizontal position of the splitter as a fraction of the screen area (without channel and status bar and softkey menu).
The point of origin (x = 0, y = 0) is in the lower left corner of the screen. The end point (x = 100, y = 100) is in the upper right corner of the screen. (See figure 9-1.)
The direction in which the splitter is moved depends on the screen layout. If the windows are positioned horizontally, the splitter also moves horizontally. If the windows are positioned vertically, the splitter also moves vertically.

Range: 0 to 100

Example:

```
LAY:SPL 1,3,50
```

Moves the splitter between window 1 ('Frequency Sweep') and 3 ('Marker Table') to the center (50%) of the screen, i.e. in the figure above, to the left.

Example: `LAY:SPL 1,4,70`
Moves the splitter between window 1 ('Frequency Sweep') and 3 ('Marker Peak List') towards the top (70%) of the screen.
The following commands have the exact same effect, as any combination of windows above and below the splitter moves the splitter vertically.
`LAY:SPL 3,2,70`
`LAY:SPL 4,1,70`
`LAY:SPL 2,1,70`

LAYout:WINDow<n>:ADD? <Direction>,<WindowType>

This command adds a measurement window to the display. Note that with this command, the suffix <n> determines the existing window next to which the new window is added, as opposed to `LAYout:ADD[:WINDow]?`, for which the existing window is defined by a parameter.

To replace an existing window, use the `LAYout:WINDow<n>:REPLace` command.

This command is always used as a query so that you immediately obtain the name of the new window as a result.

Parameters:

<Direction> LEFT | RIGHt | ABOVe | BELow

<WindowType> Type of measurement window you want to add.
See `LAYout:ADD[:WINDow]?` on page 157 for a list of available window types.

Return values:

<NewWindowName> When adding a new window, the command returns its name (by default the same as its number) as a result.

Example: `LAY:WIND1:ADD? LEFT,MTAB`
Result:
`'2'`
Adds a new window named '2' with a marker table to the left of window 1.

Usage: Query only

LAYout:WINDow<n>:IDENtify?

This command queries the **name** of a particular display window (indicated by the <n> suffix) in the active measurement channel.

Note: to query the **index** of a particular window, use the `LAYout:IDENtify[:WINDow]?` command.

Return values:

<WindowName> String containing the name of a window.
In the default state, the name of the window is its index.

Example: `LAY:WIND2:IDEN?`
Queries the name of the result display in window 2.
Response:
`'2'`

Usage: Query only

LAYout:WINDow<n>:REMove

This command removes the window specified by the suffix <n> from the display in the active measurement channel.

The result of this command is identical to the `LAYout:REMove[:WINDow]` command.

Example: `LAY:WIND2:REM`
Removes the result display in window 2.

Usage: Event

LAYout:WINDow<n>:REPLace <WindowType>

This command changes the window type of an existing window (specified by the suffix <n>) in the active measurement channel.

The result of this command is identical to the `LAYout:REPLace[:WINDow]` command.

To add a new window, use the `LAYout:WINDow<n>:ADD?` command.

Parameters:

<WindowType> Type of measurement window you want to replace another one with.
See `LAYout:ADD[:WINDow]?` on page 157 for a list of available window types.

Example: `LAY:WIND2:REPL MTAB`
Replaces the result display in window 2 with a marker table.

9.7.3 Selecting Items to Display in Result Summary

The following command defines which items are displayed in the Result Summary.

9.7.4 Configuring the Y-Axis Scaling and Units

The scaling for the vertical axis is highly configurable, using either absolute or relative values. These commands are described here.

Useful commands for configuring scaling described elsewhere:

- `DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:RLEVel` on page 138

Remote commands exclusive to scaling the y-axis

CALCulate<n>:UNIT:ANGLe <Unit>
UNIT:ANGLe <Unit>

This command selects the global unit for all phase results.

Parameters:

<Unit> DEG | RAD

Manual operation: See "Phase Unit" on page 82

CALCulate<n>:UNIT:FREQuency <Unit>

This command selects the global unit for all frequency results.

Parameters:

<Unit> REL | ABS

*RST: REL

CALCulate<n>:UNIT:POWer <Unit>

This command selects the unit of the y-axis.

The unit applies to all power-based measurement windows (regardless of the <n> suffix).

Parameters:

<Unit> DBM | V | A | W | DBPW | WATT | DBUV | DBMV | VOLT | DBUA | AMPere

*RST: dBm

Example: `CALC:UNIT:POW DBM`
Sets the power unit to dBm.

Manual operation: See "Unit" on page 69

DISPlay[:WINDow<n>]:TRACe<t>:X[:SCALe]:UNIT?

This command reads the unit type currently configured for the X-axis

Usage: Query only

DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:AUTO <State>

If enabled, the Y-axis is scaled automatically according to the current measurement.

Suffix:
<t> irrelevant

Parameters for setting and query:
<State> **OFF**
Switch the function off
ON
Switch the function on
*RST: ON

Manual operation: See "Automatic Grid Scaling" on page 83
See "Auto Scale Once" on page 83

DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:MAXimum <Value>

This command defines the maximum value of the y-axis for all traces in the selected result display.

The suffix <t> is irrelevant.

Parameters:
<Value> <numeric value>
*RST: depends on the result display
The unit and range depend on the result display.

Example:
```
DISP:TRAC:Y:MIN -60
DISP:TRAC:Y:MAX 0
```
Defines the y-axis with a minimum value of -60 and maximum value of 0.

Manual operation: See "Absolute Scaling (Min/Max Values)" on page 84

DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:MINimum <Value>

This command defines the minimum value of the y-axis for all traces in the selected result display.

The suffix <t> is irrelevant.

Parameters:
<Value> <numeric value>
*RST: depends on the result display
The unit and range depend on the result display.

Example: `DISP:TRAC:Y:MIN -60`
`DISP:TRAC:Y:MAX 0`
Defines the y-axis with a minimum value of -60 and maximum value of 0.

Manual operation: See "Absolute Scaling (Min/Max Values)" on page 84

DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:PDIVision <Value>

This remote command determines the grid spacing on the Y-axis for all diagrams, where possible.

The suffix <t> is irrelevant.

Parameters:
<Value> numeric value WITHOUT UNIT (unit according to the result display)
Defines the range per division (total range = 10*<Value>)
*RST: depends on the result display

Example: `DISP:TRAC:Y:PDIV 10`
Sets the grid spacing to 10 units (e.g. dB) per division

Manual operation: See "Per Division" on page 84

DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:RPOSition <Position>

This command defines the vertical position of the reference level on the display grid (for all traces, <t> is irrelevant).

The R&S FSW adjusts the scaling of the y-axis accordingly.

Example: `DISP:TRAC:Y:RPOS 50PCT`

Usage: SCPI confirmed

Manual operation: See "Ref Position" on page 84

DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:RVALue <Value>

This command defines the reference value assigned to the reference position in the specified window. Separate reference values are maintained for the various displays.

Suffix:
<t> irrelevant

Parameters:
<Value> numeric value WITHOUT UNIT
Default unit: dBm

Manual operation: See "Ref Value" on page 84

DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:RVALue:MAXimum <Value>

This command defines the maximum value on the y-axis for all traces in the specified window.

The suffix <t> is irrelevant.

Parameters:

<Value>	numeric value Default unit: dBm

DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:RVALue:MINimum <Value>

This command defines the minimum value on the y-axis for all traces in the specified window.

The suffix <t> is irrelevant.

Parameters:

<Value>	numeric_value Default unit: dBm

DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:UNIT?

This command reads the unit type currently configured for the Y-axis

Usage: Query only

FORMat:BSTReam <BitStreamFormat>

Switches the format of the bitstream between octet and hexadecimal values.

Parameters:

<BitStreamFormat>	OCTet | HEXadecimal

Manual operation: See "Bitstream Format" on page 82

9.8 Starting a Measurement

When a IEEE 802.11ad measurement channel is activated on the R&S FSW, a IEEE 802.11ad Modulation Accuracy Measurement, see chapter 3.1, "IEEE 802.11ad Modulation Accuracy Measurement", on page 13), is started immediately. However, you can stop and start a new measurement any time.

Furthermore, you can perform a sequence of measurements using the Sequencer (see "Multiple Measurement Channels and Sequencer Function" on page 10).

ABORt

This command aborts the measurement in the current measurement channel and resets the trigger system.

To prevent overlapping execution of the subsequent command before the measurement has been aborted successfully, use the `*OPC?` or `*WAI` command after `ABOR` and before the next command.

For details see the "Remote Basics" chapter in the R&S FSW User Manual.

To abort a sequence of measurements by the Sequencer, use the `INITiate<n>:SEQuencer:ABORt` command.

Note on blocked remote control programs:

If a sequential command cannot be completed, for example because a triggered sweep never receives a trigger, the remote control program will never finish and the remote channel to the R&S FSW is blocked for further commands. In this case, you must interrupt processing on the remote channel first in order to abort the measurement.

To do so, send a "Device Clear" command from the control instrument to the R&S FSW on a parallel channel to clear all currently active remote channels. Depending on the used interface and protocol, send the following commands:

- **Visa**: `viClear()`
- **GPIB**: `ibclr()`
- **RSIB**: `RSDLLibclr()`

Now you can send the `ABORt` command on the remote channel performing the measurement.

Example: `ABOR;:INIT:IMM`
Aborts the current measurement and immediately starts a new one.

Example: `ABOR;*WAI`
`INIT:IMM`
Aborts the current measurement and starts a new one once abortion has been completed.

Usage: Event
SCPI confirmed

CALCulate<n>:BURSt[:IMMediate]

This command forces the IQ measurement results to be recalculated according to the current settings.

INITiate<n>:CONTinuous <State>

This command controls the measurement mode for an individual measurement channel.

Note that in single measurement mode, you can synchronize to the end of the measurement with *OPC, *OPC? or *WAI. In continuous measurement mode, synchronization to the end of the measurement is not possible. Thus, it is not recommended that you use continuous measurement mode in remote control, as results like trace data or markers are only valid after a single measurement end synchronization.

