R&S®VSE-K91
WLAN Measurements Application
User Manual

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Test & Measurement

User Manual

ROHDE&SCHWARZ

This manual applies to the R&S®VSE base software (1320.7500.02) version 1.13 and higher.

The following firmware options are described:

- R&S VSE-K91 WLAN 802.11a,b,g (1320.7597.02)
- R&S VSE-K91ac WLAN 802.11ac (1320.7616.02)
- R&S VSE-K91n WLAN 802.11n (1320.7600.02)

The software contained in this product makes use of several valuable open source software packages. For information, see the "Open Source Acknowledgment" on the user documentation CD-ROM (included in delivery).

Rohde & Schwarz would like to thank the open source community for their valuable contribution to embedded computing.

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

Contents

1 Preface

1.1 About this Manual

This R&S VSE WLAN 802.11 User Manual provides all the information **specific to the application**. All general software functions and settings common to all applications and operating modes are described in the R&S VSE Base Software 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 VSE WLAN application", on page 7
  Introduction to and getting familiar with the application
- chapter 3, "WLAN I/Q Measurement and Results", on page 11
  Details on supported measurements and their result types
- chapter 4, "Measurement Basics", on page 36
  Background information on basic terms and principles in the context of the measurement
- chapter 5, "Configuring a WLAN I/Q Measurement", on page 57 and chapter 6, "Analysis", on page 100
  A concise description of all functions and settings available to configure measurements and analyze results with their corresponding remote control command
- chapter 7, "How to Perform Measurements in the R&S VSE WLAN application", on page 101
  The basic procedure to perform each measurement and step-by-step instructions for more complex tasks or alternative methods
- chapter 8, "Optimizing and Troubleshooting the Measurement", on page 102
  Hints and tips on how to handle errors and optimize the test setup
- chapter 9, "Remote Commands for WLAN Measurements", on page 105
  Remote commands required to configure and perform WLAN measurements in a remote environment, sorted by tasks
  (Commands required to set up the environment or to perform common tasks in the software are provided in the R&S VSE Base Software User Manual)
  Programming examples demonstrate the use of many commands and can usually be executed directly for test purposes
- chapter A, "Annex: Reference", on page 210
  Reference material
- **List of remote commands**
  Alphahabetical list of all remote commands described in the manual
- **Index**

1.2 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.

2 Welcome to the R&S VSE WLAN application

The R&S VSE WLAN application extends the functionality of the R&S VSE to enable accurate and reproducible Tx measurements of a WLAN device under test (DUT) in accordance with the standards specified for the device. The following standards are currently supported (if the corresponding option is installed):

- IEEE standards 802.11a
- IEEE standards 802.11ac (SISO)
- IEEE standards 802.11b
- IEEE standards 802.11g (OFDM)
- IEEE standards 802.11g (DSSS)
- IEEE standards 802.11n (SISO)

The R&S VSE WLAN application features:

Modulation measurements

- Constellation diagram for demodulated signal
- Constellation diagram for individual carriers
- I/Q offset and I/Q imbalance
- Modulation error (EVM) for individual carriers or symbols
- Amplitude response and group-delay distortion (spectrum flatness)
- Carrier and symbol frequency errors

Further measurements and results

- FFT, also over a selected part of the signal, e.g. preamble
- Payload bit information

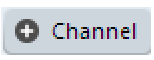
This user manual contains a description of the functionality that is specific to the application, including remote control operation.

Functions that are not discussed in this manual are the same as in the I/Q Analyzer application and are described in the R&S VSE Base Software User Manual. The latest version is available for download at the product homepage http://www2.rohde-schwarz.com/product/VSE.html.

2.1 Starting the R&S VSE WLAN application

The WLAN measurement requires a special application on the R&S VSE. It is activated by creating a new measurement channel in WLAN mode.

To activate the R&S VSE WLAN application

1. 

Select the "Add Channel" function in the Sequence tool window.

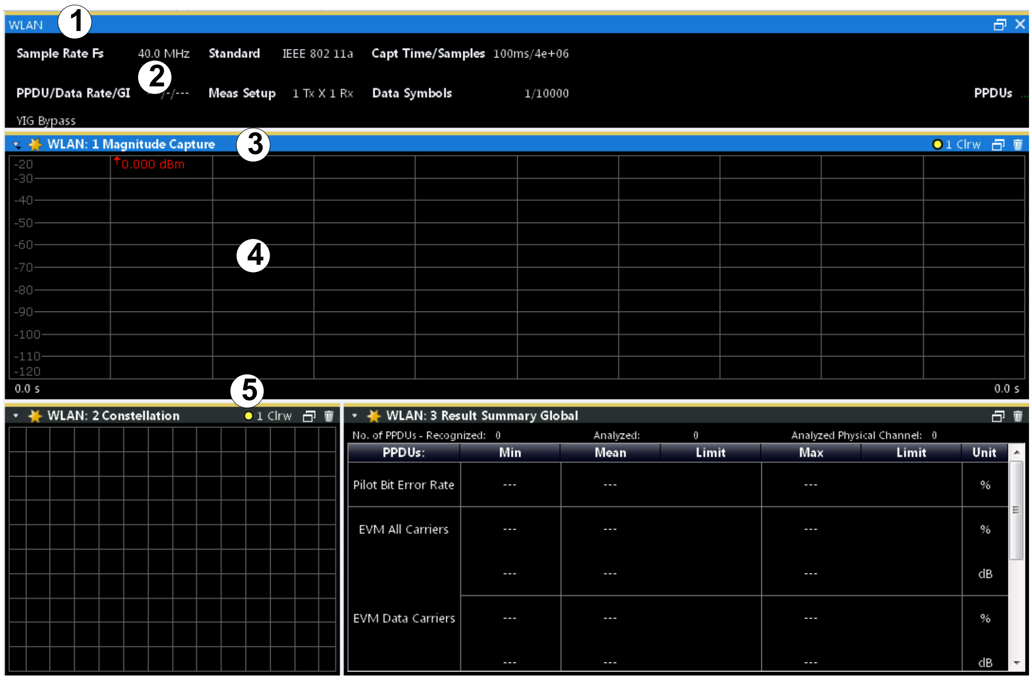
A dialog box opens that contains all operating modes and applications currently available in your R&S VSE.

2. Select the "WLAN" item.

The R&S VSE opens a new measurement channel for the R&S VSE WLAN application.

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 = Color coding for windows of same channel
2 = Channel bar with measurement settings
3 = Window title bar with diagram-specific (trace) information
4 = Diagram area
5 = Diagram footer with diagram-specific information, depending on result display

Channel bar information

In the R&S VSE WLAN application, the R&S VSE shows the following settings:

Table 2-1: Information displayed in the channel bar in the WLAN application

Label	Description
Sample Rate Fs	Input sample rate
PPDU / MCS Index / GI	WLAN 802.11**a, ac, n**: The PPDU type, MCS Index and Guard Interval used for the analysis of the signal; Depending on the demodulation settings, these values are either detected automatically from the signal or the user settings are applied.
PPDU / Data Rate	WLAN 802.11**b**: The PPDU type and data rate used for the analysis of the signal; Depending on the demodulation settings, these values are either detected automatically from the signal or the user settings are applied.
Standard	Selected WLAN measurement standard
Meas Setup	Number of Transmitter (Tx) and Receiver (Rx) channels used in the measurement (for MIMO)
Capt time / Samples	Duration of signal capture and number of samples captured

Label	Description
Data Symbols	The minimum and maximum number of data symbols that a PPDU may have if it is to be considered in results analysis.
PPDUs [x of y (z)]	For statistical evaluation over PPDUs (see "PPDU Statistic Count / No of PPDUs to Analyze" on page 95): <x> PPDUs of totally required <y> PPDUs have been analyzed so far. <z> PPDUs were analyzed in the most recent sweep.

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 VSE Base Software User Manual.

Window title bar information

For each diagram, the header provides the following information:

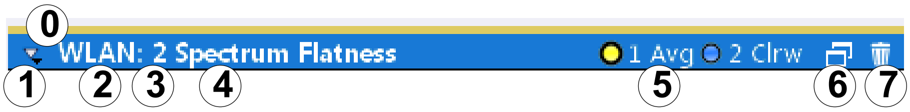


Fig. 2-1: Window title bar information in the WLAN application

0 = Color coding for windows of same channel
1 = Edit result display function
2 = Channel name
3 = Window number
4 = Window type
5 = Trace color, trace number, trace mode
6 = Dock/undock window function
7 = Close window function

Diagram footer information

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

Diagram area

The diagram area displays the results according to the selected result displays (see chapter 3.2, "Evaluation Methods for WLAN I/Q Measurements", on page 19).

Status bar information

The software status, errors and warnings and any irregularities in the software are indicated in the status bar at the bottom of the R&S VSE window.

3 WLAN I/Q Measurement and Results

The default WLAN I/Q measurement captures the I/Q data from the WLAN signal using a (nearly rectangular) filter with a relatively large bandwidth. The I/Q data captured with this filter includes magnitude and phase information, which allows the R&S VSE WLAN application to demodulate broadband signals and determine various characteristic signal parameters such as the modulation accuracy, spectrum flatness, center frequency tolerance and symbol clock tolerance in just one measurement.

3.1 Modulation Accuracy, Flatness and Tolerance Parameters

The default WLAN I/Q measurement (Modulation Accuracy, Flatness,...) captures the I/Q data from the WLAN signal and determines all the following I/Q parameters in a single sweep.

Table 3-1: WLAN I/Q parameters for IEEE 802.11a, g (OFDM), ac, n

Parameter	Description
General measurement parameters	
Sample Rate Fs	Input sample rate
PPDU	Type of analyzed PPDUs
MCS Index	Modulation and Coding Scheme (MCS) index of the analyzed PPDUs
Data Rate	Data rate used for analysis of the signal (IEEE 802.11A ONLY)
GI	Guard interval length for current measurement
Standard	Selected WLAN measurement standard
Meas Setup	Number of Transmitter (Tx) and Receiver (Rx) channels used in the measurement
Capture time	Duration of signal capture
No. of Samples	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.
Analyzed PPDUs	For statistical evaluation of PPDUs (see "PPDU Statistic Count / No of PPDUs to Analyze" on page 95): <x> PPDUs of totally required <y> PPDUs have been analyzed so far. <z> indicates the number of analyzed PPDUs in the most recent sweep.
***)** the limits can be changed via remote control (not manually, see chapter 9.4.10, "Limits", on page 154); in this case, the currently defined limits are displayed here	

Parameter	Description
Number of recognized PPDUs (global)	Number of PPDUs recognized in capture buffer
Number of analyzed PPDUs (global)	Number of analyzed PPDUs in capture buffer
Number of analyzed PPDUs in physical channel	Number of PPDUs analyzed in entire signal (if available)
TX and Rx carrier parameters	
I/Q offset [dB]	Transmitter center frequency leakage relative to the total Tx channel power (see chapter 3.1.1, "I/Q Offset", on page 14)
Gain imbalance [%/dB]	Amplification of the quadrature phase component of the signal relative to the amplification of the in-phase component (see chapter 3.1.2, "Gain Imbalance", on page 14)
Quadrature offset [°]	Deviation of the quadrature phase angle from the ideal 90° (see chapter 3.1.3, "Quadrature Offset", on page 15).
PPDU power [dBm]	Mean PPDU power
Crest factor [dB]	The ratio of the peak power to the mean power of the signal (also called Peak to Average Power Ratio, PAPR).
Center frequency error [Hz]	Frequency error between the signal and the current center frequency of the R&S VSE; the corresponding limits specified in the standard are also indicated***)** The absolute frequency error includes the frequency error of the R&S VSE and that of the DUT. If possible, the transmitterR&S VSE and the DUT should be synchronized (using an external reference).
Symbol clock error [ppm]	Clock error between the signal and the sample clock of the R&S VSE in parts per million (ppm), i.e. the symbol timing error; the corresponding limits specified in the standard are also indicated ***)** If possible, the transmitterR&S VSE and the DUT should be synchronized (using an external reference).
Stream parameters	
Pilot bit error rate [%]	
EVM all carriers [%/dB]	EVM (Error Vector Magnitude) of the payload symbols over all carriers; the corresponding limits specified in the standard are also indicated***)**
EVM data carriers [%/dB]	EVM (Error Vector Magnitude) of the payload symbols over all data carriers; the corresponding limits specified in the standard are also indicated***)**
EVM pilot carriers [%/dB]	EVM (Error Vector Magnitude) of the payload symbols over all pilot carriers; the corresponding limits specified in the standard are also indicated***)**
***)** the limits can be changed via remote control (not manually, see chapter 9.4.10, "Limits", on page 154); in this case, the currently defined limits are displayed here	

Table 3-2: WLAN I/Q parameters for IEEE 802.11b or g (DSSS)

Parameter	Description
Sample Rate Fs	Input sample rate
PPDU	Type of the analyzed PPDU

Parameter	Description
Data Rate	Data rate used for analysis of the signal
SGL	Indicates single measurement mode (as opposed to continuous)
Standard	Selected WLAN measurement standard
Meas Setup	Number of Transmitter (Tx) and Receiver (Rx) channels used in the measurement
Capture time	Duration of signal capture
No. of Samples	Number of samples captured (= sample rate * capture time)
PSDU Data Length	The duration in seconds of the PSDU data
Analyzed PPDUs	For statistical evaluation of PPDUs (see "PPDU Statistic Count / No of PPDUs to Analyze" on page 95): <x> PPDUs of totally required <y> PPDUs have been analyzed so far. <z> indicates the number of analyzed PPDUs in the most recent sweep.
Number of recognized PPDUs (global)	Number of PPDUs recognized in capture buffer
Number of analyzed PPDUs (global)	Number of analyzed PPDUs in capture buffer
Number of analyzed PPDUs in physical channel	Number of PPDUs analyzed in entire signal (if available)
Peak vector error	Peak vector error (EVM) over the complete PPDU including the preamble in % and in dB; calculated according to the IEEE 802.11b or g (DSSS) definition of the normalized error vector magnitude (see chapter 3.1.7.2, "Peak Vector Error (IEEE method)", on page 18); The corresponding limits specified in the standard are also indicated ***)**
PPDU EVM	EVM (Error Vector Magnitude) over the complete PPDU including the preamble in % and dB
I/Q offset [dB]	Transmitter center frequency leakage relative to the total Tx channel power (see chapter 3.1.1, "I/Q Offset", on page 14)
Gain imbalance [%/dB]	Amplification of the quadrature phase component of the signal relative to the amplification of the in-phase component (see chapter 3.1.2, "Gain Imbalance", on page 14)
Quadrature error [°]	Measure for the crosstalk of the Q-branch into the I-branch (see "Gain imbalance, I/Q offset, quadrature error" on page 47).
Center frequency error [Hz]	Frequency error between the signal and the current center frequency of the R&S VSE; the corresponding limits specified in the standard are also indicated***)** The absolute frequency error includes the frequency error of the R&S VSE and that of the DUT. If possible, the transmitterR&S VSE and the DUT should be synchronized (using an external reference).
Chip clock error [ppm]	Clock error between the signal and the chip clock of the R&S VSE in parts per million (ppm), i.e. the chip timing error; the corresponding limits specified in the standard are also indicated ***)** If possible, the transmitterR&S VSE and the DUT should be synchronized (using an external reference).

Parameter	Description
Rise time	Time the signal needs to increase its power level from 10% to 90% of the maximum or the average power (depending on the reference power setting) The corresponding limits specified in the standard are also indicated ***)**
Fall time	Time the signal needs to decrease its power level from 90% to 10% of the maximum or the average power (depending on the reference power setting) The corresponding limits specified in the standard are also indicated ***)**
Mean power [dBm]	Mean PPDU power
Peak power [dBm]	Peak PPDU power
Crest factor [dB]	The ratio of the peak power to the mean power of the PPDU (also called Peak to Average Power Ratio, PAPR).

The R&S VSE WLAN application also performs statistical evaluation over several PPDUs and displays one or more of the following results:

Table 3-3: Calculated summary results

Result type	Description
Min	Minimum measured value
Mean/ Limit	Mean measured value / limit defined in standard
Max/Limit	Maximum measured value / limit defined in standard

3.1.1 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.

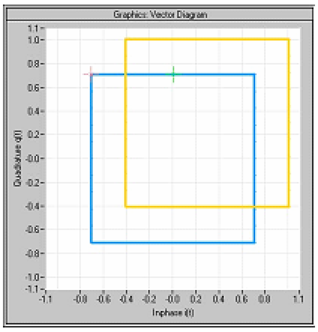


Fig. 3-1: I/Q offset in a vector diagram

3.1.2 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)

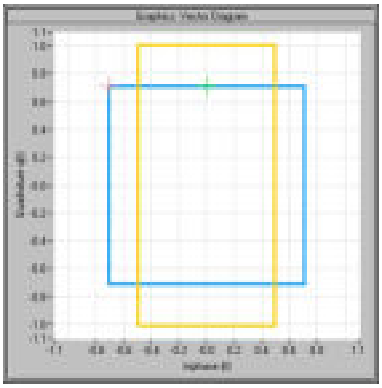


Fig. 3-2: Positive gain imbalance

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)

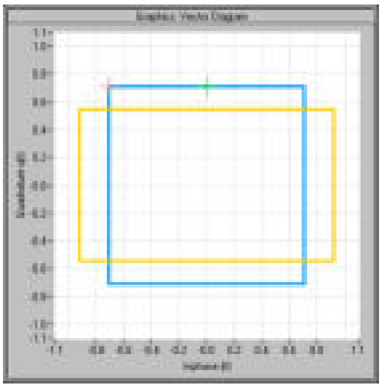


Fig. 3-3: Negative gain imbalance

3.1.3 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:

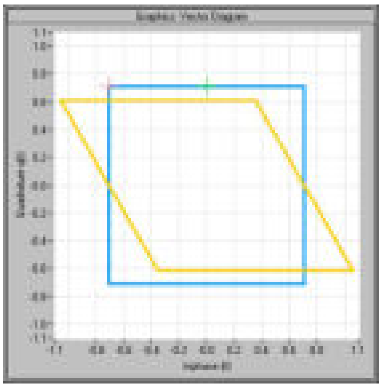


Fig. 3-4: Positive quadrature offset

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

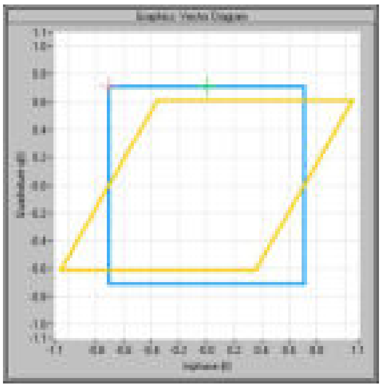


Fig. 3-5: Negative quadrature offset

3.1.4 I/Q Skew

If transmission of the data on the I path is delayed compared to the Q path, or vice versa, the I/Q data becomes *skewed*.

The I/Q skew results are currently not measured directly, but can be compensated for together with Gain Imbalance and Quadrature Offset (see "I/Q Mismatch Compensation" on page 80).

3.1.5 I/Q Mismatch

I/Q mismatch is a comprehensive term for Gain Imbalance, Quadrature Offset, and I/Q Skew.

Compensation for I/Q mismatch is useful, for example, if the device under test is known to be affected by these impairments but the EVM without these effects is of interest. Note, however, that measurements strictly according to IEEE 802.11-2012, IEEE 802.11ac-2013 WLAN standard may not use compensation.

3.1.6 RF Carrier Suppression (IEEE 802.11b, g (DSSS))

Standard definition

The RF carrier suppression, measured at the channel center frequency, shall be at least 15 dB below the peak SIN(x)/x power spectrum. The RF carrier suppression shall be measured while transmitting a repetitive 01 data sequence with the scrambler disabled using DQPSK modulation. A 100 kHz resolution bandwidth shall be used to perform this measurement.

Comparison to I/Q offset measurement in the R&S VSE WLAN application

The I/Q offset measurement in the R&S VSE WLAN application returns the current carrier feedthrough normalized to the mean power at the symbol timings. This measurement does not require a special test signal and is independent of the transmit filter shape.

The RF carrier suppression measured according to the standard is inversely proportional to the I/Q offset measured in the R&S VSE WLAN application. The difference (in dB) between the two values depends on the transmit filter shape and should be determined with a reference measurement.

The following table lists the difference exemplarily for three transmit filter shapes (±0.5 dB):

Transmit filter	– I/Q-Offset [dB] – RF-Carrier-Suppression [dB]
Rectangular	11 dB
Root raised cosine, "α" = 0.3	10 dB
Gaussian, "α" = 0.3	9 dB

3.1.7 EVM Measurement

The R&S VSE WLAN application provides two different types of EVM calculation.

3.1.7.1 PPDU EVM (Direct method)

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.

he PPDU EVM is not part of the IEEE 802.11 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.

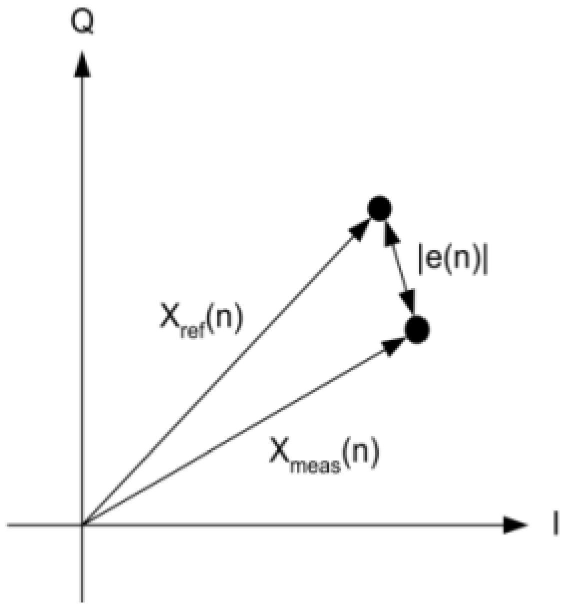


Fig. 3-6: I/Q diagram for EVM calculation

3.1.7.2 Peak Vector Error (IEEE method)

The peak vector error (Peak EVM) is defined in section 18.4.7.8 "Transmit modulation accuracy" of the IEEE 802.11b standard. The phase, timing and gain tracking errors of the measurement signal (center frequency error, common phase error, sampling frequency error) are compensated for before EVM calculation.

The standard does not specify a normalization factor for the error vector magnitude. To get an EVM value that is independent of the level, the R&S VSE WLAN application normalizes the EVM values. Thus, an EVM of 100% indicates that the error power on the I- or Q-channels equals the mean power on the I- or Q-channels, respectively.

The peak vector error is the maximum EVM over all payload symbols and all active carriers for one PPDU. If more than one PPDU is analyzed (several analyzed PPDUs in the capture buffer or due to the PPDU Statistic Count / No of PPDUs to Analyze setting), the Min / Mean / Max columns show the minimum, mean or maximum Peak EVM of all analyzed PPDUs.

The IEEE 802.11b or g (DSSS) standards allow a peak vector error of less than 35%. In contrary to the specification, the R&S VSE WLAN application does not limit the measurement to 1000 chips length, but searches the maximum over the whole PPDU.

3.2 Evaluation Methods for WLAN I/Q Measurements

The captured I/Q data from the WLAN signal can be evaluated using various different methods without having to start a new measurement or sweep. Which results are displayed depends on the selected evaluation.

Result display windows

For each measurement, a separate measurement channel is activated. Each measurement channel can provide multiple result displays, which are displayed in individual windows. The measurement windows can be rearranged and configured in the R&S VSE to meet your requirements. All windows that belong to the same measurement (including the channel bar) are indicated by a colored line at the top of the window title bar.

► To add further result displays for the WLAN 802.11 channel, select the "Add Window" icon from the toolbar, or select the "Window > New Window" menu item.

  For details on working with channels and windows see the "Operating Basics" chapter in the R&S VSE Base Software User Manual.

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 186).

The WLAN measurement provides the following evaluation methods:

Bitstream

This result display shows and demodulated payload 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 WLAN standard. See for example *IEEE Std. 802.11-2012 'Fig. 18-10 BPSK, QPSK, 16-QAM and 64-QAM constellation bit encoding'*. Thus, the bitstream is *NOT* channel-decoded.

For multicarrier measurements (**IEEE 802.11a, g (OFDM), ac, n**) the results are grouped by symbol and carrier.

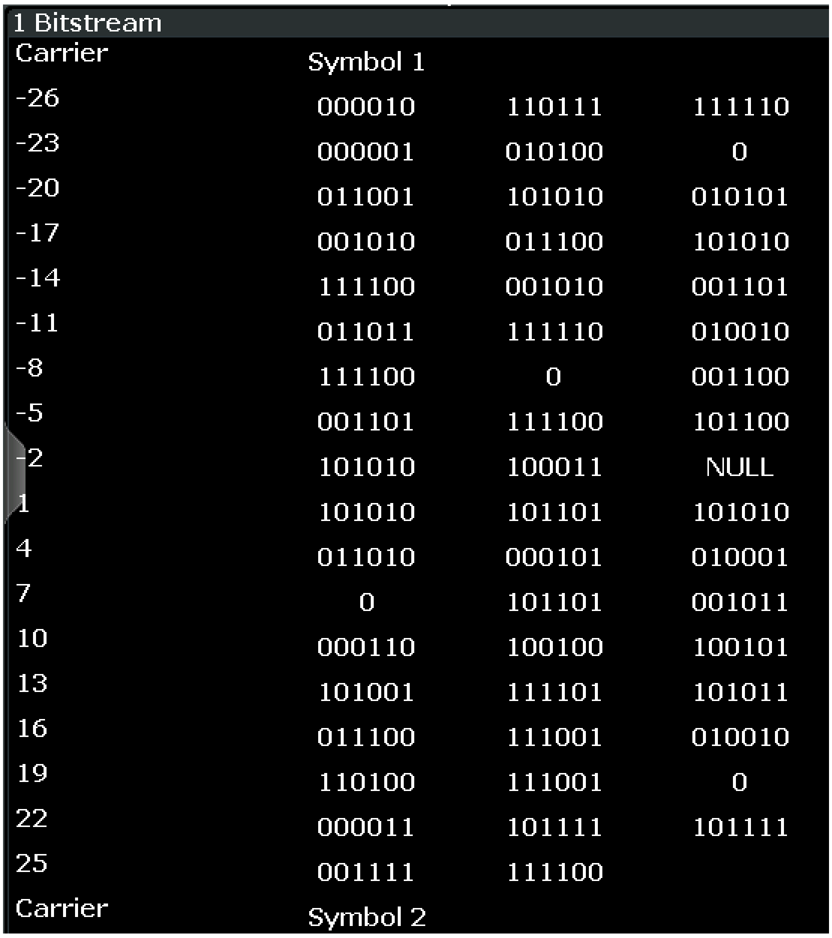


Fig. 3-7: Bitstream result display for IEEE 802.11a, g (OFDM), ac, n standards

For single-carrier measurements (**IEEE 802.11b, g (DSSS)**) the results are grouped by PPDU.

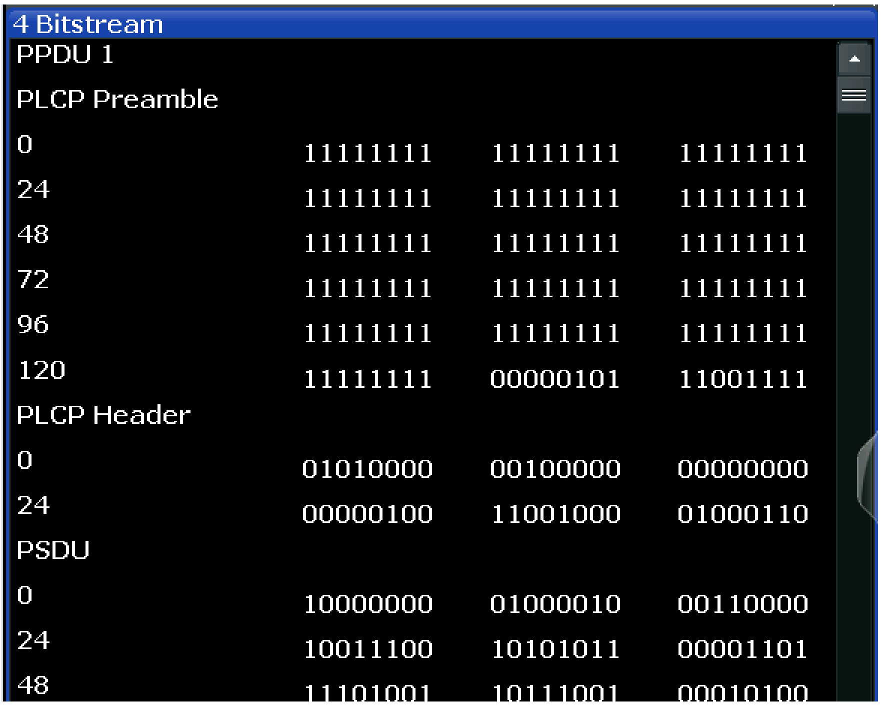


Fig. 3-8: Bitstream result display for IEEE 802.11b, g (DSSS) standards

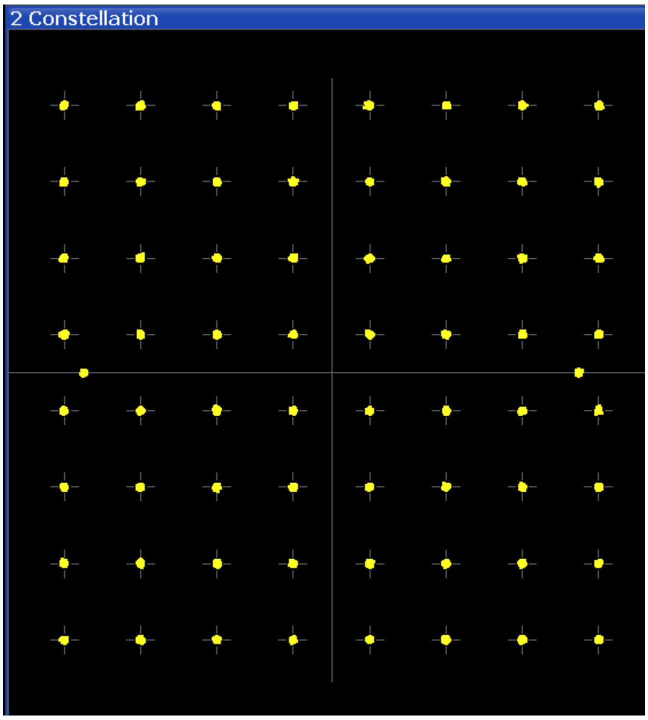
The numeric trace results for this evaluation method are described in chapter 9.6.3.1, "Bitstream", on page 191.

Remote command:
`LAY:ADD? '1',RIGH, BITS`, see `LAYout:ADD[:WINDow]?` on page 161
or:
`CONFigure:BURSt:STATistics:BSTReam[:IMMediate]` on page 169
Querying results:
`TRACe<n>[:DATA]`, see chapter 9.6.3.1, "Bitstream", on page 191

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.



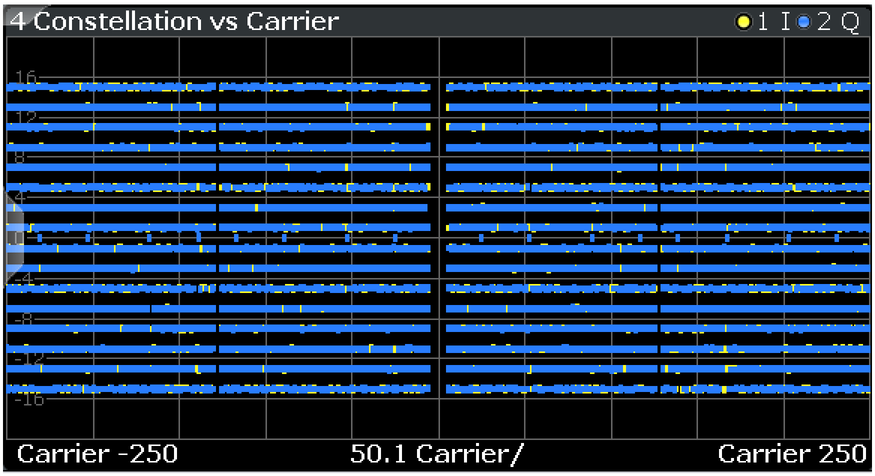
The numeric trace results for this evaluation method are described in chapter 9.6.3.2, "Constellation", on page 192.

Remote command:
`LAY:ADD? '1',RIGH, CONS`, see `LAYout:ADD[:WINDow]?` on page 161
or:
`CONFigure:BURSt:CONSt:CSYMbol[:IMMediate]` on page 168
Querying results:
`TRACe<n>[:DATA]`, see chapter 9.6.3.2, "Constellation", on page 192

Constellation vs Carrier
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.

This result display is **not** available for single-carrier measurements (**IEEE 802.11b, g (DSSS)**).

The x-axis represents the carriers. The magnitude of the in-phase and quadrature part is shown on the y-axis, both are displayed as separate traces (I-> trace 1, Q-> trace 2).