For details on synchronization see the "Remote Basics" chapter in the R&S FSW User Manual.

If the measurement mode is changed for a measurement channel while the Sequencer is active (see `INITiate<n>:SEQuencer:IMMediate` on page 170) the mode is only considered the next time the measurement in that channel is activated by the Sequencer.

Suffix:

<n>	irrelevant

Parameters:

<State> ON | OFF | 0 | 1

ON | 1
Continuous measurement

OFF | 0
Single measurement

*RST: 1

Example:
`INIT:CONT OFF`
Switches the measurement mode to single measurement.
`INIT:CONT ON`
Switches the measurement mode to continuous measurement.

Manual operation: See "Continuous Sweep/RUN CONT" on page 79

INITiate<n>[:IMMediate]

This command starts a (single) new measurement.

You can synchronize to the end of the measurement with *OPC, *OPC? or *WAI.

For details on synchronization see the "Remote Basics" chapter in the R&S FSW User Manual.

Suffix:

<n>	irrelevant

Usage: Event

Manual operation: See "Single Sweep/ RUN SINGLE" on page 80

INITiate<n>:SEQuencer:ABORt

This command stops the currently active sequence of measurements. The Sequencer itself is not deactivated, so you can start a new sequence immediately using `INITiate<n>:SEQuencer:IMMediate` on page 170.

To deactivate the Sequencer use `SYSTem:SEQuencer` on page 171.

Suffix:

<n>	irrelevant
Usage:	Event

INITiate<n>:SEQuencer:IMMediate

This command starts a new sequence of measurements by the Sequencer.

Its effect is similar to the `INITiate<n>[:IMMediate]` command used for a single measurement.

Before this command can be executed, the Sequencer must be activated (see `SYSTem:SEQuencer` on page 171).

Suffix:

<n>	irrelevant

Example:	`SYST:SEQ ON`
	Activates the Sequencer.
	`INIT:SEQ:MODE SING`
	Sets single sequence mode so each active measurement will be performed once.
	`INIT:SEQ:IMM`
	Starts the sequential measurements.

Usage:	Event

INITiate<n>:SEQuencer:MODE <Mode>

This command selects the way the R&S FSW application performs measurements sequentially.

Before this command can be executed, the Sequencer must be activated (see `SYSTem:SEQuencer` on page 171).

A detailed programming example is provided in the "Operating Modes" chapter in the R&S FSW User Manual.

Note: In order to synchronize to the end of a sequential measurement using *OPC, *OPC? or *WAI you must use `SINGle` Sequence mode.

For details on synchronization see the "Remote Basics" chapter in the R&S FSW User Manual.

Suffix:

<n>	irrelevant

Parameters:

<Mode>

SINGle
Each measurement is performed once (regardless of the channel's sweep mode), considering each channels' sweep count, until all measurements in all active channels have been performed.

CONTinuous
The measurements in each active channel are performed one after the other, repeatedly (regardless of the channel's sweep mode), in the same order, until the Sequencer is stopped.

CDEFined
First, a single sequence is performed. Then, only those channels in continuous sweep mode (`INIT:CONT ON`) are repeated.

*RST: CONTinuous

Example:

`SYST:SEQ ON`
Activates the Sequencer.
`INIT:SEQ:MODE SING`
Sets single sequence mode so each active measurement will be performed once.
`INIT:SEQ:IMM`
Starts the sequential measurements.

SYSTem:SEQuencer <State>

This command turns the Sequencer on and off. The Sequencer must be active before any other Sequencer commands (`INIT:SEQ...`) are executed, otherwise an error will occur.

Parameters:

<State> ON | OFF | 0 | 1

ON | 1
The Sequencer is activated and a sequential measurement is started immediately.

OFF | 0
The Sequencer is deactivated. Any running sequential measurements are stopped. Further Sequencer commands (`INIT:SEQ...`) are not available.

*RST: 0

Example:

`SYST:SEQ ON`
Activates the Sequencer.
`INIT:SEQ:MODE SING`
Sets single Sequencer mode so each active measurement will be performed once.
`INIT:SEQ:IMM`
Starts the sequential measurements.
`SYST:SEQ OFF`

9.9 Analysis

The following commands define general result analysis settings concerning the traces and markers in standard IEEE 802.11ad measurements. Currently, only one (Clear/ Write) trace and one marker are available for standard IEEE 802.11ad measurements.

Analysis for RF measurements

General result analysis settings concerning the trace, markers, lines etc. for RF measurements are identical to the analysis functions in the Spectrum application except for some special marker functions and spectrograms, which are not available in the R&S FSW 802.11ad application.

For details see the "General Measurement Analysis and Display" chapter in the R&S FSW User Manual.

9.9.1 Working with Markers

9.9.1.1 Individual Marker Settings

CALCulate<n>:MARKer<m>:AOFF

This command turns all markers off.

Example: `CALC:MARK:AOFF`
Switches off all markers.

Usage: Event

Manual operation: See "All Markers Off" on page 93

CALCulate<n>:MARKer<m>:LINK:TO:MARKer<m> <State>

This command links normal marker <m1> to any active normal marker <m2>.

If you change the horizontal position of marker <m2>, marker <m1> changes its horizontal position to the same value.

Parameters:

<State> ON | OFF

*RST: OFF

Example: `CALC:MARK4:LINK:TO:MARK2 ON`

Links marker 4 to marker 2.

Manual operation: See "Linking to Another Marker" on page 93

CALCulate<n>:MARKer<m>[:STATe] <State>

This command turns markers on and off. If the corresponding marker number is currently active as a deltamarker, it is turned into a normal marker.

Parameters:

<State> ON | OFF

*RST: OFF

Example: `CALC:MARK3 ON`

Switches on marker 3.

Manual operation: See "Marker 1 / Marker 2 / Marker 3 / ... Marker 16,/ Marker Norm/Delta" on page 91

See "Marker State" on page 92

See "Marker Type" on page 92

CALCulate<n>:MARKer<m>:TRACe <Trace>

This command selects the trace the marker is positioned on.

Note that the corresponding trace must have a trace mode other than "Blank".

If necessary, the command activates the marker first.

Parameters:

<Trace> **1 to 6**

Trace number the marker is assigned to.

Example: `CALC:MARK3:TRAC 2`

Assigns marker 3 to trace 2.

Manual operation: See "Assigning the Marker to a Trace" on page 93

CALCulate<n>:MARKer<m>:X <Position>

This command moves a marker to a particular coordinate on the x-axis.

If necessary, the command activates the marker.

If the marker has been used as a delta marker, the command turns it into a normal marker.

Parameters:

<Position> Numeric value that defines the marker position on the x-axis.

Range: The range depends on the current x-axis range.

Example: `CALC:MARK2:X 1.7MHz`
Positions marker 2 to frequency 1.7 MHz.

Manual operation: See "Marker Table" on page 30
See "Marker Peak List" on page 30
See "Marker 1 / Marker 2 / Marker 3 / … Marker 16,/ Marker Norm/Delta" on page 91
See "X-value" on page 92

CALCulate<n>:DELTamarker<m>:AOFF

This command turns *all* delta markers off.

(<m> is irrelevant)

Example: `CALC:DELT:AOFF`
Turns all delta markers off.

Usage: Event

CALCulate<n>:DELTamarker<m>:LINK <State>

This command links delta marker <m> to marker 1.

If you change the horizontal position (x-value) of marker 1, delta marker <m> changes its horizontal position to the same value.

Parameters:

<State> ON | OFF

*RST: OFF

Example: `CALC:DELT2:LINK ON`

Manual operation: See "Linking to Another Marker" on page 93

CALCulate<n>:DELTamarker<m>:LINK:TO:MARKer<m> <State>

This command links delta marker <m1> to any active normal marker <m2>.

If you change the horizontal position of marker <m2>, delta marker <m1> changes its horizontal position to the same value.

Parameters:
<State> ON | OFF
*RST: OFF

Example: `CALC:DELT4:LINK:TO:MARK2 ON`
Links the delta marker 4 to the marker 2.

Manual operation: See "Linking to Another Marker" on page 93

CALCulate<n>:DELTamarker<m>:MREF <Reference>

This command selects a reference marker for a delta marker other than marker 1.

Parameters:
<Reference>

Example: `CALC:DELT3:MREF 2`
Specifies that the values of delta marker 3 are relative to marker 2.

Manual operation: See "Reference Marker" on page 93

CALCulate<n>:DELTamarker<m>[:STATe] <State>

This command turns delta markers on and off.

If necessary, the command activates the delta marker first.

No suffix at DELTamarker turns on delta marker 1.

Parameters:
<State> ON | OFF
*RST: OFF

Example: `CALC:DELT2 ON`
Turns on delta marker 2.

Manual operation: See "Marker 1 / Marker 2 / Marker 3 / … Marker 16,/ Marker Norm/Delta" on page 91
See "Marker State" on page 92
See "Marker Type" on page 92

CALCulate<n>:DELTamarker<m>:TRACe <Trace>

This command selects the trace a delta marker is positioned on.

Note that the corresponding trace must have a trace mode other than "Blank".

If necessary, the command activates the marker first.

Parameters:
<Trace> Trace number the marker is assigned to.

Example: `CALC:DELT2:TRAC 2`
Positions delta marker 2 on trace 2.

CALCulate<n>:DELTamarker<m>:X <Position>

This command moves a delta marker to a particular coordinate on the x-axis.

If necessary, the command activates the delta marker and positions a reference marker to the peak power.

Example: `CALC:DELT:X?`
Outputs the absolute x-value of delta marker 1.

Manual operation: See "Marker 1 / Marker 2 / Marker 3 / … Marker 16,/ Marker Norm/Delta" on page 91
See "X-value" on page 92

9.9.1.2 General Marker Settings

CALCulate<n>:MARKer<m>:LINK <State>

This command defines whether all markers within the selected result display are linked. If enabled, and you move one marker along the x-axis, all other markers in the display are moved to the same x-axis position.

(The suffix <m> is irrelevant.)

Parameters:
<State> ON | OFF
*RST: OFF

Example: `CALC2:MARK:LINK ON`

DISPlay:MTABle <DisplayMode>

This command turns the marker table on and off.