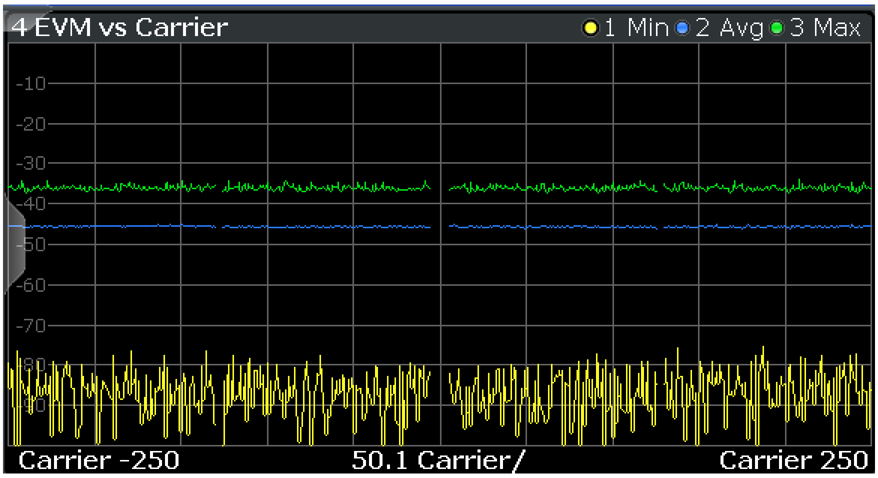
The numeric trace results for this evaluation method are described in chapter 9.6.3.3, "Constellation vs Carrier", on page 193.

Remote command:
`LAY:ADD? '1',RIGH, CVC`, see `LAYout:ADD[:WINDow]?` on page 161
or:
`CONFigure:BURSt:CONSt:CCARrier[:IMMediate]` on page 167
Querying results:
`TRACe<n>[:DATA]`, see chapter 9.6.3.3, "Constellation vs Carrier", on page 193

EVM vs Carrier

This result display shows all EVM values recorded on a per-subcarrier basis over the number of analyzed PPDUs as defined by the "Evaluation Range > Statistics". The Tracking/Channel Estimation according to the user settings is applied (see chapter 5.6, "Tracking and Channel Estimation", on page 78). The Minhold, Average and Maxhold traces are displayed.

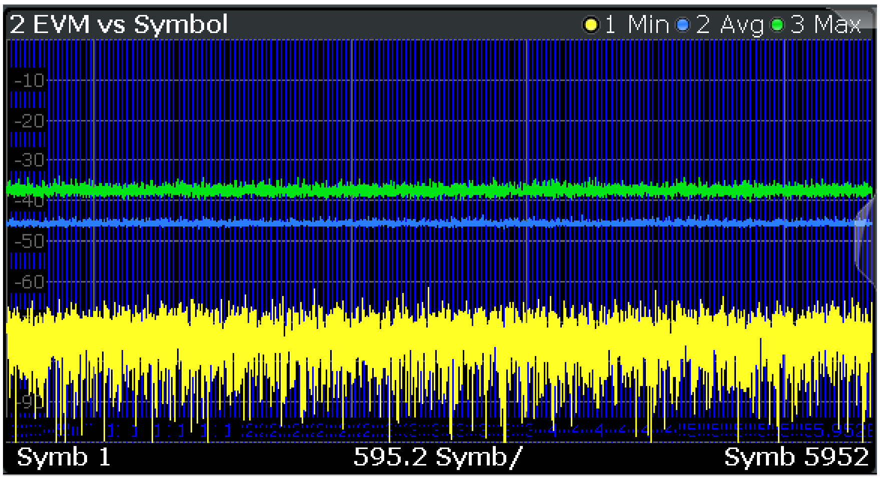
This result display is **not** available for single-carrier measurements (**IEEE 802.11b, g (DSSS)**).



The numeric trace results for this evaluation method are described in chapter 9.6.3.4, "EVM vs Carrier", on page 193.

Remote command:
`LAY:ADD? '1',RIGH, EVC`, see `LAYout:ADD[:WINDow]?` on page 161
or:
`CONFigure:BURSt:EVM:ECARrier[:IMMediate]` on page 168
Querying results:
`TRACe<n>[:DATA]`, see chapter 9.6.3.4, "EVM vs Carrier", on page 193

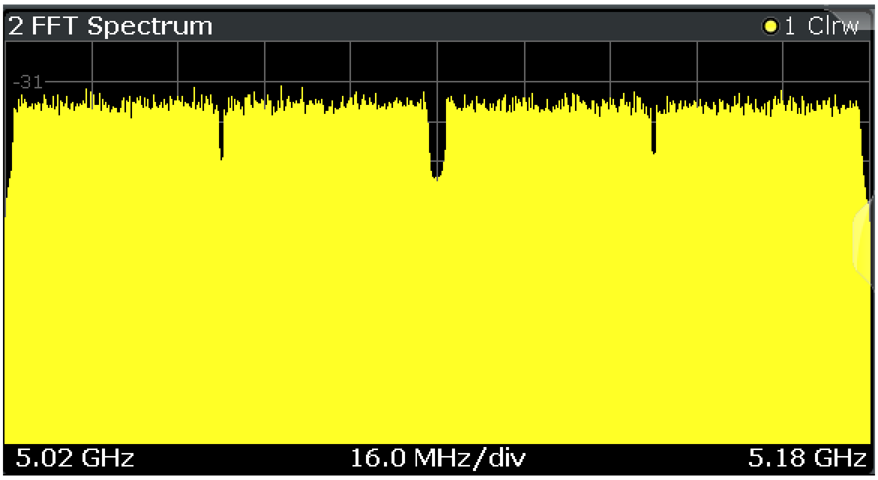
EVM vs Symbol
This result display shows all EVM values calculated on a per-carrier basis over the number of analyzed PPDUs as defined by the "Evaluation Range > Statistics" settings (see "PPDU Statistic Count / No of PPDUs to Analyze" on page 95). The Tracking/ Channel Estimation according to the user settings is applied (see chapter 5.6, "Tracking and Channel Estimation", on page 78). The MinHold, Maxhold, and Average traces are displayed.



This result display is **not** available for single-carrier measurements (**IEEE 802.11b, g (DSSS)**).

Remote command:
`LAY:ADD? '1',RIGH, EVSY`, see `LAYout:ADD[:WINDow]?` on page 161
or:
`CONFigure:BURSt:EVM:ESYMbol[:IMMediate]` on page 168
Querying results:
`TRACe<n>[:DATA]`, see chapter 9.6.3.6, "EVM vs Symbol", on page 194

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



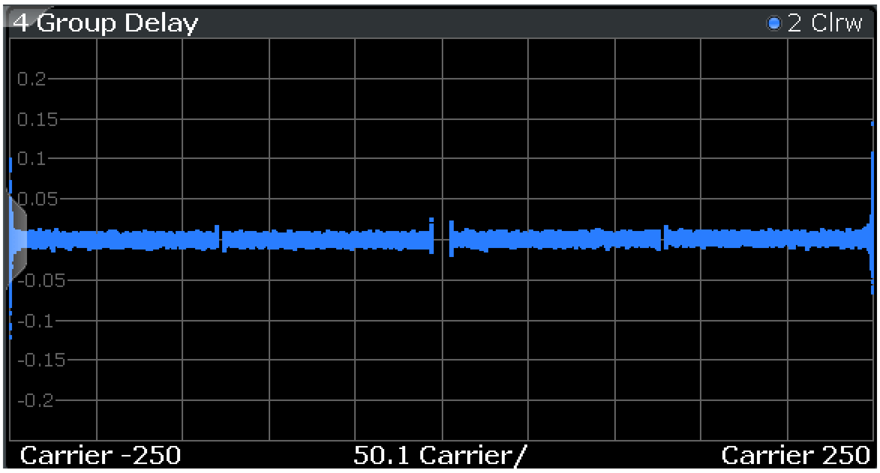
The numeric trace results for this evaluation method are described in chapter 9.6.3.7, "FFT Spectrum", on page 194.

Remote command:
`LAY:ADD? '1',RIGH, FSP`, see `LAYout:ADD[:WINDow]?` on page 161
or:
`CONFigure:BURSt:SPECtrum:FFT[:IMMediate]` on page 168
Querying results:
`TRACe<n>[:DATA]`, see chapter 9.6.3.7, "FFT Spectrum", on page 194

Group Delay
Displays all Group Delay (GD) values recorded on a per-subcarrier basis - over the number of analyzed PPDUs as defined by the "Evaluation Range > Statistics" settings (see "PPDU Statistic Count / No of PPDUs to Analyze" on page 95.

All 57 carriers are shown, including the unused carrier 0.

This result display is **not** available for single-carrier measurements (**IEEE 802.11b, g (DSSS)**).



Group delay is a measure of phase distortion and defined as the derivation of phase over frequency.

To calculate the group delay, the estimated channel is upsampled, inactive carriers are interpolated and phases are unwrapped before they are differentiated over the carrier frequencies. Thus, the group delay indicates the time a pulse in the channel is delayed for each carrier frequency. However, not the absolute delay is of interest, but rather the deviation between carriers. Thus, the mean delay over all carriers is deducted.

For an ideal channel, the phase increases linearly, which causes a constant time delay over all carriers. In this case, a horizontal line at the zero value would be the result.

The numeric trace results for this evaluation method are described in chapter 9.6.3.8, "Group Delay", on page 195.

Remote command:
`LAY:ADD? '1',RIGH, GDEL`, see `LAYout:ADD[:WINDow]?` on page 161
or:
`CONF:BURS:SPEC:FLAT:SEL GRD`, see `CONFigure:BURSt:SPECtrum:FLATness:SELect` on page 169 and
`CONFigure:BURSt:SPECtrum:FLATness[:IMMediate]` on page 169
Querying results:
`TRACe<n>[:DATA]`, see chapter 9.6.3.8, "Group Delay", on page 195

Magnitude Capture
The Magnitude Capture Buffer display shows 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.

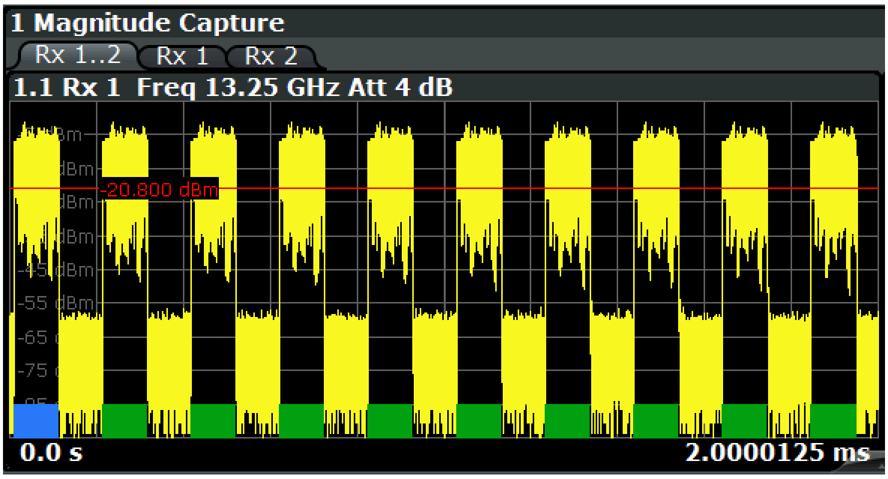


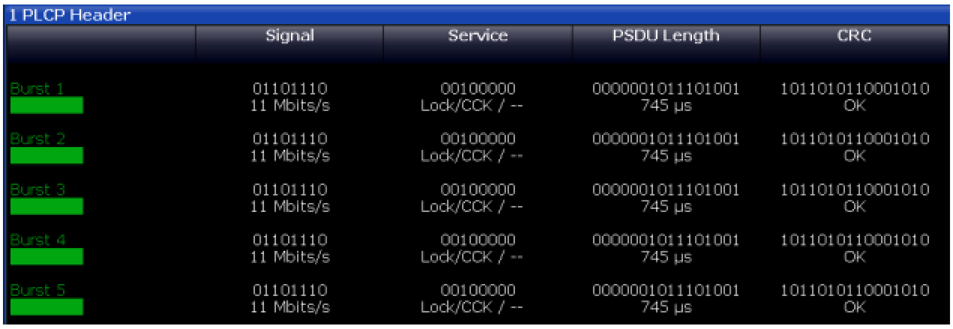
Fig. 3-9: Magnitude capture display

Numeric trace results are not available for this evaluation method.

Remote command:
`LAY:ADD? '1',RIGH, CMEM`, see `LAYout:ADD[:WINDow]?` on page 161
Querying results:
`TRACe<n>[:DATA]`, see chapter 9.6.3.9, "Magnitude Capture", on page 195

PLCP Header (IEEE 802.11b, g (DSSS)
This result display shows the decoded data from the PLCP header of the PPDU.

This result display is **only** available for single-carrier measurements (**IEEE 802.11b, g (DSSS)**); for other standards, use Signal Field instead.



1 PLCP Header

	Signal	Service	PSDU Length	CRC
Burst 1	01101110 11 Mbits/s	00100000 Lock/CCK / --	0000001011101001 745 µs	1011010110001010 OK
Burst 2	01101110 11 Mbits/s	00100000 Lock/CCK / --	0000001011101001 745 µs	1011010110001010 OK
Burst 3	01101110 11 Mbits/s	00100000 Lock/CCK / --	0000001011101001 745 µs	1011010110001010 OK
Burst 4	01101110 11 Mbits/s	00100000 Lock/CCK / --	0000001011101001 745 µs	1011010110001010 OK
Burst 5	01101110 11 Mbits/s	00100000 Lock/CCK / --	0000001011101001 745 µs	1011010110001010 OK

Fig. 3-10: PLCP Header result display for IEEE 802.11b, g (DSSS) standards

The following information is provided:

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

Table 3-4: Demodulation results in PLCP Header result display (IEEE 802.11b, g (DSSS))

Result	Description	Example
PPDU	Number of the decoded PPDU A colored block indicates that the PPDU was successfully decoded.	PPDU 1
Signal	Information in "signal" field The decoded data rate is shown below.	01101110 11 MBits/s
Service	Information in "service" field <Symbol clock state> /<Modulation format> / <Length extension bit state> where: <Symbol clock state>: Locked / - - <Modulation format>: see table 4-1 <Length extension bit state>: 1 (set) / - - (not set)	00100000 Lock/CCK/- -
PSDU Length	Information in "length" field Time required to transmit the PSDU	0000000001111000 120 µs
CRC	Information in "CRC" field Result of cyclic redundancy code check: "OK" or "Failed"	1110100111001110 OK

Remote command:

`LAY:ADD? '1',RIGH, SFI`, see `LAYout:ADD[:WINDow]?` on page 161

or:

`CONFigure:BURSt:STATistics:SFIeld[:IMMediate]` on page 169

Querying results:

`TRACe<n>[:DATA]`, see chapter 9.6.3.11, "Signal Field", on page 196

PvT Full PPDU

Displays the minimum, average and maximum power vs time diagram for all PPDUs.

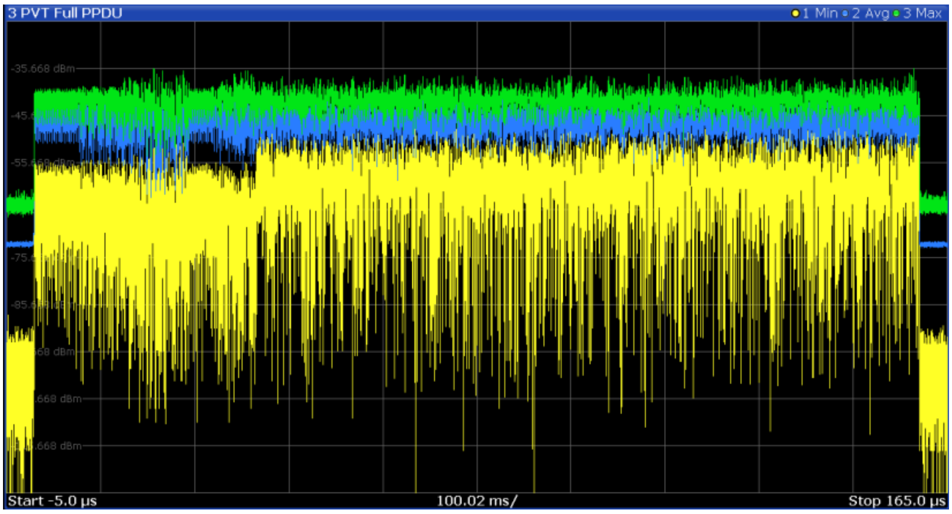


Fig. 3-11: PvT Full PPDU result display for IEEE 802.11a, g (OFDM), ac, n standards

For single-carrier measurements (**IEEE 802.11b, g (DSSS)**), the PVT results are displayed as percentage values of the reference power. The reference can be set to either the maximum or mean power of the PPDU.

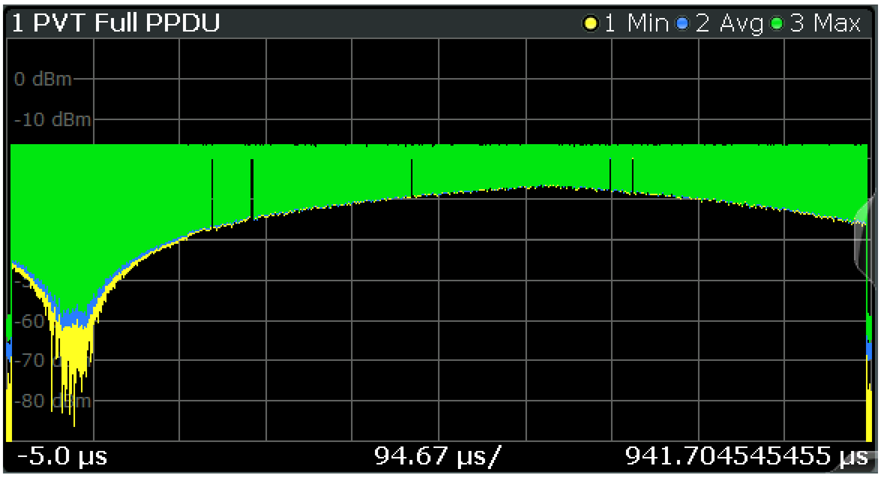


Fig. 3-12: PvT Full PPDU result display for IEEE 802.11b, g (DSSS) standards

Remote command:

`LAY:ADD:WIND '2',RIGH,PFPP` see `LAYout:ADD[:WINDow]?` on page 161

or:

`CONFigure:BURSt:PVT[:IMMediate]` on page 168

Querying results:

`TRACe<n>[:DATA]`, see chapter 9.6.3.10, "Power vs Time (PVT)", on page 195

Result Summary Detailed

The *detailed* result summary contains individual measurement results for the Transmitter and Receiver channels and for the bitstream.

This result display is **not** available for single-carrier measurements (**IEEE 802.11b, g (DSSS)**).

The "Result Summary Detailed" contains the following information:

Note: You can configure which results are displayed (see chapter 5.9.1, "Result Summary Configuration", on page 99). However, the results are always calculated, regardless of their visibility.

Tx channel ("Tx All"):
- I/Q offset [dB]
- Gain imbalance [%/dB]
- Quadrature offset [°]
- PPDU power [dBm]
- Crest factor [dB]

Receive channel ("Rx All"):
- PPDU power [dBm]
- Crest factor [dB]

Bitstream ("Stream All"):
- Pilot bit error rate [%]
- EVM all carriers [%/dB]
- EVM data carriers [%/dB]
- EVM pilot carriers [%/dB]

For details on the individual parameters and the summarized values see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Remote command:
`LAY:ADD? '1',RIGH, RSD`, see `LAYout:ADD[:WINDow]?` on page 161
Querying results:
`FETCh:BURSt:ALL` on page 175

Result Summary Global

The *global* result summary provides measurement results based on the complete signal, consisting of all channels and streams. The observation length is the number of PPDUs to be analyzed as defined by the "Evaluation Range > Statistics" settings. In contrast, the *detailed* result summary provides results for each individual channel and stream.

1 Result Summary Global
No. of PPDUs - Recognized: 19 Analyzed: 18 Analyzed Physical Channel: 18

PPDUs:	Min	Mean	Limit	Max	Limit	Unit
Pilot Bit Error Rate	0.00	0.00	0.00	0.00	0.00	%
EVM All Carriers	0.34	0.38	31.62	0.49	31.62	%
	-49.25	-48.46	-10.00	-46.15	-10.00	dB
EVM Data Carriers	0.34	0.38	31.62	0.50	31.62	%
	-49.25	-48.44	-10.00	-46.07	-10.00	dB
EVM Pilot Carriers	0.29	0.34	56.23	0.45	56.23	%
	-50.62	-49.31	-5.00	-46.99	-5.00	dB
Center Frequency Error	-4.34	-0.85	±100000.00	3.55	±100000.00	Hz
Symbol Clock Error	0.02	0.09	±20.00	0.17	±20.00	ppm

Fig. 3-13: Global result summary for IEEE 802.11a, g (OFDM), ac, n standards

1 Result Summary Global

No. of PPDUs - Recognized: 3 Analyzed: 3 Analyzed Physical Channel: 0

PPDUs:	Min	Mean	Limit	Max	Limit	Unit
Peak Vector Error	1.18	1.37	35.00	1.47	35.00	%
PPDU EVM	0.19	0.19		0.19		%
	-54.59	-54.57		-54.54		dB
IQ Offset	-67.45	-67.33		-67.24		dB
Gain Imbalance	82.34	82.34		82.34		%
	-15.06	-15.06		-15.06		dB
Quadrature Error	0.00	0.00		0.00		°
Center Freq Error	0.00	0.00	±331250.00	0.00	±331250.00	Hz
Chip Clock Error	-0.00	-0.00	±25.00	-0.00	±25.00	ppm
Rise Time	1.00	1.00	2.00	1.00	2.00	uS
Fall Time	3.18	3.18*	2.00	3.18*	2.00	uS
Mean Power	-2.62	-2.62		-2.62		dBm
Peak Power	-1.67	-1.67		-1.66		dBm
Crest Factor	0.94	0.95		0.95		dB

Fig. 3-14: Global result summary for IEEE 802.11b, g (DSSS) standards

The "Result Summary Global" contains the following information:

Note: You can configure which results are displayed (see chapter 5.9.1, "Result Summary Configuration", on page 99). However, the results are always calculated, regardless of their visibility.

- Number of recognized PPDUs
- Number of analyzed PPDUs
- Number of analyzed PPDUs in entire physical channel (if available)

IEEE 802.11a, g (OFDM), ac, n standards:
- Pilot bit error rate [%]
- EVM all carriers [%/dB]
- EVM data carriers [%/dB]
- EVM pilot carriers [%/dB]
- Center frequency error [Hz]
- Symbol clock error [ppm]

IEEE 802.11b, g (DSSS) standards:
- Peak vector error
- PPDU EVM
- Quadrature offset
- Gain imbalance

- Quadrature error
- Center frequency error
- Chip cock error
- Rise time
- Fall time
- Mean power
- Peak power
- Crest power

For details on the individual results and the summarized values see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Remote command:
`LAY:ADD? '1',RIGH, RSG`, see `LAYout:ADD[:WINDow]?` on page 161
Querying results:
`FETCh:BURSt:ALL` on page 175

Signal Field
This result display shows the decoded data from the "Signal" field of each recognized PPDU. This field contains information on the modulation used for transmission.

This result display is **not** available for single-carrier measurements (**IEEE 802.11b, g (DSSS)**).

Fig. 3-15: Signal Field display for IEEE 802.11n

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

The currently applied demodulation settings (as defined by the user, see chapter 5.7, "Demodulation", on page 80) are indicated beneath the table header for reference. Since the demodulation settings define which PPDUs are to be analyzed, this *logical filter* may be the reason if the "Signal Field" display is not as expected.

Table 3-5: Demodulation parameters and results for Signal Field result display (IEEE 802.11a, g (OFDM))

Parameter	Description
Format	PPDU format used for measurement (Not part of the IEEE 802.11a, g (OFDM) signal field, displayed for convenience; see "PPDU Format to measure" on page 82)
CBW	Channel bandwidth to measure (Not part of the signal field, displayed for convenience)
Rate / Mbit/s	Symbol rate per second
R	Reserved bit

Parameter	Description
Length / Sym	Human-readable length of payload in OFDM symbols
P	Parity bit
(Signal) Tail	Signal tail (preset to 0)

Table 3-6: Demodulation parameters and results for Signal Field result display (IEEE 802.11ac)

Parameter	Description
Format	PPDU format used for measurement (Not part of the IEEE 802.11ac signal field, displayed for convenience; see "PPDU Format to measure" on page 82)
MCS	Modulation and Coding Scheme (MCS) index of the PPDU as defined in IEEE Std 802.11-2012 section "20.6 Parameters for HT MCSs"
BW	Channel bandwidth to measure 0: 20 MHz 1: 40 MHz 2: 80 MHz 3: 80+80 MHz and 160MHz
L-SIG Length / Sym	Human-readable length of payload in OFDM symbols
STBC	Space-Time Block Coding 0: no spatial streams of any user has space time block coding 1: all spatial streams of all users have space time block coding
GI	Guard interval length PPDU must have to be measured 1: short guard interval is used in the Data field 0: short guard interval is not used in the Data field
Ness	Number of extension spatial streams (N_{ESS}, see "Extension Spatial Streams (sounding)" on page 93)
CRC	Cyclic redundancy code

Table 3-7: Demodulation parameters and results for Signal Field result display (IEEE 802.11n)

Parameter	Description
Format	PPDU format used for measurement (Not part of the IEEE 802.11n signal field, displayed for convenience; see "PPDU Format to measure" on page 82)
MCS	Modulation and Coding Scheme (MCS) index of the PPDU as defined in IEEE Std 802.11-2012 section "20.6 Parameters for HT MCSs"
CBW	Channel bandwidth to measure 0: 20 MHz or 40 MHz upper/lower 1: 40 MHz
HT-SIG Length / Sym	Human-readable length of payload in OFDM symbols The number of octets of data in the PSDU in the range of 0 to 65 535

Parameter	Description
SNRA	**S**moothing/**N**ot Sounding/**R**eserved/**A**ggregation: **Smoothing:** 1: channel estimate smoothing is recommended 0: only per-carrier independent (unsmoothed) channel estimate is recommended **Not Sounding:** 1: PPDU is not a sounding PPDU 0: PPDU is a sounding PPDU **Reserved:** Set to 1 **Aggregation:** 1: PPDU in the data portion of the packet contains an AMPDU 0: otherwise
STBC	Space-Time Block Coding 00: no STBC (NSTS = NSS) ≠0: the difference between the number of spacetime streams (NSTS) and the number of spatial streams (NSS) indicated by the MCS
GI	Guard interval length PPDU must have to be measured 1: short GI used after HT training 0: otherwise
Ness	Number of extension spatial streams (N_{ESS}, see "Extension Spatial Streams (sounding)" on page 93)
CRC	Cyclic redundancy code of bits 0–23 in HT-SIG1 and bits 0–9 in HT-SIG2
Tail Bits	Used to terminate the trellis of the convolution coder. Set to 0.

The values for the individual demodulation parameters are described in chapter 5.7, "Demodulation", on page 80. The following abbreviations are used in the "Signal Field" table:

Table 3-8: Abbreviations for demodulation parameters shown in "Signal Field" display

Abbreviation in "Signal Field" display	Parameter in "Demodulation" settings
A1st	Auto, same type as first PPDU
AI	Auto, individual for each PPDU
M<x>	Meas only the specified PPDUs (<x>)
D<x>	Demod all with specified parameter <y>

The Signal Field measurement indicates certain inconsistencies in the signal or discrepancies between the demodulation settings and the signal to be analyzed. In both cases, an appropriate warning is displayed and the results for the PPDU are highlighted orange - both in the "Signal Field" display and the "Magnitude Capture" display. If the signal was analyzed with warnings the results – indicated by a message - also contribute to the overall analysis results.

PPDUs detected in the signal that do not pass the logical filter, i.e. are not to be included in analysis, are dismissed. An appropriate message is provided. The corresponding PPDU in the capture buffer is not highlighted.

The numeric trace results for this evaluation method are described in chapter 9.6.3.11, "Signal Field", on page 196.

Remote command:
`LAY:ADD? '1',RIGH, SFI`, see `LAYout:ADD[:WINDow]?` on page 161
or:
`CONFigure:BURSt:STATistics:SFIeld[:IMMediate]` on page 169
Querying results:
`TRACe<n>[:DATA]`, see chapter 9.6.3.11, "Signal Field", on page 196

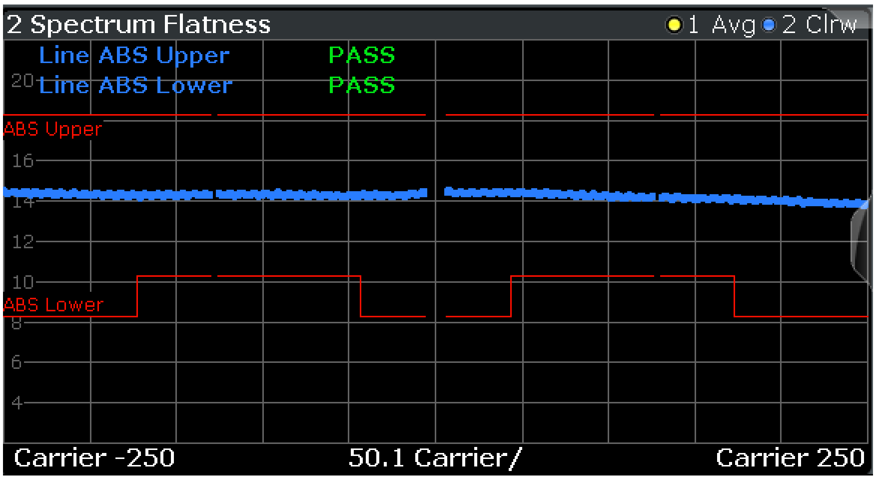
Spectrum Flatness

The Spectrum Flatness trace is derived from the magnitude of the estimated channel transfer function. Since this estimated channel is calculated from all payload symbols of the PPDU, it represents a carrier-wise mean gain of the channel. Assuming that we have a cable connection between the DUT and the R&S VSE that adds no residual channel distortion, the "Spectrum Flatness" shows the spectral distortion caused by the DUT (for example the transmit filter).

This result display is **not** available for single-carrier measurements (**IEEE 802.11b, g (DSSS)**).

The diagram shows the absolute power per carrier. All carriers are displayed, including the unused carrier(s).

In contrast to the SISO measurements in previous Rohde & Schwarz signal and spectrum analyzers, the trace is no longer normalized to 0 dB (scaled by the mean gain of all carriers).



The numeric trace results for this evaluation method are described in chapter 9.6.3.12, "Spectrum Flatness", on page 196.

Remote command:
`LAY:ADD? '1',RIGH, SFL`, see `LAYout:ADD[:WINDow]?` on page 161
or:
`CONF:BURS:SPEC:FLAT:SEL FLAT` (see `CONFigure:BURSt:SPECtrum:FLATness:SELect` on page 169) and
`CONFigure:BURSt:SPECtrum:FLATness[:IMMediate]` on page 169
Querying results:
`TRACe<n>[:DATA]`, see chapter 9.6.3.12, "Spectrum Flatness", on page 196

4 Measurement Basics

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

4.1 Signal Processing for Multicarrier Measurements (IEEE 802.11a, g (OFDM))

This description gives a rough view of the signal processing when using the R&S VSE WLAN application with the IEEE 802.11a, g (OFDM) standards. Details are disregarded in order to provide a concept overview.

Abbreviations

$a_{l,k}$	symbol at symbol l of subcarrier k
EVM_k	error vector magnitude of subcarrier k
EVM	error vector magnitude of current packet
g	signal gain
Δf	frequency deviation between Tx and Rx
l	symbol index l = {1 ... nof_Symbols}
nof_symbols	number of symbols of payload
H_k	channel transfer function of subcarrier k
k	channel index k = {–31 ... 32}
K_{mod}	modulation-dependent normalization factor
ξ	relative clock error of reference oscillator
$r_{l,k}$	subcarrier of symbol l

4.1.1 Block Diagram for Multicarrier Measurements

A diagram of the significant blocks when using the IEEE 802.11a, g (OFDM) standard in the R&S VSE WLAN application is shown in figure 4-1.

First the RF signal is downconverted to the IF frequency f_{IF}. The resulting IF signal $r_{IF}(t)$ is shown on the left-hand side of the figure. After bandpass filtering, the signal is sampled by an analog to digital converter (ADC) at a sample rate of f_{s1}. This digital sequence is resampled. Thus, the sample rate of the downsampled sequence r(i) is the Nyquist rate of f_{s3} = 20 MHz. Up to this point the digital part is implemented in an ASIC.

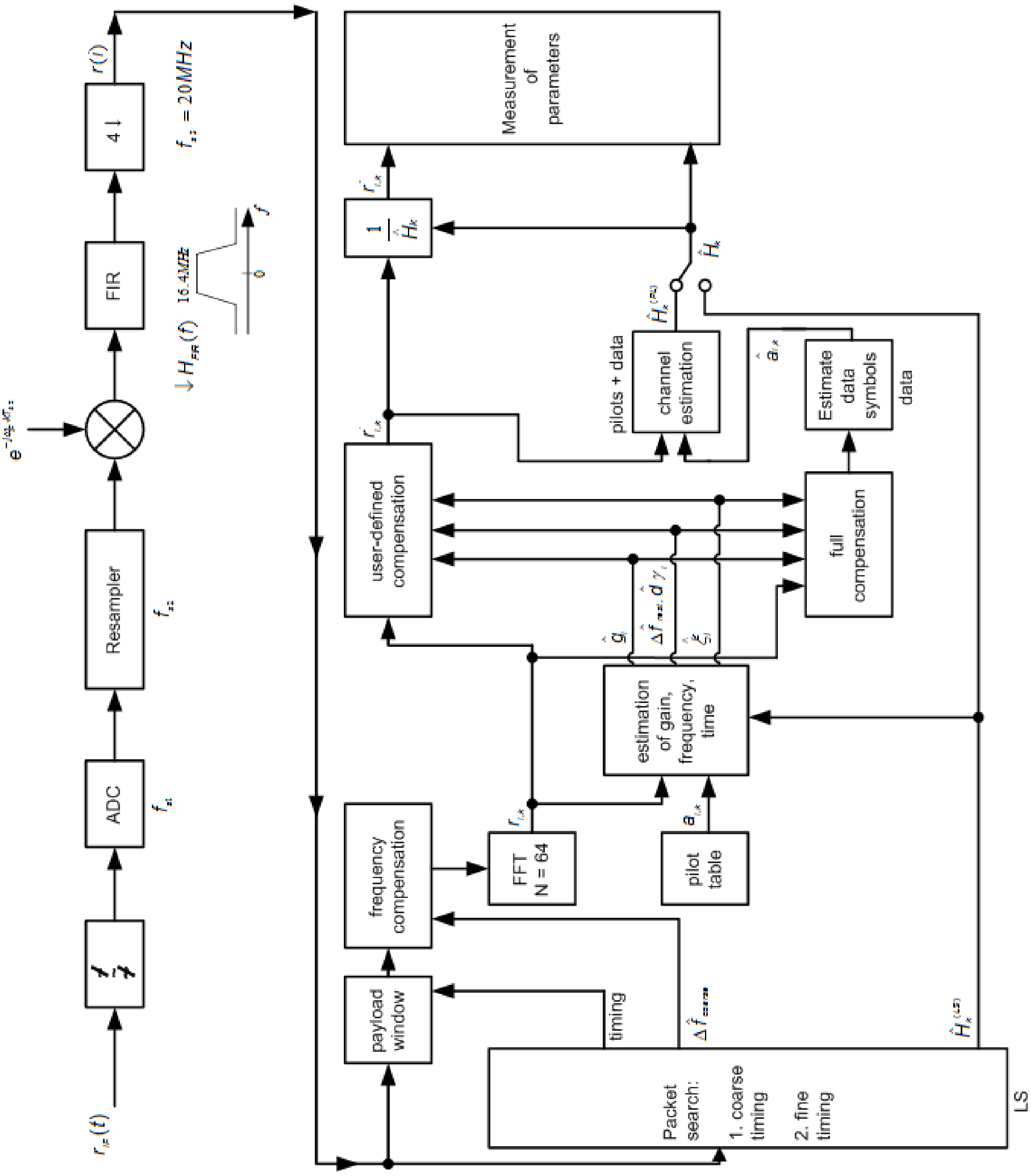


Fig. 4-1: Block diagram for the R&S VSE WLAN application using the IEEE 802.11a, g (OFDM) standard

In the lower part of the figure the subsequent digital signal processing is shown.

Packet search and timing detection

In the first block the **packet search** is performed. This block detects the *long symbol* (LS) and recovers the timing. The **coarse timing** is detected first. This search is implemented in the time domain. The algorithm is based on cyclic repetition within the LS after N = 64 samples. Numerous treatises exist on this subject, e.g. [1] to [3].

Furthermore, a coarse estimate $\Delta\hat{f}_{coarse}$ of the Rx-Tx frequency offset Δf is derived from the metric in [6]. (The hat generally indicates an estimate, e.g. $\hat{x}$ is the estimate of x.) This can easily be understood because the phase of *r(i)* $\cdot\Delta$ *r* (i + N)* is determined by the frequency offset. As the frequency deviation Δf can exceed half a bin (distance between neighboring subcarriers) the preceding *short symbol* (SS) is also analyzed in order to detect the ambiguity.

After the coarse timing calculation the time estimate is improved by the **fine timing** calculation. This is achieved by first estimating the coarse frequency response $\hat{H}^{(LS)}_k$, where k = {–26.. 26} denotes the channel index of the *occupied* subcarriers. First the FFT of the LS is calculated. After the FFT calculation the known symbol information of the LS subcarriers is removed by dividing by the symbols. The result is a coarse estimate $\hat{H}_k$ of the channel transfer function. In the next step, the complex channel impulse response is computed by an IFFT. Then the energy of the windowed impulse response (the window size is equal to the guard period) is calculated for each trial time. Afterwards the trial time of the maximum energy is detected. This trial time is used to adjust the timing.

Determing the payload window

Now the position of the LS is known and the starting point of the useful part of the first payload symbol can be derived. In the next block this calculated time instant is used to position the **payload window**. Only the payload part is windowed. This is sufficient because the payload is the only subject of the subsequent measurements.

In the next block the windowed sequence is **compensated** by the coarse frequency estimate $\Delta\hat{f}_{course}$. This is necessary because otherwise inter-channel interference (ICI) would occur in the frequency domain.

The transition to the frequency domain is achieved by an FFT of length 64. The FFT is performed symbol-wise for each symbol of the payload ("nof_symbols"). The calculated FFTs are described by $r_{l,k}$ with:

- l = {1 .. nof_symbols} as the symbol index
- k = {–31 .. 32} as the channel index

In case of an additive white Gaussian noise (AWGN) channel, the FFT is described by [4], [5]

$$r_{l,k} = K_{\text{mod}} \times a_{l,k} \times g_l \times H_k \times e^{j(phase_l^{(common)} + phase_{l,k}^{(\text{timing})})} + n_{l,k}$$

FFT (4 - 1)

with:

- K_{mod}: the modulation-dependant normalization factor

- $a_{l,k}$: the symbol of subcarrier k at symbol l
- g_l: the gain at the symbol l in relation to the reference gain g = 1 at the long symbol (LS)
- H_k: the channel frequency response at the long symbol (LS)
- $phase_l^{(common)}$: the common phase drift phase of all subcarriers at symbol l (see Common phase drift)
- $phase_{l,k}^{(timing)}$: the phase of subcarrier k at symbol l caused by the timing drift (see Common phase drift)
- $n_{l,k}$: the independent Gaussian distributed noise samples

Phase drift and frequency deviation

The common phase drift in FFT is given by:

$$phase_l^{(common)} = 2\pi \times N_s / N \times \Delta f_{rest} T \times l + d\gamma_l$$

Common phase drift (4 - 2)

with

- N_s = 80: the number of Nyquist samples of the symbol period
- N = 64: the number of Nyquist samples of the useful part of the symbol
- Δf_{rest}: the (not yet compensated) frequency deviation
- $d\Upsilon_l$: the phase jitter at the symbol l

In general, the coarse frequency estimate $\Delta \hat{f}_{coarse}$ (see figure 4-1) is not error-free. Therefore the remaining frequency error Δf_{rest} represents the frequency deviation in $r_{l,k}$ not yet compensated. Consequently, the overall frequency deviation of the device under test (DUT) is calculated by:

$\Delta f = \Delta \hat{f}_{coarse} + \Delta f_{rest}$

The common phase drift in Common phase drift is divided into two parts to calculate the overall frequency deviation of the DUT.

The reason for the phase jitter $d\gamma_l$ in Common phase drift may be different. The nonlinear part of the phase jitter may be caused by the phase noise of the DUT oscillator. Another reason for nonlinear phase jitter may be the increase of the DUT amplifier temperature at the beginning of the PPDU. Note that besides the nonlinear part the phase jitter, $d\gamma_l$ also contains a constant part. This constant part is caused by the frequency deviation Δf_{rest} not yet compensated. To understand this, keep in mind that the measurement of the phase starts at the first symbol l = 1 of the payload. In contrast, the channel frequency response H_k in FFT represents the channel at the long symbol of the preamble. Consequently, the frequency deviation Δf_{rest} not yet compensated produces a phase drift between the long symbol and the first symbol of the payload. Therefore, this phase drift appears as a constant value ("DC value") in $d\Upsilon_l$.

Tracking the phase drift, timing jitter and gain

Referring to the IEEE 802.11a, g (OFDM) measurement standard, chapter 17.3.9.7 "Transmit modulation accuracy test" [6], the common phase drift $phase_l^{(common)}$ must be estimated and compensated from the pilots. Therefore this "symbol-wise phase tracking" is activated as the default setting of the R&S VSE WLAN application (see "Phase Tracking" on page 79).

Furthermore, the timing drift in FFT is given by:

$$phase_{l,k}^{(\text{timing})} = 2\pi \times N_s / N \times \xi \times k \times l$$

Timing drift (4 - 3)

with ξ: the relative clock deviation of the reference oscillator

Normally, a symbol-wise timing jitter is negligible and thus not modeled in Timing drift. However, there may be situations where the timing drift has to be taken into account. This is illustrated by an example: In accordance to [6], the allowed clock deviation of the DUT is up to ξ_{max} = 20 ppm. Furthermore, a long packet with 400 symbols is assumed. The result of FFT and Timing drift is that the phase drift of the highest sub-carrier k = 26 in the last symbol l = **nof_symbols** is 93 degrees. Even in the noise-free case, this would lead to symbol errors. The example shows that it is actually necessary to estimate and compensate the clock deviation, which is accomplished in the next block.

Referring to the IEEE 802.11a, g (OFDM) measurement standard [6], the timing drift $phase_{l,k}^{(timing)}$ is not part of the requirements. Therefore the "time tracking" is not activated as the default setting of the R&S VSE WLAN application (see "Timing Error Tracking" on page 79). The time tracking option should rather be seen as a powerful analyzing option.

In addition, the tracking of the gain g_l in FFT is supported for each symbol in relation to the reference gain g = 1 at the time instant of the long symbol (LS). At this time the coarse channel transfer function $\hat{H}^{(LS)}_k$ is calculated.

This makes sense since the sequence $r'_{l,k}$ is compensated by the coarse channel transfer function $\hat{H}^{(LS)}_k$ before estimating the symbols. Consequently, a potential change of the gain at the symbol l (caused, for example, by the increase of the DUT amplifier temperature) may lead to symbol errors especially for a large symbol alphabet M of the MQAM transmission. In this case, the estimation and the subsequent compensation of the gain are useful.

Referring to the IEEE 802.11a, g (OFDM) measurement standard [6], the compensation of the gain g_l is not part of the requirements. Therefore the "gain tracking" is not activated as the default setting of the R&S VSE WLAN application (see "Level Error (Gain) Tracking" on page 80).

Determining the error parameters (log likelihood function)

How can the parameters above be calculated? In this application the optimum maximum likelihood algorithm is used. In the first estimation step the symbol-independent parameters Δf_{rest} and ξ are estimated. The symbol dependent parameters can be neglected in this step, i.e. the parameters are set to $g_l = 1$ and $d\gamma = 0$. Referring to FFT, the log likelihood function L must be calculated as a function of the trial parameters $\Delta\tilde{f}_{rest}$ and $\tilde{\xi}$. (The tilde generally describes a trial parameter. Example: $\tilde{x}$ is the trial parameter of x.)

$$L_1(\Delta\tilde{f}_{rest},\tilde{\xi}) = \sum_{l=1}^{nof\_symbols} \sum_{k=-21,-7,7,21} \left| r_{l,k} - a_{l,k} \times \hat{H}_k^{(LS)} \times e^{j(\tilde{p}hase_l^{(common)} + \tilde{p}hase_{l,k}^{(timing)})} \right|^2$$

$$\text{with}$$

$$\tilde{p}hase_l^{(common)} = 2\pi \times N_s / N \times \Delta\tilde{f}_{rest} T \times l$$

$$\tilde{p}hase_l^{(timing)} = 2\pi \times N_s / N \times \tilde{\xi} \times k \times l$$

Log likelihood function (step 1) (4 - 4)

The trial parameters leading to the minimum of the log likelihood function are used as estimates $\Delta\hat{f}_{rest}$ and $\hat{\xi}$. In Log likelihood function (step 1) the known pilot symbols $a_{l,k}$ are read from a table.

In the second step, the log likelihood function is calculated for every symbol l as a function of the trial parameters $\tilde{g}_l$ and $d\tilde{\gamma}_l$:

$$L_2(\tilde{g}_l, d\tilde{\gamma}_l) = \sum_{k=-21,-7,7,21} \left| r_{l,k} - a_{l,k} \times \tilde{g}_l \times \hat{H}_k^{(LS)} \times e^{j(\tilde{p}hase_l^{(common)} + \tilde{p}hase_{l,k}^{(timing)})} \right|^2$$

$$\text{with}$$

$$\tilde{p}hase_l^{(common)} = 2\pi \times N_s / N \times \Delta\hat{f}_{rest} T \times l + d\tilde{\gamma}_l$$

$$\tilde{p}hase_l^{(timing)} = 2\pi \times N_s / N \times \hat{\xi} \times k \times l$$

Log likelihood function (step 2) (4 - 5)

Finally, the trial parameters leading to the minimum of the log likelihood function are used as estimates $\hat{g}_l$ and $d\tilde{\gamma}_l$.

This robust algorithm works well even at low signal to noise ratios with the Cramer Rao Bound being reached.

Compensation

After estimation of the parameters, the sequence $r_{l,k}$ is compensated in the compensation blocks.

In the upper analyzing branch the compensation is user-defined i.e. the user determines which of the parameters are compensated. This is useful in order to extract the influence of these parameters. The resulting output sequence is described by: $\gamma'_{\delta,k}$.

Data symbol estimation

In the lower compensation branch the full compensation is always performed. This separate compensation is necessary in order to avoid symbol errors. After the full compensation the secure estimation of the data symbols $\hat{a}_{l,k}$ is performed. From FFT it is clear that first the channel transfer function H_k must be removed. This is achieved by dividing the known coarse channel estimate $\hat{H}^{(LS)}_k$ calculated from the LS. Usually an error free estimation of the data symbols can be assumed.

Improving the channel estimation

In the next block a better channel estimate $\hat{H}^{(PL)}_k$ of the data and pilot subcarriers is calculated by using all "nof_symbols" symbols of the payload (PL). This can be accomplished at this point because the phase is compensated and the data symbols are known. The long observation interval of nof_symbols symbols (compared to the short interval of 2 symbols for the estimation of $\hat{H}^{(LS)}_k$) leads to a nearly error-free channel estimate.

In the following equalizer block, $\hat{H}^{(LS)}_k$ is compensated by the channel estimate. The resulting channel-compensated sequence is described by $\gamma_{\delta,k}''$. The user may either choose the coarse channel estimate $\hat{H}^{(LS)}_k$ (from the long symbol) or the nearly error-free channel estimate $\hat{H}^{(PL)}_k$ (from the payload) for equalization. If the improved estimate $\hat{H}^{(LS)}_k$ is used, a 2 dB reduction of the subsequent EVM measurement can be expected.

According to the IEEE 802.11a measurement standard [6], the coarse channel estimation $\hat{H}^{(LS)}_k$ (from the long symbol) has to be used for equalization. Therefore the default setting of the R&S VSE WLAN application is equalization from the coarse channel estimate derived from the long symbol.

Calculating error parameters

In the last block the parameters of the demodulated signal are calculated. The most important parameter is the error vector magnitude of the subcarrier "k" of the current packet:

$$\overline{EVM} = \sqrt{\frac{1}{nof\_packets} \sum_{counter=1}^{nof\_packets} EVM^2(counter)}$$

Error vector magnitude of the subcarrier k in current packet (4 - 6)

Furthermore, the packet error vector magnitude is derived by averaging the squared EVM_k versus k:

$$EVM = \sqrt{\frac{1}{52} \sum_{k=-26(k\neq 0)}^{26} EVM_k^2}$$

Error vector magnitude of the entire packet (4 - 7)

Finally, the average error vector magnitude is calculated by averaging the packet EVM of all nof_symbols detected packets:

$$EVM_k = \sqrt{\frac{1}{nof\_symbols} \sum_{l=1}^{nof\_symbols} \left| r''_{l,k} - K_{\text{mod}} \times a_{l,k} \right|^2}$$

Average error vector magnitude (4 - 8)

This parameter is equivalent to the "RMS average of all errors": $Error_{RMS}$ of the IEEE 802.11a measurement commandment (see [6]).

4.1.2 Literature on the IEEE 802.11a Standard

[1]	Speth, Classen, Meyr: "Frame synchronization of OFDM systems in frequency selective fading channels", VTC '97, pp. 1807-1811
[2]	Schmidl, Cox: "Robust Frequency and Timing Synchronization of OFDM", IEEE Trans. on Comm., Dec. 1997, pp. 1613-621
[3]	Minn, Zeng, Bhargava: "On Timing Offset Estimation for OFDM", IEEE Communication Letters, July 2000, pp. 242-244
[4]	Speth, Fechtel, Fock, Meyr: "Optimum receive antenna Design for Wireless Broad-Band Systems Using OFDM – Part I", IEEE Trans. On Comm. VOL. 47, NO 11, Nov. 1999
[5]	Speth, Fechtel, Fock, Meyr: "Optimum receive antenna Design for Wireless Broad-Band Systems Using OFDM – Part II", IEEE Trans. On Comm. VOL. 49, NO 4, April. 2001
[6]	IEEE 802.11a, Part 11: WLAN Medium Access Control (MAC) and Physical Layer (PHY) specifications

4.2 Signal Processing for Single-Carrier Measurements (IEEE 802.11b, g (DSSS))

This description gives a rough overview of the signal processing concept of the WLAN 802.11 application for IEEE 802.11b or g (DSSS) signals.

Abbreviations

ε	timing offset
Δ"f"	frequency offset
ΔΦ	phase offset
$\hat{g}_I$	estimate of the gain factor in the I-branch
$\hat{g}_Q$	estimate of the gain factor in the Q-branch
$\Delta\hat{g}_Q$	accurate estimate of the crosstalk factor of the Q-branch in the I-branch
$\hat{h}_s(v)$	estimated baseband filter of the transmit antenna
$\hat{h}_r(v)$	estimated baseband filter of the receive antenna
$\hat{o}_I$	estimate of the IQ-offset in the I-branch
$\hat{o}_Q$	estimate of the IQ-offset in the I-branch
r(v)	measurement signal
$\hat{s}(v)$	estimate of the reference signal

$\hat{s}_n(v)$	estimate of the power-normalized and undisturbed reference signal
ARG{...}	calculation of the angle of a complex value
EVM	error vector magnitude
IMAG{...}	calculation of the imaginary part of a complex value
PPDU	protocol data unit - a burst in the signal containing transmission data
PSDU	protocol service data unit- a burst in the signal containing service data
REAL{...}	calculation of the real part of a complex value

4.2.1 Block Diagram for Single-Carrier Measurements

A block diagram of the measurement application is shown below in figure 4-2. The baseband signal of an IEEE 802.11b or g (DSSS) wireless LAN system transmit antenna is sampled with a sample rate of 44 MHz.

The first task of the measurement application is to detect the position of the PPDU within the measurement signal $r_1(v)$. The detection algorithm is able to find the the beginning of short and long PPDUs and can distinguish between them. The algorithm also detects the initial state of the scrambler, which is not specified by the IEEE 802.11 standard.

If the start position of the PPDU is known, the header of the PPDU can be demodulated. The bits transmitted in the header provide information about the length of the PPDU and the modulation type used in the PSDU.

Once the start position and the PPDU length are fully known, better estimates of timing offset, timing drift, frequency offset and phase offset can be calculated using the entire data of the PPDU.

At this point of the signal processing, demodulation can be performed without decision error. After demodulation the normalized (in terms of power) and undisturbed reference signal s(v) is available.

If the frequency offset is not constant and varies with time, the frequency offset and phase offset in several partitions of the PPDU must be estimated and corrected. Additionally, timing offset, timing drift and gain factor can be estimated and corrected in several partitions of the PPDU. These corrections can be switched off individually in the demodulation settings of the application.

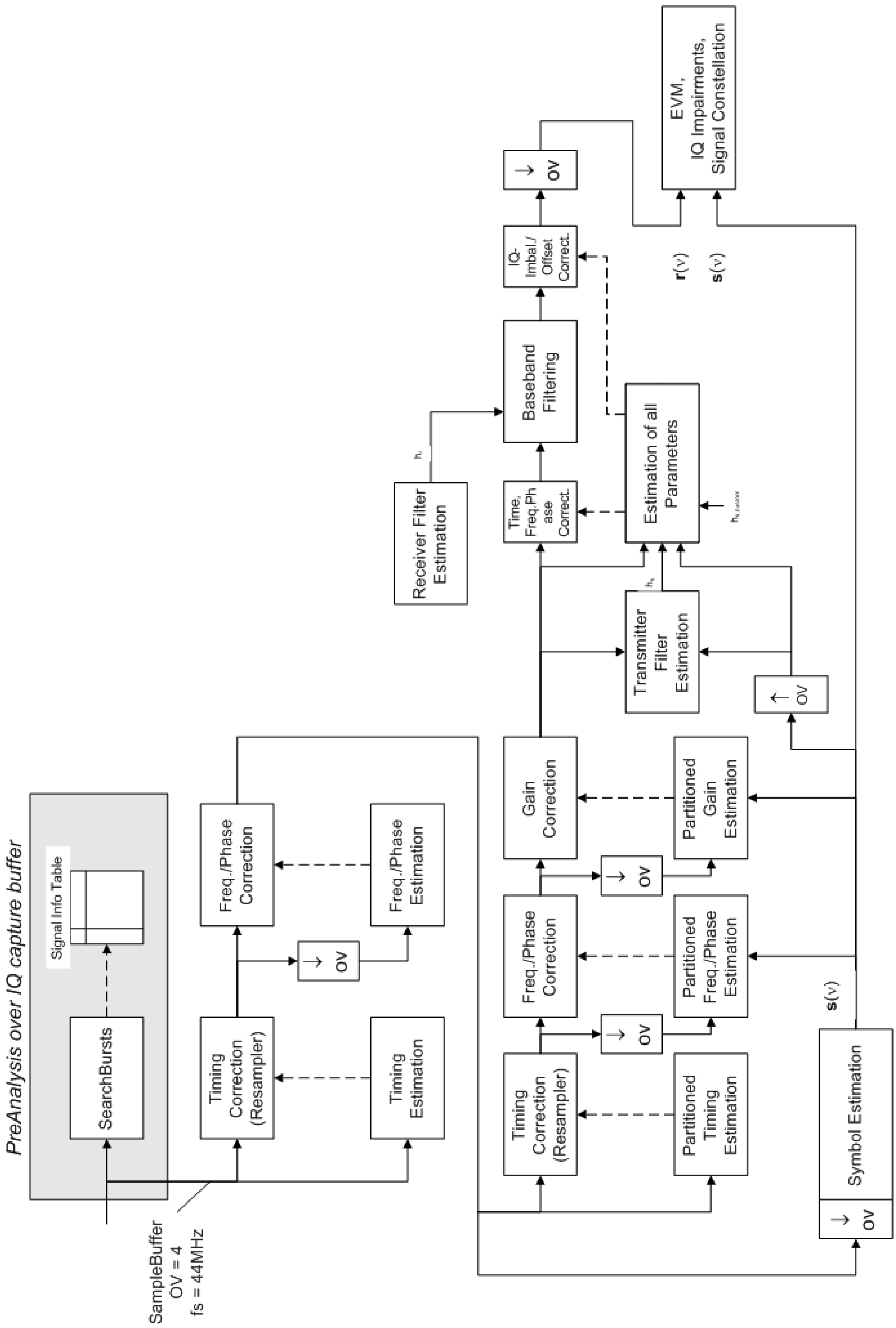


Fig. 4-2: Signal processing for IEEE 802.11b or g (DSSS) signals

Once the the normalized and undisturbed reference signal is available, the transmit antenna baseband filter (Tx filter) is estimated by minimizing the cost function of a maximum-likelihood-based estimator:

$$L_1 = \sum_{\nu=0}^{N-1} \left| r(\nu) \times e^{-j2\pi\Delta\tilde{f}\nu} \times e^{-j\Delta\tilde{\phi}} - \sum_{i=-L}^{+L} \tilde{h}_s(i) \times \hat{s}_n(\nu - i) - \tilde{o}_I - j\tilde{o}_Q \right|^2$$

transmit antenna baseband filter (Tx filter) estimation (4 - 9)

where:

$r(\nu)$: the oversampled measurement signal

$\hat{s}_n(\nu)$: the normalized oversampled power of the undisturbed reference signal

N : the observation length

L : the filter length

$\Delta\tilde{f}\nu$: the variation parameters of the frequency offset

$\Delta\tilde{\phi}$: the variation parameters of the phase offset

$\tilde{o}_I$ $\tilde{o}_Q$: the variation parameters of the IQ-offset

$\tilde{h}_s(i)$: the coefficients of the transmitter filter

4.2.2 Calculation of Signal Parameters

The frequency offset, the phase offset and the IQ-offset are estimated jointly with the coefficients of the transmit filter to increase the estimation quality.

Once the transmit filter is known, all other unknown signal parameters are estimated with a maximum-likelihood-based estimation, which minimizes the cost function:

$$L_2 = \sum_{\nu=0}^{N-1} \left| r(\nu - \tilde{\varepsilon}) \times e^{-j2\pi\tilde{f}\nu} \times e^{-j\Delta\tilde{\phi}} - \tilde{g}_I \times s_I(\nu) - j\tilde{g}_Q \times s_Q(\nu) + \Delta\tilde{g}_Q \times s_Q(\nu) - \tilde{o}_I - j\tilde{o}_Q \right|^2$$

Cost function for signal parameters (4 - 10)

where:

$\tilde{g}_I$ $\tilde{g}_Q$: the variation parameters of the gain used in the I/Q-branch

$\Delta\tilde{g}_Q$: the crosstalk factor of the Q-branch into the I-branch

$s_I(\nu)$ $s_Q(\nu)$: the filtered reference signal of the I/Q-branch

The unknown signal parameters are estimated in a joint estimation process to increase the accuracy of the estimates.

The accurate estimates of the frequency offset, the gain imbalance, the quadrature error and the normalized I/Q offset are displayed by the measurement software.

Gain imbalance, I/Q offset, quadrature error

The gain imbalance is the quotient of the estimates of the gain factor of the Q-branch, the crosstalk factor and the gain factor of the I-branch:

$$Gain - imbalance = \left| \frac{\hat{g}_Q + \Delta\hat{g}_Q}{\hat{g}_I} \right|$$

Gain imbalance (4 - 11)

The quadrature error is a measure for the crosstalk of the Q-branch into the I-branch:

$$Quadrature - Error = ARG\left\{ \hat{g}_Q + j \times \Delta\hat{g}_Q \right\}$$

Quadrature error (crosstalk) (4 - 12)

The normalized I/Q offset is defined as the magnitude of the I/Q offset normalized by the magnitude of the reference signal:

$$IQ - Offset = \frac{\sqrt{\hat{o}_I^2 + \hat{o}_Q^2}}{\sqrt{\frac{1}{2} \cdot \left[\hat{g}_I^2 + \hat{g}_Q^2 \right]^2}}$$

I/Q offset (4 - 13)

At this point of the signal processing all unknown signal parameters such as timing off-set, frequency offset, phase offset, I/Q offset and gain imbalance have been evaluated and the measurement signal can be corrected accordingly.

Error vector magnitude (EVM) - R&S VSE method

Using the corrected measurement signal r(v) and the estimated reference signal ŝ(v), the modulation quality parameters can be calculated. The mean error vector magnitude (EVM) is the quotient of the root-mean-square values of the error signal power and the reference signal power:

$$EVM = \frac{\sqrt{\sum_{v=0}^{N-1} \left| r(v) - \hat{s}(v) \right|^2}}{\sqrt{\sum_{v=0}^{N-1} \left| \hat{s}(v) \right|^2}}$$

Mean error vector magnitude (EVM) (4 - 14)

Whereas the symbol error vector magnitude is the momentary error signal magnitude normalized by the root mean square value of the reference signal power:

$$EVM(v) = \frac{|r(v) - \hat{s}(v)|}{\sqrt{\sum_{v=0}^{N-1} |\hat{s}(v)|^2}}$$

Symbol error vector magnitude (4 - 15)

Error vector magnitude (EVM) - IEEE 802.11b or g (DSSS) method

In [2] a different algorithm is proposed to calculate the error vector magnitude. In a first step the IQ-offset in the I-branch and the IQ-offset of the Q-branch are estimated separately:

$$\hat{o}_I = \frac{1}{N} \sum_{v=0}^{N-1} \mathrm{REAL}\{r(v)\}$$

I/Q offset I-branch (4 - 16)

$$\hat{o}_Q = \frac{1}{N} \sum_{v=0}^{N-1} \mathrm{IMAG}\{r(v)\}$$

I/Q offset Q-branch (4 - 17)

where r(v) is the measurement signal which has been corrected with the estimates of the timing offset, frequency offset and phase offset, but not with the estimates of the gain imbalance and I/Q offset

With these values the gain imbalance of the I-branch and the gain imbalance of the Q-branch are estimated in a non-linear estimation in a second step:

$$\hat{g}_I = \frac{1}{N} \sum_{v=0}^{N-1} \left| \mathrm{REAL}\{r(v) - \hat{o}_I\} \right|$$

Gain imbalance I-branch (4 - 18)

$$\hat{g}_Q = \frac{1}{N} \sum_{v=0}^{N-1} \left| \mathrm{IMAG}\{r(v) - \hat{o}_Q\} \right|$$

Gain imbalance Q-branch (4 - 19)

Finally, the mean error vector magnitude can be calculated with a non-data-aided calculation:

$$V_{err}(v) = \frac{\sqrt{\frac{1}{2} \sum_{v=0}^{N-1} \left[\left| \mathrm{REAL}\{r(v)\} - \hat{o}_I \right| - \hat{g}_I \right]^2 + \frac{1}{2} \sum_{v=0}^{N-1} \left[\left| \mathrm{IMAG}\{r(v)\} - \hat{o}_Q \right| - \hat{g}_Q \right]^2}}{\sqrt{\frac{1}{2} \cdot \left[\hat{g}_I^2 + \hat{g}_Q^2 \right]}}$$

Mean error vector magnitude (4 - 20)

The symbol error vector magnitude is the error signal magnitude normalized by the root mean square value of the estimate of the measurement signal power:

$$V_{\mathrm{err}}(v) = \frac{\sqrt{\frac{1}{2}\left[\left|\mathrm{REAL}\{r(v)\} - \hat{o}_I\right| - \hat{g}_I\right]^2 + \frac{1}{2}\left[\left|\mathrm{IMAG}\{r(v)\} - \hat{o}_Q\right| - \hat{g}_Q\right]^2}}{\sqrt{\frac{1}{2}\cdot\left[\hat{g}_I^2 + \hat{g}_Q^2\right]^2}}$$

Symbol error vector magnitude (4 - 21)

The advantage of this method is that no estimate of the reference signal is needed, but the I/Q offset and gain imbalance values are not estimated in a joint estimation procedure. Therefore, each estimation parameter disturbs the estimation of the other parameter and the accuracy of the estimates is lower than the accuracy of the estimations achieved by transmit antenna baseband filter (Tx filter) estimation. If the EVM value is dominated by Gaussian noise this method yields similar results as Cost function for signal parameters.

The EVM vs Symbol result display shows two traces, each using a different calculation method, so you can easily compare the results

(see "EVM vs Symbol" on page 24).

4.2.3 Literature on the IEEE 802.11b Standard

[1]	Institute of Electrical and Electronic Engineers, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications, IEEE Std 802.11-1999, Institute of Electrical and Electronic Engineers, Inc., 1999.
[2]	Institute of Electrical and Electronic Engineers, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Higher-Speed Physical Layer Extensions in the 2.4 GHz Band, IEEE Std 802.11b-1999, Institute of Electrical and Electronic Engineers, Inc., 1999.

4.3 Channels and Carriers

In an OFDM system such as WLAN, the channel is divided into carriers using FFT / IFFT. Depending on the channel bandwidth, the FFT window varies between 64 and 512 (see also chapter 4.5, "Demodulation Parameters - Logical Filters", on page 50). Some of these carriers can be used (active carriers), others are inactive (e.g. guard carriers at the edges). The channel can then be determined using the active carriers as known points; inactive carriers are interpolated.

4.4 Recognized vs. Analyzed PPDUs

A PPDU in a WLAN signal consists of the following parts:

- **Preamble**

Information required to recognize the PPDU within the signal, for example training fields

- **Signal Field**
  Information on the modulation used for transmission of the useful data
- **Payload**
  The useful data

During signal processing, PPDUs are recognized by their preamble symbols. The recognized PPDUs and the information on the modulation used for transmission of the useful data are shown in the "Signal Field" result display

(see "Signal Field" on page 31).

Not all of the recognized PPDUs are analyzed. Some are dismissed because the PPDU parameters do not match the user-defined demodulation settings, which act as a *logical filter* (see also chapter 4.5, "Demodulation Parameters - Logical Filters", on page 50). Others may be dismissed because they contain too many or too few payload symbols (as defined by the user), or due to other irregularities or inconsistency.