Parameters:
<DisplayMode>

ON
Turns the marker table on.

OFF
Turns the marker table off.

AUTO
Turns the marker table on if 3 or more markers are active.

*RST: AUTO

Example: `DISP:MTAB ON`
Activates the marker table.

Manual operation: See "Marker Table Display" on page 94

9.9.1.3 Configuring and Performing a Marker Search

The following commands control the marker search.

CALCulate<n>:MARKer<m>:LOEXclude <State>

This command turns the suppression of the local oscillator during automatic marker positioning on and off (for *all* markers in *all* windows; <m>, <n> are irrelevant).

Parameters:

<State> ON | OFF | 0 | 1

*RST: 1

Example: `CALC:MARK:LOEX ON`

CALCulate<n>:MARKer<m>:PEXCursion <Excursion>

This command defines the peak excursion (for *all* markers in *all* windows; <m>, <n> are irrelevant).

The peak excursion sets the requirements for a peak to be detected during a peak search.

The unit depends on the measurement.

9.9.1.4 Positioning the Marker

This chapter contains remote commands necessary to position the marker on a trace.

Positioning Normal Markers

The following commands position markers on the trace.

CALCulate<n>:MARKer<m>:MAXimum:LEFT

This command moves a marker to the next lower peak.

The search includes only measurement values to the left of the current marker position.

Usage: Event

CALCulate<n>:MARKer<m>:MAXimum:NEXT

This command moves a marker to the next lower peak.

Usage: Event

CALCulate<n>:MARKer<m>:MAXimum[:PEAK]

This command moves a marker to the highest level.

If the marker is not yet active, the command first activates the marker.

Usage: Event

CALCulate<n>:MARKer<m>:MAXimum:RIGHt

This command moves a marker to the next lower peak.

The search includes only measurement values to the right of the current marker position.

Usage: Event

CALCulate<n>:MARKer<m>:MINimum:LEFT

This command moves a marker to the next minimum value.

The search includes only measurement values to the right of the current marker position.

Usage: Event

CALCulate<n>:MARKer<m>:MINimum:NEXT

This command moves a marker to the next minimum value.

Usage: Event

CALCulate<n>:MARKer<m>:MINimum[:PEAK]

This command moves a marker to the minimum level.

If the marker is not yet active, the command first activates the marker.

Usage: Event

CALCulate<n>:MARKer<m>:MINimum:RIGHt

This command moves a marker to the next minimum value.

The search includes only measurement values to the right of the current marker position.

Usage: Event

Positioning Delta Markers

The following commands position delta markers on the trace.

CALCulate<n>:DELTamarker<m>:MAXimum:LEFT

This command moves a delta marker to the next higher value.

The search includes only measurement values to the left of the current marker position.

Usage: Event

CALCulate<n>:DELTamarker<m>:MAXimum:NEXT

This command moves a marker to the next higher value.

Usage: Event

CALCulate<n>:DELTamarker<m>:MAXimum[:PEAK]

This command moves a delta marker to the highest level.

If the marker is not yet active, the command first activates the marker.

Usage: Event

CALCulate<n>:DELTamarker<m>:MAXimum:RIGHt

This command moves a delta marker to the next higher value.

The search includes only measurement values to the right of the current marker position.

Usage: Event

CALCulate<n>:DELTamarker<m>:MINimum:LEFT

This command moves a delta marker to the next higher minimum value.

The search includes only measurement values to the right of the current marker position.

Usage: Event

CALCulate<n>:DELTamarker<m>:MINimum:NEXT

This command moves a marker to the next higher minimum value.

Usage: Event

CALCulate<n>:DELTamarker<m>:MINimum[:PEAK]

This command moves a delta marker to the minimum level.

If the marker is not yet active, the command first activates the marker.

Usage: Event

CALCulate<n>:DELTamarker<m>:MINimum:RIGHt

This command moves a delta marker to the next higher minimum value.

The search includes only measurement values to the right of the current marker position.

Usage: Event

9.9.2 Configuring Standard Traces

DISPlay[:WINDow<n>]:TRACe<t>:MODE <Mode>

This command selects the trace mode.

In case of max hold, min hold or average trace mode, you can set the number of single measurements with `[SENSe:]SWEep:COUNt`. Note that synchronization to the end of the measurement is possible only in single sweep mode.

Parameters:

<Mode>

WRITe
Overwrite mode: the trace is overwritten by each sweep. This is the default setting.

AVERage
The average is formed over several sweeps. The "Sweep/Average Count" determines the number of averaging procedures.

MAXHold
The maximum value is determined over several sweeps and displayed. The R&S FSW saves the sweep result in the trace memory only if the new value is greater than the previous one.

MINHold
The minimum value is determined from several measurements and displayed. The R&S FSW saves the sweep result in the trace memory only if the new value is lower than the previous one.

VIEW
The current contents of the trace memory are frozen and displayed.

BLANk
Hides the selected trace.

*RST: Trace 1: WRITe, Trace 2-6: BLANk

Example:

`INIT:CONT OFF`
Switching to single sweep mode.
`SWE:COUN 16`
Sets the number of measurements to 16.
`DISP:TRAC3:MODE WRIT`
Selects clear/write mode for trace 3.
`INIT;*WAI`
Starts the measurement and waits for the end of the measurement.

DISPlay[:WINDow<n>]:TRACe<t>[:STATe] <State>

This command turns a trace on and off.

The measurement continues in the background.

Parameters:

<State> ON | OFF | 0 | 1

*RST: 1 for TRACe1, 0 for TRACe 2 to 6

Example: `DISP:TRAC3 ON`

Usage: SCPI confirmed

[SENSe:]SWEep:POINts <Points>

Sets/queries the number of trace points to be displayed and used for statistical evaluation.

Parameters:
<Points>

[SENSe:]AVERage<n>:COUNt <AverageCount>
[SENSe:]SWEep:COUNt <SweepCount>

This command defines the number of measurements that the application uses to average traces.

In case of continuous measurement mode, the application calculates the moving average over the average count.

In case of single measurement mode, the application stops the measurement and calculates the average after the average count has been reached.

Example: `SWE:COUN 64`
Sets the number of measurements to 64.
`INIT:CONT OFF`
Switches to single measurement mode.
`INIT;*WAI`
Starts a measurement and waits for its end.

Usage: SCPI confirmed

Manual operation: See "Sweep / Average Count" on page 80

[SENSe:]SWEep:COUNt:CURRent?

Usage: Query only

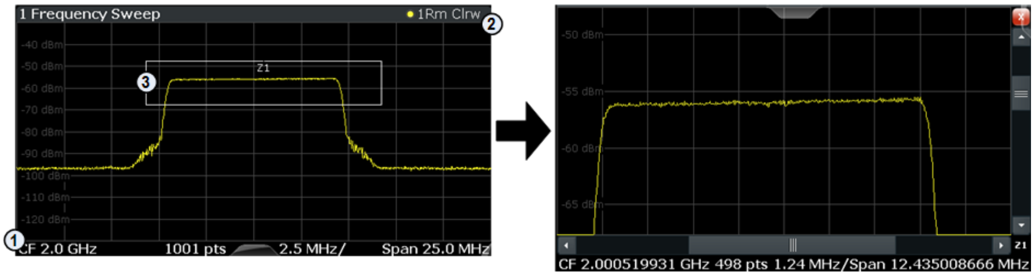
9.9.3 Zooming into the Display

9.9.3.1 Using the Single Zoom

DISPlay[:WINDow<n>]:ZOOM:AREA <x1>,<y1>,<x2>,<y2>

This command defines the zoom area.

To define a zoom area, you first have to turn the zoom on.



1 = origin of coordinate system (x1 = 0, y1 = 0)
2 = end point of system (x2 = 100, y2= 100)
3 = zoom area (e.g. x1 = 60, y1 = 30, x2 = 80, y2 = 75)

Parameters:

<x1>,<y1>, <x2>,<y2> — Diagram coordinates in % of the complete diagram that define the zoom area.
The lower left corner is the origin of coordinate system. The upper right corner is the end point of the system.

Range: 0 to 100
Default unit: PCT

DISPlay[:WINDow<n>]:ZOOM:STATe <State>

This command turns the zoom on and off.

Parameters:

<State> — ON | OFF

*RST: OFF

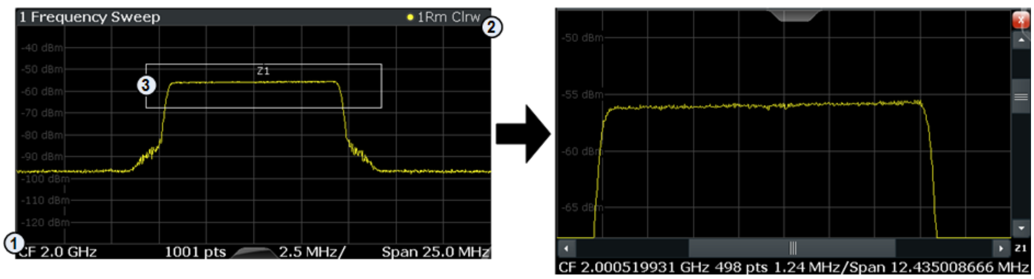
Example: `DISP:ZOOM ON`
Activates the zoom mode.

9.9.3.2 Using the Multiple Zoom

DISPlay[:WINDow<n>]:ZOOM:MULTiple<zoom>:AREA <x1>,<y1>,<x2>,<y2>

This command defines the zoom area for a multiple zoom.

To define a zoom area, you first have to turn the zoom on.



1 = origin of coordinate system (x1 = 0, y1 = 0)
2 = end point of system (x2 = 100, y2= 100)
3 = zoom area (e.g. x1 = 60, y1 = 30, x2 = 80, y2 = 75)

Suffix:
<zoom> 1...4
Selects the zoom window.

Parameters:
<x1>,<y1>, <x2>,<y2> Diagram coordinates in % of the complete diagram that define the zoom area.
The lower left corner is the origin of coordinate system. The upper right corner is the end point of the system.
Range: 0 to 100
Default unit: PCT

DISPlay[:WINDow<n>]:ZOOM:MULTiple<zoom>:STATe <State>

This command turns the mutliple zoom on and off.