Dismissed PPDUs are indicated as such in the "Signal Field" result display (highlighted red, with a reason for dismissal).

PPDUs with detected inconsistencies are indicated by orange highlighting and a warning in the "Signal Field" result display, but are nevertheless analyzed and included in statistical and global evaluations.

The remaining correct PPDUs are highlighted green in the "Magnitude Capture" buffer and "Signal Field" result displays and analyzed according to the current user settings.

Example:

The evaluation range is configured to take the "Source of Payload Length" from the signal field. If the power period detected for a PPDU deviates from the PPDU length coded in the signal field, a warning is assigned to this PPDU. The decoded signal field length is used to analyze the PPDU. The decoded and measured PPDU length together with the apropriate information is shown in the "Signal Field" result display.

4.5 Demodulation Parameters - Logical Filters

The demodulation settings define which PPDUs are to be analyzed, thus they define a *logical filter*. They can either be defined using specific values or according to the first measured PPDU.

Which of the WLAN demodulation parameter values are supported depends on the selected digital standard, some are also interdependant.

Table 4-1: Supported modulation formats, PPDU formats and channel bandwidths depending on standard

Standard	Modulation formats	PPDU formats	Channel bandwidths
IEEE 802.11a, g (OFDM)	BPSK (6 Mbps & 9 Mbps) QPSK (12 Mbps & 18 Mbps) 16QAM (24 Mbps & 36 Mbps) 64QAM (48 Mbps & 54 Mbps)	Non-HT Short PPDU Long PPDU	5 MHz, 10 MHz, 20 MHz*)
IEEE 802.11ac	16QAM 64QAM 256QAM 1024QAM	VHT	20 MHz*), 40 MHz*), 80 MHz*), 160 MHz*)
IEEE 802.11b, g (DSSS)	DBPSK (1 Mbps) DQPSK (2 Mbps) CCK (5.5 Mbps & 11 Mbps) PBCC (5.5 Mbps & 11 Mbps)	Short PPDU Long PPDU	22 MHz
IEEE 802.11n	BPSK (6.5, 7.2, 13.5 & 15 Mbps) QPSK (13, 14.4, 19.5, 21.7, 27, 30, 40,5 & 45 Mbps) 16QAM (26, 28.9, 39, 43.3, 54, 60, 81 & 90 Mbps) 64QAM (52, 57.8, 58.5, 65, 72.2, 108, 121.5, 135, 120, 135 & 150 Mbps)	HT-MF (Mixed format) HT-GF (Greenfield format)	20 MHz*), 40 MHz*)
*): requires R&S VSE bandwidth extension option, see chapter A.3, "Sample Rate and Maximum Usable I/Q Bandwidth for RF Input", on page 217			

4.6 Receiving Data Input and Providing Data Output

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

4.6.1 Input from Noise Sources

The instrument in use may provide 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 via the software, you can activate or deactive the connected device as required.

External noise sources are useful when you are measuring power levels that fall below the noise floor of the instrument in use 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 instrument in use and measure the total noise power. From this value you can determine the noise power of the instrument in use. 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

4.6.2 Receiving and Providing Trigger Signals

Using one of the TRIGGER INPUT / OUTPUT connectors of the instrument in use, the R&S VSE can use a signal from an external device as a trigger to capture data. Alternatively, the internal trigger signal used by the instrument in use 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 VSE "Getting Started" manual.

External trigger as input

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

Trigger output

The instrument in use can provide output to another device either to pass on the internal trigger signal, or to indicate that the instrument in use itself is ready to trigger.

The trigger signal can be output by the instrument in use automatically, or manually by the user. If it is provided automatically, a high signal is output when the instrument in use has triggered due to a measurement start ("Device Triggered"), or when the instrument in use 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 VSE User Manual.

4.7 Preparing the R&S VSE for the Expected Input Signal - Frontend Parameters

On the R&S VSE, 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 VSE'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 VSE 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 VSE 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

When measuring in a 75 Ω system, connect an external matching pad to the RF input and adapt the reference impedance for power results. The insertion loss is compensated for numerically.

4.8 Triggered Measurements

In a basic measurement with default settings, the measurement is started immediately when you select the ▶"Capture" icon. However, sometimes you want the measurement to start only when a specific condition is fulfilled on the instrument in use, for example a signal level is exceeded, or in certain time intervals. For these cases you can define a trigger for the measurement.

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

4.8.1 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 VSE captures data continuously in the time domain, even before the trigger occurs.

See "Trigger Offset" on page 75.

4.8.2 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.

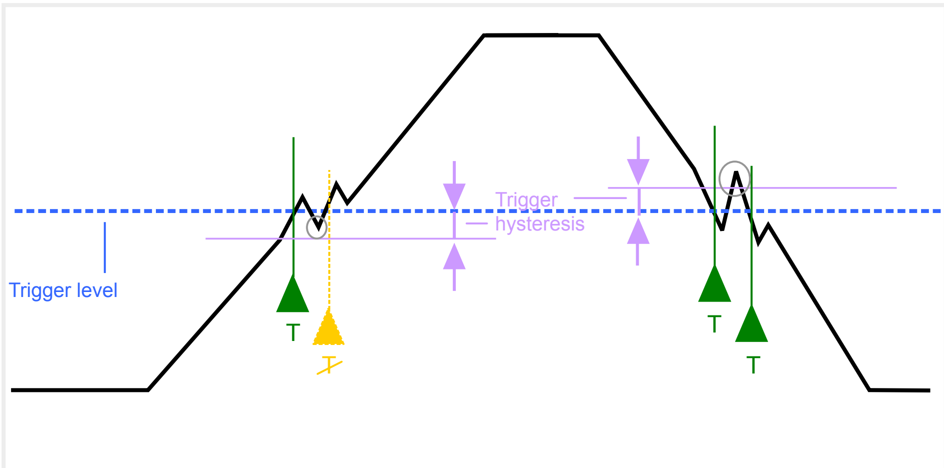


Fig. 4-3: Effects of the trigger hysteresis

See "Hysteresis" on page 76

4.8.3 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.

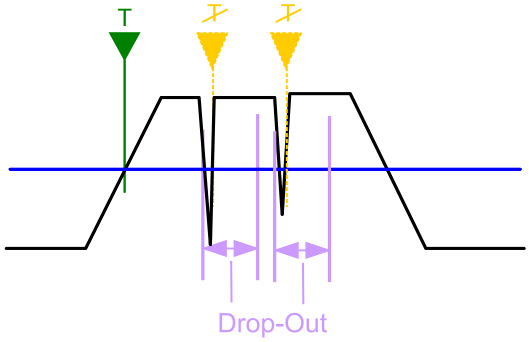


Fig. 4-4: Effect of the trigger drop-out time

See "Drop-Out Time" on page 75.

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!

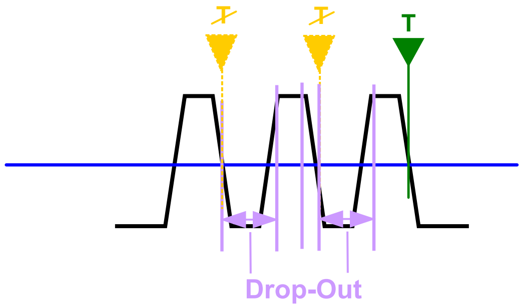


Fig. 4-5: Trigger drop-out time for falling edge trigger

4.8.4 Trigger Holdoff

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

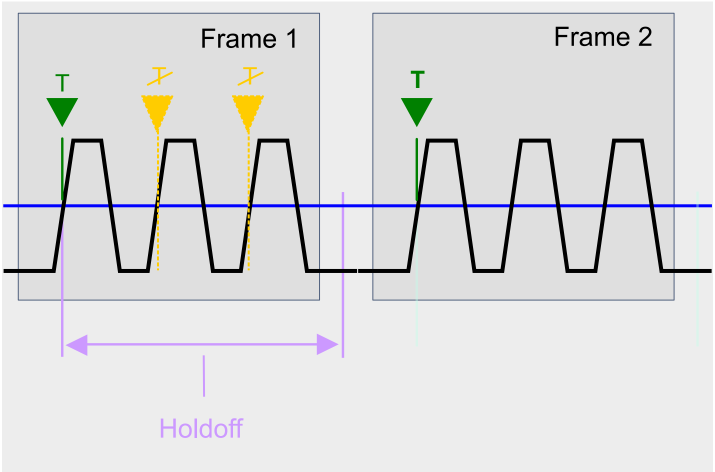


Fig. 4-6: Effect of the trigger holdoff

See "Trigger Holdoff" on page 76.

5 Configuring a WLAN I/Q Measurement

WLAN 802.11 measurements require a special application on the R&S VSE.

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" icon from the main toolbar or the "Meas Setup" > "Overview" menu item.

Alternatively, you can access the individual dialog boxes from the corresponding menu items, 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". For an overview of all available menu items and toolbar icons see chapter A, "Annex: Reference", on page 210.

General R&S VSE functions

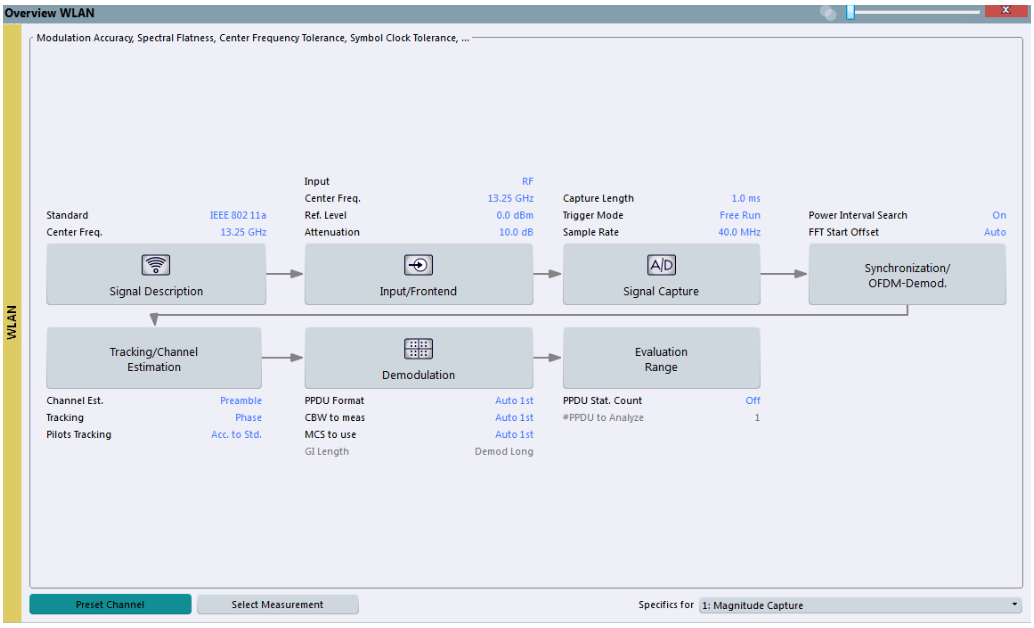
The application-independent functions for general tasks on the R&S VSE are also available for WLAN 802.11 measurements and are described in the R&S VSE Base Software User Manual. In particular, this comprises the following functionality:

- Controlling Instruments and Capturing I/Q Data
- Data Management
- General Software Preferences and Information

5.1 Configuration Overview

Access: "Meas Setup" > "Overview"

Throughout the measurement 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".

For the WLAN I/Q measurement, the "Overview" provides quick access to the following configuration dialog boxes (listed in the recommended order of processing):

1. "Signal Description"
   See chapter 5.2, "Signal Description", on page 59
2. "Input/ Frontend"
   See and chapter 5.3, "Input, Output, and Frontend Settings", on page 60
3. "Signal Capture"
   See chapter 5.4, "Signal Capture (Data Acquisition)", on page 71
4. "Synchronization / OFDM demodulation"
   See chapter 5.5, "Synchronization and OFDM Demodulation", on page 77
5. "Tracking / Channel Estimation"
   See chapter 5.6, "Tracking and Channel Estimation", on page 78
6. "Demodulation"
   See chapter 5.7, "Demodulation", on page 80
7. "Evaluation Range"
   See chapter 5.8, "Evaluation Range", on page 94

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.

Remote command:
`SYSTem:PRESet:CHANnel[:EXECute]` on page 111

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.

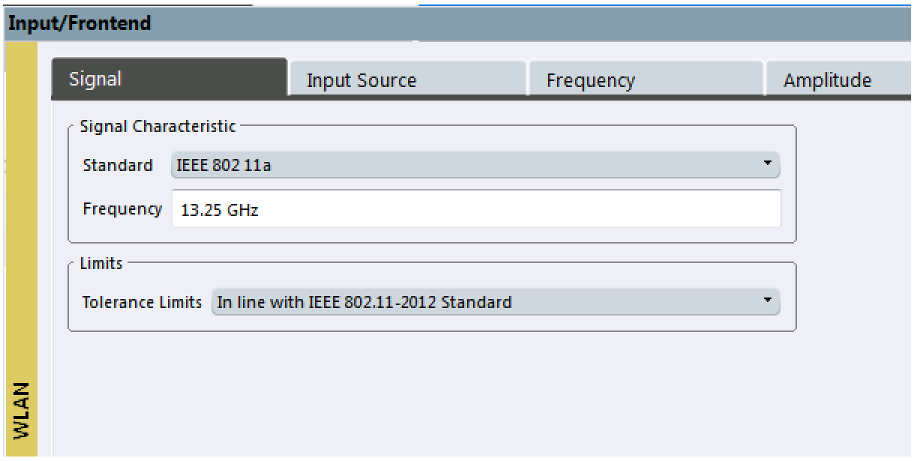
Select an active window from the "Specifics for" selection list that is displayed in the "Overview" and in all window-specific configuration dialog boxes.

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

5.2 Signal Description

Access: "Overview" > "Signal Description"

The signal description provides information on the expected input signal.



Standard
Defines the WLAN standard (depending on which WLAN options are installed). The measurements are performed according to the specified standard with the correct limit values and limit lines.

Many other WLAN measurement settings depend on the selected standard (see chapter 4.5, "Demodulation Parameters - Logical Filters", on page 50).

Remote command:
`CONFigure:STANdard` on page 112

Frequency
Specifies the center frequency of the signal to be measured.

Remote command:
[SENSe:]FREQuency:CENTer on page 117

Tolerance Limit
Defines the tolerance limit to be used for the measurement. The required tolerance limit depends on the used standard:

"Prior IEEE 802.11-2012 Standard"
Tolerance limits are based on the IEEE 802.11 specification **prior to 2012**.
Default for OFDM standards (except 802.11ac).

"In line with IEEE 802.11-2012 Standard"
Tolerance limits are based on the IEEE 802.11 specification from **2012.**
Required for DSSS standards. Also possible for OFDM standards (except 802.11ac).

"In line with IEEE 802.11ac standard"
Tolerance limits are based on the **IEEE 802.11ac** specification.
Required by IEEE 802.11ac standard.

Remote command:
CALCulate:LIMit:TOLerance on page 112

5.3 Input, Output, and Frontend Settings

Access: "Overview" > "Input/Frontend"

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

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

5.3.1 Input Source Settings

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

or: "Input & Output" > "Input Source"

The R&S VSE can control the input sources of the connected instruments.

5.3.1.1 Radio Frequency Input

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

or: "Input & Output" > "Input Source" > "IQ File"

The default input source for the instrument in use is "Radio Frequency". Depending on the instrument in use, different input parameters are available.

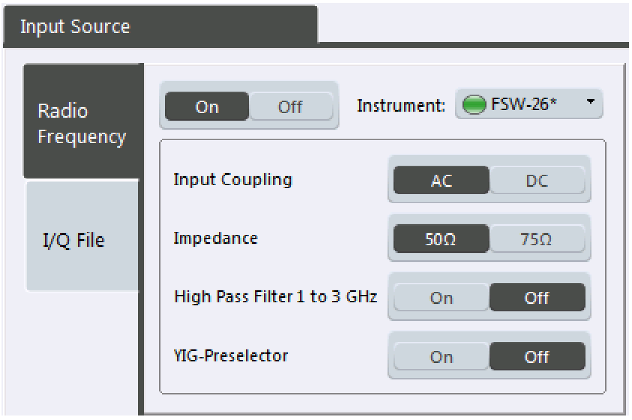


Fig. 5-1: RF input source settings for an R&S FSW

Input Type

Selects an instrument or a file as the type of input provided to the channel.

Remote command:

`INSTrument:BLOCk:CHANnel[:SETTings]:SOURce` on page 116

`INPut:SELect` on page 115

Instrument

Specifies a configured instrument to be used for input.

Input Coupling

The RF input of the instrument in use 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 114

Impedance
For some measurements, the reference impedance for the measured levels of the instrument in use can be set to 50 Ω or 75 Ω.

75 Ω should be selected if the 50 Ω input impedance is transformed to a higher impedance using a 75 Ω adapter of the RAZ type (= 25 Ω in series to the input impedance of the instrument). The correction value in this case is 1.76 dB = 10 log (75Ω/50Ω).

Remote command:
INPut:IMPedance on page 115

High-Pass Filter 1...3 GHz
Activates an additional internal high-pass filter for RF input signals from 1 GHz to 3 GHz. This filter is used to remove the harmonics of the analyzer in order to measure the harmonics for a DUT, for example.

This function may require an additional hardware option on the instrument in use.

Remote command:
INPut:FILTer:HPASs[:STATe] on page 114

YIG-Preselector
Activates or deactivates the YIG-preselector, if available on the instrument in use.

An internal YIG-preselector at the input of the instrument in use ensures that image frequencies are rejected. However, the YIG filter may limit the bandwidth of the I/Q data and will add some magnitude and phase distortions. You can check the impact in the Spectrum Flatness and Group Delay result displays.

Remote command:
INPut:FILTer:YIG[:STATe] on page 114

Preselector State
Turns the preselector on and off.

When you turn the preselector on, you can configure the characteristics of the preselector and add the preamplifier into the signal path.

When you turn the preselector off, the signal bypasses the preselector and the preamplifier, and is fed into the input mixer directly.

Remote command:
INPut:PRESelection[:STATe] on page 115

Preselector Mode
Selects the preselection filters to be applied to the measurement.

"Auto"	Performs a measurement by automatically applying all available bandpass filters. Available with the optional preamplifier.

"Auto Wide" Performs a measurement by automatically applying the wideband filters consecutively:
- Lowpass 40 MHz
- Bandpass 30 MHz to 2250 MHz
- Bandpass 2 GHz to 8 GHz
- Bandpass 8 GHz to 26.5 GHz

Available with the optional preselector.

"Auto Narrow" Performs a measurement by automatically applying the most suitable narrowband preselection filters, depending on the bandwidth you have selected.
For measurement frequencies up to 30 MHz, the instrument in use uses combinations of lowpass and highpass filters. For higher frequencies, the instrument in use uses bandpass filters.
Available with the optional preselector.

"Manual" Performs a measurement with the filter settings you have defined manually.

Remote command:
`INPut:PRESelection:SET` on page 115

10 dB Minimum Attenuation
Turns the availabilty of attenuation levels of less than 10 dB on and off.

When you turn the feature on, the attenuation level is always at least 10 dB to protect the input mixer and avoid accidental setting of 0 dB, especially if you measure DUTs with high RFI voltage.

When you turn it off, you can also select attenuation levels of less than 10 dB.

The setting applies to a manual selection of the attenuation as well as the automatic selection of the attenuation.

Remote command:
`INPut:ATTenuation:PROTection[:STATe]` on page 113

Input Selection
Selects the RF input you would like to use for a measurement.

Note that you can not use both RF inputs simultaneously.

Remote command:
Global: `INPut:TYPE` on page 116

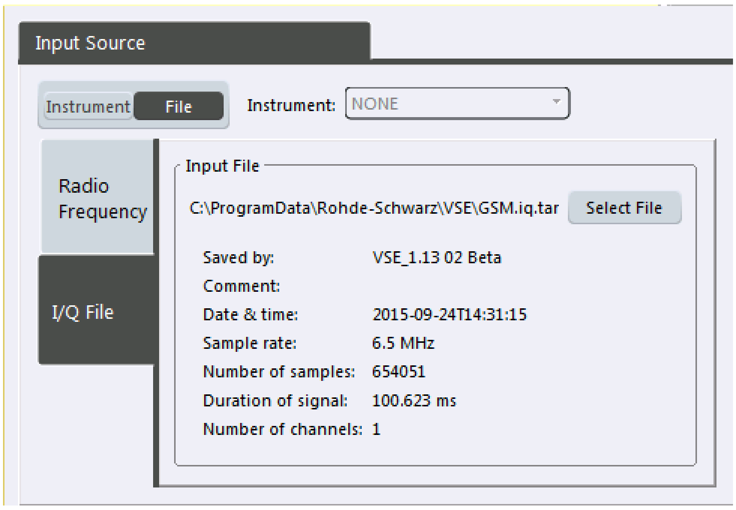
5.3.1.2 I/Q File Input

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

or: "Input & Output" > "Input Source" > "IQ File"

Alternatively to "live" data input from a connected instrument, measurement data to be analyzed by the R&S VSE software can also be provided "offline" by a stored data file. This allows you to perform a measurement on any instrument, store the results to a file, and analyze the stored data partially or as a whole at any time using the R&S VSE software.

The "Input Source" settings defined in the "Input" dialog box are identical to those configured for a specific channel in the "Measurement Group Setup" window.



Input Type

Selects an instrument or a file as the type of input provided to the channel.

Remote command:
`INSTrument:BLOCk:CHANnel[:SETTings]:SOURce` on page 116
`INPut:SELect` on page 115

Input File

Specifies the I/Q data file to be used for input.

Select "Select File" to open the "Load I/Q File" dialog box.

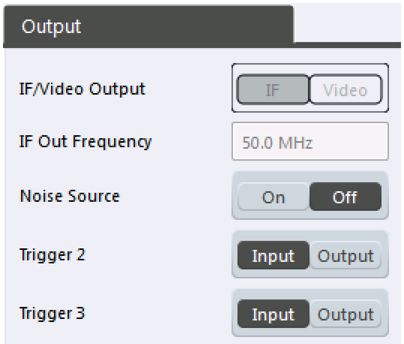
5.3.2 Output Settings

or: "Input & Output" > "Output"

The R&S VSE can control the output provided by the instrument in use to special connectors for other devices.

Which output settings and connectors are available depends on the instrument in use.

For details on the output connectors refer to the instrument's Getting Started manual.



Noise Source

Switches the supply voltage for an external noise source on the instrument in use on or off, if available.

External noise sources are useful when you are measuring power levels that fall below the noise floor of the instrument in use itself, for example when measuring the noise level of a DUT.

For details see chapter 4.6.1, "Input from Noise Sources", on page 51

Remote command:

`DIAGnostic:SERVice:NSOurce` on page 117

Trigger 2/3

Defines the usage of variable trigger input/output connectors on the instrument in use. Which output settings are available depends on the type of instrument in use. For details see the instrument's documentation.

"Input"	The signal at the connector is used as an external trigger source by the instrument in use. Trigger input parameters are available in the "Trigger" dialog box.
"Output"	The instrument in use 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 132

`OUTPut:TRIGger<port>:DIRection` on page 131

Output Type ← Trigger 2/3

Type of signal to be sent to the output

"Device Triggered"	(Default) Sends a trigger when the instrument in use triggers.

"Trigger Armed" Sends a (high level) trigger when the instrument in use 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) of the instrument in use, if available.

"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 132

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 132

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 133

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.

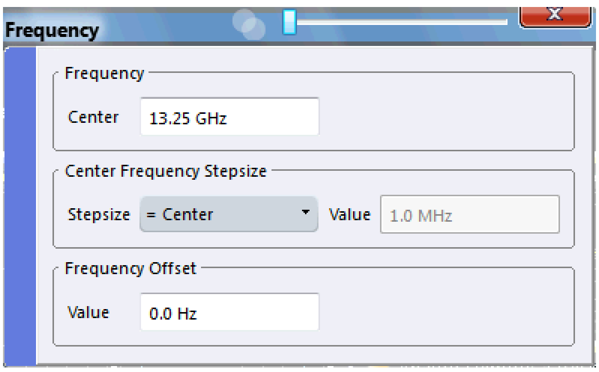
Which pulse level will be sent is indicated by a graphic on the button.

Remote command:
`OUTPut:TRIGger<port>:PULSe:IMMediate` on page 132

5.3.3 Frequency Settings

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

or: "Input & Output" > "Frequency"



Center frequency

Defines the center frequency of the signal in Hertz.

$0\ Hz \le f_{center} \le f_{max}$

Note: For file input you can shift the center frequency of the current measurement compared to the stored measurement data. The maximum shift depends on the channel's current analysis bandwidth.

$$CFshift_{max} = CF_{file} \pm \frac{ABW_{file} - ABW_{channel}}{2}$$

If the file does not provide the center frequency, it is assumed to be 0 Hz.

Remote command:
[SENSe:]FREQuency:CENTer on page 117

Center Frequency Stepsize

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

When you use the mouse wheel, 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 118

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.

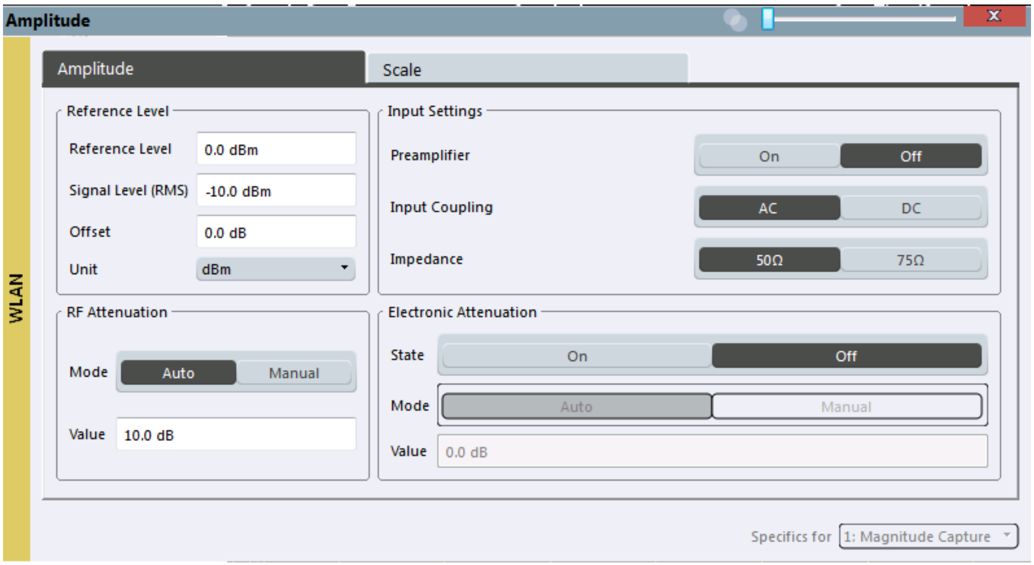
The allowed values range from -100 GHz to 100 GHz. The default setting is 0 Hz.

Remote command:
[SENSe:]FREQuency:OFFSet on page 118

5.3.4 Amplitude Settings

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

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



Reference Level Settings

The reference level defines the expected maximum signal level. Signal levels above this value may not be measured correctly, which is indicated by the "IF OVLD" status display.

Reference Level ← Reference Level Settings

Defines the expected maximum signal level. Signal levels above this value may not be measured correctly, which is indicated by the "IF OVLD" status display.

Remote command:

`DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:RLEVel` on page 120

Signal Level (RMS) ← Reference Level Settings
Specifies the mean power level of the source signal as supplied to the instrument's RF input. This value is overwritten if "Auto Level" mode is turned on.

Remote command:
`CONFigure:POWer:EXPected:RF` on page 120

Shifting the Display (Offset) ← Reference Level Settings
Defines an arithmetic level offset. This offset is added to the measured level irrespective of the selected unit. 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 VSE so the application shows correct power results. All displayed power level results will be shifted by this value.

Note, however, that the Reference Level value ignores the "Reference Level Offset". It is important to know the actual power level the R&S VSE must handle.

To determine the required offset, consider the external attenuation or gain applied to the input signal. A positive value indicates that an attenuation took place (R&S VSE increases the displayed power values) , a negative value indicates an external gain (R&S VSE decreases the displayed power values).

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

Remote command:
`DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:RLEVel:OFFSet` on page 121

Unit ← Reference Level Settings
The instrument in use measures the signal voltage at the RF input.

The following units are available and directly convertible:
- dBm
- dBmV
- dBμV

Remote command:
`CALCulate<n>:UNIT:POWer` on page 119

RF Attenuation
Defines the attenuation applied to the RF input.

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.

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 121
`INPut:ATTenuation:AUTO` on page 121

Using Electronic Attenuation

If the (optional) Electronic Attenuation hardware is installed on the instrument in use, 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: Note that restrictions may apply concerning which frequencies electronic attenuation is available for, depending on which instrument is connected to the R&S VSE software. Check your instrument documentation for details.
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.

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 122
`INPut:EATT:AUTO` on page 122
`INPut:EATT` on page 122

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 5.3.1.1, "Radio Frequency Input", on page 61.

Preamplifier ← Input Settings

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

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

Depending on the connected instrument, different settings are available. See the instrument's documentation for details.

Remote command:
`INPut:GAIN:STATe` on page 123
`INPut:GAIN[:VALue]` on page 123

5.4 Signal Capture (Data Acquisition)

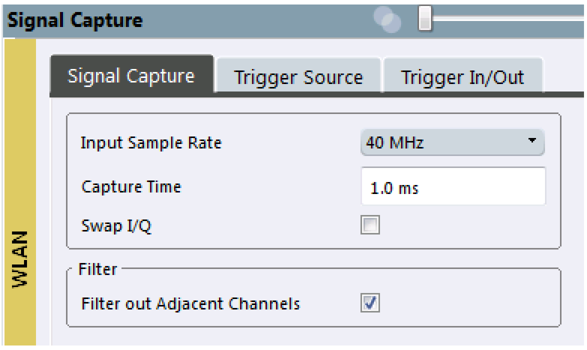
Access: "Overview" > "Signal Capture"

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

5.4.1 General Capture Settings

Access: "Overview" > "Signal Capture" > "Signal Capture"

The general capture settings define how much and which data is to be captured during the WLAN I/Q measurement.



Input Sample Rate

This is the sample rate the R&S VSE WLAN application expects the I/Q input data to have. If necessary, the R&S VSE has to resample the data.

During data processing in the R&S VSE, the sample rate usually changes (decreases). The RF input is captured by the R&S VSE using a high sample rate, and is resampled before it is processed by the R&S VSE WLAN application.

Remote command:
`TRACe:IQ:SRATe` on page 125

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 124

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 VSE 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 124

Suppressing (Filter out) Adjacent Channels (IEEE 802.11a, ac, g (OFDM), n)
If activated (default), only the useful signal is analyzed, all signal data in adjacent channels is removed by the filter.

This setting improves the signal to noise ratio and thus the EVM results for signals with strong or a large number of adjacent channels. However, for some measurements information on the effects of adjacent channels on the measured signal may be of interest.

Remote command:
`[SENSe:]BANDwidth[:RESolution]:FILTer[:STATe]` on page 124

Transmit Filter (IEEE 802.11b, g (DSSS))
Indicates the used transmit filter setting (read-only)

See also chapter 4.2.1, "Block Diagram for Single-Carrier Measurements", on page 44

"Auto" default filter

Receive Filter (IEEE 802.11b, g (DSSS))
Indicates the used receive filter setting (read-only)

See also chapter 4.2.1, "Block Diagram for Single-Carrier Measurements", on page 44

"Auto" default filter

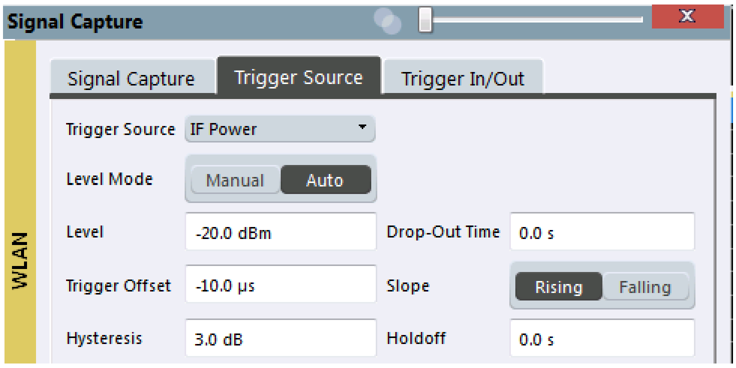
Equalizer Filter Length (IEEE 802.11b, g (DSSS))
Specifies the length of the equalizer filter in chips

Remote command:
`[SENSe<n>:]DEMod:FILTer:EFLength` on page 124

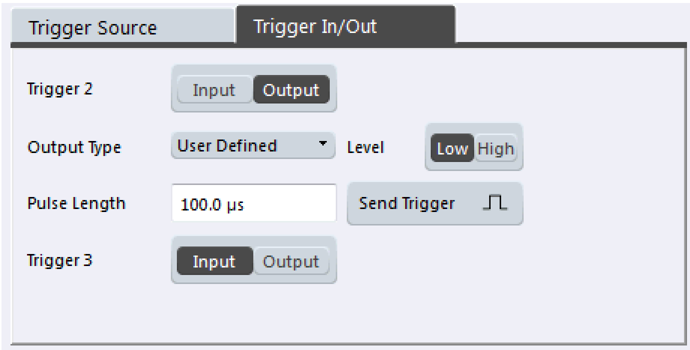
5.4.2 Trigger Settings

Access: "Overview" > "Signal Capture" > "Trigger Source"

Trigger settings determine when the R&S VSE starts to capture the input signal.