Suffix:
<zoom> 1...4
Selects the zoom window.
If you turn off one of the zoom windows, all subsequent zoom windows move up one position.

Parameters:
<State> ON | OFF
*RST: OFF

9.10 Retrieving Results

The following commands are required to retrieve the results from a IEEE 802.11ad measurement in a remote environment.

The `*OPC` command should be used after commands that retrieve data so that subsequent commands to change the trigger or data capturing settings are held off until after the data capture is completed and the data has been returned.

9.10.1 Numeric Modulation Accuracy Results

The following commands describe how to retrieve the numeric results from the standard IEEE 802.11ad measurements.

The commands to retrieve results from SEM measurements for IEEE 802.11ad signals are described in chapter 9.10.2, "Numeric Results for SEM Measurements", on page 190.

9.10.1.1 PPDU and Symbol Count Results

The following commands are required to retrieve PPDU and symbol count results from the IEEE 802.11ad Modulation Accuracy measurement on the captured I/Q data (see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13).

FETCh:BURSt:COUNt?

This command returns the number of analyzed PPDUs from the current capture buffer.

Return values:
<PPDUs> integer

Usage: Query only

FETCh:BURSt:LENGths?

This command returns the EVM symbol count of the analyzed PPDUs from the current measurement.

The result is a comma-separated list of symbol counts, one for each PPDU.

Return values:
<PPDULength> integer value
number of symbols as counted for the EVM calculation

Usage: Query only

FETCh:BURSt:STARts?

This command returns the start position of each analyzed PPDU in the current capture buffer.

Return values:

<Position> Comma-separated list of samples indicating the start position of each PPDU.

Usage: Query only

9.10.1.2 Error Parameter Results

The following commands are required to retrieve individual results from the IEEE 802.11ad Modulation Accuracy measurement on the captured I/Q data (see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13).

FETCh:BURSt:ALL?

This command returns all results from the default IEEE 802.11ad I/Q measurement (see "Result Summary" on page 27).

For details on individual parameters see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

The results are output as a list of result strings separated by commas in ASCII format. The results are output in the following order:

Return values:

<Result> <min_EVM_All>,<avg_EVM_All>,<max_EVM_All>,
<min_EVM_Data>,<avg_EVM_Data>,<max_EVM_Data>,
<min_EVM_Pilots>,<avg_EVM_Pilots>,<max_EVM_Pilots>,
<min_IQ_Offset>, <avg_IQ_Offset>,<max_IQ_Offset>,
<min_Gain_Imb>,<avg_Gain_Imb>,<max_Gain_Imb>,
<min_Quad_Error>,<avg_Quad_Error>,<max_Quad_Error>,
<min_CFreqErr>,<avg_CFreqErr>,<max_CFreqErr>,
<min_SymClockErr>,<avg_SymClockErr>,<max_SymClockErr>,
<min_RiseTime>,<avg_RiseTime>,<max_RiseTime>,
<min_FallTime>,<avg_FallTime>,<max_FallTime>,
<min_TimeSkew>,<avg_TimeSkew>,<max_TimeSkew>,
<min_TDPow>,<avg_TDPow>,<max_TDPow>,
<min_CrestFactor>,<avg_CrestFactor>,<max_CrestFactor>

Example:

```
FETC:BURS:ALL?
//Result:
-24.259804,3.6840858,16.140923,
-24.202038,3.8634479,16.32444,
-25.87265,-25.131031,-24.265713,
-50.468945,-40.341217,-37.684074,
-0.00034274373,-0.00020165637,7.5068659e-005,
0.02957472,0.0350154,0.0439591,
40.021568,-6955.4434,-29974.053,
0.076774932,0.020238044,-0.19806632,
NAN,NAN,NAN,
NAN,NAN,NAN,
NAN,NAN,NAN,
-8.2310677,-8.2265606,-8.2229691,
5.7754779,6.0745926,6.3284931
```

Usage: Query only

Manual operation: See "Result Summary" on page 27

FETCh:CFACtor:AVERage?
FETCh:CFACtor:MAXimum?
FETCh:CFACtor:MINimum?

This command returns the average, maximum or minimum crest factor for the PPDU in dB.

For details see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Usage: Query only

FETCh:CFERror:AVERage?
FETCh:CFERror:MAXimum?
FETCh:CFERror:MINimum?

This command returns the average, maximum or minimum center frequency error for the PPDU in Hz.

For details see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Usage: Query only

FETCh:EVM:ALL:AVERage?
FETCh:EVM:ALL:MAXimum?
FETCh:EVM:ALL:MINimum?

This command returns the average, maximum or minimum EVM for all symbols for the PPDU in dB.

For details see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Usage: Query only

FETCh:EVM:DATA:AVERage?
FETCh:EVM:DATA:MAXimum?
FETCh:EVM:DATA:MINimum?

This command returns the average, maximum or minimum EVM for data symbols for the PPDU in dB.

For details see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Usage: Query only

FETCh:EVM:PILot:AVERage?
FETCh:EVM:PILot:MAXimum?
FETCh:EVM:PILot:MINimum?

This command returns the average, maximum or minimum EVM for pilot symbols for the PPDU in dB.

For details see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Usage: Query only

FETCh:FTIMe:AVERage?
FETCh:FTIMe:MAXimum?
FETCh:FTIMe:MINimum?

This command returns the average, maximum or minimum fall time for the PPDU in s.

For details see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Usage: Query only

FETCh:GIMBalance:AVERage?
FETCh:GIMBalance:MAXimum?
FETCh:GIMBalance:MINimum?

This command returns the average, maximum or minimum gain imbalance for the PPDU in dB.

For details see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Usage: Query only

FETCh:IQOFfset:AVERage?
FETCh:IQOFfset:MAXimum?
FETCh:IQOFfset:MINimum?

This command returns the average, maximum or minimum I/Q offset for the PPDU in dB.

For details see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Usage: Query only

FETCh:QUADerror:AVERage?
FETCh:QUADerror:MAXimum?
FETCh:QUADerror:MINimum?

This command returns the average, maximum or minimum quadrature error for the PPDU in degrees (°).

For details see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Usage: Query only

FETCh:RTIMe:AVERage?
FETCh:RTIMe:MAXimum?
FETCh:RTIMe:MINimum?

This command returns the average, maximum or minimum rise time for the PPDU in s.

For details see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Usage: Query only

FETCh:SYMBolerror:AVERage?
FETCh:SYMBolerror:MAXimum?
FETCh:SYMBolerror:MINimum?

This command returns the average, maximum or minimum symbol clock error for the PPDu in ppm.

For details see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Usage: Query only

FETCh:TDPower:AVERage?
FETCh:TDPower:MAXimum?
FETCh:TDPower:MINimum?

This command returns the average, maximum or minimum time domain power for the PPDU in dBm.

For details see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Usage: Query only

FETCh:TSKew:AVERage?
FETCh:TSKew:MAXimum?
FETCh:TSKew:MINimum?

This command returns the average, maximum or minimum time skew for the PPDU in s.

For details see chapter 3.1.1, "Modulation Accuracy Parameters", on page 13.

Usage: Query only

9.10.2 Numeric Results for SEM Measurements

The following commands are required to retrieve the numeric results of the IEEE 802.11ad SEM measurements (see chapter 3.2, "SEM Measurements", on page 28.

In the following commands used to retrieve the numeric results for RF data, the suffixes <n> for CALCulate and <k> for LIMit are irrelevant.

CALCulate<n>:LIMit<k>:FAIL?

This command queries the result of a limit check.

Note that for SEM measurements, the limit line suffix <k> is irrelevant, as only one specific SEM limit line is checked for the currently relevant power class.

To get a valid result, you have to perform a complete measurement with synchronization to the end of the measurement before reading out the result. This is only possible for single measurement mode.

See also `INITiate<n>:CONTinuous` on page 169.

Return values:

<Result>
: **0**
PASS
: **1**
FAIL

Example:
`INIT;*WAI`
Starts a new sweep and waits for its end.
`CALC:LIM3:FAIL?`
Queries the result of the check for limit line 3.

Usage:
Query only
SCPI confirmed

CALCulate<n>:MARKer<m>:X <Position>

This command moves a marker to a particular coordinate on the x-axis.

If necessary, the command activates the marker.

If the marker has been used as a delta marker, the command turns it into a normal marker.

Parameters:

<Position>
: Numeric value that defines the marker position on the x-axis.
Range: The range depends on the current x-axis range.

Example:
`CALC:MARK2:X 1.7MHz`
Positions marker 2 to frequency 1.7 MHz.

Manual operation:
See "Marker Table" on page 30
See "Marker Peak List" on page 30
See "Marker 1 / Marker 2 / Marker 3 / … Marker 16,/ Marker Norm/Delta" on page 91
See "X-value" on page 92

9.10.3 Retrieving Trace Results

The following commands describe how to retrieve the trace data from the IEEE 802.11ad Modulation Accuracy measurement. Note that for these measurements, only 1 trace per window can be configured.

The traces for SEM measurements are identical to those in the Spectrum application.

Remote commands exclusive to retrieving trace results:

FORMat[:DATA] <Format>

This command selects the data format that is used for transmission of trace data from the R&S FSW to the controlling computer.

Note that the command has no effect for data that you send to the R&S FSW. The R&S FSW automatically recognizes the data it receives, regardless of the format.

Parameters:

<Format> **ASCii**
ASCii format, separated by commas.
This format is almost always suitable, regardless of the actual data format. However, the data is not as compact as other formats may be.

REAL,32
32-bit IEEE 754 floating-point numbers in the "definite length block format".
In the Spectrum application, the format setting `REAL` is used for the binary transmission of trace data.
For I/Q data, 8 bytes per sample are returned for this format setting.

*RST: ASCII

Example: `FORM REAL,32`

Usage: SCPI confirmed

TRACe<n>[:DATA]? <ResultType>

This command queries current trace data and measurement results from the specified window.

For details see chapter 9.10.4, "Measurement Results for TRACe<n>[:DATA]? TRACE<n>", on page 195.

Suffix:

<n> irrelevant

Parameters:

<ResultType> Selects the type of result to be returned.

TRACE1 | ... | TRACE6
Returns the trace data for the corresponding trace.
Note that for the default IEEE 802.11ad I/Q measurement (Modulation Accuracy, Flatness and Tolerance), only 1 trace per window (TRACE1) is available.

LIST
Returns the results of the peak list evaluation for Spectrum Emission Mask measurements.

Return values:

<TraceData> For more information see tables below.

Example:
```
DISP:WIND2:SEL
TRAC? TRACE3
```
Queries the data of trace 3 in window 2.

Usage: Query only

Manual operation:
See "Bitstream" on page 19
See "Channel Frequency Response" on page 20
See "Constellation" on page 20
See "EVM vs Symbol" on page 21
See "Freq. Error vs Symbol" on page 21
See "Header information" on page 22
See "Magnitude Capture" on page 23
See "Phase Error vs Symbol" on page 24
See "Phase Tracking vs Symbol" on page 25
See "Power Spectrum" on page 25
See "PvT Full PPDU" on page 26
See "PvT Rising Edge" on page 26
See "PvT Falling Edge" on page 27

Table 9-7: Return values for TRACE1 to TRACE6 parameter

For I/Q data traces, the results depend on the evaluation method (window type) selected for the current window (see `LAYout:ADD[:WINDow]?` on page 157. The results for the various window types are described in chapter 9.10.4, "Measurement Results for TRACe<n>[:DATA]? TRACE<n>", on page 195.
For RF data traces, the trace data consists of a list of 1001 power levels that have been measured. The unit depends on the measurement and on the unit you have currently set.
For SEM measurements, the x-values should be queried as well, as they are not equi-distant (see `TRACe<n>[:DATA]:X?` on page 194).

Table 9-8: Return values for LIST parameter

This parameter is only available for SEM measurements. For each sweep list range you have defined (range 1...n), the command returns eight values in the following order. <No>,<StartFreq>,<StopFreq>,<RBW>,<PeakFreq>,<PowerAbs>,<PowerRel>,<PowerDelta>,<LimitCheck>,<Unused1>,<Unused2> ● <No>: range number ● <StartFreq>,<StopFreq>: start and stop frequency of the range ● <RBW>: resolution bandwidth ● <PeakFreq>: frequency of the peak in a range ● <PowerAbs>: absolute power of the peak in dBm ● <PowerRel>: power of the peak in relation to the channel power in dBc ● <PowerDelta>: distance from the peak to the limit line in dB, positive values indicate a failed limit check ● <LimitCheck>: state of the limit check (0 = PASS, 1 = FAIL) ● <Unused1>,<Unused2>: reserved (0.0)

TRACe<n>[:DATA]:X? <TraceNumber>

This command queries the horizontal trace data for each sweep point in the specified window, for example the frequency in frequency domain or the time in time domain measurements.

This is especially useful for traces with non-equidistant x-values, e.g. for SEM or Spurious Emissions measurements.

Query parameters:

<TraceNumber> Trace number.

TRACE1 | ... | TRACE6

Example: `TRAC3:X? TRACE1`

Returns the x-values for trace 1 in window 3.

Usage: Query only

TRACe:IQ:DATA:MEMory <OffsetSamp>, <NumSamples>

Returns all the I/Q trace data in the capture buffer. The result values are scaled in Volts. The command returns a comma-separated list of the measured voltage values in floating point format (Comma Separated Values = CSV). The number of values returned is 2 * the number of complex samples, the first half being the I values, the second half the Q values.

Parameters:

<OffsetSamp> Offset of the values to be read related to the start of the capture buffer.

Range: 0 to (<NumSamples>-1)

<NumSamples> Number of measurement values to be read.

Range: 1 to (<NumSamples>-<OffsetSa>)

9.10.4 Measurement Results for TRACe<n>[:DATA]? TRACE<n>

The evaluation method selected by the `LAY:ADD:WIND` command also affects the results of the trace data query (see TRACe<n>[:DATA]? TRACE<n>).

Details on the returned trace data depending on the evaluation method are provided here.

No trace data is available for the following evaluation methods:

- Magnitude Capture
- Result Summary (Global/Detailed)

For details on the graphical results of these evaluation methods, see chapter 3.1.2, "Evaluation Methods for IEEE 802.11ad Modulation Accuracy Measurements", on page 18.

9.10.4.1 Bitstream

For a given OFDM symbol and a given subcarrier, the bitstream result is derived from the corresponding complex constellation point according to *Std IEEE802.11-2012 "Figure 18-10—BPSK, QPSK, 16-QAM, and 64-QAM constellation bit encoding"*. The bit pattern (binary representation) is converted to its equivalent integer value as the final measurement result. The number of values returend for each analyzed OFDM symbol corresponds to the number of data subcarriers plus the number of pilot subcariers (N_{SD} $+N_{SP}$) in remote mode.

As opposed to the graphical Bitstream results, the DC and NULL carriers are not available in remote mode.

9.10.4.2 Constellation

This measurement represents the complex constellation points as I and Q data. See for example IEEE Std. 802.11-2012 'Fig. 18-10 BPSK, QPSK, 16-QAM and 64-QAM constellation bit encoding'. Each I and Q point is returned in floating point format.

Data is returned as a repeating array of interleaved I and Q data in groups of selected carriers per OFDM-Symbol, until all the I and Q data for the analyzed OFDM-Symbols is exhausted.

The following carrier selections are possible:

- "All Carriers": `CONFigure:BURSt:CONStellation:CARRier:SELect ALL`
  N_{ST} pairs of I and Q data per OFDM-Symbol
  OFDM-Symbol 1: $(I_{1,1}, Q_{1,1}), (I_{1,2},Q_{1,2}), \ldots,(I_{1,Nst}, Q_{1,Nst})$
  OFDM-Symbol 2: $(I_{2,1}, Q_{2,1}), (I_{2,2},Q_{2,2}),\ldots,(I_{2,Nst}, Q_{2,Nst})$
  …
  OFDM-Symbol N:
  $(I_{N,1}, Q_{N,1}), (I_{N,2},Q_{N,2}),\ldots,(I_{N,Nst}, Q_{N,Nst})$
- "Pilots Only": `CONFigure:BURSt:CONStellation:CARRier:SELect PILOTS`
  N_{SP} pairs of I and Q data per OFDM-Symbol in the natural number order.
  OFDM-Symbol 1: $(I_{1,1}, Q_{1,1}), (I_{1,2},Q_{1,2}), \ldots,(I_{1,Nsp}, Q_{1,Nsp})$
  OFDM-Symbol 2: $(I_{2,1}, Q_{2,1}), (I_{2,2},Q_{2,2}),\ldots,(I_{2,Nsp}, Q_{2,Nsp})$
  …
  OFDM-Symbol N:
  $(I_{N,1}, Q_{N,1}), (I_{N,2},Q_{N,2}),\ldots,(I_{N,Nsp}, Q_{N,Nsp})$
- Single carrier:
  1 pair of I and Q data per OFDM-Symbol for the selected carrier
  `CONFigure:BURSt:CONStellation:CARRier:SELect k`
  with
  $$\boldsymbol{k} \in \left\{-(\boldsymbol{N_{used}} - 1)/2, -(\boldsymbol{N_{used}} - 1)/2 + 1, \ldots, (\boldsymbol{N_{used}} - 1)/2\right\}$$
  OFDM-Symbol 1: $(I_{1,1}, Q_{1,1})$
  OFDM-Symbol 2: $(I_{2,1}, Q_{2,1})$
  …
  OFDM-Symbol N: $(I_{N,1}, Q_{N,1})$

9.10.4.3 EVM vs Symbol

EVM value as measured for each symbol over the complete capture period.

Each EVM value is returned as a floating point number, expressed in units of dBm.

Supported data formats (see `FORMat[:DATA]` on page 192): `ASCii|REAL`

9.10.4.4 Frequency Error vs Symbol

Frequency offset as measured for each symbol over the complete capture period.

Each offset value is returned as a floating point number, expressed in units of Hz.

9.10.4.5 Header Info

The `TRAC:DATA?` command returns the information as read from the header for each analyzed PPDU. The header bit sequence is converted to an equivalent sequence of hexadecimal digits for each analyzed PPDU in transmit order.

That is, the first transmitted bit has the highest significance and the last transmitted bit has the lowest significance.

9.10.4.6 Magnitude Capture

Returns the magnitude for each measurement point as measured over the complete capture period. The number of measurement points depends on the input sample rate and the capture time (see "Sample Rate" on page 72 and "Capture Time" on page 72).

9.10.4.7 Phase Error vs Symbol

Phase error value as calculated for each symbol over the complete capture period. The number of values is:

<No of symbols> * <No of PPDUs>

Each offset value is returned as a floating point number, expressed in units of degrees (°).

9.10.4.8 Phase Tracking vs. Symbol

Returns the average phase tracking result for each symbol over the complete capture period. The number of values is:

<No of symbols> * <No of PPDUs>

Each value is returned as a floating point number, expressed in units of degrees (°).

9.10.4.9 Power Spectrum

Returns the power vs frequency values obtained from the FFT. This is an exhaustive call, due to the fact that there are nearly always more FFT points than I/Q samples. The number of FFT points is a power of 2 that is higher than the total number of I/Q samples, i.e.; number of FFT points := round number of I/Q-samples to next power of 2.

E.g. if there were 20000 samples, then 32768 FFT points are returned.

Data is returned in floating point format in dBm.

9.10.4.10 Power vs Time (PVT)

All complete PPDUs within the capture time are analyzed in three master PPDUs. The three master PPDUs relate to the minimum, maximum and average values across all complete PPDUs. This data is returned in dBm values on a per sample basis. Each sample relates to an analysis of each corresponding sample within each processed PPDU.

For PVT Rising and PVT Falling displays, the results are restricted to the rising or falling edge of the analyzed PPDUs.