External triggers from one of the TRIGGER INPUT/OUTPUT connectors on the instrument in use are configured in a separate tab of the dialog box.



For more information on trigger settings see chapter 4.8, "Triggered Measurements", on page 53.

Trigger Source Settings
The Trigger Source settings define when data is captured.

Trigger Source ← Trigger Source Settings
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 130

Free Run ← Trigger Source ← Trigger Source Settings
No trigger source is considered. Data acquisition is started manually or automatically and continues until stopped explicitly.

Remote command:
`TRIG:SOUR IMM`, see `TRIGger[:SEQuence]:SOURce` on page 130

External Trigger<X> ← Trigger Source ← Trigger Source Settings
Data acquisition starts when the signal fed into the specified input connector or input channel of the instrument in use meets or exceeds the specified trigger level.

(See "Trigger Level" on page 75).

Note: Which input and output connectors are available depends on the connected instrument. For details see the "Instrument Tour" chapter in the instrument's Getting Started manual.

Remote command:
`TRIG:SOUR EXT`, `TRIG:SOUR EXT2`, `TRIG:SOUR EXT3`, `TRIG:SOUR EXT4`
See `TRIGger[:SEQuence]:SOURce` on page 130

RF Power ← Trigger Source ← Trigger Source Settings
Defines triggering of the measurement via signals which are outside the displayed measurement range.

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

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 130

I/Q Power ← Trigger Source ← Trigger Source Settings
Triggers the measurement when the magnitude of the sampled I/Q data exceeds the trigger threshold.

The trigger bandwidth corresponds to the "Usable I/Q Bandwidth", which depends on the sample rate of the captured I/Q data (see "Input Sample Rate" on page 71 and chapter A.3, "Sample Rate and Maximum Usable I/Q Bandwidth for RF Input", on page 217).

Remote command:
`TRIG:SOUR IQP`, see `TRIGger[:SEQuence]:SOURce` on page 130

Time ← Trigger Source ← Trigger Source Settings
Triggers in a specified repetition interval.

Remote command:
`TRIG:SOUR TIME`, see `TRIGger[:SEQuence]:SOURce` on page 130

Magnitude (offline) ← Trigger Source ← Trigger Source Settings
For (offline) input from a file, rather than an instrument. Triggers on a specified signal level.

Remote command:
`TRIG:SOUR MAGN`, see `TRIGger[:SEQuence]:SOURce` on page 130

Trigger Level Mode ← Trigger Source Settings
By default, the optimum trigger level for power triggers is automatically measured and determined at the start of each sweep (for Modulation Accuracy, Flatness, Tolerance... measurements).

In order to define the trigger level manually, switch to "Manual" mode.

Remote command:
`TRIG:SEQ:LEV:POW:AUTO ON`, see `TRIGger:SEQuence:LEVel:POWer:AUTO` on page 128

Trigger Level ← Trigger Source Settings
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 127
`TRIGger[:SEQuence]:LEVel:IQPower` on page 128
`TRIGger[:SEQuence]:LEVel[:EXTernal<port>]` on page 127
`TRIGger[:SEQuence]:LEVel:RFPower` on page 129
`TRIGger[:SEQuence]:LEVel:MAPower` on page 128

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

For more information on the drop-out time see chapter 4.8.3, "Trigger Drop-Out Time", on page 55.

Remote command:
`TRIGger[:SEQuence]:DTIMe` on page 126

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

For more information see chapter 4.8.1, "Trigger Offset", on page 54.

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

(If supported by the instrument in use.)

Remote command:
`TRIGger[:SEQuence]:HOLDoff[:TIME]` on page 126

Hysteresis ← Trigger Source Settings
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" or "Magnitude (offline)" trigger sources. The range of the value depends on the instrument in use.

For more information see chapter 4.8.2, "Trigger Hysteresis", on page 54.

Remote command:
`TRIGger[:SEQuence]:IFPower:HYSTeresis` on page 127
`TRIGger[:SEQuence]:MAPower:HYSTeresis` on page 129

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

For more information see chapter 4.8.4, "Trigger Holdoff", on page 55.

Remote command:
`TRIGger[:SEQuence]:IFPower:HOLDoff` on page 126
`TRIGger[:SEQuence]:MAPower:HOLDoff` on page 129

Slope ← Trigger Source Settings
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 130

Trigger 2/3
Defines the usage of variable trigger input/output connectors on the instrument in use. Which output settings are available depends on the type of instrument in use. For details see the instrument's documentation.

"Input" The signal at the connector is used as an external trigger source by the instrument in use. Trigger input parameters are available in the "Trigger" dialog box.

"Output" The instrument in use 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 132
`OUTPut:TRIGger<port>:DIRection` on page 131

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

"Device Triggered" (Default) Sends a trigger when the instrument in use triggers.

"Trigger Armed" Sends a (high level) trigger when the instrument in use 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) of the instrument in use, if available.

"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 132

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 132

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 133

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.

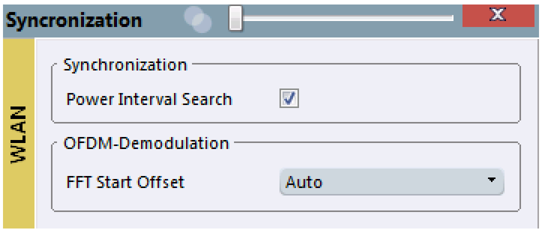
Which pulse level will be sent is indicated by a graphic on the button.

Remote command:
`OUTPut:TRIGger<port>:PULSe:IMMediate` on page 132

5.5 Synchronization and OFDM Demodulation

Access: "Overview" > "Synchronization/OFDM-Demod."

Synchronization settings have an effect on which parts of the input signal are processed during the WLAN measurement.



Power Interval Search

If enabled, the R&S VSE WLAN application initially performs a coarse burst search on the input signal in which increases in the power vs time trace are detected. Further time-consuming processing is then only performed where bursts are assumed. This improves the measurement speed for signals with low duty cycle rates.

However, for signals in which the PPDU power levels differ significantly, this option should be disabled as otherwise some PPDUs may not be detected.

Remote command:
`[SENSe:]DEMod:TXARea` on page 133

FFT Start Offset

This command specifies the start offset of the FFT for OFDM demodulation (not for the FFT Spectrum display).

This function is **not** available for **IEEE 802.11b or g (DSSS)**.

"AUTO"
: The FFT start offset is automatically chosen to minimize the intersymbol interference.

"Guard Interval Cntr"
: Guard Interval Center: The FFT start offset is placed to the center of the guard interval.

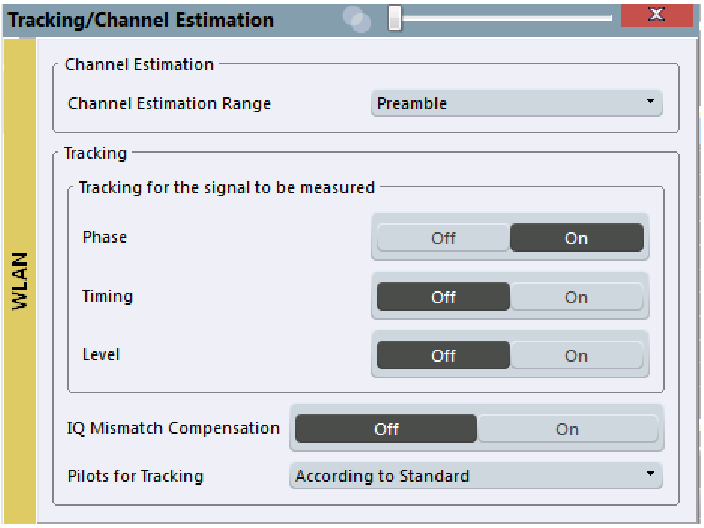
"Peak"
: The peak of the fine timing metric is used to determine the FFT start offset.

Remote command:
`[SENSe:]DEMod:FFT:OFFSet` on page 133

5.6 Tracking and Channel Estimation

Access: "Overview" > "Tracking/Channel Estimation"

The channel estimation settings determine which channels are assumed in the input signal. Tracking settings allow for compensation of some transmission effects in the signal (see "Tracking the phase drift, timing jitter and gain" on page 40).



Channel Estimation Range

Specifies the signal range used to estimate the channels.

This function is **not** available for **IEEE 802.11b or g (DSSS)**.

"Preamble" The channel estimation is performed in the preamble as required in the standard.

"Payload" The channel estimation is performed in the preamble and the payload. The EVM results can be calculated more accurately.

Remote command:
[SENSe:]DEMod:CESTimation on page 134

Phase Tracking

Activates or deactivates the compensation for phase drifts. If activated, the measurement results are compensated for phase drifts on a per-symbol basis.

Remote command:
SENSe:TRACking:PHASe on page 135

Timing Error Tracking

Activates or deactivates the compensation for timing drift. If activated, the measurement results are compensated for timing error on a per-symbol basis.

Remote command:
SENSe:TRACking:TIME on page 136

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 135

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. Since the quadrature offset is compensated carrier-wise, I/Q skew impairments are compensated as well.

This setting is **not available for standards IEEE 802.11b and g (DSSS)**.

For details see chapter 3.1.5, "I/Q Mismatch", on page 16.

Note: For EVM measurements according to the IEEE 802.11-2012, IEEE 802.11ac-2013 WLAN standard, I/Q mismatch compensation must be deactivated.

Remote command:
`SENSe:TRACking:IQMComp` on page 134

Pilots for Tracking
In case tracking is used, the used pilot sequence has an effect on the measurement results.

This function is **not** available for **IEEE 802.11b or g (DSSS)**.

"According to standard"
The pilot sequence is determined according to the corresponding WLAN standard. In case the pilot generation algorithm of the device under test (DUT) has a problem, the non-standard-conform pilot sequence might affect the measurement results, or the WLAN application might not synchronize at all onto the signal generated by the DUT.

"Detected"
The pilot sequence detected in the WLAN signal to be analyzed is used by the WLAN application. In case the pilot generation algorithm of the device under test (DUT) has a problem, the non-standard-conform pilot sequence will not affect the measurement results. In case the pilot sequence generated by the DUT is correct, it is recommended that you use the "According to Standard" setting because it generates more accurate measurement results.

Remote command:
`SENSe:TRACking:PILots` on page 135

5.7 Demodulation

Access: "Overview" > "Demodulation"

The demodulation settings define which PPDUs are to be analyzed, thus they define a *logical filter*.

The available demodulation settings vary depending on the selected digital standard in the "Signal Description" (see "Standard" on page 59).

5.7.1 Demodulation - IEEE 802.11a, g (OFDM)

Access: "Overview" > "Demodulation"

The following settings are available for demodulation of IEEE 802.11a, g (OFDM) signals.

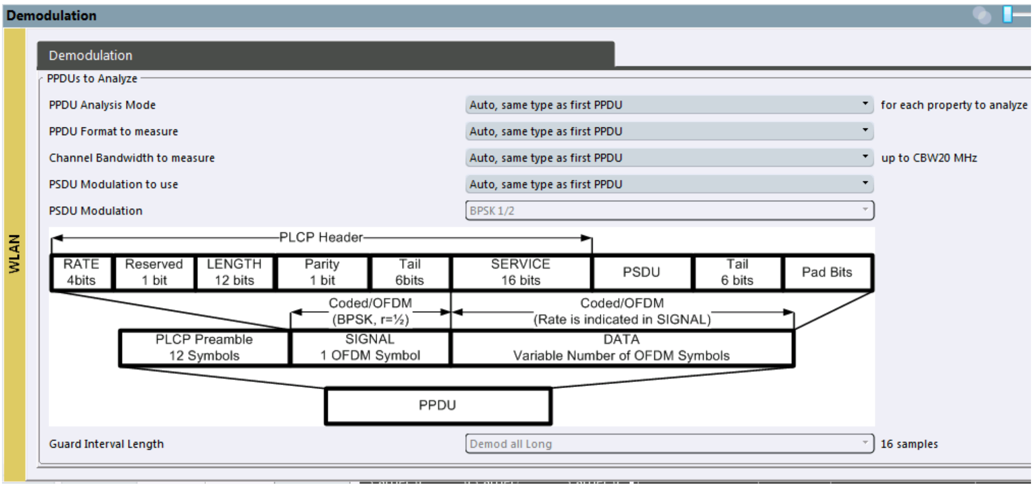


Fig. 5-2: Demodulation settings for IEEE 802.11a, g (OFDM) standard

PPDU Analysis Mode

Defines whether all or only specific PPDUs are to be analyzed.

"Auto, same type as first PPDU"

The signal symbol field, i.e. the PLCP header field, of the first recognized PPDU is analyzed to determine the details of the PPDU. All PPDUs identical to the first recognized PPDU are analyzed.
All subsequent settings are set to "Auto" mode.

"Auto, individually for each PPDU"
All PPDUs are analyzed

"User-defined"
User-defined settings define which PPDUs are analyzed. This setting is automatically selected when any of the subsequent settings are changed to a value other than "Auto".

Remote command:
[SENSe:]DEMod:FORMat[:BCONtent]:AUTO on page 145

PPDU Format to measure
Defines which PPDU formats are to be included in the analysis. Depending on which standards the communicating devices are using, different formats of PPDUs are available. Thus you can restrict analysis to the supported formats.

Note: The PPDU format determines the available channel bandwidths.

For details on supported PPDU formats and channel bandwidths depending on the standard see table 4-1.

Note: The terms in brackets in the following description indicate how the setting is referred to in the Signal Field result display ("Format" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU(A1st)"
The format of the first valid PPDU is detected and subsequent PPDUs are analyzed only if they have the same format.

"Auto, individually for each PPDU(AI)"
All PPDUs are analyzed regardless of their format

"Meas only ...(M ...)"
Only PPDUs with the specified format are analyzed

"Demod all as ...(D ...)"
All PPDUs are assumed to have the specified PPDU format

Remote command:
[SENSe:]DEMod:FORMat:BANalyze:BTYPe:AUTO:TYPE on page 143
[SENSe:]DEMod:FORMat:BANalyze on page 142

Channel Bandwidth to measure (CBW)
Defines the channel bandwidth of the PPDUs taking part in the analysis. Depending on which standards the communicating devices are using, different PPDU formats and channel bandwidths are supported.

For details on supported PPDU formats and channel bandwidths depending on the standard see table 4-1.

Note: The terms in brackets in the following description indicate how the setting is referred to in the Signal Field result display ("Format" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU""(A1st)"
The channel bandwidth of the first valid PPDU is detected and subsequent PPDUs are analyzed only if they have the same channel bandwidth.

"Auto, individually for each PPDU""(AI)"
All PPDUs are analyzed regardless of their channel bandwidth

"Meas only ... signal""(M ...)"
Only PPDUs with the specified channel bandwidth are analyzed

"Demod all as ... signal""(D ...)"
All PPDUs are assumed to have the specified channel bandwidth

Remote command:
`[SENSe:]BANDwidth:CHANnel:AUTO:TYPE` on page 140

PSDU Modulation to use

Specifies which PSDUs are to be analyzed depending on their modulation. Only PSDUs using the selected modulation are considered in measurement analysis.

For details on supported modulation depending on the standard see table 4-1.

"Auto, same type as first PPDU""(A1st)"
All PSDUs using the same modulation as the first recognized PPDU are analyzed.

"Auto, individually for each PPDU""(AI)"
All PSDUs are analyzed

"Meas only the specified PSDU Modulation""(M ...)"
Only PSDUs with the modulation specified by the PSDU Modulation setting are analyzed

"Demod all with specified PSDU modulation""(D ...)"
The PSDU modulation of the PSDU Modulation setting is used for all PSDUs.

Remote command:
`[SENSe:]DEMod:FORMat:BANalyze:BTYPe:AUTO:TYPE` on page 143
`[SENSe:]DEMod:FORMat:BANalyze` on page 142

PSDU Modulation

If analysis is restricted to PSDU with a particular modulation type, this setting defines which type.

For details on supported modulation depending on the standard see table 4-1.

Remote command:
`[SENSe:]DEMod:FORMat:BANalyze` on page 142

Guard Interval Length

Defines the PPDUs taking part in the analysis depending on the guard interval length.

Note: The terms in brackets in the following description indicate how the setting is referred to in the Signal Field result display ("Format" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU""(A1st)"
All PPDUs using the guard interval length identical to the first recognized PPDU are analyzed.

"Auto, individually for each PPDU""(AI)"
All PPDUs are analyzed.

"Meas only Short""(MS)"
Only PPDUs with short guard interval length are analyzed.

"Meas only Long""(ML)"
Only PPDUs with long guard interval length are analyzed.

"Demod all as short""(DS)"
All PPDUs are demodulated assuming short guard interval length.

"Demod all as long ""(DL)"
All PPDUs are demodulated assuming long guard interval length.

Remote command:
`CONFigure:WLAN:GTIMe:AUTO` on page 137
`CONFigure:WLAN:GTIMe:AUTO:TYPE` on page 138
`CONFigure:WLAN:GTIMe:SELect` on page 139

5.7.2 Demodulation - IEEE 802.11ac

Access: "Overview" > "Demodulation"

The following settings are available for demodulation of IEEE 802.11ac signals.

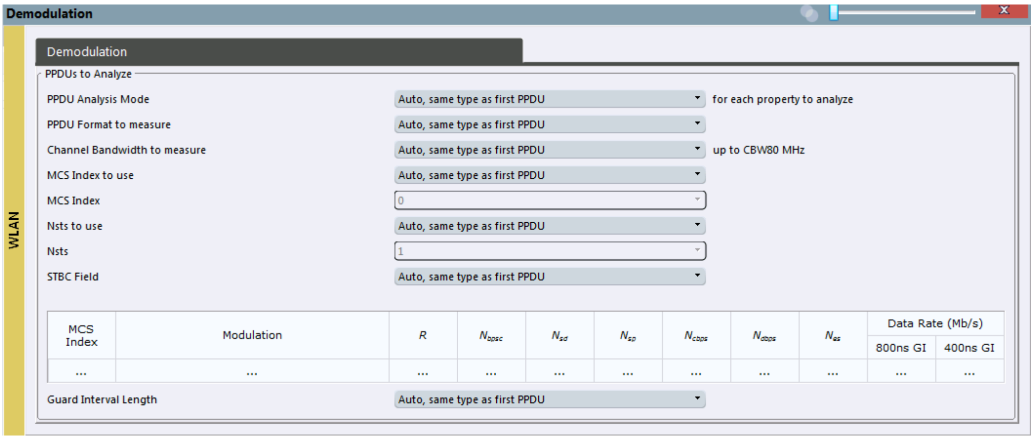


Fig. 5-3: Demodulation settings for IEEE 802.11ac standard

PPDU Analysis Mode
Defines whether all or only specific PPDUs are to be analyzed.

"Auto, same type as first PPDU"
The signal symbol field, i.e. the PLCP header field, of the first recognized PPDU is analyzed to determine the details of the PPDU. All PPDUs identical to the first recognized PPDU are analyzed.
All subsequent settings are set to "Auto" mode.

"Auto, individually for each PPDU"
All PPDUs are analyzed

"User-defined"
User-defined settings define which PPDUs are analyzed. This setting is automatically selected when any of the subsequent settings are changed to a value other than "Auto".

Remote command:
[SENSe:]DEMod:FORMat[:BCONtent]:AUTO on page 145

PPDU Format to measure
Defines which PPDU formats are to be included in the analysis. Depending on which standards the communicating devices are using, different formats of PPDUs are available. Thus you can restrict analysis to the supported formats.

Note: The PPDU format determines the available channel bandwidths.

For details on supported PPDU formats and channel bandwidths depending on the standard see table 4-1.

Note: The terms in brackets in the following description indicate how the setting is referred to in the Signal Field result display ("Format" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU(A1st)"
The format of the first valid PPDU is detected and subsequent PPDUs are analyzed only if they have the same format.

"Auto, individually for each PPDU(AI)"
All PPDUs are analyzed regardless of their format

"Meas only ...(M ...)"
Only PPDUs with the specified format are analyzed

"Demod all as ...(D ...)"
All PPDUs are assumed to have the specified PPDU format

Remote command:
[SENSe:]DEMod:FORMat:BANalyze:BTYPe:AUTO:TYPE on page 143
[SENSe:]DEMod:FORMat:BANalyze on page 142

Channel Bandwidth to measure (CBW)
Defines the channel bandwidth of the PPDUs taking part in the analysis. Depending on which standards the communicating devices are using, different PPDU formats and channel bandwidths are supported.

For details on supported PPDU formats and channel bandwidths depending on the standard see table 4-1.

Note: The terms in brackets in the following description indicate how the setting is referred to in the Signal Field result display ("Format" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU""(A1st)"
The channel bandwidth of the first valid PPDU is detected and subsequent PPDUs are analyzed only if they have the same channel bandwidth.

"Auto, individually for each PPDU""(AI)"
All PPDUs are analyzed regardless of their channel bandwidth

"Meas only ... signal""(M ...)"
Only PPDUs with the specified channel bandwidth are analyzed

"Demod all as ... signal""(D ...)"
All PPDUs are assumed to have the specified channel bandwidth

Remote command:
[SENSe:]BANDwidth:CHANnel:AUTO:TYPE on page 140

MCS Index to use

Defines the PPDUs taking part in the analysis depending on their Modulation and Coding Scheme (MCS) index.

Note: The terms in brackets in the following description indicate how the setting is referred to in the Signal Field result display ("Format" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU:""(A1st)"
All PPDUs using the MCS index identical to the first recognized PPDU are analyzed.

" Auto, individually for each PPDU""(AI)"
All PPDUs are analyzed

"Meas only the specified MCS""(M ...)"
Only PPDUs with the MCS index specified for the MCS Index setting are analyzed

"Demod all with specified MCS""(D ...)"
The MCS Index setting is used for all PPDUs.

Remote command:
[SENSe:]DEMod:FORMat:MCSindex:MODE on page 145

MCS Index

Defines the MCS index of the PPDUs taking part in the analysis manually. This field is enabled for "MCS index to use" = "Meas only the specified MCS" or "Demod all with specified MCS".

Remote command:
[SENSe:]DEMod:FORMat:MCSindex on page 145

Nsts to use

Defines the the PPDUs taking part in the analysis depending on their Nsts.

Note: The terms in brackets in the following description indicate how the setting is referred to in the "Signal Field" result display ("NSTS" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU:""(A1st)"
All PPDUs using the Nsts identical to the first recognized PPDU are analyzed.

" Auto, individually for each PPDU""(AI)"
All PPDUs are analyzed

"Meas only the specified Nsts""(M ...)"
Only PPDUs with the Nsts specified for the "Nsts" on page 87 setting are analyzed

"Demod all with specified Nsts""(D ...)"
The "Nsts" on page 87 setting is used for all PPDUs.

Remote command:
`[SENSe:]DEMod:FORMat:NSTSindex:MODE` on page 146

Nsts

Defines the Nsts of the PPDUs taking part in the analysis. This field is enabled for Nsts to use = "Meas only the specified Nsts" or "Demod all with specified Nsts".

Remote command:
`[SENSe:]DEMod:FORMat:NSTSindex` on page 146

STBC Field

Defines the PPDUs taking part in the analysis according to the Space-Time Block Coding (STBC) field content.

Note: The terms in brackets in the following description indicate how the setting is referred to in the Signal Field result display ("Format" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU""(A1st)"
All PPDUs using a STBC field content identical to the first recognized PPDU are analyzed.

"Auto, individually for each PPDU""(AI)"
All PPDUs are analyzed.

"Meas only if STBC field = 1 (+1 Stream)""(M1)"(IEEE 802.11N)
Only PPDUs with the specified STBC field content are analyzed.

"Meas only if STBC field = 2 (+2 Stream)""(M2)"(IEEE 802.11N)
Only PPDUs with the specified STBC field content are analyzed.

"Demod all as STBC field = 1""(D1)"(IEEE 802.11N)
All PPDUs are analyzed assuming the specified STBC field content.

"Demod all as STBC field = 2""(D2)"(IEEE 802.11N)
All PPDUs are analyzed assuming the specified STBC field content.

"Meas only if STBC = 1 (Nsts = 2Nss)""(M1)"(IEEE 802.11AC)
Only PPDUs with the specified STBC field content are analyzed.

"Demod all as STBC = 1 (Nsts = 2Nss)""(D1)"(IEEE 802.11AC)
All PPDUs are analyzed assuming the specified STBC field content.

Remote command:
`CONFigure:WLAN:STBC:AUTO:TYPE` on page 140

Table info overview

Depending on the selected channel bandwidth, MCS index or NSS (STBC), the relevant information from the modulation and coding scheme (MCS) as defined in the WLAN 802.11 standard is displayed here. This information is for reference only, for example so you can determine the required data rate.

Guard Interval Length

Defines the PPDUs taking part in the analysis depending on the guard interval length.

Note: The terms in brackets in the following description indicate how the setting is referred to in the Signal Field result display ("Format" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU""(A1st)"
: All PPDUs using the guard interval length identical to the first recognized PPDU are analyzed.

"Auto, individually for each PPDU""(AI)"
: All PPDUs are analyzed.

"Meas only Short""(MS)"
: Only PPDUs with short guard interval length are analyzed.

"Meas only Long""(ML)"
: Only PPDUs with long guard interval length are analyzed.

"Demod all as short""(DS)"
: All PPDUs are demodulated assuming short guard interval length.

"Demod all as long ""(DL)"
: All PPDUs are demodulated assuming long guard interval length.

Remote command:
`CONFigure:WLAN:GTIMe:AUTO` on page 137
`CONFigure:WLAN:GTIMe:AUTO:TYPE` on page 138
`CONFigure:WLAN:GTIMe:SELect` on page 139

5.7.3 Demodulation - IEEE 802.11b, g (DSSS)

Access: "Overview" > "Demodulation"

The following settings are available for demodulation of IEEE 802.11b or g (DSSS) signals.

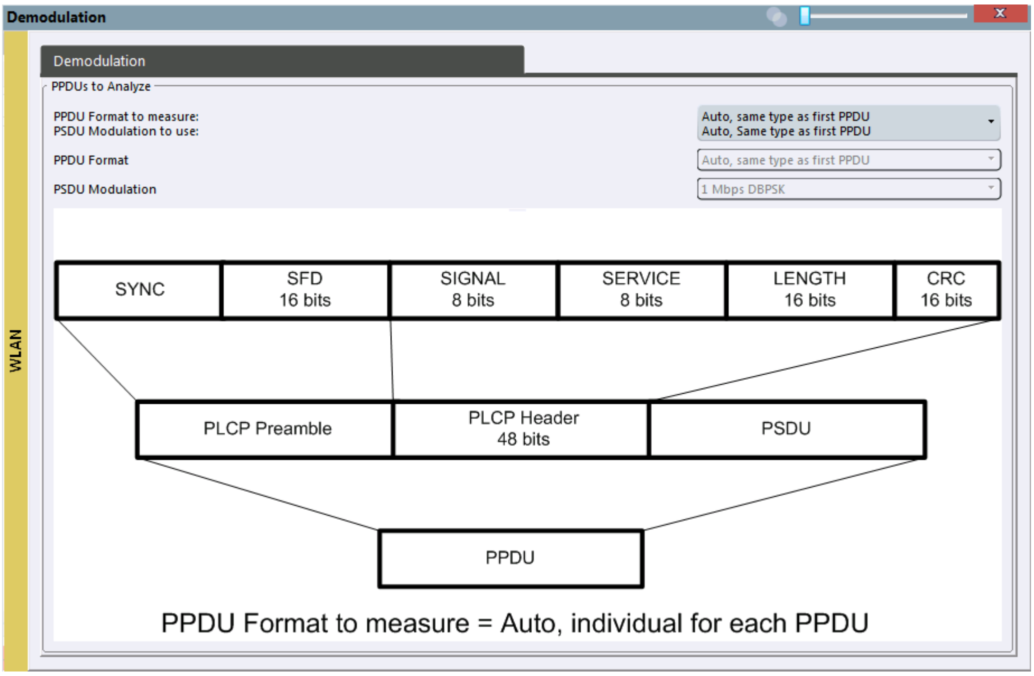


Fig. 5-4: Demodulation settings for IEEE 802.11b, g (DSSS) signals

PPDU Format to measure / PSDU Modulation to use

Defines which PPDU formats/modulations are to be included in the analysis. Depending on which standards the communicating devices are using, different formats of PPDUs are available. Thus you can restrict analysis to the supported formats.

Note: The PPDU format determines the available channel bandwidths.

For details on supported PPDU formats, modulations, and channel bandwidths depending on the standard see table 4-1.

"Auto, same type as first PPDU"
The format/modulation of the first valid PPDU is detected and subsequent PPDUs are analyzed only if they have the same format.

"Auto, individually for each PPDU"
All PPDUs are analyzed regardless of their format/modulation

"Meas only ..."
Only PPDUs with the specified format or PSDUs with the specified modulation are analyzed

"Demod all as ..."
All PPDUs are assumed to have the specified PPDU format/ PSDU modulation

Remote command:
[SENSe:]DEMod:FORMat:BANalyze:BTYPe:AUTO:TYPE on page 143
[SENSe:]DEMod:FORMat:BANalyze on page 142
[SENSe:]DEMod:FORMat:SIGSymbol on page 147

PPDU Format

If analysis is restricted to PPDUs with a particular format (see PPDU Format to measure / PSDU Modulation to use), this setting defines which type.

For details on supported modulation depending on the standard see table 4-1.

Remote command:
[SENSe:]DEMod:FORMat:BANalyze on page 142
[SENSe:]DEMod:FORMat:BANalyze:BTYPe on page 204

PSDU Modulation

If analysis is restricted to PSDU with a particular modulation type, this setting defines which type.

For details on supported modulation depending on the standard see table 4-1.

Remote command:
[SENSe:]DEMod:FORMat:BANalyze on page 142

5.7.4 Demodulation - IEEE 802.11n

Access: "Overview" > "Demodulation"

The following settings are available for demodulation of IEEE 802.11n signals.

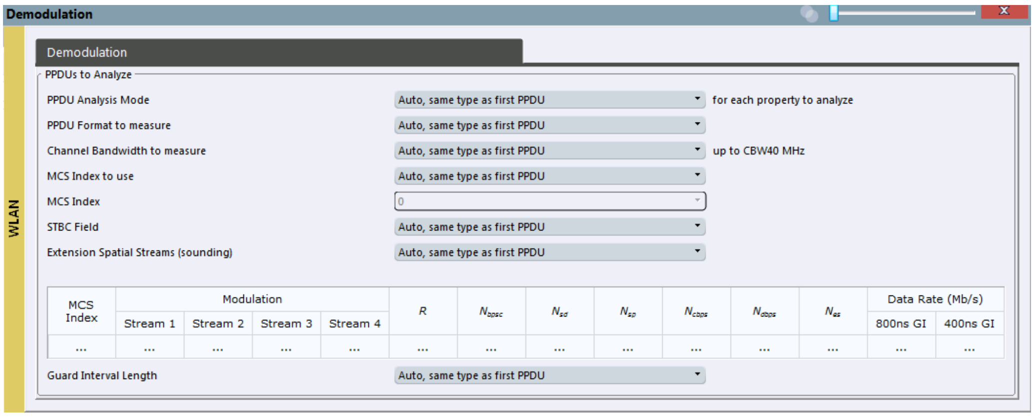


Fig. 5-5: Demodulation settings for IEEE 802.11n standard

PPDU Analysis Mode

Defines whether all or only specific PPDUs are to be analyzed.

"Auto, same type as first PPDU"
: The signal symbol field, i.e. the PLCP header field, of the first recognized PPDU is analyzed to determine the details of the PPDU. All PPDUs identical to the first recognized PPDU are analyzed.
All subsequent settings are set to "Auto" mode.

"Auto, individually for each PPDU"
: All PPDUs are analyzed

"User-defined"
: User-defined settings define which PPDUs are analyzed. This setting is automatically selected when any of the subsequent settings are changed to a value other than "Auto".

Remote command:
`[SENSe:]DEMod:FORMat[:BCONtent]:AUTO` on page 145

PPDU Format to measure

Defines which PPDU formats are to be included in the analysis. Depending on which standards the communicating devices are using, different formats of PPDUs are available. Thus you can restrict analysis to the supported formats.

Note: The PPDU format determines the available channel bandwidths.

For details on supported PPDU formats and channel bandwidths depending on the standard see table 4-1.

Note: The terms in brackets in the following description indicate how the setting is referred to in the Signal Field result display ("Format" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU(A1st)"
: The format of the first valid PPDU is detected and subsequent PPDUs are analyzed only if they have the same format.

"Auto, individually for each PPDU(AI)"
: All PPDUs are analyzed regardless of their format

"Meas only ...(M ...)"
: Only PPDUs with the specified format are analyzed

"Demod all as ...(D ...)"
: All PPDUs are assumed to have the specified PPDU format

Remote command:
`[SENSe:]DEMod:FORMat:BANalyze:BTYPe:AUTO:TYPE` on page 143
`[SENSe:]DEMod:FORMat:BANalyze` on page 142

Channel Bandwidth to measure (CBW)

Defines the channel bandwidth of the PPDUs taking part in the analysis. Depending on which standards the communicating devices are using, different PPDU formats and channel bandwidths are supported.