The type of PVT data returned is determined by the TRACE number passed as an argument to the SCPI command:

TRACE1	minimum PPDU data values
TRACE2	mean PPDU data values
TRACE3	maximum PPDU data values

Supported data formats (see FORMat[:DATA] on page 192): ASCii|REAL

9.10.4.11 Channel Frequency Response

The Channel Frequency Response evaluation returns absolute power values per carrier.

Two trace types are provided for this evaluation:

Table 9-9: Query parameter and results for Channel Frequency Response

TRACE1	All channel frequency response values per channel
TRACE2	An average channel frequency response value for each of the 53 (or 57/117 within the IEEE 802.11 n standard) carriers

Absolute power results are returned in dB.

Supported data formats (FORMat:DATA): ASCii|REAL

9.10.5 Retrieving Marker Results

The following commands are required to retrieve marker results.

Useful commands for retrieving marker results described elsewhere:

- CALCulate<n>:DELTamarker<m>:X on page 176
- CALCulate<n>:MARKer<m>:X on page 174

Remote commands exclusive to retrieving marker results:

CALCulate<n>:DELTamarker<m>:X:RELative?

This command queries the relative position of a delta marker on the x-axis.

If necessary, the command activates the delta marker first.

Return values:
<Position> Position of the delta marker in relation to the reference marker.

Example: CALC:DELT3:X:REL?
Outputs the frequency of delta marker 3 relative to marker 1 or relative to the reference position.

Usage: Query only

Manual operation: See "Marker 1 / Marker 2 / Marker 3 / … Marker 16,/ Marker Norm/Delta" on page 91

CALCulate<n>:DELTamarker<m>:Y?

This command queries the relative position of a delta marker on the y-axis.

If necessary, the command activates the delta marker first.

To get a valid result, you have to perform a complete measurement with synchronization to the end of the measurement before reading out the result. This is only possible for single measurement mode.

See also INITiate<n>:CONTinuous on page 169.

The unit depends on the application of the command.

Return values:
<Position> Position of the delta marker in relation to the reference marker or the fixed reference.

Example: INIT:CONT OFF
Switches to single sweep mode.
INIT;*WAI
Starts a sweep and waits for its end.
CALC:DELT2 ON
Switches on delta marker 2.
CALC:DELT2:Y?
Outputs measurement value of delta marker 2.

Usage: Query only

Manual operation: See "Marker 1 / Marker 2 / Marker 3 / … Marker 16,/ Marker Norm/Delta" on page 91

CALCulate<n>:MARKer<m>:Y?

This command queries the position of a marker on the y-axis.

If necessary, the command activates the marker first.

To get a valid result, you have to perform a complete measurement with synchronization to the end of the measurement before reading out the result. This is only possible for single measurement mode.

See also INITiate<n>:CONTinuous on page 169.

Return values:

<Result> Result at the marker position.

Example:
`INIT:CONT OFF`
Switches to single measurement mode.
`CALC:MARK2 ON`
Switches marker 2.
`INIT;*WAI`
Starts a measurement and waits for the end.
`CALC:MARK2:Y?`
Outputs the measured value of marker 2.

Usage: Query only

Manual operation: See "Marker Table" on page 30
See "Marker Peak List" on page 30
See "Marker 1 / Marker 2 / Marker 3 / … Marker 16,/ Marker Norm/Delta" on page 91

9.10.6 Importing and Exporting I/Q Data and Results

The I/Q data to be evaluated in the R&S FSW 802.11ad application can not only be measured by the R&S FSW 802.11ad application itself, it can also be imported to the application, provided it has the correct format. Furthermore, the evaluated I/Q data from the R&S FSW 802.11ad application can be exported for further analysis in external applications.

For details on importing and exporting I/Q data see the R&S FSW User Manual.

MMEMory:LOAD:IQ:STATe 1,<FileName>

This command restores I/Q data from a file.

The file extension is *.iq.tar.

Parameters:

<FileName> String containing the path and name of the source file.

Example: Loads IQ data from the specified file.

Usage: Setting only

Manual operation: See "I/Q Import" on page 96

MMEMory:STORe<n>:IQ:COMMent <Comment>

This command adds a comment to a file that contains I/Q data.

The suffix <n> is irrelevant.

Parameters:

<Comment> String containing the comment.

Example: `MMEM:STOR:IQ:COMM 'Device test 1b'`
Creates a description for the export file.
`MMEM:STOR:IQ:STAT 1, 'C:\R_S\Instr\user\data.iq.tar'`
Stores I/Q data and the comment to the specified file.

Manual operation: See "I/Q Export" on page 96

MMEMory:STORe<n>:IQ:STATe 1, <FileName>

This command writes the captured I/Q data to a file.

The suffix <n> is irrelevant.

The file extension is *.iq.tar. By default, the contents of the file are in 32-bit floating point format.

Secure User Mode

In secure user mode, settings that are to be stored on the instrument are stored to volatile memory, which is restricted to 256 MB. Thus, a "Memory full" error may occur although the hard disk indicates that storage space is still available.

To store data permanently, select an external storage location such as a USB memory device.

For details see "Protecting Data Using the Secure User Mode" in the "Data Management" section of the R&S FSW User Manual.

Parameters:

1

<FileName> String containing the path and name of the target file.

Example: `MMEM:STOR:IQ:STAT 1, 'C:\R_S\Instr\user\data.iq.tar'`
Stores the captured I/Q data to the specified file.

Manual operation: See "I/Q Export" on page 96

9.10.7 Exporting Trace Results to an ASCII File

Trace results can be exported to an ASCII file for further evaluation in other (external) applications.

FORMat:DEXPort:DSEParator <Separator>

This command selects the decimal separator for data exported in ASCII format.

Parameters:

<Separator>

COMMa
Uses a comma as decimal separator, e.g. *4,05*.

POINt
Uses a point as decimal separator, e.g. *4.05*.

*RST: *RST has no effect on the decimal separator. Default is POINt.

Example: `FORM:DEXP:DSEP POIN`
Sets the decimal point as separator.

Manual operation: See "Decimal Separator" on page 90

FORMat:DEXPort:GRAPh <State>

If enabled, all traces for the currently selected graphical result display are included in the export file.

Parameters:

<State> ON | OFF | 0 | 1

OFF | 0
Switches the function off

ON | 1
Switches the function on

*RST: 0

Manual operation: See "Export all Traces for Selected Graph" on page 90

FORMat:DEXPort:HEADer <State>

If enabled, additional instrument and measurement settings are included in the header of the export file for result data. If disabled, only the pure result data from the selected traces and tables is exported.

Parameters:

<State> ON | OFF | 0 | 1

*RST: 1

Usage: SCPI confirmed

Manual operation: See "Include Instrument Measurement Settings" on page 90

FORMat:DEXPort:TRACes <Selection>

This command selects the data to be included in a data export file (see `MMEMory:STORe<n>:TRACe` on page 203).

Parameters:

<Selection>

SINGle
Only a single trace is selected for export, namely the one specified by the MMEMory:STORe<n>:TRACe command.

ALL
Selects all active traces and result tables (e.g. Result Summary, marker peak list etc.) in the current application for export to an ASCII file.
The <trace> parameter for the MMEMory:STORe<n>:TRACe command is ignored.

*RST: SINGle

Usage: SCPI confirmed

Manual operation: See "Export all Traces and all Table Results" on page 89

MMEMory:STORe<n>:TRACe <Trace>, <FileName>

This command exports trace data from the specified window to an ASCII file.

Secure User Mode

In secure user mode, settings that are to be stored on the instrument are stored to volatile memory, which is restricted to 256 MB. Thus, a "Memory full" error may occur although the hard disk indicates that storage space is still available.

To store data permanently, select an external storage location such as a USB memory device.

For details see "Protecting Data Using the Secure User Mode" in the "Data Management" section of the R&S FSW User Manual.

Parameters:

<Trace> Number of the trace to be stored

<FileName> String containing the path and name of the target file.

Example: `MMEM:STOR1:TRAC 3,'C:\TEST.ASC'`
Stores trace 3 from window 1 in the file `TEST.ASC`.

Usage: SCPI confirmed

Manual operation: See "Export Trace to ASCII File" on page 90

9.11 Status Registers

The R&S FSW 802.11ad application uses the standard status registers of the R&S FSW (depending on the measurement type). However, some registers are used differently. Only those differences are described in the following sections.

For details on the common R&S FSW status registers refer to the description of remote control basics in the R&S FSW User Manual.

*RST does not influence the status registers.

9.11.1 The STATus:QUEStionable:SYNC Register

The `STATus:QUEStionable:SYNC` register contains application-specific information about synchronization errors or errors during pilot symbol detection. If any errors occur in this register, the status bit #11 in the `STATus:QUEStionable` register is set to 1.

Each active channel uses a separate `STATus:QUEStionable:SYNC` register. Thus, if the status bit #11 in the `STATus:QUEStionable` register indicates an error, the error may have occurred in any of the channel-specific `STATus:QUEStionable:SYNC` registers. In this case, you must check the register of each channel to determine which channel caused the error. By default, querying the status of a register always returns the result for the currently selected channel. However, you can specify any other channel name as a query parameter.

Table 9-10: Meaning of the bits used in the STATus:QUEStionable:SYNC register

Bit No.	Meaning
0	PPDU not found This bit is set if an I/Q measurement is performed and no PPDUs are detected
1 - 14	These bits are not used.
15	This bit is always 0.

9.11.2 Querying the Status Registers

The following commands are required to query the status of the R&S FSW and the R&S FSW 802.11ad application.

For details on the common R&S FSW status registers refer to the description of remote control basics in the R&S FSW User Manual.

9.11.2.1 General Status Register Commands

STATus:PRESet

This command resets the edge detectors and `ENABle` parts of all registers to a defined value. All `PTRansition` parts are set to `FFFFh`, i.e. all transitions from 0 to 1 are detected. All `NTRansition` parts are set to 0, i.e. a transition from 1 to 0 in a `CONDition` bit is not detected. The `ENABle` part of the `STATus:OPERation` and `STATus:QUEStionable` registers are set to 0, i.e. all events in these registers are not passed on.