For details on supported PPDU formats and channel bandwidths depending on the standard see table 4-1.

Note: The terms in brackets in the following description indicate how the setting is referred to in the Signal Field result display ("Format" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU""(A1st)"
: The channel bandwidth of the first valid PPDU is detected and subsequent PPDUs are analyzed only if they have the same channel bandwidth.

"Auto, individually for each PPDU""(AI)"
: All PPDUs are analyzed regardless of their channel bandwidth

"Meas only ... signal""(M ...)"
: Only PPDUs with the specified channel bandwidth are analyzed

"Demod all as ... signal""(D ...)"
: All PPDUs are assumed to have the specified channel bandwidth

Remote command:
`[SENSe:]BANDwidth:CHANnel:AUTO:TYPE` on page 140

MCS Index to use

Defines the PPDUs taking part in the analysis depending on their Modulation and Coding Scheme (MCS) index.

Note: The terms in brackets in the following description indicate how the setting is referred to in the Signal Field result display ("Format" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU:""(A1st)"
: All PPDUs using the MCS index identical to the first recognized PPDU are analyzed.

" Auto, individually for each PPDU""(AI)"
: All PPDUs are analyzed

"Meas only the specified MCS""(M ...)"
: Only PPDUs with the MCS index specified for the MCS Index setting are analyzed

"Demod all with specified MCS""(D ...)"
: The MCS Index setting is used for all PPDUs.

Remote command:
`[SENSe:]DEMod:FORMat:MCSindex:MODE` on page 145

MCS Index

Defines the MCS index of the PPDUs taking part in the analysis manually. This field is enabled for "MCS index to use" = "Meas only the specified MCS" or "Demod all with specified MCS".

Remote command:
`[SENSe:]DEMod:FORMat:MCSindex` on page 145

STBC Field

Defines the PPDUs taking part in the analysis according to the Space-Time Block Coding (STBC) field content.

Note: The terms in brackets in the following description indicate how the setting is referred to in the Signal Field result display ("Format" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU""(A1st)"
: All PPDUs using a STBC field content identical to the first recognized PPDU are analyzed.

"Auto, individually for each PPDU""(AI)"
: All PPDUs are analyzed.

"Meas only if STBC field = 1 (+1 Stream)""(M1)"(IEEE 802.11N)
: Only PPDUs with the specified STBC field content are analyzed.

"Meas only if STBC field = 2 (+2 Stream)""(M2)"(IEEE 802.11N)
: Only PPDUs with the specified STBC field content are analyzed.

"Demod all as STBC field = 1""(D1)"(IEEE 802.11N)
: All PPDUs are analyzed assuming the specified STBC field content.

"Demod all as STBC field = 2""(D2)"(IEEE 802.11N)
: All PPDUs are analyzed assuming the specified STBC field content.

"Meas only if STBC = 1 (Nsts = 2Nss)""(M1)"(IEEE 802.11AC)
: Only PPDUs with the specified STBC field content are analyzed.

"Demod all as STBC = 1 (Nsts = 2Nss)""(D1)"(IEEE 802.11AC)
: All PPDUs are analyzed assuming the specified STBC field content.

Remote command:
`CONFigure:WLAN:STBC:AUTO:TYPE` on page 140

Extension Spatial Streams (sounding)

Defines the PPDUs taking part in the analysis according to the Ness field content.

Note: The terms in brackets in the following description indicate how the setting is referred to in the Signal Field result display ("NESS" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU""(A1st)"
: All PPDUs using a Ness value identical to the first recognized PPDU are analyzed.

"Auto, individually for each PPDU""(AI)"
: All PPDUs are analyzed.

"Meas only if Ness = <x>""(M ...)"
: Only PPDUs with the specified Ness value are analyzed.

"Demod all as Ness = <x>"
All PPDUs are analyzed assuming the specified Ness value.

Remote command:
CONFigure:WLAN:EXTension:AUTO:TYPE on page 137

Table info overview
Depending on the selected channel bandwidth, MCS index or NSS (STBC), the relevant information from the modulation and coding scheme (MCS) as defined in the WLAN 802.11 standard is displayed here. This information is for reference only, for example so you can determine the required data rate.

Guard Interval Length
Defines the PPDUs taking part in the analysis depending on the guard interval length.

Note: The terms in brackets in the following description indicate how the setting is referred to in the Signal Field result display ("Format" column, see "Signal Field" on page 31).

"Auto, same type as first PPDU""(A1st)"
All PPDUs using the guard interval length identical to the first recognized PPDU are analyzed.

"Auto, individually for each PPDU""(AI)"
All PPDUs are analyzed.

"Meas only Short""(MS)"
Only PPDUs with short guard interval length are analyzed.

"Meas only Long""(ML)"
Only PPDUs with long guard interval length are analyzed.

"Demod all as short""(DS)"
All PPDUs are demodulated assuming short guard interval length.

"Demod all as long ""(DL)"
All PPDUs are demodulated assuming long guard interval length.

Remote command:
CONFigure:WLAN:GTIMe:AUTO on page 137
CONFigure:WLAN:GTIMe:AUTO:TYPE on page 138
CONFigure:WLAN:GTIMe:SELect on page 139

5.8 Evaluation Range

Access: "Overview" > "Evaluation Range"

The evaluation range defines which objects the result displays are based on. The available settings depend on the selected standard.

5.8.1 Evaluation Range Settings for IEEE 802.11a, ac, g (OFDM), n

Access: "Overview" > "Evaluation Range"

The following settings are available to configure the evaluation range for standards IEEE 802.11a, ac, g (OFDM), n.

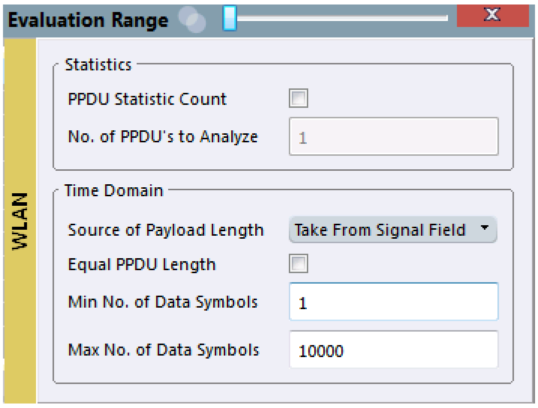


Fig. 5-6: Evaluation range settings for IEEE 802.11a, ac, g (OFDM), n standards

PPDU Statistic Count / No of PPDUs to Analyze

If the statistic count is enabled, the specified number of PPDUs is taken into consideration for the statistical evaluation. Sweeps are performed continuously until the required number of PPDUs are available. The number of captured and required PPDUs, as well as the number of PPDUs detected in the current sweep, are indicated as "Analyzed PPDUs" in the channel bar.

(See "Channel bar information" on page 9).

If disabled, all valid PPDUs in the current capture buffer are considered. Note that in this case, the number of PPDUs contributing to the current results may vary extremely.

Remote command:
`[SENSe:]BURSt:COUNt:STATe` on page 150
`[SENSe:]BURSt:COUNt` on page 149

Source of Payload Length

Defines which signal source is used to determine the payload length of a PPDU.

"Take from Signal Field" (IEEE 802.11 A)
Uses the length defined by the signal field

"L-Signal" (IEEE 802.11 AC)
Determines the length of the L signal

"HT-Signal" (IEEE 802.11 N)
Determines the length of the HT signal

"Estimate from signal"
Uses an estimated length

Remote command:
CONFigure:WLAN:PAYLoad:LENGth:SRC on page 148

Equal PPDU Length
If enabled, only PPDUs with the specified (Min./Max.) Payload Length are considered for measurement analysis.

If disabled, a maximum and minimum (Min./Max.) Payload Length can be defined and all PPDUs whose length is within this range are considered.

Remote command:
IEEE 802.11a, ac, g (OFDM), n
[SENSe:]DEMod:FORMat:BANalyze:SYMBols:EQUal on page 153
IEEE 802.11 b, g (DSSS):
[SENSe:]DEMod:FORMat:BANalyze:DURation:EQUal on page 152
[SENSe:]DEMod:FORMat:BANalyze:DBYTes:EQUal on page 151

(Min./Max.) No. of Data Symbols
If the Equal PPDU Length setting is enabled, the number of data symbols defines the exact length a PPDU must have to be considered for analysis.

If the Equal PPDU Length setting is disabled, you can define the minimum and maximum number of data symbols a PPDU must contain to be considered in measurement analysis.

Remote command:
[SENSe:]DEMod:FORMat:BANalyze:SYMBols:MIN on page 153
[SENSe:]DEMod:FORMat:BANalyze:SYMBols:MAX on page 153

5.8.2 Evaluation Range Settings for IEEE 802.11b, g (DSSS)

Access: "Overview" > "Evaluation Range"

The following settings are available to configure the evaluation range for standards IEEE 802.11b, g (DSSS).

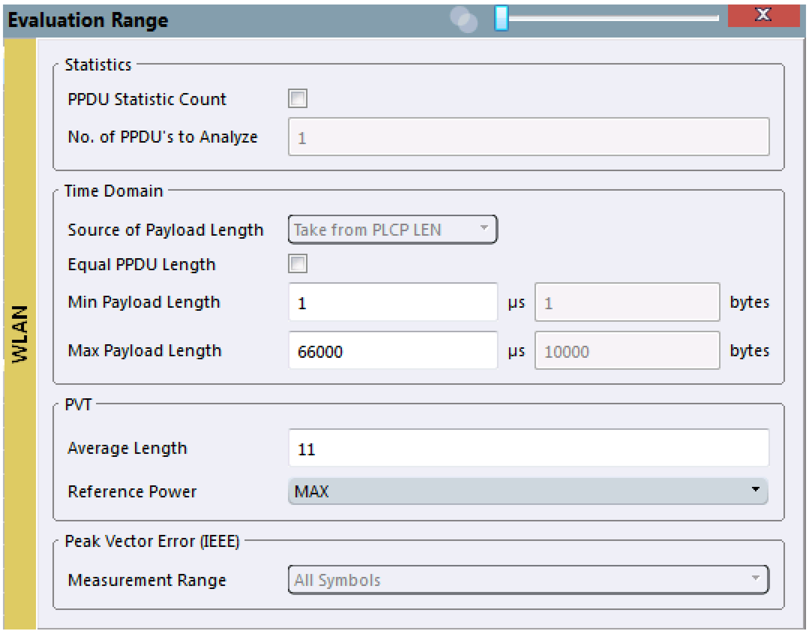


Fig. 5-7: Evaluation range settings for IEEE 802.11b and g (DSSS) standards

PPDU Statistic Count / No of PPDUs to Analyze

If the statistic count is enabled, the specified number of PPDUs is taken into consideration for the statistical evaluation. Sweeps are performed continuously until the required number of PPDUs are available. The number of captured and required PPDUs, as well as the number of PPDUs detected in the current sweep, are indicated as "Analyzed PPDUs" in the channel bar.

(See "Channel bar information" on page 9).

If disabled, all valid PPDUs in the current capture buffer are considered. Note that in this case, the number of PPDUs contributing to the current results may vary extremely.

Remote command:

`[SENSe:]BURSt:COUNt:STATe` on page 150

`[SENSe:]BURSt:COUNt` on page 149

Equal PPDU Length

If enabled, only PPDUs with the specified (Min./Max.) Payload Length are considered for measurement analysis.

If disabled, a maximum and minimum (Min./Max.) Payload Length can be defined and all PPDUs whose length is within this range are considered.

Remote command:
IEEE 802.11a, ac, g (OFDM), n
[SENSe:]DEMod:FORMat:BANalyze:SYMBols:EQUal on page 153
IEEE 802.11 b, g (DSSS):
[SENSe:]DEMod:FORMat:BANalyze:DURation:EQUal on page 152
[SENSe:]DEMod:FORMat:BANalyze:DBYTes:EQUal on page 151

(Min./Max.) Payload Length

If the Equal PPDU Length setting is enabled, the payload length defines the exact length a PPDU must have to be considered for analysis.

If the Equal PPDU Length setting is disabled, you can define the minimum and maximum payload length a PPDU must contain to be considered in measurement analysis.

The payload length can be defined as a duration in µs or a number of bytes (only if specific PPDU modulation and format are defined for analysis, see "PPDU Format to measure" on page 82).

Remote command:
[SENSe:]DEMod:FORMat:BANalyze:DBYTes:MIN on page 151
[SENSe:]DEMod:FORMat:BANalyze:DURation:MIN on page 152
[SENSe:]DEMod:FORMat:BANalyze:DBYTes:MAX on page 151
[SENSe:]DEMod:FORMat:BANalyze:DURation:MAX on page 152

PVT : Average Length

Defines the number of samples used to adjust the length of the smoothing filter for PVT measurement.

For details see "PvT Full PPDU" on page 28.

Remote command:
CONFigure:BURSt:PVT:AVERage on page 148

PVT : Reference Power

Sets the reference for the rise and fall time in PVT calculation to the maximum or mean PPDU power.

For details see "PvT Full PPDU" on page 28.

Remote command:
CONFigure:BURSt:PVT:RPOWer on page 148

Peak Vector Error : Meas Range

Displays the used measurement range for peak vector error measurement (for reference only).

"All Symbols" Peak Vector Error results are calculated over the complete PPDU

"PSDU only" Peak Vector Error results are calculated over the PSDU only

Remote command:
CONFigure:WLAN:PVERror:MRANge? on page 149

5.9 Result Configuration

Access: "Meas Setup" > "Result Config"

For some result displays, additional settings are available.

This function is only available if a window with additional settings is currently selected.

Depending on the selected result display, different settings are available.

5.9.1 Result Summary Configuration

Access: "Meas Setup" > "Result Config"

You can configure which results are displayed in Result Summary displays (see "Result Summary Detailed" on page 28 and "Result Summary Global" on page 29). However, the results are always *calculated*, regardless of their visibility on the screen.

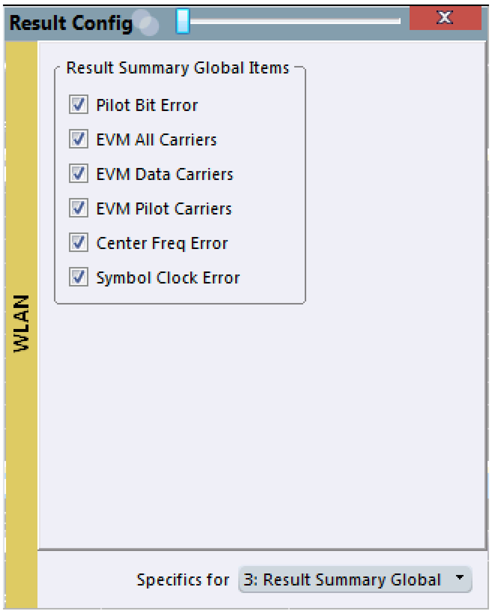


Fig. 5-8: Result Summary Global configuration for IEEE 802.11a, ac, g (OFDM), n standards

Remote command:

`DISPlay[:WINDow<n>]:TABLe:ITEM` on page 170

6 Analysis

General result analysis settings concerning the trace and markers etc. are currently not available for the standard WLAN I/Q measurements. Only one (Clear/Write) trace and one marker are available for these measurements.

The remote commands required to perform these tasks are described in chapter 9.7, "Analysis", on page 196.

Place New Marker

Activates the next currently unused marker and sets it to the peak value of the current trace in the current window.

All Markers Off

Deactivates all markers in one step.

Remote command:
`CALCulate<n>:MARKer<m>:AOFF` on page 197

7 How to Perform Measurements in the R&S VSE WLAN application

The following step-by-step instructions demonstrate how to perform measurements in the R&S VSE WLAN application.

How to Determine Modulation Accuracy, Flatness and Tolerance Parameters for WLAN Signals

1. Open a new channel or replace an existing one and select the "WLAN 802.11" application.
2. Select the "Meas Setup > Overview" menu item to display the "Overview" for a WLAN 802.11 measurement.
3. Select the "Signal Description" button to define the digital standard to be used.
4. Select the "Input/Frontend" button and then the "Frequency" tab to define the input signal's center frequency.
5. Select the "Signal Capture" button to define how much and which data to capture from the input signal.
6. To define a particular starting point for the FFT or to improve the measurement speed for signals with a low duty cycle, select the "Synchronization/OFDM-Demod." button and set the required parameters.
7. Select the "Tracking/Channel Estimation" button to define how the data channels are to be estimated and which distortions will be compensated for.
8. Select the "Demod" button to provide information on the modulated signal and how the PPDUs detected in the capture buffer are to be demodulated.
9. Select the "Evaluation Range" button to define which data in the capture buffer you want to analyze.
10. Select the "Add Window" icon from the toolbar to add further result displays for the WLAN 802.11 channel.
11. Select the "Capture" icon from the toolbar to start a new measurement with the defined settings.

    Measurement results are updated once the measurement has completed.

8 Optimizing and Troubleshooting the Measurement

8.1 Optimizing the Measurement Results

If the results do not meet your expectations, try the following methods to optimize the measurement.

8.1.1 Improving Performance

Performing a coarse burst search

For signals with **low duty cycle rates**, enable the "Power Interval Search" for synchronization (see "Power Interval Search" on page 78). In this case, the R&S VSE WLAN application initially performs a coarse burst search on the input signal in which increases in the power vs time trace are detected. Further time-consuming processing is then only performed where bursts are assumed. This improves the measurement speed.

However, for signals in which the PPDU power levels differ significantly, this option should be disabled as otherwise some PPDUs may not be detected.

8.1.2 Improving Channel Estimation and EVM Accuracy

The channels in the WLAN signal are estimated based on the expected input signal description and the information provided by the PPDUs themselves. The more accurate the channel estimation, the more accurate the EVM based on these channels can be calculated.

Increasing the basis for channel estimation

The more information that can be used to estimate the channels, the more accurate the results. For measurements that need not be performed strictly according to the WLAN 802.11 standard, set the "Channel Estimation Range" to "Payload" (see "Channel Estimation Range" on page 79).

The channel estimation is performed in the preamble and the payload. The EVM results can be calculated more accurately.

Accounting for phase drift in the EVM

According to the WLAN 802.11 standards, the common phase drift must be estimated and compensated from the pilots. Thus, these deviations are not included in the EVM. To include the phase drift, disable "Phase Tracking" (see "Phase Tracking" on page 79).

Analyzing time jitter

Normally, a symbol-wise timing jitter is negligible and not required by the IEEE 802.11a measurement standard [6], and thus not considered in channel estimation. However, there may be situations where the timing drift has to be taken into account.

However, to analyze the time jitter per symbol, enable "Timing Tracking" (see "Timing Error Tracking" on page 79).

Compensating for non-standard-conform pilot sequences

In case the pilot generation algorithm of the device under test (DUT) has a problem, the non-standard-conform pilot sequence might affect the measurement results, or the WLAN application might not synchronize at all onto the signal generated by the DUT.

In this case, set the "Pilots for Tracking" to "Detected" (see "Pilots for Tracking" on page 80), so that the pilot sequence detected in the signal is used instead of the sequence defined by the standard.

However, if the pilot sequence generated by the DUT is correct, it is recommended that you use the "According to Standard" setting because it generates more accurate measurement results.

8.2 Error Messages and Warnings

The following messages are displayed in the status bar in case of errors.

Results contribute to overall results despite inconsistencies:

"Info: Comparison between HT-SIG Payload Length and Estimated Payload Length not performed due to insufficient SNR"

The R&S VSE WLAN application compares the HT-SIG length against the length estimated from the PPDU power profile. If the two values do not match, the corresponding entry is highlighted orange. If the signal quality is very bad, this comparison is suppressed and the message above is shown.

"Warning: HT-SIG of PPDU was not evaluated"

Decoding of the HT-SIG was not possible because there was to not enough data in the Capture Memory (potential PPDU truncation).

"Warning: Mismatch between HT-SIG and estimated (SNR+Power) PPDU length"

The HT-SIG length and the length estimated by the R&S VSE WLAN application (from the PPDU power profile) are different.

"Warning: Physical Channel estimation impossible / Phy Chan results not available Possible reasons: channel matrix not square or singular to working precision"

The Physical Channel results could not be calculated for one or both of the following reasons:

- The spatial mapping can not be applied due to a rectangular mapping matrix (the number of space time streams is not equal to the number of transmit antennas).
- The spatial mapping matrices are singular to working precision.

PPDUs are dismissed due to inconsistencies

"Hint: PPDU requires at least one payload symbol"

Currently at least one payload symbol is required in order to successfully analyze the PPDU. Null data packet (NDP) sounding PPDUs will generate this message.

"Hint: PPDU dismissed due to a mismatch with the PPDU format to be analyzed"

The properties causing the mismatches for this PPDU are highlighted.

"Hint: PPDU dismissed due to truncation"

The first or the last PPDU was truncated during the signal capture process, for example.

"Hint: PPDU dismissed due to HT-SIG inconsistencies"

One or more of the following HT-SIG decoding results are outside of specified range: MCS index, Number of additional STBC streams, Number of space time streams (derived from MCS and STBC), CRC Check failed, Non zero tail bits.

"Hint: PPDU dismissed because payload channel estimation was not possible"

The payload based channel estimation was not possible because the channel matrix is singular to working precision.

"Hint: Channel matrix singular to working precision"

Channel equalizing (for PPDU Length Detection, fully and user compensated measurement signal) is not possible because the estimated channel matrix is singular to working precision.

9 Remote Commands for WLAN Measurements

The following commands are required to perform measurements in the R&S VSE WLAN application in a remote environment.

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

General R&S VSE Remote Commands

The application-independent remote commands for general tasks on the R&S VSE are also available for Analog Demodulation measurements and are described in the R&S VSE Base Software User Manual. In particular, this comprises the following functionality:

- Controlling instruments and capturing data
- Managing Settings and Results
- Setting Up the Instrument
- Using the Status Register

Channel-specific commands

Apart from a few general commands on the R&S VSE, most commands refer to the currently active channel. Thus, always remember to activate a WLAN 802.11 channel before starting a remote program for a WLAN 802.11 measurement.

9.1 Common Suffixes

For the description of the remote commands in the WLAN application, the following common suffixes are used:

Table 9-1: Common suffixes for WLAN measurements on I/Q data

Suffix	Value range	Description
<n>	1..x	Window
<k>	1..8	Limit
<t>	1	Trace
<m>	1..4	Marker

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 VSE.

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 VSE 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 107.

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 WLAN 802.11 Measurements

WLAN 802.11 measurements require a special application in the R&S VSE. The common commands for configuring and controlling measurement channels, as well as blocks and sequences, are also used in the R&S VSE WLAN application.

They are described in the R&S VSE Base Software User Manual.

9.4 Configuring the WLAN I/Q Measurement (Modulation Accuracy, Flatness and Tolerance)

The following commands are required to configure the WLAN I/Q measurement described in chapter 3, "WLAN I/Q Measurement and Results", on page 11.

9.4.1 Restoring the Default Configuration (Preset)

SYSTem:PRESet:CHANnel[:EXECute]

This command restores the default software 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 59

9.4.2 Signal Description

The signal description provides information on the expected input signal.

Useful commands for describing the WLAN signal described elsewhere:

- `[SENSe:]FREQuency:CENTer` on page 117

Remote commands exclusive to describing the WLAN signal:

CONFigure:STANdard <Standard>

This remote control command specifies which WLAN standard the option is configured to measure.

The availability of many commands depends on the selected standard!

Parameters:

<Standard>

0
IEEE 802.11a

1
IEEE 802.11b

4
IEEE 802.11g

6
IEEE 802.11n

8
IEEE 802.11ac

*RST: 0

Manual operation: See "Standard" on page 59

CALCulate:LIMit:TOLerance <Limit>

This command defines or queries the tolerance limit to be used for the measurement. The required tolerance limit depends on the used standard.

Parameters:

<Limit> PRIOR11_2012 | STD11_2012 | P11ACD5_1

PRIOR11_2012
Tolerance limits are based on the IEEE 802.11 specification **prior to 2012**.
Default for OFDM standards (except 802.11ac).

STD11_2012
Tolerance limits are based on the IEEE 802.11 specification from **2012.**
Required for DSSS standards. Also possible for OFDM standards (except 802.11ac).

P11ACD5_1
Tolerance limits are based on the **IEEE 802.11ac** specification.
Required by IEEE 802.11ac standard.

*RST: STD11_2012

Manual operation: See "Tolerance Limit" on page 60

9.4.3 Configuring the Data Input and Output

9.4.3.1 RF Input

INPut:ATTenuation:PROTection[:STATe] <State>

This command turns the availability of attenuation levels of 10 dB or less on and off.

Parameters:

<State> ON | OFF

*RST: OFF

Example: `INP:ATT:PROT ON`

Manual operation: See "10 dB Minimum Attenuation" on page 63

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 61

INPut:FILTer:HPASs[:STATe] <State>

Activates an additional internal high-pass filter for RF input signals from 1 GHz to 3 GHz. This filter is used to remove the harmonics of the instrument in use in order to measure the harmonics for a DUT, for example.

This function requires an additional high-pass filter hardware option.

(Note: for RF input signals outside the specified range, the high-pass filter has no effect. For signals with a frequency of approximately 4 GHz upwards, the harmonics are suppressed sufficiently by the YIG filter.)

Parameters:
<State> ON | OFF
*RST: OFF

Example: `INP:FILT:HPAS ON`
Turns on the filter.

Usage: SCPI confirmed

Manual operation: See "High-Pass Filter 1...3 GHz" on page 62

INPut:FILTer:YIG[:STATe] <State>

This command turns the YIG-preselector on and off.

Note the special conditions and restrictions for the YIG filter described in "YIG-Preselector" on page 62.

Example: `INP:FILT:YIG OFF`
Deactivates the YIG-preselector.

Manual operation: See "YIG-Preselector" on page 62

INPut:IMPedance <Impedance>

This command selects the nominal input impedance of the RF input. In some applications, only 50 Ω are supported.

75 Ω should be selected if the 50 Ω input impedance is transformed to a higher impedance using a matching pad of the RAZ type (= 25 Ω in series to the input impedance of the instrument). The power loss correction value in this case is 1.76 dB = 10 log (75Ω/50Ω).

Parameters:

<Impedance> 50 | 75
*RST: 50 Ω

Example: `INP:IMP 75`

Usage: SCPI confirmed

Manual operation: See "Impedance" on page 62

INPut:PRESelection:SET <Mode>

This command selects the preselector mode.

The command is available with the optional preselector.

Parameters:

<Mode>

NARRow
Performs a measurement by automatically applying all available combinations of low and high pass filters consecutively. These combinations all have a narrow bandwidth.

WIDE
Performs a measurement by automatically applying all available bandpass filters consecutively. The bandpass filters have a wide bandwidth.

Manual operation: See "Preselector Mode" on page 62

INPut:PRESelection[:STATe] <State>

This command turns the preselector on and off.

Manual operation: See "Preselector State" on page 62

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 VSE.

Parameters:

<Source>

RF
Radio Frequency ("RF INPUT" connector)

FIQ
I/Q data file

*RST: RF

Manual operation: See "Input Type" on page 61

INPut:TYPE <Input>

The command selects the signal source.

Parameters:

<Input>

INPUT1
Selects RF input 1.

INPUT2
Selects RF input 2.

*RST: INPUT1

Example: `INP:TYPE INPUT1`
Selects RF input 1.

Manual operation: See "Input Selection" on page 63

INSTrument:BLOCk:CHANnel[:SETTings]:SOURce <Type>

Selects an instrument or a file as the source of input provided to the channel.

Parameters:

<Type> FILE | DEVice | NONE

FILE
A loaded file is used for input.

DEVice
A configured device provides input for the measurement

NONE
No input source defined.

Manual operation: See "Input Type" on page 61

9.4.3.2 Configuring the Outputs

Configuring trigger input/output is described in "Configuring the Trigger Output" on page 131.

DIAGnostic:SERVice:NSOurce <State>

This command turns the 28 V supply of the BNC connector labeled NOISE SOURCE CONTROL on the instrument in use on and off.

For details see chapter 4.6.1, "Input from Noise Sources", on page 51.

Parameters:
<State> ON | OFF
*RST: OFF

Example: `DIAG:SERV:NSO ON`

Manual operation: See "Noise Source" on page 65

9.4.4 Frontend Configuration

The following commands configure frequency, amplitude and y-axis scaling settings, which represent the "frontend" of the measurement setup.

9.4.4.1 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 "Frequency" on page 60
See "Center frequency" on page 67

[SENSe:]FREQuency:CENTer:STEP <StepSize>

This command defines the center frequency step size.

You can increase or decrease the center frequency quickly in fixed steps using the `SENS:FREQ UP` AND `SENS:FREQ DOWN` commands, see `[SENSe:]FREQuency:CENTer` on page 117.

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.

In time domain (zero span) measurements, the center frequency is coupled to the RBW.

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.

See also "Frequency Offset" on page 67.

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

9.4.4.2 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 114
- `INPut:IMPedance` on page 115

Remote commands exclusive to amplitude settings:

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> *RST: dBm

Example: `CALC:UNIT:POW DBM`
Sets the power unit to dBm.

Manual operation: See "Unit" on page 69

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 120)

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

CONFigure:POWer:AUTO:SWEep:TIME <Value>

This command is used to specify the auto track time, i.e. the sweep time for auto level detection.

This setting can currently only be defined in remote control, not in manual operation.

Parameters for setting and query:

<Value> numeric value

Auto level measurement sweep time

Range: 0.01 to 1
*RST: 0.1 s
Default unit: S

Example: `CONF:POW:AUTO:SWE:TIME 0.01 MS`

CONFigure:POWer:EXPected:RF <Value>

This command specifies the mean power level of the source signal as supplied to the instrument's RF input. This value is overwritten if "Auto Level" mode is turned on.

Parameters:

<Value> Default unit: DBM

Manual operation: See "Signal Level (RMS)" on page 69

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 69

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 VSE 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 69

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 122).

If the current reference level is not compatible with an attenuation that has been set manually, the command also adjusts the reference level.

This command requires the electronic attenuation hardware option.

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.

This command requires the electronic attenuation hardware option.

Parameters:

<State> ON | OFF | 0 | 1

*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.

This command requires the electronic attenuation hardware option.

Parameters:

<State> ON | OFF

*RST: OFF

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 123).

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 instrument in use.

*RST: OFF

Example: `INP:GAIN:VAL 30`
Switches on 30 dB preamplification.

Usage: SCPI confirmed

Manual operation: See "Preamplifier" on page 70

INPut:GAIN:STATe <State>

This command turns the preamplifier on the instrument in use on and off. It requires the additional preamplifiier hardware option on the connected instrument.

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 70

9.4.5 Signal Capturing

The following commands are required to configure how much and how data is captured from the input signal.

9.4.5.1 General Capture Settings

[SENSe:]BANDwidth[:RESolution]:FILTer[:STATe] <State>

This remote control command enables or disables use of the adjacent channel filter.

If activated, only the useful signal is analyzed, all signal data in adjacent channels is removed by the filter. This setting improves the signal to noise ratio and thus the EVM results for signals with strong or a large number of adjacent channels. However, for some measurements information on the effects of adjacent channels on the measured signal may be of interest.

Parameters:

<State> ON | OFF | 0 | 1

*RST: 1

Manual operation: See "Suppressing (Filter out) Adjacent Channels (IEEE 802.11a, ac, g (OFDM), n)" on page 72

[SENSe<n>:]DEMod:FILTer:EFLength <Length>

This command specifies the equalizer filter length in chips.

Parameters:

<Length> Range: 2 to 30

*RST: 10

Manual operation: See "Equalizer Filter Length (IEEE 802.11b, g (DSSS))" on page 72

[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 VSE 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 71

TRACe:IQ:SRATe <SampleRate>

This command sets the final user sample rate for the acquired I/Q data. Thus, the user sample rate can be modified without affecting the actual data capturing settings on the R&S VSE.

Parameters:
<SampleRate> The valid sample rates depend on the instrument in use. Refer to the instrument's documentation.
*RST: 32 MHz

Manual operation: See "Input Sample Rate" on page 71

9.4.5.2 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 5.4.2, "Trigger Settings", on page 72.

Note that the availability of trigger settings depends on the instrument in use.

> 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.

Note that the availability of trigger sources depends on the instrument in use.

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 75

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 75

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).

For (offline) input from a file, this command does not apply. In this case, use `TRIGger[:SEQuence]:MAPower:HOLDoff` on page 129.

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.

For details on the trigger source see "Trigger Source Settings" on page 74.

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.

For details on the trigger settings see "Trigger Source Settings" on page 74.

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.

For details on the trigger source see "Trigger Source Settings" on page 74.

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:MAPower <TriggerLevel>

This command defines the power level that must be exceeded to cause a trigger event for (offline) input from a file.

Parameters:

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

Example: `TRIG:LEV:MAP -30DBM`

Manual operation: See "Trigger Level" on page 75

TRIGger:SEQuence:LEVel:POWer:AUTO <State>

By default, the optimum trigger level for power triggers is automatically measured and determined at the start of each sweep (for Modulation Accuracy, Flatness, Tolerance... measurements).