Usage: Event

STATus:QUEue[:NEXT]?

This command queries the most recent error queue entry and deletes it.

Positive error numbers indicate device-specific errors, negative error numbers are error messages defined by SCPI. If the error queue is empty, the error number 0, "No error", is returned.

Usage: Query only

9.11.2.2 Reading Out the EVENt Part

STATus:OPERation[:EVENt]?
STATus:QUEStionable[:EVENt]?
STATus:QUEStionable:SYNC[:EVENt]? <ChannelName>

This command reads out the EVENt section of the status register.

The command also deletes the contents of the EVENt section.

Query parameters:

<ChannelName> String containing the name of the channel.
The parameter is optional. If you omit it, the command works for the currently active channel.

Usage: Query only

9.11.2.3 Reading Out the CONDition Part

STATus:OPERation:CONDition?
STATus:QUEStionable:CONDition?
STATus:QUEStionable:SYNC:CONDition? <ChannelName>

This command reads out the CONDition section of the status register.

The command does not delete the contents of the EVENt section.

Query parameters:

<ChannelName> String containing the name of the channel.
The parameter is optional. If you omit it, the command works for the currently active channel.

Usage: Query only

9.11.2.4 Controlling the ENABle Part

STATus:OPERation:ENABle <SumBit>
STATus:QUEStionable:ENABle <SumBit>
STATus:QUEStionable:SYNC:ENABle <BitDefinition>, <ChannelName>

This command controls the ENABle part of a register.

The ENABle part allows true conditions in the EVENt part of the status register to be reported in the summary bit. If a bit is 1 in the enable register and its associated event bit transitions to true, a positive transition will occur in the summary bit reported to the next higher level.

Parameters:

<BitDefinition> Range: 0 to 65535

<ChannelName> String containing the name of the channel.
The parameter is optional. If you omit it, the command works for the currently active channel.

9.11.2.5 Controlling the Negative Transition Part

STATus:OPERation:NTRansition <SumBit>
STATus:QUEStionable:NTRansition <SumBit>
STATus:QUEStionable:SYNC:NTRansition <BitDefinition>,<ChannelName>

This command controls the Negative TRansition part of a register.

Setting a bit causes a 1 to 0 transition in the corresponding bit of the associated register. The transition also writes a 1 into the associated bit of the corresponding EVENt register.

Parameters:

<BitDefinition> Range: 0 to 65535

<ChannelName> String containing the name of the channel.
The parameter is optional. If you omit it, the command works for the currently active channel.

9.11.2.6 Controlling the Positive Transition Part

STATus:OPERation:PTRansition <SumBit>
STATus:QUEStionable:PTRansition <SumBit>
STATus:QUEStionable:SYNC:PTRansition <BitDefinition>,<ChannelName>

These commands control the Positive TRansition part of a register.

Setting a bit causes a 0 to 1 transition in the corresponding bit of the associated register. The transition also writes a 1 into the associated bit of the corresponding EVENt register.

Parameters:

<BitDefinition>	Range: 0 to 65535
<ChannelName>	String containing the name of the channel. The parameter is optional. If you omit it, the command works for the currently active channel.

9.12 Programming Examples (R&S FSW 802.11ad application)

This example demonstrates how to configure a IEEE 802.11ad measurement in a remote environment.

9.12.1 Measurement 1: Measuring Modulation Accuracy for IEEE 802.11ad Signals

This example demonstrates how to configure a IEEE 802.11ad I/Q measurement according to the IEEE 802.11ad standard in a remote environment.

Note that some commands may not be necessary as they reflect the default settings, but are included to demonstrate the commands.

```
//---------- Preparing the application ------------
// Preset the instrument
*RST
// Enter the 802.11ad option K95
INSTrument:SELect WiGig
// Switch to single sweep mode and stop sweep
INITiate:CONTinuous OFF;:ABORt

//---------- Configuring the result display ------------
// Activate following result displays:
// 1: Magnitude Capture (default, top)
// 2: Bitstream of data, decoded (lower left)
// 3: Result Summary (default, lower right)
// 4: EVM vs Symbol (next to Mag Capt)

LAY:ADD:WIND? '1',RIGH,EVSY
//Result: '4'
LAY:REPL:WIND '2',DDBS
```

```
//---------- Configuring Data Acquisition ---------------------
//Each measurement captures data for 1 ms.
SWE:TIME 1ms
//Perform 10 measurements
SENS:SWE:COUN 10
//Set the input sample rate for the captured I/Q data to 2.64 GHz
TRAC:IQ:SRAT 2.64GHZ

// Number of samples captured per measurement: 0.001s * 2.64e9 samples per second
// = 2 640 000 samples



//---------- Tracking -----------------
//Disable all tracking and compensation functions
SENS:TRAC:LEV OFF
SENS:TRAC:PHAS OFF
SENS:TRAC:IQMC OFF


//---------- Result configuration settings --------------------
//Define units for EVM (dBm)and bitstream (hexa) results
CALC:UNIT:POW DBM
FORM:BSTR HEXA

//---------- Performing the Measurements -----
// Run 10 (blocking) single measurements
INITiate:IMMediate;*WAI

//---------- Evaluation range settings -----------------
//Analyze only the first PPDU
SENS:BURS:SEL:STAT ON
SENS:BURS:SEL 1

//---------- Retrieving Results -------------
//Query the I/Q data from magnitude capture buffer for first ms
// 2 640 000 samples per second -> 2640 samples
TRACe1:IQ:DATA:MEMory? 0,2640
//Note: result will be too long to display in IECWIN, but is stored in log file
//Query the I/Q data from magnitude capture buffer for second ms
TRACe1:IQ:DATA:MEMory? 2641,5282
//Note: result will be too long to display in IECWIN, but is stored in log file


//Query the current EVM vs symbol trace (window 4)
TRAC4:DATA? TRACE1
//Note: result will be too long to display in IECWIN, but is stored in log file

//Query the result of the average EVM for all symbols in the PPDU
FETC:EVM:ALL:AVER?
```

```
//---------- Exporting Captured I/Q Data-------------
//Store the captured I/Q data to a file.
MMEM:STOR:IQ:STAT 1, 'C:\R_S\Instr\user\data.iq.tar'
```

9.12.2 Measurement 2: Determining the Spectrum Emission Mask

```
//---------- Preparing the application ------------
*RST
//Reset the instrument
INST:CRE:NEW WiGig,'SEMMeasurement'
//Activate a 802.11ad measurement channel named "SEMMeasurement"

//---------- Configuring the measurement ------------
DISP:TRAC:Y:SCAL:RLEV 0
//Set the reference level to 0 dBm
FREQ:CENT 2.1175 GHz
//Set the center frequency to 2.1175 GHz
SENS:SWE:MODE ESP
//Select the spectrum emission mask measurement

//---------- Performing the Measurement-----
INIT:CONT OFF
//Stops continuous sweep
SWE:COUN 100
//Sets the number of sweeps to be performed to 100
INIT;*WAI
//Start a new measurement with 100 sweeps and wait for the end

//---------- Retrieving Results-------------
CALC:LIM:FAIL?
//Queries the result of the limit check
//Result: 0 [passed]
TRAC:DATA? LIST
//Retrieves the peak list of the spectrum emission mask measurement
//Result:
//+1.000000000,-1.275000000E+007,-8.500000000E+006,+1.000000000E+006,
//+2.108782336E+009,-8.057177734E+001,-7.882799530E+001,-2.982799530E+001,
//+0.000000000,+0.000000000,+0.000000000,

//+2.000000000,-8.500000000E+006,-7.500000000E+006,+1.000000000E+006,
//+2.109000064E+009,-8.158547211E+001,-7.984169006E+001,-3.084169006E+001,
//+0.000000000,+0.000000000,+0.000000000,

//+3.000000000,-7.500000000E+006,-3.500000000E+006,+1.000000000E+006,
//+2.113987200E+009,-4.202708435E+001,-4.028330231E+001,-5.270565033,
//+0.000000000,+0.000000000,+0.000000000,

// [...]
```

Table 9-11: Trace results for SEM measurement

Range No.	Start freq. [Hz]	Stop freq. [Hz]	RBW [Hz]	Freq. peak power [Hz]	Abs. peak power [dBm]	Rel. peak power [%]	Delta to margin [dB]	Limit check result	-	-	-
1	+1.000000000	-1.275000000E+007	-8.500000000E+006	+1.000000000E+006	+2.108782336E+009	-8.057177734E+001	-7.882799530E+001	-2.982799530E+001	+0.000000000	+0.000000000	+0.000000000
2	+2.000000000	-8.500000000E+006	-7.500000000E+006	+1.000000000E+006	+2.109000064E+009	-8.158547211E+001	-7.984169006E+001	-3.084169006E+001	+0.000000000	+0.000000000	+0.000000000
3	+3.000000000	-7.500000000E+006	-3.500000000E+006	+1.000000000E+006	+2.113987200E+009	-4.202708435E+001	-4.028330231E+001	-5.270565033	+0.000000000	+0.000000000	+0.000000000
...	...										

A Annex

A.1 References

[1] IEEE: IEEE Std 802.11ad™-2012. Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 3: Enhancements for Very High Throughput in the 60 GHz Band

A.2 I/Q Data File Format (iq-tar)

I/Q data is packed in a file with the extension `.iq.tar`. An iq-tar file contains I/Q data in binary format together with meta information that describes the nature and the source of data, e.g. the sample rate. The objective of the iq-tar file format is to separate I/Q data from the meta information while still having both inside one file. In addition, the file format allows you to preview the I/Q data in a web browser, and allows you to include user-specific data.

The iq-tar container packs several files into a single `.tar` archive file. Files in `.tar` format can be unpacked using standard archive tools (see http://en.wikipedia.org/wiki/Comparison_of_file_archivers) available for most operating systems. The advantage of `.tar` files is that the archived files inside the `.tar` file are not changed (not compressed) and thus it is possible to read the I/Q data directly within the archive without the need to unpack (untar) the `.tar` file first.