This function is only considered for `TRIG:SEQ:SOUR IFP` and `TRIG:SEQ:SOUR RFP`, see `TRIGger[:SEQuence]:SOURce` on page 130

In order to define the trigger level manually, switch this function off and define the level using `TRIGger[:SEQuence]:LEVel:IFPower` on page 127 or `TRIGger[:SEQuence]:LEVel:RFPower` on page 129.

Parameters for setting and query:

<State> **OFF**
Switches the auto level detection function off

ON
Switches the auto level detection function on

*RST: ON

Manual operation: See "Trigger Level Mode" 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.

For details on the trigger source see "Trigger Source Settings" on page 74.

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]:MAPower:HOLDoff <Period>

This command defines the holding time before the next trigger event for (offline) input from a file.

Parameters:

<Period> Range: 0 s to 10 s
*RST: 0 s

Example: `TRIG:SOUR MAGN`
Sets an offline magnitude trigger source.
`TRIG:MAP:HOLD 200 ns`
Sets the holding time to 200 ns.

Manual operation: See "Trigger Holdoff" on page 76

TRIGger[:SEQuence]:MAPower:HYSTeresis <Hysteresis>

This command defines the trigger hysteresis for the (offline) magnitude trigger source (used for input from a file).

Parameters:

<Hysteresis> Range: 3 dB to 50 dB
*RST: 3 dB

Example: `TRIG:SOUR MAP`
Sets the (offline) magnitude trigger source.
`TRIG:MAP:HYST 10DB`
Sets the hysteresis limit value.

Manual operation: See "Hysteresis" on page 76

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 that the availability of trigger sources depends on the instrument in use.

For details on the available trigger sources see "Trigger Source Settings" on page 74.

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

EXT | EXT2 | EXT3 | EXT4
Trigger signal from the corresponding TRIGGER INPUT/OUTPUT connector on the instrument in use, or the oscilloscope's corresponding input channel.
For details on the connectors see the instrument's Getting Started manual.

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.

MAGNitude
For (offline) input from a file, rather than an instrument. Triggers on a specified signal level.

*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<X>" on page 74
See "RF Power" on page 74
See "I/Q Power" on page 74
See "Time" on page 75
See "Magnitude (offline)" 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 instrument in use.

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>

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.

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.

Parameters:

<OutputType>

DEVice
Sends a trigger signal when the R&S VSE 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 65

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.

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.

Parameters:
<Length> Pulse length in seconds.

Manual operation: See "Pulse Length" on page 66

9.4.6 Synchronization and OFDM Demodulation

[SENSe:]DEMod:FFT:OFFSet <Mode>

This command specifies the start offset of the FFT for OFDM demodulation (not for the FFT Spectrum display).

Parameters:
<Mode> AUTO | GICenter | PEAK

AUTO
The FFT start offset is automatically chosen to minimize the intersymbol interference.

GICenter
Guard Interval Center: The FFT start offset is placed to the center of the guard interval.

PEAK
The peak of the fine timing metric is used to determine the FFT start offset.

*RST: AUTO

Manual operation: See "FFT Start Offset" on page 78

[SENSe:]DEMod:TXARea <State>

If enabled, the R&S VSE WLAN application initially performs a coarse burst search on the input signal in which increases in the power vs time trace are detected. Further time-consuming processing is then only performed where bursts are assumed. This improves the measurement speed for signals with low duty cycle rates.

However, for signals in which the PPDU power levels differ significantly, this option should be disabled as otherwise some PPDUs may not be detected.

Parameters:

<State> ON | OFF | 0 | 1

ON | 1
A coarse burst search is performed based on the power levels of the input signal.

OFF | 0
No pre-evaluation is performed, the entire signal is processed.

*RST: 1

Manual operation: See "Power Interval Search" on page 78

9.4.7 Tracking and Channel Estimation

[SENSe:]DEMod:CESTimation <State>

This command defines whether channel estimation will be done in preamble and payload or only in preamble. The effect of this is most noticeable for the EVM measurement results, where the results will be improved when this feature is enabled.

However, this functionality is not supported by the IEEE 802.11 standard and must be disabled if the results are to be measured strictly according to the standard.

Parameters:

<State> ON | OFF

ON
The channel estimation is performed in the preamble and the payload. The EVM results can be calculated more accurately.

OFF
The channel estimation is performed in the preamble as required in the standard.

*RST: OFF

Manual operation: See "Channel Estimation Range" on page 79

SENSe:TRACking:IQMComp <State>

Activates or deactivates the compensation for I/Q mismatch (gain imbalance, quadrature offset, I/Q skew, see chapter 3.1.5, "I/Q Mismatch", on page 16).

This setting is **not available for standards IEEE 802.11b and g (DSSS)**.

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 802.11-2012, IEEE 802.11ac-2013 WLAN standard

*RST: OFF

Example: `SENS:TRAC:IQMC ON`

Manual operation: See "I/Q Mismatch Compensation" on page 80

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 80

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 79

SENSe:TRACking:PILots <Mode>

In case tracking is used, the used pilot sequence has an effect on the measurement results.

Parameters:
<Mode> STANdard | DETected

STANdard
The pilot sequence is determined according to the corresponding WLAN standard. In case the pilot generation algorithm of the device under test (DUT) has a problem, the non-standard-conform pilot sequence might affect the measurement results, or the WLAN application might not synchronize at all onto the signal generated by the DUT.

DETected
The pilot sequence detected in the WLAN signal to be analyzed is used by the WLAN application. In case the pilot generation algorithm of the device under test (DUT) has a problem, the non-standard-conform pilot sequence will not affect the measurement results. In case the pilot sequence generated by the DUT is correct, it is recommended that you use the "According to Standard" setting because it generates more accurate measurement results.

*RST: STANdard

Example: `SENS:TRAC:PIL DET`

Manual operation: See "Pilots for Tracking" on page 80

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`

Manual operation: See "Timing Error Tracking" on page 79

9.4.8 Demodulation

The demodulation settings define which PPDUs are to be analyzed, thus they define a *logical filter*.

The available demodulation settings vary depending on the selected digital standard (see `CONFigure:STANdard` on page 112).

Manual configuration is described in chapter 5.7, "Demodulation", on page 80.

CONFigure:WLAN:EXTension:AUTO:TYPE <PPDUType>

Defines the PPDUs taking part in the analysis according to the Ness (Extension Spatial Streams) field content (for **IEEE 802.11n** standard only).

Parameters:

<PPDUType> FBURst | ALL | M0 | M1 | M2 | M3 | D0 | D1 | D2 | D3

The first PPDU is analyzed and subsequent PPDUs are analyzed only if they match

FBURst
The Ness field contents of the first PPDU is detected and subsequent PPDUs are analyzed only if they have the same Ness field contents (corresponds to "Auto, same type as first PPDU")

ALL
All recognized PPDUs are analyzed according to their individual Ness field contents (corresponds to "Auto, individually for each PPDU")

M0 | M1 | M2 | M3
Only PPDUs with the specified Ness value are analyzed.

D0 | D1 | D2| D3
All PPDUs are analyzed assuming the specified Ness value.

*RST: FBURst

Example: `CONF:WLAN:EXT:AUTO:TYPE M0`

Manual operation: See "Extension Spatial Streams (sounding)" on page 93

CONFigure:WLAN:GTIMe:AUTO <State>

This remote control command specifies whether the guard time of the input signal is automatically detected or specified manually (**IEEE 802.11n or ac** only).

Parameters:

<State>

ON

The guard time is detected automatically according to CONFigure:WLAN:GTIMe:AUTO:TYPE on page 138.

OFF

The guard time is defined by the CONFigure:WLAN:GTIMe:SELect command.

*RST: ON

Manual operation: See "Guard Interval Length" on page 83

CONFigure:WLAN:GTIMe:AUTO:TYPE <Type>

This remote control command specifies which PPDUs are analyzed depending on their guard length if automatic detection is used (`CONF:WLAN:GTIM:AUTO ON`, see CONFigure:WLAN:GTIMe:AUTO on page 137).

This command is available for **IEEE 802.11 n, ac** standards only.

Note: On previous Rohde & Schwarz signal and spectrum analyzers, this command configured both the guard interval type and the channel bandwidth. On the R&S VSE, this command only configures the guard type. The channel bandwidth of the PPDU to be measured must be configured separately using the [SENSe:]BANDwidth:CHANnel:AUTO:TYPE command.

Parameters:

<Type>

FBURst
The Gurad interval length of the first PPDU is detected and subsequent PPDUs are analyzed only if they have the same length (corresponds to "Auto, same type as first PPDU")

ALL
All PPDUs are analyzed regardless of their guard length (corresponds to "Auto, individually for each PPDU").

MS
Only PPDUs with short guard interval length are analyzed.
(corresponds to "Meas only Short" in manual operation; MN8 | MN16 parameters in previous Rohde & Schwarz signal and spectrum analyzers)

ML
Only PPDUs with long guard interval length are analyzed.
(corresponds to "Meas only Long" in manual operation; ML16 | ML32 parameters in previous Rohde & Schwarz signal and spectrum analyzers)

DS
All PPDUs are demodulated assuming short guard interval length.
(corresponds to "Demod all as short" in manual operation; DN8 | DN16 parameters in previous Rohde & Schwarz signal and spectrum analyzers)

DL
All PPDUs are demodulated assuming long guard interval length.
(corresponds to "Demod all as long" in manual operation; DL16 | DL32 parameters in previous Rohde & Schwarz signal and spectrum analyzers)

*RST: 'ALL'

Example: `CONF:WLAN:GTIM:AUTO:TYPE DL`

Manual operation: See "Guard Interval Length" on page 83

CONFigure:WLAN:GTIMe:SELect <GuardTime>

This remote control command specifies the guard time the PPDUs in the **IEEE 802.11n or ac** input signal should have. If the guard time is specified to be detected from the input signal using the `CONFigure:WLAN:GTIMe:AUTO` command then this command is query only and allows the detected guard time to be obtained.

Parameters:

<GuardTime> SHORt | NORMal

SHORt
Only the PPDUs with short guard interval are analyzed.

NORMal
Only the PPDUs with long guard interval are analyzed.
("Long" in manual operation)

*RST: NORMal

Example: `CONF:WLAN:GTIM:SEL SHOR`

Manual operation: See "Guard Interval Length" on page 83

CONFigure:WLAN:STBC:AUTO:TYPE <PPDUType>

This remote control command specifies which PPDUs are analyzed according to STBC streams (for **IEEE 802.11n, ac** standards only).

Parameters:

<PPDUType> FBURst | ALL | M0 | M1 | M2 | D0 | D1 | D2

FBURst
The STBC of the first PPDU is detected and subsequent PPDUs are analyzed only if they have the same STBC (corresponds to "Auto, same type as first PPDU")

ALL
All recognized PPDUs are analyzed according to their individual STBC (corresponds to "Auto, individually for each PPDU")

M0 | M1 | M2
Measure only if STBC field = 0 | 1 | 2
For details see "STBC Field" on page 87

D0 | D1 | D2
Demod all as STBC field = 0 | 1 | 2
For details see "STBC Field" on page 87

Example: `CONF:WLAN:STBC:AUTO:TYPE M0`

Manual operation: See "STBC Field" on page 87

[SENSe:]BANDwidth:CHANnel:AUTO:TYPE <Bandwidth>

This remote control command specifies the bandwidth in which the PPDUs are analyzed.

This command is only available for standards **IEEE 802.11a, ac, n**.

Note that channel bandwidths larger than 10 MHz require a bandwidth extension option on the instrument in use, see chapter A.3, "Sample Rate and Maximum Usable I/Q Bandwidth for RF Input", on page 217.

Parameters:

<Bandwidth> FBURst | ALL | MB5 | MB10 | MB20 | MB40 | MB80 | MB160 | DB5 | DB10 | DB20 | DB40 | DB80 | DB160

FBURSt
The channel bandwidth of the first valid PPDU is detected and subsequent PPDUs are analyzed only if they have the same channel bandwidth (corresponds to "Auto, same type as first PPDU")

ALL
All PPDUs are analyzed regardless of the channel bandwidth (corresponds to "Auto, individually for each PPDU")

MB5
Only PPDUs within a channel bandwidth of 5MHz are analyzed (**IEEE 802.11 a only**)

MB10
Only PPDUs within a channel bandwidth of 10MHz are analyzed (**IEEE 802.11 a only**)

MB20
Only PPDUs within a channel bandwidth of 20MHz are analyzed

MB40
Only PPDUs within a channel bandwidth of 40MHz are analyzed (**IEEE 802.11 n, ac only**)

MB80
Only PPDUs within a channel bandwidth of 80MHz are analyzed (**IEEE 802.11 ac only**)

MB160
Only PPDUs within a channel bandwidth of 160MHz are analyzed
(**IEEE 802.11 ac only**)

DB5
All PPDUs are analyzed within a channel bandwidth of 5MHz (**IEEE 802.11 a only**)

DB10
All PPDUs are analyzed within a channel bandwidth of 10MHz (**IEEE 802.11 a only**)

DB20
All PPDUs are analyzed within a channel bandwidth of 20MHz

DB40
All PPDUs are analyzed within a channel bandwidth of 40MHz (**IEEE 802.11 n, ac only**)

DB80
All PPDUs are analyzed within a channel bandwidth of 80MHz (**IEEE 802.11 n, ac only**)

DB160
All PPDUs are analyzed within a channel bandwidth of 160MHz

(**IEEE 802.11 n, ac only**)
*RST: FBURst

Example: `SENS:BAND:CHAN:AUTO:TYPE MB20`

Manual operation: See "Channel Bandwidth to measure (CBW)" on page 82

[SENSe:]DEMod:FORMat:BANalyze <Format>

Specifies which PSDUs are to be analyzed depending on their modulation. Only PSDUs using the selected modulation are considered in result analysis.

Note: to analyze all PPDUs that are identical to the first detected PPDU (corresponds to "Auto, same type as first PPDU"), use the command:
`SENS:DEMO:FORM:BANA:BTYP:AUTO:TYPE FBUR`.

To analyze all PPDUs regardless of their format and modulation (corresponds to "Auto, individually for each PPDU") , use the command:
`SENS:DEMO:FORM:BANA:BTYP:AUTO:TYPE ALL`.

See `[SENSe:]DEMod:FORMat:BANalyze:BTYPe:AUTO:TYPE` on page 143.

Parameters:
<Format> *RST: QAM64

Example: `SENS:DEMO:FORM:BAN 'BPSK6'`

Manual operation: See "PPDU Format to measure" on page 82
See "PSDU Modulation to use" on page 83
See "PSDU Modulation" on page 83
See "PPDU Format to measure / PSDU Modulation to use" on page 89
See "PPDU Format" on page 90

Table 9-2: Modulation format parameters for IEEE 802.11a, g (OFDM) standard

SCPI parameter	Dialog parameter
BPSK6	BPSK 1/2
BPSK9	BPSK 3/4
QPSK12	QPSK 1/2
QPSK18	QPSK 3/4
QAM1624	16-QAM 1/2
QAM1636	16-QAM 3/4
QAM6448	64-QAM 2/3
QAM6454	64-QAM 3/4

Table 9-3: Modulation format parameters for IEEE 802.11b or g (DSSS) standard

SCPI parameter	Dialog parameter
CCK11	Complementary Code Keying at 11 Mbps
CCK55	Complementary Code Keying at 5.5 Mbps
DBPSK1	Differential BI-Phase shift keying
DQPSK2	Differential Quadrature phase shift keying
PBCC11	PBCC at 11 Mbps
PBCC22	PBCC at 11 Mbps
PBCC55	PBCC at 5.5 Mbps

Table 9-4: Modulation format parameters for IEEE 802.11n standard

SCPI parameter	Dialog parameter
BPSK65	BI-Phase shift keying at 6.5 Mbps
BPSK72	BI-Phase shift keying at 7.2 Mbps
QAM1626	Quadrature Amplitude Modulation at 26 Mbps
QAM1639	Quadrature Amplitude Modulation at 39 Mbps
QAM16289	Quadrature Amplitude Modulation at 28.9 Mbps
QAM16433	Quadrature Amplitude Modulation at 43.3 Mbps
QAM6452	Quadrature Amplitude Modulation at 52 Mbps
QAM6465	Quadrature Amplitude Modulation at 65 Mbps
QAM16289	Quadrature Amplitude Modulation at 28.9 Mbps
QAM16433	Quadrature Amplitude Modulation at 43.3 Mbps
QAM64578	Quadrature Amplitude Modulation at 57.8 Mbps
QAM64585	Quadrature Amplitude Modulation at 58.5 Mbps
QAM64722	Quadrature Amplitude Modulation at 72.2 Mbps
QPSK13	Quadrature phase shift keying at 13 Mbps
QPSK144	Quadrature phase shift keying at 14.4 Mbps
QPSK195	Quadrature phase shift keying at 19.5 Mbps
QPSK217	Quadrature phase shift keying at 21.7 Mbps

[SENSe:]DEMod:FORMat:BANalyze:BTYPe:AUTO:TYPE <Analysis>

This remote control command specifies how signals are analyzed.

Parameters:

<Analysis> FBURst | ALL | MMIX | MGRF | DMIX | DGRF | MVHT | DVHT | MNHT | DNHT

FBURst
The format of the first valid PPDU is detected and subsequent PPDUs are analyzed only if they have the same format (corresponds to "Auto, same type as first PPDU")

ALL
All PPDUs are analyzed regardless of their format (corresponds to "Auto, individually for each PPDU")

MNHT
Only PPDUs with format "Non-HT" are analyzed
IEEE 802.11a, g (OFDM)

DNHT
All PPDUs are assumed to have the PPDU format "Non-HT"
IEEE 802.11a, g (OFDM)

MMIX
Only PPDUs with format "HT-MF" (Mixed) are analyzed
(IEEE 802.11 n)

MGRF
Only PPDUs with format "HT-GF" (Greenfield) are analyzed
(IEEE 802.11 n)

DMIX
All PPDUs are assumed to have the PPDU format "HT-MF"
(IEEE 802.11 n)

DGRF
All PPDUs are assumed to have the PPDU format "HT-GF"
(IEEE 802.11 n)

MVHT
Only PPDUs with format "VHT" are analyzed
(IEEE 802.11 ac)

DVHT
All PPDUs are assumed to have the PPDU format "VHT"
(IEEE 802.11 ac)

FMMM
Only PPDUs with specified format are analyzed (see `[SENSe:]DEMod:FORMat:BANalyze` on page 142)
(IEEE 802.11 b, g (DSSS))

FMMD
All PPDUs are assumed to have the specified PPDU format (see `[SENSe:]DEMod:FORMat:BANalyze` on page 142)
(IEEE 802.11 b, g (DSSS))

*RST: FBURst

Example: `SENS:DEM:FORM:BAN:BTYP:AUTO:TYPE FBUR`

Manual operation: See "PPDU Format to measure" on page 82
See "PSDU Modulation to use" on page 83
See "PPDU Format to measure / PSDU Modulation to use" on page 89

[SENSe:]DEMod:FORMat[:BCONtent]:AUTO <State>

This command determines whether the PPDUs to be analyzed are determined automatically or by the user.

Parameters:

<State>

ON
The signal field, i.e. the PLCP header field, of the first recognized PPDU is analyzed to determine the details of the PPDU. All PPDUs identical to the first recognized PPDU are analyzed.

OFF
Only PPDUs that match the user-defined PPDU type and modulation are considered in results analysis (see `[SENSe:]DEMod:FORMat:BANalyze:BTYPe:AUTO:TYPE` on page 143 and `[SENSe:]DEMod:FORMat:BANalyze` on page 142).

Manual operation: See "PPDU Analysis Mode" on page 81

[SENSe:]DEMod:FORMat:MCSindex <Index>

This command specifies the MCS index which controls the data rate, modulation and streams (for **IEEE 802.11n, ac** standards only, see document: IEEE 802.11n/D11.0 June 2009).

This command is required if `[SENSe:]DEMod:FORMat:MCSindex:MODE` is set to `MEAS` or `DEM`.

Parameters:

<Index> *RST: 1

Example:

```
SENS:DEM:FORM:MCS:MODE MEAS
SENS:DEM:FORM:MCS 1
```

Manual operation: See "MCS Index" on page 86

[SENSe:]DEMod:FORMat:MCSindex:MODE <Mode>

This command defines the PPDUs taking part in the analysis depending on their Modulation and Coding Scheme (MCS) index (for **IEEE 802.11n, ac** standards only).

Parameters:

<Mode> FBURst | ALL | MEASure | DEMod

FBURst
The MCS index of the first PPDU is detected and subsequent PPDUs are analyzed only if they have the same MCS index (corresponds to "Auto, same type as first PPDU")

ALL
All recognized PPDUs are analyzed according to their individual MCS indexes (corresponds to "Auto, individually for each PPDU")

MEASure
Only PPDUs with an MCS index which matches that specified by `[SENSe:]DEMod:FORMat:MCSindex` are analyzed

DEMod
All PPDUs will be analyzed according to the MCS index specified by `[SENSe:]DEMod:FORMat:MCSindex`.

*RST: FBURst

Example:

```
SENS:DEM:FORM:MCS:MODE MEAS
SENS:DEM:FORM:MCS 1
```

Manual operation: See "MCS Index to use" on page 86

[SENSe:]DEMod:FORMat:NSTSindex <Index>

Defines the the PPDUs taking part in the analysis depending on their Nsts.

This command is only available for the **IEEE 802.11 ac** standard.

This command is available for `DEM:FORM:NSTS:MODE MEAS` or `DEM:FORM:NSTS:MODE DEM` (see `[SENSe:]DEMod:FORMat:NSTSindex:MODE` on page 146).

Parameters:

<Index>

Example:

```
SENS:DEM:FORM:NSTS:MODE MEAS
SENS:DEM:FORM:NSTS 1
```

Manual operation: See "Nsts" on page 87

[SENSe:]DEMod:FORMat:NSTSindex:MODE <Mode>

Defines the the PPDUs taking part in the analysis depending on their Nsts.

This command is only available for the **IEEE 802.11 ac** standard.

Parameters:

<Mode> FBURst | ALL | MEASure | DEMod

FBURst
The Nsts of the first PPDU is detected and subsequent PPDUs are analyzed only if they have the same Nsts (corresponds to "Auto, same type as first PPDU")

ALL
All recognized PPDUs are analyzed according to their individual Nsts (corresponds to "Auto, individually for each PPDU")

MEASure
Only PPDUs with the Nsts specified by `[SENSe:]DEMod:FORMat:NSTSindex` are analyzed

DEMod
The "Nsts" index specified by `[SENSe:]DEMod:FORMat:NSTSindex`is used for all PPDUs.

*RST: FBURst

Example:
```
SENS:DEM:FORM:NSTS:MODE MEAS
SENS:DEM:FORM:NSTS 1
```

Manual operation: See "Nsts to use" on page 86

[SENSe:]DEMod:FORMat:SIGSymbol <State>

Activates and deactivates signal symbol field decoding.

For IEEE 802.11b this command can only be queried as the decoding of the signal field is always performed for this standard.

Parameters for setting and query:

<State> **OFF**
Deactivates signal symbol field decoding. All PPDUs are assumed to have the specified PPDU format / PSDU modulation, regardless of the actual format or modulation.

ON
If activated, the signal symbol field of the PPDU is analyzed to determine the details of the PPDU. Only PPDUs which match the PPDU type/ PSDU modulation defined by `[SENSe:]DEMod:FORMat:BANalyze` and `[SENSe:]DEMod:FORMat:BANalyze:BTYPe` are considered in results analysis.

*RST: OFF

Example:
```
DEM:FORM:SIGS ON
```

Manual operation: See "PPDU Format to measure / PSDU Modulation to use" on page 89

9.4.9 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.

CONFigure:BURSt:PVT:AVERage <Value>

Defines the number of samples used to adjust the length of the smoothing filter for PVT measurement.

This command is **only** available for **IEEE 802.11b, g (DSSS)** standards.

Parameters:
<Value>

Manual operation: See "PVT : Average Length" on page 98

CONFigure:BURSt:PVT:RPOWer <Mode>

This remote control command configures the use of either mean or maximum PPDU power as a reference power for the 802.11b, g (DSSS) PVT measurement.

Parameters:
<Mode> MEAN | MAXimum

Manual operation: See "PVT : Reference Power" on page 98

CONFigure:WLAN:PAYLoad:LENGth:SRC <Source>

Defines which payload length is used to determine the minimum or maximum number of required data symbols (**IEEE 802.11n, ac**).

Parameters:

<Source> ESTimate | HTSignal

ESTimate
Uses a length estimated from the input signal

HTSignal
(**IEEE811.02 n**)
Determines the length of the HT signal (from the signal field)

LSIGnal
(**IEEE811.02 ac**)
Determines the length of the L signal (from the signal field)

Manual operation: See "Source of Payload Length" on page 95

CONFigure:WLAN:PVERror:MRANge? <Range>

This remote control command queries whether the Peak Vector Error results are calculated over the complete PPDU or just over the PSDU.

This command is supported for **802.11b and 802.11g (DSSS)** only.

Return values:

<Range> ALL | PSDU

ALL
Peak Vector Error results are calculated over the complete PPDU

PSDU
Peak Vector Error results are calculated over the PSDU only

Usage: Query only

Manual operation: See "Peak Vector Error : Meas Range" on page 98

[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
```

Manual operation: See "PPDU Statistic Count / No of PPDUs to Analyze" on page 95

[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
```

Manual operation: See "PPDU Statistic Count / No of PPDUs to Analyze" on page 95

[SENSe:]BURSt:SELect <Value>

If single PPDU analysis is enabled (see `[SENSe:]BURSt:SELect:STATe` on page 150), the WLAN 802.11 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.

[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 WLAN 802.11 I/Q results are based on one individual PPDU only, namely the defined using `[SENSe:]BURSt:SELect` on page 150. 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.

[SENSe:]DEMod:FORMat:BANalyze:DBYTes:EQUal <State>

For **IEEE 802.11b and g (DSSS)** signals only:

If **enabled**, only PPDUs with a **specific** payload length are considered for measurement analysis.

If **disabled**, only PPDUs whose length is within a specified **range** are considered.

The payload length is specified by the `[SENSe:]DEMod:FORMat:BANalyze:DBYTes:MIN` command.

A payload length **range** is defined as a minimum and maximum number of symbols the payload may contain (see `[SENSe:]DEMod:FORMat:BANalyze:DBYTes:MAX` on page 151 and `[SENSe:]DEMod:FORMat:BANalyze:DBYTes:MIN`).

Parameters:

<State> ON | OFF

*RST: OFF

Manual operation: See "Equal PPDU Length" on page 96

[SENSe:]DEMod:FORMat:BANalyze:DBYTes:MAX <NumDataBytes>

If the `[SENSe:]DEMod:FORMat:BANalyze:DBYTes:EQUal` command is set to **false**, this command specifies the maximum number of data bytes allowed for a PPDU to take part in measurement analysis.

If the `[SENSe:]DEMod:FORMat:BANalyze:DBYTes:EQUal` command is set to **true**, then this command has no effect.

Parameters:

<NumDataBytes> *RST: 64

Default unit: bytes

Manual operation: See "(Min./Max.) Payload Length" on page 98

[SENSe:]DEMod:FORMat:BANalyze:DBYTes:MIN <NumDataBytes>

For **IEEE 802.11b and g (DSSS)** signals only:

If the `[SENSe:]DEMod:FORMat:BANalyze:DBYTes:EQUal` command is set to **true**, then this command specifies the exact number of data bytes a PPDU must have to take part in measurement analysis.

If the `[SENSe:]DEMod:FORMat:BANalyze:DBYTes:EQUal` command is set to **false**, this command specifies the minimum number of data bytes required for a PPDU to take part in measurement analysis.

Parameters:

<NumDataBytes> *RST: 1

Default unit: bytes

Manual operation: See "(Min./Max.) Payload Length" on page 98

[SENSe:]DEMod:FORMat:BANalyze:DURation:EQUal <State>

For **IEEE 802.11b and g (DSSS)** signals only:

If **enabled**, only PPDUs with a **specific** duration are considered for measurement analysis.

If **disabled**, only PPDUs whose duration is within a specified **range** are considered.

The duration is specified by the `[SENSe:]DEMod:FORMat:BANalyze:DURation:MIN` command.

A duration **range** is defined as a minimum and maximum duration the PPDU may have (see `[SENSe:]DEMod:FORMat:BANalyze:DURation:MAX` and `[SENSe:]DEMod:FORMat:BANalyze:DURation:MIN`).

Parameters:

<State> ON | OFF
*RST: OFF

Manual operation: See "Equal PPDU Length" on page 96

[SENSe:]DEMod:FORMat:BANalyze:DURation:MAX <Duration>

For **IEEE 802.11b and g (DSSS)** signals only:

If the `[SENSe:]DEMod:FORMat:BANalyze:DURation:EQUal` command is set to **false**, this command specifies the maximum number of symbols allowed for a PPDU to take part in measurement analysis.

If the `[SENSe:]DEMod:FORMat:BANalyze:DURation:EQUal` command is set to **true**, then this command has no effect.

Parameters:

<Duration> *RST: 5464
Default unit: us

Manual operation: See "(Min./Max.) Payload Length" on page 98

[SENSe:]DEMod:FORMat:BANalyze:DURation:MIN <Duration>

For **IEEE 802.11b and g (DSSS)** signals only:

If the `[SENSe:]DEMod:FORMat:BANalyze:DURation:EQUal` command is set to **true** then this command specifies the **exact** duration required for a PPDU to take part in measurement analysis.

If the `[SENSe:]DEMod:FORMat:BANalyze:DURation:EQUal` command is set to **false** this command specifies the **minimum** duration required for a PPDU to take part in measurement analysis.

Parameters:

<Duration> *RST: 1
Default unit: us

Manual operation: See "(Min./Max.) Payload Length" on page 98

[SENSe:]DEMod:FORMat:BANalyze:SYMBols:EQUal <State>

For **IEEE 802.11a, ac, g (OFDM), n** signals only:

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 153 and `[SENSe:]DEMod:FORMat:BANalyze:SYMBols:MIN` on page 153).