Contained files

An iq-tar file must contain the following files:

- **I/Q parameter XML file**, e.g. `xyz.xml`
  Contains meta information about the I/Q data (e.g. sample rate). The filename can be defined freely, but there must be only one single I/Q parameter XML file inside an iq-tar file.
- **I/Q data binary file**, e.g. `xyz.complex.float32`
  Contains the binary I/Q data of all channels. There must be only one single I/Q data binary file inside an iq-tar file.

Optionally, an iq-tar file can contain the following file:

- **I/Q preview XSLT file**, e.g. `open_IqTar_xml_file_in_web_browser.xslt`
  Contains a stylesheet to display the I/Q parameter XML file and a preview of the I/Q data in a web browser.
  A sample stylesheet is available at http://www.rohde-schwarz.com/file/open_IqTar_xml_file_in_web_browser.xslt.

A.2.1 I/Q Parameter XML File Specification

The content of the I/Q parameter XML file must comply with the XML schema RsIqTar.xsd available at: http://www.rohde-schwarz.com/file/RsIqTar.xsd.

In particular, the order of the XML elements must be respected, i.e. iq-tar uses an "ordered XML schema". For your own implementation of the iq-tar file format make sure to validate your XML file against the given schema.

The following example shows an I/Q parameter XML file. The XML elements and attributes are explained in the following sections.

Sample I/Q parameter XML file: xyz.xml

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet type="text/xsl"
href="open_IqTar_xml_file_in_web_browser.xslt"?>
<RS_IQ_TAR_FileFormat fileFormatVersion="1"
xsi:noNamespaceSchemaLocation="RsIqTar.xsd"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <Name>FSV-K10</Name>
  <Comment>Here is a comment</Comment>
  <DateTime>2011-01-24T14:02:49</DateTime>
  <Samples>68751</Samples>
  <Clock unit="Hz">6.5e+006</Clock>
  <Format>complex</Format>
  <DataType>float32</DataType>
  <ScalingFactor unit="V">1</ScalingFactor>
  <NumberOfChannels>1</NumberOfChannels>
<DataFilename>xyz.complex.float32</DataFilename>
<UserData>
  <UserDefinedElement>Example</UserDefinedElement>
</UserData>
  <PreviewData>...</PreviewData>
</RS_IQ_TAR_FileFormat>
```

Element	Description
RS_IQ_TAR_File-Format	The root element of the XML file. It must contain the attribute fileFormatVersion that contains the number of the file format definition. Currently, fileFormatVersion "2" is used.
Name	Optional: describes the device or application that created the file.
Comment	Optional: contains text that further describes the contents of the file.
DateTime	Contains the date and time of the creation of the file. Its type is xs:dateTime (see RsIqTar.xsd).

Element	Description
Samples	Contains the number of samples of the I/Q data. For multi-channel signals all channels have the same number of samples. One sample can be: ● A complex number represented as a pair of I and Q values ● A complex number represented as a pair of magnitude and phase values ● A real number represented as a single real value See also `Format` element.
Clock	Contains the clock frequency in Hz, i.e. the sample rate of the I/Q data. A signal generator typically outputs the I/Q data at a rate that equals the clock frequency. If the I/Q data was captured with a signal analyzer, the signal analyzer used the clock frequency as the sample rate. The attribute `unit` must be set to "Hz".
Format	Specifies how the binary data is saved in the I/Q data binary file (see `DataFilename` element). Every sample must be in the same format. The format can be one of the following: ● `complex`: Complex number in cartesian format, i.e. I and Q values interleaved. I and Q are unitless ● `real`: Real number (unitless) ● `polar`: Complex number in polar format, i.e. magnitude (unitless) and phase (rad) values interleaved. Requires `DataType` = `float32` or `float64`
DataType	Specifies the binary format used for samples in the I/Q data binary file (see `DataFilename` element and chapter A.2.2, "I/Q Data Binary File", on page 215). The following data types are allowed: ● `int8`: 8 bit signed integer data ● `int16`: 16 bit signed integer data ● `int32`: 32 bit signed integer data ● `float32`: 32 bit floating point data (IEEE 754) ● `float64`: 64 bit floating point data (IEEE 754)
ScalingFactor	Optional: describes how the binary data can be transformed into values in the unit Volt. The binary I/Q data itself has no unit. To get an I/Q sample in the unit Volt the saved samples have to be multiplied by the value of the `ScalingFactor`. For polar data only the magnitude value has to be multiplied. For multi-channel signals the `ScalingFactor` must be applied to all channels. The attribute `unit` must be set to "`V`". The `ScalingFactor` must be > 0. If the `ScalingFactor` element is not defined, a value of 1 V is assumed.
NumberOfChannels	Optional: specifies the number of channels, e.g. of a MIMO signal, contained in the I/Q data binary file. For multi-channels, the I/Q samples of the channels are expected to be interleaved within the I/Q data file (see chapter A.2.2, "I/Q Data Binary File", on page 215). If the `NumberOfChannels` element is not defined, one channel is assumed.
DataFilename	Contains the filename of the I/Q data binary file that is part of the iq-tar file. It is recommended that the filename uses the following convention: <xyz>.<Format>.<Channels>ch.<Type> ● <xyz> = a valid Windows file name ● <Format> = complex, polar or real (see `Format` element) ● <Channels> = Number of channels (see `NumberOfChannels` element) ● <Type> = float32, float64, int8, int16, int32 or int64 (see `DataType` element) Examples: ● xyz.complex.1ch.float32 ● xyz.polar.1ch.float64 ● xyz.real.1ch.int16 ● xyz.complex.16ch.int8

Element	Description
UserData	Optional: contains user, application or device-specific XML data which is not part of the iq-tar specification. This element can be used to store additional information, e.g. the hardware configuration. User data must be valid XML content.
PreviewData	Optional: contains further XML elements that provide a preview of the I/Q data. The preview data is determined by the routine that saves an iq-tar file (e.g. R&S FSW). For the definition of this element refer to the `RsIqTar.xsd` schema. Note that the preview can be only displayed by current web browsers that have JavaScript enabled and if the XSLT stylesheet `open_IqTar_xml_file_in_web_browser.xslt` is available.

Example: ScalingFactor

Data stored as `int16` and a desired full scale voltage of 1 V

`ScalingFactor` = 1 V / maximum int16 value = 1 V / 2^{15} = 3.0517578125e-5 V

Scaling Factor	Numerical value	Numerical value x ScalingFactor
Minimum (negative) int16 value	$- 2^{15} = - 32768$	-1 V
Maximum (positive) int16 value	$2^{15}-1= 32767$	0.999969482421875 V

Example: PreviewData in XML

```
<PreviewData>
    <ArrayOfChannel length="1">
      <Channel>
        <PowerVsTime>
          <Min>
            <ArrayOfFloat length="256">
              <float>-134</float>
              <float>-142</float>
              ...
              <float>-140</float>
            </ArrayOfFloat>
          </Min>
          <Max>
            <ArrayOfFloat length="256">
              <float>-70</float>
              <float>-71</float>
              ...
              <float>-69</float>
            </ArrayOfFloat>
          </Max>
        </PowerVsTime>
        <Spectrum>
          <Min>
            <ArrayOfFloat length="256">
              <float>-133</float>
              <float>-111</float>
              ...
```

```
            <float>-111</float>
          </ArrayOfFloat>
        </Min>
        <Max>
          <ArrayOfFloat length="256">
            <float>-67</float>
            <float>-69</float>
            ...
            <float>-70</float>
            <float>-69</float>
          </ArrayOfFloat>
        </Max>
      </Spectrum>
      <IQ>
        <Histogram width="64" height="64">0123456789...0</Histogram>
      </IQ>
    </Channel>
  </ArrayOfChannel>
</PreviewData>
```

A.2.2 I/Q Data Binary File

The I/Q data is saved in binary format according to the format and data type specified in the XML file (see `Format` element and `DataType` element). To allow reading and writing of streamed I/Q data, all data is interleaved, i.e. complex values are interleaved pairs of I and Q values and multi-channel signals contain interleaved (complex) samples for channel 0, channel 1, channel 2 etc. If the `NumberOfChannels` element is not defined, one channel is presumed.

Example: Element order for real data (1 channel)

```
I[0],                    // Real sample 0
I[1],                    // Real sample 1
I[2],                    // Real sample 2
...
```

Example: Element order for complex cartesian data (1 channel)

```
I[0], Q[0],              // Real and imaginary part of complex sample 0
I[1], Q[1],              // Real and imaginary part of complex sample 1
I[2], Q[2],              // Real and imaginary part of complex sample 2
...
```

Example: Element order for complex polar data (1 channel)

```
Mag[0], Phi[0],          // Magnitude and phase part of complex sample 0
Mag[1], Phi[1],          // Magnitude and phase part of complex sample 1
Mag[2], Phi[2],          // Magnitude and phase part of complex sample 2
...
```

Example: Element order for complex cartesian data (3 channels)

Complex data: I[channel no][time index], Q[channel no][time index]

```
I[0][0], Q[0][0],            // Channel 0, Complex sample 0
I[1][0], Q[1][0],            // Channel 1, Complex sample 0
I[2][0], Q[2][0],            // Channel 2, Complex sample 0

I[0][1], Q[0][1],            // Channel 0, Complex sample 1
I[1][1], Q[1][1],            // Channel 1, Complex sample 1
I[2][1], Q[2][1],            // Channel 2, Complex sample 1

I[0][2], Q[0][2],            // Channel 0, Complex sample 2
I[1][2], Q[1][2],            // Channel 1, Complex sample 2
I[2][2], Q[2][2],            // Channel 2, Complex sample 2
...
```

Example: Element order for complex cartesian data (1 channel)

This example demonstrates how to store complex cartesian data in float32 format using MATLAB®.

```
% Save vector of complex cartesian I/Q data, i.e. iqiqiq...
N = 100
iq = randn(1,N)+1j*randn(1,N)
fid = fopen('xyz.complex.float32','w');
for k=1:length(iq)
  fwrite(fid,single(real(iq(k))),'float32');
  fwrite(fid,single(imag(iq(k))),'float32');
end
fclose(fid)
```

List of Remote Commands (802.11ad)

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