Parameters:

<State> ON | OFF

*RST: OFF

Manual operation: See "Equal PPDU Length" on page 96

[SENSe:]DEMod:FORMat:BANalyze:SYMBols:MAX <NumDataSymbols>

For **IEEE 802.11a, ac, g (OFDM), n** signals only:

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

Manual operation: See "(Min./Max.) No. of Data Symbols" on page 96

[SENSe:]DEMod:FORMat:BANalyze:SYMBols:MIN <NumDataSymbols>

For **IEEE 802.11a, ac, g (OFDM), n** signals only:

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
```

Manual operation: See "(Min./Max.) No. of Data Symbols" on page 96

9.4.10 Limits

The following commands are required to define the limits against which the individual parameter results are checked. Principally, the limits are defined in the WLAN 802.11 standards. However, you can change the limits for your own test cases and reset the limits to the standard values later. Note that changing limits is currently only possible via remote control, not manually via the user interface.

The commands required to retrieve the limit check results are described in chapter 9.6.1.3, "Limit Check Results", on page 181.

Useful commands for defining limits described elsewhere:

- UNIT:EVM on page 181
- UNIT:GIMBalance on page 181

Remote commands exclusive to defining limits:

CALCulate:LIMit:BURSt:ALL <Limits>

This command sets or returns the limit values for the parameters determined by the default WLAN measurement all in one step.

(see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11).

To define individual limit values use the individual `CALCulate<n>:LIMit<k>:BURSt...` commands.

Note that the units for the EVM and gain imbalance parameters must be defined in advance using the following commands:

- `UNIT:EVM` on page 181
- `UNIT:GIMBalance` on page 181

Parameters:

<Limits>	The parameters are input or output as a list of (ASCII) values separated by ',' in the following order: <average CF error>, <max CF error>, <average symbol clock error>, <max symbol clock error>, <average I/Q offset>, <maximum I/Q offset>, <average EVM all carriers>, <max EVM all carriers>, <average EVM data carriers>, <max EVM data carriers> <average EVM pilots>, <max EVM pilots>

CALCulate:LIMit:BURSt:EVM:ALL[:AVERage] <Limit>
CALCulate:LIMit:BURSt:EVM:ALL:MAXimum <Limit>

This command sets or queries the average or maximum error vector magnitude limit for all carriers as determined by the default WLAN measurement.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Parameters:

<Limit>	numeric value in dB The unit for the EVM parameters can be changed in advance using `UNIT:EVM` on page 181. Default unit: DB

CALCulate:LIMit:BURSt:EVM:DATA[:AVERage] <Limit>
CALCulate:LIMit:BURSt:EVM:DATA:MAXimum <Limit>

This command sets or queries the average or maximum error vector magnitude limit for the data carrier determined by the default WLAN measurement.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Parameters:

<Limit>	numeric value in dB The unit for the EVM parameters can be changed in advance using `UNIT:EVM` on page 181. Default unit: DB

CALCulate:LIMit:BURSt:EVM:PILot[:AVERage] <Limit>
CALCulate:LIMit:BURSt:EVM:PILot:MAXimum <Limit>

This command sets or queries the average or maximum error vector magnitude limit for the pilot carriers determined by the default WLAN measurement.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Parameters:

<Limit> numeric value in dB
The unit for the EVM parameters can be changed in advance using `UNIT:EVM` on page 181.
Default unit: DB

CALCulate:LIMit:BURSt:FERRor[:AVERage] <Limit>
CALCulate:LIMit:BURSt:FERRor:MAXimum <Limit>

This command sets or queries the average or maximum center frequency error limit determined by the default WLAN measurement.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Parameters:

<Limit> numeric value in Hertz
Default unit: HZ

CALCulate:LIMit:BURSt:IQOFfset[:AVERage] <Limit>
CALCulate:LIMit:BURSt:IQOFfset:MAXimum <Limit>

This command sets or queries the average or maximum I/Q offset error limit determined by the default WLAN measurement..

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Parameters:

<Limit> Range: -1000000 to 1000000
Default unit: DB

CALCulate:LIMit:BURSt:SYMBolerror[:AVERage] <Limit>
CALCulate:LIMit:BURSt:SYMBolerror:MAXimum <Limit>

This command sets or queries the average or maximum symbol clock error limit determined by the default WLAN measurement.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Parameters:

<Limit>	numeric value in parts per million Default unit: PPM

9.5 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 the R&S VSE Base Software User Manual.

The suffix <n> in the following remote commands represents the window (1..x) in the currently selected measurement channel.

9.5.1 Configuring the Result Display

The commands required to configure the screen display in a remote environment are described here.

9.5.1.1 Global Layout Commands

The following commands are required to change the evaluation type and rearrange the screen layout across measurement channels as you do in manual operation.

For compatibility with other Rohde & Schwarz Signal and Spectrum Analyzers, the layout commands described in chapter 9.5.1.2, "Working with Windows in the Display", on page 161 are also supported. Note, however, that the commands described there only allow you to configure the layout within the *active* measurement channel.

LAYout:GLOBal:ADD[:WINDow]? <ExChanName>,<ExWinName>,<Direction>,<NewChanName>,<NewWinType>

This command adds a window to the display next to an existing window. The new window may belong to a different channel than the existing window.

To replace an existing window, use the `LAYout:GLOBal:REPLace[:WINDow]` command.

Parameters:

<ExChanName> string
Name of an existing channel

<ExWinName> string
Name of the existing window within the <ExChanName> channel 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:GLOBal:IDENtify[:WINDow]?` query.

<Direction> LEFT | RIGHt | ABOVe | BELow | TAB
Direction the new window is added relative to the existing window.
TAB
The new window is added as a new tab in the specified existing window.

<NewChanName> string
Name of the channel for which a new window is to be added.

<NewWinType> string
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:
```
LAYout:GLOBal:ADD:WINDow? 'IQ
Analyzer','1',RIGH,'IQ Analyzer2','FREQ'
```
Adds a new window named 'Spectrum' with a Spectrum display to the right of window 1 in the channel 'IQ Analyzer'.

Usage: Query only

Table 9-5: <WindowType> parameter values for WLAN application

Parameter value	Window type
BITStream	Bitstream
CMEMory	Magnitude Capture
CONStellation	Constellation
CVCarrier	Constellation vs Carrier (**IEEE 802.11a, ac, g (OFDM), n** only)

Parameter value	Window type
EVCarrier	EVM vs Carrier (**IEEE 802.11a, ac, g (OFDM), n** only)
EVCHip	EVM vs Chip (**IEEE 802.11b and g (DSSS)** only)
EVSYmbol	EVM vs Symbol (**IEEE 802.11a, ac, g (OFDM), n** only)
FSPectrum	FFT Spectrum
GDELay	Group Delay (**IEEE 802.11a, ac, g (OFDM), n** only)
PFPPdu	PvT Full PPDU
RSDetailed	Result Summary Detailed (**IEEE 802.11a, ac, g (OFDM), n** only)
RSGLobal	Result Summary Global
SFIeld	Signal Field (**IEEE 802.11a, ac, g (OFDM), n**) PLCP Header (**IEEE 802.11b and g (DSSS)**)
SFLatness	Spectrum Flatness (**IEEE 802.11a, ac, g (OFDM), n** only)

LAYout:GLOBal:CATalog[:WINDow]?

This command queries the name and index of all active windows from top left to bottom right for each active channel. The result is a comma-separated list of values for each window, with the syntax:

<ChannelName_1>: <WindowName_1>,<WindowIndex_1>..<WindowName_n>,<WindowIndex_n>

..

<ChannelName_m>: <WindowName_1>,<WindowIndex_1>..<WindowName_n>,<WindowIndex_n>

Return values:

<ChannelName> String containing the name of the channel. The channel name is displayed as the tab label for the measurement channel.

<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:GLOB:CAT?`
Result:
`IQ Analyzer: '1',1,'2',2`
`Analog Demod: '1',1,'4',4`
For the I/Q Analyzer channel, two windows are displayed, named '2' (at the top or left), and '1' (at the bottom or right).
For the Analog Demodulation channel, two windows are displayed, named '1' (at the top or left), and '4' (at the bottom or right).

Usage: Query only

LAYout:GLOBal:IDENtify[:WINDow]? <ChannelName>,<WindowName>

This command queries the **index** of a particular display window in the specified channel.

Note: to query the **name** of a particular window, use the `LAYout:WINDow<n>:IDENtify?` query.

Parameters:

<ChannelName> String containing the name of the channel. The channel name is displayed as the tab label for the measurement channel.

Query parameters:

<WindowName> String containing the name of a window.

Return values:

<WindowIndex> Index number of the window.

Example:
```
LAYout:GLOBal:ADD:WINDow? IQ,'1',RIGH,
'Spectrum',FREQ
```
Adds a new window named 'Spectrum' with a Spectrum display to the right of window 1.

Example:
```
LAYout:GLOBal:IDENtify? 'IQ Analyzer',
'Spectrum'
```
Result:
```
2
```
Window index is: 2.

Usage: Query only

LAYout:GLOBal:REMove[:WINDow] <ChannelName>,<WindowName>

This command removes a window from the display.

Parameters:

<ChannelName> String containing the name of the channel.

<WindowName> String containing the name of the window.

Usage: Event

LAYout:GLOBal:REPLace[:WINDow]
<ExChannelName>,<WindowName>,<NewChannelName>,<WindowType>

This command replaces the window type (for example from "Diagram" to "Result Summary") of an already existing window while keeping its position, index and window name.

To add a new window, use the `LAYout:GLOBal:ADD[:WINDow]?` command.

Parameters:

<ExChannelName> String containing the name of the channel in which a window is to be replaced. The channel name is displayed as the tab label for the measurement channel.

<WindowName> String containing the name of the existing window.
To determine the name and index of all active windows, use the `LAYout:GLOBal:CATalog[:WINDow]?` query.

<NewChannelName> String containing the name of the channel for which a new window will be created.

<WindowType> Type of result display you want to use in the existing window.
Note that the window type must be valid for the specified channel (<NewChannelName>).
See `LAYout:ADD[:WINDow]?` on page 161 for a list of available window types.

Example:
```
LAY:GLOB:REPL:WIND 'IQ Analyzer','1',
'AnalogDemod',MTAB
```
Replaces the I/Q Analyzer result display in window 1 by a marker table for the AnalogDemod channel.

9.5.1.2 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.

Note that the suffix <n> always refers to the window *in the currently selected measurement channel*.

To configure the layout of windows across measurement channels, use the chapter 9.5.1.1, "Global Layout Commands", on page 157.

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. Note that the window type must be valid for the active measurement channel. To create a window for a different measurement channel use the LAYout:GLOBal:REPLace[:WINDow] command.

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 20
See "Constellation" on page 21
See "Constellation vs Carrier" on page 22
See "EVM vs Carrier" on page 23
See "EVM vs Symbol" on page 24
See "FFT Spectrum" on page 24
See "Group Delay" on page 25
See "Magnitude Capture" on page 26
See "PLCP Header (IEEE 802.11b, g (DSSS)" on page 26
See "PvT Full PPDU" on page 28
See "Result Summary Detailed" on page 28
See "Result Summary Global" on page 29
See "Signal Field" on page 31
See "Spectrum Flatness" on page 34

Table 9-6: <WindowType> parameter values for WLAN application

Parameter value	Window type
Window types for I/Q data	
BITStream	Bitstream

Parameter value	Window type
CMEMory	Magnitude Capture
CONStellation	Constellation
CVCarrier	Constellation vs Carrier (**IEEE 802.11a, ac, g (OFDM), n** only)
EVCarrier	EVM vs Carrier (**IEEE 802.11a, ac, g (OFDM), n** only)
EVCHip	EVM vs Chip (**IEEE 802.11b and g (DSSS)** only)
EVSYmbol	EVM vs Symbol (**IEEE 802.11a, ac, g (OFDM), n** only)
FSPectrum	FFT Spectrum
GDELay	Group Delay (**IEEE 802.11a, ac, g (OFDM), n** only)
PFPPdu	PvT Full PPDU
RSDetailed	Result Summary Detailed (**IEEE 802.11a, ac, g (OFDM), n** only)
RSGLobal	Result Summary Global
SFIeld	Signal Field (**IEEE 802.11a, ac, g (OFDM), n**) PLCP Header (**IEEE 802.11b and g (DSSS)**)
SFLatness	Spectrum Flatness (**IEEE 802.11a, ac, g (OFDM), n** only)

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>

To query the name and index of all windows in all measurement channels use the `LAYout:GLOBal:CATalog[:WINDow]?` command.

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.

To query the index of a window in a different measurement channel use the `LAYout:GLOBal:IDENtify[:WINDow]?` command.

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.

To remove a window for a different measurement channel use the `LAYout:GLOBal:REMove[:WINDow]` command.

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 161 for a list of available window types.
Note that the window type must be valid for the active measurement channel. To create a window for a different measurement channel use the LAYout:GLOBal:REPLace[:WINDow] command.

Example: `LAY:REPL:WIND '1',MTAB`
Replaces the result display in window 1 with a marker table.

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 161 for a list of available window types.
Note that the window type must be valid for the active measurement channel. To create a window for a different measurement channel use the LAYout:GLOBal:ADD[:WINDow]? command.

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.

To remove a window in a different measurement channel use the `LAYout:GLOBal: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 161 for a list of available window types.
Note that the window type must be valid for the active measurement channel. To create a window for a different measurement channel use the `LAYout:GLOBal:REPLace[:WINDow]` command.

Example: `LAY:WIND2:REPL MTAB`
Replaces the result display in window 2 with a marker table.

9.5.1.3 General Window Commands

The following commands are required to work with windows, independently of the application.

Note that the suffix <n> always refers to the window *in the currently selected measurement channel*.

DISPlay[:WINDow<n>]:SELect

This command sets the focus on the selected result display window.

This window is then the active window.

Example: DISP:WIND1:SEL
Sets the window 1 active.

Usage: Setting only

9.5.2 Result Display Commands for Compatibility

The following commands can also be used to change the type of result displays for the R&S VSE WLAN application. They are maintained for compatibility reasons, for example when re-using existing remote control programs for previous Rohde & Schwarz signal and spectrum analyzers. For new programs, use the LAYout commands to change the display (see chapter 9.5.1, "Configuring the Result Display", on page 157.

Note that the CONF:BURS:<ResultType>:IMM commands change the screen layout to display the Magnitude Capture buffer in window 1 and the selected result type in window 2 for the WLAN 802.11 channel. Any other active windows are closed.

CONFigure:BURSt:CONSt:CCARrier[:IMMediate]

This remote control command configures the result display type of window 2 to be Constellation vs Carrier.

Usage: Event

Manual operation: See "Constellation vs Carrier" on page 22

CONFigure:BURSt:CONSt:CSYMbol[:IMMediate]

This remote control command configures the result display type of window 2 to be Constellation (vs Symbol).

Usage: Event

Manual operation: See "Constellation" on page 21

CONFigure:BURSt:EVM:ECARrier[:IMMediate]

This remote control command configures the result display type of window 2 to be EVM vs Carrier.

Usage: Event

Manual operation: See "EVM vs Carrier" on page 23

CONFigure:BURSt:EVM:ESYMbol[:IMMediate] (IEEE 802.11b and g (DSSS))
CONFigure:BURSt:EVM:ECHip[:IMMediate]

Both of these commands configure the measurement type to be EVM vs Chip for **IEEE 802.11b and g (DSSS)** standards. For compatibility reasons, the `CONFigure:BURSt:EVM:ESYMbol[:IMMediate]` command is also supported for the IEEE 802.11b and g (DSSS) standards. However, for new remote control programs use the `LAYout` commands (see chapter 9.5.1.2, "Working with Windows in the Display", on page 161).

CONFigure:BURSt:EVM:ESYMbol[:IMMediate]

This remote control command configures the measurement type to be EVM vs Symbol.

For **IEEE 802.11b and g (DSSS)** standards, this command selects the EVM vs Chip result display.

Usage: Event

Manual operation: See "EVM vs Symbol" on page 24

CONFigure:BURSt:PVT[:IMMediate]

This remote control command configures the measurement type to be Power vs Time.

Manual operation: See "PvT Full PPDU" on page 28

CONFigure:BURSt:SPECtrum:FFT[:IMMediate]

This remote control command configures the result display type of window 2 to be FFT Spectrum.

Usage: Event

Manual operation: See "FFT Spectrum" on page 24

CONFigure:BURSt:SPECtrum:FLATness:SELect <MeasType>

This remote control command configures result display type of window 2 to be either Spectrum Flatness or Group Delay.

Parameters:

<MeasType> FLATness | GRDelay

Example: `CONF:BURS:SPEC:FLAT:SEL FLAT`
Configures the result display of window 2 to be Spectrum Flatness.
`CONF:BURS:SPEC:FLAT:IMM`
Performs a default WLAN measurement. When the measurement is completed, the Spectrum Flatness results are displayed.

Usage: Event

Manual operation: See "Group Delay" on page 25
See "Spectrum Flatness" on page 34

CONFigure:BURSt:SPECtrum:FLATness[:IMMediate]

This remote control command configures the result display in window 2 to be Spectrum Flatness or Group Delay, depending on which result display was selected last using `CONFigure:BURSt:SPECtrum:FLATness:SELect` on page 169.

Example: `CONF:BURS:SPEC:FLAT:SEL FLAT`
Configures the result display of window 2 to be Spectrum Flatness.
`CONF:BURS:SPEC:FLAT:IMM`
Performs a default WLAN measurement. When the measurement is completed, the Spectrum Flatness results are displayed.

Usage: Event

Manual operation: See "Group Delay" on page 25
See "Spectrum Flatness" on page 34

CONFigure:BURSt:STATistics:BSTReam[:IMMediate]

This remote control command configures the result display type of window 2 to be Bitstream.

Usage: Event

Manual operation: See "Bitstream" on page 20

CONFigure:BURSt:STATistics:SFIeld[:IMMediate]

This remote control command configures the result display type of window 2 to be Signal Field.

Usage: Event

Manual operation: See "PLCP Header (IEEE 802.11b, g (DSSS)" on page 26
See "Signal Field" on page 31

DISPlay[:WINDow<n>]:SELect

This command sets the focus on the selected result display window.

This window is then the active window.

Example: `DISP:WIND1:SEL`
Sets the window 1 active.

Usage: Setting only

9.5.3 Selecting Items to Display in Result Summary

The following command defines which items are displayed in the Result Summary.

DISPlay[:WINDow<n>]:TABLe:ITEM <Item>,<State>

Defines which items are *displayed* in the Result Summary

(see "Result Summary Detailed" on page 28 and "Result Summary Global" on page 29)

Note that the results are always *calculated*, regardless of their visibility in the Result Summary.

Parameters:

<Item> Item to be included in Result Summary. For an overview of possible results and the required parameters see the tables below.

<State> ON | OFF

ON
Item is displayed in Result Summary.

OFF
Item is not displayed in Result Summary.

*RST: ON

Table 9-7: Parameters for the items of the "Result Summary Detailed"

Result in table	SCPI parameter
TX channel ("Tx All")	TALL
I/Q offset	IOFSset
Gain imbalance	GIMBalance
Quadrature offset	QOFFset
PPDU power	TPPower
Crest factor	TCFactor
Receive channel ("Rx All")	RALL

Result in table	SCPI parameter
PPDU power	RPPower
Crest factor	RCFactor
Bitstream ("Stream All")	SALL
Pilot bit error rate	BPILot
EVM all carriers	SEACarriers
EVM data carriers	SEDCarriers
EVM pilot carriers	SEPCarriers

Table 9-8: Parameters for the items of the "Result Summary Global"

Result in table	SCPI parameter
Pilot bit error rate	PBERate
EVM all carriers	EACarriers
EVM data carriers	EDCarriers
EVM pilot carriers	EPCarriers
Center frequency error	CFERror
Symbol clock error	SCERror

9.5.4 Configuring the Spectrum Flatness and Group Delay Result Displays

The following command is only relevant for the Spectrum Flatness and Group Delay result displays.

CONFigure:BURSt:SPECtrum:FLATness:CSELect <ChannelType>

This remote control command configures the Spectrum Flatness and Group Delay results to be based on either effective or physical channels. This command is only valid for IEEE 802.11n and IEEE 802.11ac standards.

While the physical channels cannot always be determined, the effective channel can always be estimated from the known training fields. Thus, for some PPDUs or measurement scenarios, only the results based on the mapping of the space-time stream to the Rx antenna (effective channel) are available, as the mapping of the Rx antennas to the Tx antennas (physical channel) could not be determined.

Parameters:

<ChannelType> EFFective | PHYSical

*RST: EFF

Example: `CONF:BURS:SPEC:FLAT:CSEL PHYS`

Configures the Spectrum Flatness and Group Delay result displays to calculate the results based on the physical channel.

Usage: Event

9.6 Retrieving Results

The following commands are required to retrieve the results from a WLAN measurement in a remote environment.

Before retrieving measurement results, check if PPDU synchronization was successful or not by checking the status register (see chapter 9.8.1, "The STATus:QUEStionable:SYNC Register", on page 200). If no PPDUs were found, `STAT:QUES:SYNC:COND?` returns 0 (see `STATus:QUEStionable:SYNC:CONDition?` on page 202).

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.

9.6.1 Numeric Modulation Accuracy, Flatness and Tolerance Results

The following commands describe how to retrieve the numeric results from the standard WLAN measurements.

9.6.1.1 PPDU and Symbol Count Results

The following commands are required to retrieve PPDU and symbol count results from the WLAN I/Q measurement on the captured I/Q data (see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11).

FETCh:BURSt:COUNt?

This command returns the number of analyzed PPDUs from the current capture buffer. If multiple measurements are required because the number of PPDUs to analyze is greater than the number of PPDUs that can be captured in one buffer, this command only returns the number of captured PPDUs *in the current capture buffer* (as opposed to `FETCh:BURSt:COUNt:ALL?`).

Usage: Query only

FETCh:BURSt:COUNt:ALL?

This command returns the number of analyzed PPDUs for the entire measurement. If multiple measurements are required because the number of PPDUs to analyze is greater than the number of PPDUs that can be captured in one buffer, this command returns the number of analyzed PPDUs in *all* measurements (as opposed to `FETCh:BURSt:COUNt?`.

Usage: Query only

FETCh:SYMBol:COUNt?

This command returns the number of symbols in each analyzed PPDU as a comma separated list. The length of the list corresponds to the number of PPDUs, i.e. the result of `FETCh:BURSt:COUNt:ALL?`.

Usage: Query only

FETCh:BURSt:LENGths?

This command returns the length of the analyzed PPDUs from the current measurement. If the number of PPDUs to analyze is greater than the number of PPDUs that can be captured in one buffer, this command only returns the lengths of the PPDUs *in the current capture buffer*.

The result is a comma-separated list of lengths, one for each PPDU.

Return values:
<PPDULength> Length of the PPDU in the unit specified by the `UNIT:BURSt` command.

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 or symbols (depending on the UNIT:BURSt command) indicating the start position of each PPDU.

Usage: Query only

UNIT:BURSt <Unit>

This command specifies the units for PPDU length results (see FETCh:BURSt:LENGths? on page 173).

Parameters:

<Unit> SYMBol | SAMPle

*RST: SYMBol

9.6.1.2 Error Parameter Results

The following commands are required to retrieve individual results from the WLAN I/Q measurement on the captured I/Q data (see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11).

FETCh:BURSt:ALL

This command returns all results from the default WLAN measurement (Modulation Accuracy, Flatness and Tolerance

(see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11).

The results are output as a list of result strings separated by commas in ASCII format. The results are output in the following order:

<Global Result>, <Stream 1 result> ... <Stream n result>

Return values:

<Global Result> <preamble power>, <payload power>, <peak power>,
<min rms power>, <avg rms power>, <max rms power>,
'nan','nan','nan',
<min freq error>,<avg freq error>, <max freq error>,
<min symbol error>, <avg symbol error>, <max symbol error>,
'nan','nan','nan',
'nan','nan','nan',
'nan','nan','nan',
<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>
'nan','nan','nan',
'nan','nan','nan',
'nan','nan','nan',
'nan','nan','nan',

<Stream Results> 'nan','nan','nan',
'nan','nan','nan',
<peak power>,
<min rms power>, <avg rms power>, <max rms power>,
<min crest factor>,<avg crest factor>,<max crest factor>,
<min freq error>,<avg freq error>, <max freq error>,
<min symbol error>, <avg symbol error>, <max symbol error>,
<min IQ offset>, <avg IQ offset>, <max IQ offset>,
<min gain imb>, <avg gain imb>, <max gain imb>,
<min quad offset>, <avg quad offset>, <max quad offset>,
<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 BER>, <avg BER >, <max BER>
<min IQ skew>, <avg IQ skew>, <max IQ skew>
<min MIMO CP>, <avg MIMO CP>, <max MIMO CP>
<min CPE>, <avg CPE>, <max CPE>

Manual operation: See "Result Summary Detailed" on page 28
See "Result Summary Global" on page 29

FETCh:BURSt:CRESt[:AVERage]?
FETCh:BURSt:CRESt:MAXimum?
FETCh:BURSt:CRESt:MINimum?

This command returns the average, maximum or minimum determined CREST factor (= ratio of peak power to average power) in dB.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Usage: Query only

FETCh:BURSt:EVM:ALL:AVERage?
FETCh:BURSt:EVM:ALL:MAXimum?
FETCh:BURSt:EVM:ALL:MINimum?

This command returns the average, maximum or minimum EVM in dB. This is a combined figure that represents the pilot, data and the free carrier.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Return values:

<Result>	<Global Result>, <Stream 1 result> ... <Stream n result>
Usage:	Query only

FETCh:BURSt:EVM:DATA:AVERage?
FETCh:BURSt:EVM:DATA:MAXimum?
FETCh:BURSt:EVM:DATA:MINimum?

This command returns the average, maximum or minimum EVM for the data carrier in dB.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Return values:

<Result>	<Global Result>, <Stream 1 result> ... <Stream n result>
Usage:	Query only

FETCh:BURSt:EVM:DIRect:AVERage?
FETCh:BURSt:EVM:DIRect:MAXimum?
FETCh:BURSt:EVM:DIRect:MINimum?

This command returns the average, maximum or minimum EVM in dB for the IEEE 802.11b standard. This result is the value after filtering.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Usage: Query only

FETCh:BURSt:EVM:PILot:AVERage?
FETCh:BURSt:EVM:PILot:MAXimum?
FETCh:BURSt:EVM:PILot:MINimum?

This command returns the average, maximum or minimum EVM in dB for the pilot carrier.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Return values:

<Result>	<Global Result>, <Stream 1 result> ... <Stream n result>

Usage: Query only

FETCh:BURSt:EVM[:IEEE]:AVERage?
FETCh:BURSt:EVM[:IEEE]:MAXimum?
FETCh:BURSt:EVM[:IEEE]:MINimum?

This command returns the average, maximum or minimum EVM in dB for the IEEE 802.11b standard. This result is the value before filtering.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Usage: Query only

FETCh:BURSt:CFERror:AVERage
FETCh:BURSt:CFERror:MAXimum
FETCh:BURSt:CFERror:MINimum
FETCh:BURSt:FERRor:AVERage?
FETCh:BURSt:FERRor:MAXimum?
FETCh:BURSt:FERRor:MINimum?

This command returns the average, maximum or minimum center frequency errors in Hertz.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Return values:

<Result> <Global Result>, <Stream 1 result> ... <Stream n result>

Usage: Query only

FETCh:BURSt:GIMBalance:AVERage?
FETCh:BURSt:GIMBalance:MAXimum?
FETCh:BURSt:GIMBalance:MINimum?

This command returns the average, maximum or minimum I/Q imbalance in dB.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Usage: Query only

FETCh:BURSt:IQOFfset:AVERage?
FETCh:BURSt:IQOFfset:MAXimum?
FETCh:BURSt:IQOFfset:MINimum?

This command returns the average, maximum or minimum I/Q offset in dB.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Usage: Query only

FETCh:BURSt:EVM:ALL:AVERage?
FETCh:BURSt:EVM:ALL:MAXimum?
FETCh:BURSt:EVM:ALL:MINimum?

This command returns the average, maximum or minimum I/Q skew in picoseconds.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Usage: Query only

FETCh:BURSt:PAYLoad[:AVERage]?
FETCh:BURSt:PAYLoad:MINimum?
FETCh:BURSt:PAYLoad:MAXimum?

This command returns the average, maximum or minimum of the "Payload Power per PPDU" (in dBm). All analyzed PPDUs, up to the statistic length, take part in the statistical evaluation.

Usage: Query only

FETCh:BURSt:PEAK[:AVERage]?
FETCh:BURSt:PEAK:MINimum?
FETCh:BURSt:PEAK:MAXimum?

This command returns the average, maximum or minimum of the "Peak Power per PPDU" (in dBm). All analyzed PPDUs, up to the statistic length, take part in the statistical evaluation.

Usage: Query only

FETCh:BURSt:PREamble[:AVERage]?
FETCh:BURSt:PREamble:MINimum?
FETCh:BURSt:PREamble:MAXimum?

This command returns the average, maximum or minimum of the "Preamble Power per PPDU" (in dBm). All analyzed PPDUs, up to the statistic length, take part in the statistical evaluation.

Usage: Query only

FETCh:BURSt:QUADoffset:AVERage?
FETCh:BURSt:QUADoffset:MAXimum?
FETCh:BURSt:QUADoffset:MINimum?

This command returns the average, maximum or minimum quadrature offset of symbols within a PPDU. This value indicates the phase accuracy.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Usage: Query only

FETCh:BURSt:RMS[:AVERage]?
FETCh:BURSt:RMS:MAXimum?
FETCh:BURSt:RMS:MINimum?

This command returns the average, maximum or minimum RMS power in dBm for all analyzed PPDUs.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Return values:

<Result> <Global Result>, <Stream 1 result> ... <Stream n result>

Usage: Query only

FETCh:BURSt:SYMBolerror:AVERage?
FETCh:BURSt:SYMBolerror:MAXimum?
FETCh:BURSt:SYMBolerror:MINimum?

This command returns the average, maximum or minimum percentage of symbols that were outside the allowed demodulation range within a PPDU (as defined by the standard).

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Return values:

<Result> <Global Result>, <Stream 1 result> ... <Stream n result>

Usage: Query only

FETCh:BURSt:TFALl:AVERage?
FETCh:BURSt:TFALl:MAXimum?
FETCh:BURSt:TFALl:MINimum?

This command returns the average, maximum or minimum PPDU fall time in seconds.

This command is only applicable to IEEE802.11b & IEEE802.11g (DSSS) signals.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Usage: Query only

FETCh:BURSt:TRISe:AVERage?
FETCh:BURSt:TRISe:MAXimum?
FETCh:BURSt:TRISe:MINimum?

This command returns the average, maximum or minimum burst rise time in seconds.

This command is only applicable to IEEE802.11b & IEEE802.11g (DSSS) signals.

For details see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11.

Usage: Query only

UNIT:EVM <Unit>

This command specifies the units for EVM limits and results

Parameters:

<Unit> DB | PCT

*RST: DB

UNIT:GIMBalance <Unit>

This command specifies the units for gain imbalance results

(see chapter 3.1, "Modulation Accuracy, Flatness and Tolerance Parameters", on page 11)

Parameters:

<Unit> DB | PCT

*RST: DB

UNIT:PREamble <Unit>

This command specifies the units for preamble error results.

Parameters:

<Unit> HZ | PCT

9.6.1.3 Limit Check Results

The following commands are required to query the results of the limit checks.

Useful commands for retrieving results described elsewhere:

- `UNIT:EVM` on page 181
- `UNIT:GIMBalance` on page 181

Remote commands exclusive to retrieving limit check results

CALCulate:LIMit:BURSt:ALL:RESult?

This command returns the result of the EVM limit check for all carriers. The limit value is defined by the standard or the user (see `CALCulate:LIMit:BURSt:ALL` on page 154).

Return values:

<LimitCheck> **PASS**
The defined limit for the parameter was not exceeded.
FAILED
The defined limit for the parameter was exceeded.

Usage: Query only

CALCulate:LIMit:BURSt:EVM:ALL[:AVERage]:RESult?
CALCulate:LIMit:BURSt:EVM:ALL:MAXimum:RESult?

This command returns the result of the average or maximum EVM limit check. The limit value is defined by the standard or the user (see `CALCulate:LIMit:BURSt:EVM:ALL:MAXimum` on page 155).

Return values:

<LimitCheck> **PASS**
The defined limit for the parameter was not exceeded.
FAILED
The defined limit for the parameter was exceeded.

Usage: Query only

CALCulate:LIMit:BURSt:EVM:DATA[:AVERage]:RESult?
CALCulate:LIMit:BURSt:EVM:DATA:MAXimum:RESult?

This command returns the result of the average or maximum EVM limit check for data carriers. The limit value is defined by the standard or the user (see `CALCulate:LIMit:BURSt:EVM:DATA:MAXimum` on page 155).

Return values:

<LimitCheck> **PASS**
The defined limit for the parameter was not exceeded.
FAILED
The defined limit for the parameter was exceeded.

Usage: Query only

CALCulate:LIMit:BURSt:EVM:PILot[:AVERage]:RESult?
CALCulate:LIMit:BURSt:EVM:PILot:MAXimum:RESult?

This command returns the result of the average or maximum EVM limit check for pilot carriers. The limit value is defined by the standard or the user (see `CALCulate:LIMit:BURSt:EVM:PILot:MAXimum` on page 156).

Return values:

<LimitCheck>

PASS
The defined limit for the parameter was not exceeded.

FAILED
The defined limit for the parameter was exceeded.

Usage: Query only

CALCulate:LIMit:BURSt:FERRor[:AVERage]:RESult?
CALCulate:LIMit:BURSt:FERRor:MAXimum:RESult?

This command returns the result of the average or maximum center frequency error limit check. The limit value is defined by the standard or the user (see `CALCulate:LIMit:BURSt:FERRor:MAXimum` on page 156).

Return values:

<LimitCheck>

PASS
The defined limit for the parameter was not exceeded.

FAILED
The defined limit for the parameter was exceeded.

Usage: Query only

CALCulate:LIMit:BURSt:IQOFfset[:AVERage]:RESult?
CALCulate:LIMit:BURSt:IQOFfset:MAXimum:RESult?

This command returns the result of the average or maximum I/Q offset limit check. The limit value is defined by the standard or the user (see `CALCulate:LIMit:BURSt:IQOFfset:MAXimum` on page 156).

Return values:

<LimitCheck>

PASS
The defined limit for the parameter was not exceeded.

FAILED
The defined limit for the parameter was exceeded.

Usage: Query only

CALCulate:LIMit:BURSt:SYMBolerror[:AVERage]:RESult?
CALCulate:LIMit:BURSt:SYMBolerror:MAXimum:RESult?

This command returns the result of the average or maximum symbol clock error limit check. The limit value is defined by the standard or the user (see `CALCulate:LIMit:BURSt:SYMBolerror:MAXimum` on page 156).

Return values:

<LimitCheck> **PASS**
The defined limit for the parameter was not exceeded.
FAILED
The defined limit for the parameter was exceeded.

Usage: Query only

9.6.2 Retrieving Trace Results

The following commands describe how to retrieve the trace data from the WLAN I/Q measurement (Modulation Accuracy, Flatness and Tolerance). Note that for these measurements, only 1 trace per window can be configured.

The traces for frequency sweep measurements are identical to those in the Spectrum application.

Useful commands for retrieving results described elsewhere:

- `DISPlay[:WINDow<n>]:SELect` on page 167

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 VSE to the controlling computer.

Note that the command has no effect for data that you send to the R&S VSE. The R&S VSE 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".
For I/Q data, 8 bytes per sample are returned for this format setting.

UINT
In the R&S VSE WLAN application, bitstream data can be sent as unsigned integers format to improve the data transfer speed (compared to ASCII format).

*RST: ASCII

Example: `FORM REAL,32`

Usage: SCPI confirmed

[SENSe:]BURSt:SELect <Value>

This command selects the PPDU for which the trace data is queried (using `TRACe<n>[:DATA]`) for the "EVM vs Symbol" and "EVM vs Carrier" result displays if `[SENSe:]BURSt:SELect:STATe` is `ON`.

The selected PPDU does not affect the corresponding graphical trace displays.

Parameters:

<Value>

Range: 1 to <statistic count>
*RST: 1

Example:

```
LAY:WIND2:REPL EVSY
SENS:BURS:SEL:STAT ON
SENS:BURS:SEL 10
TRAC2:DATA? TRACE1
```

Returns the trace results for the PPDU number 10 in window 2 ("EVM vs Symbol").

[SENSe:]BURSt:SELect:STATe <State>

Determines whether a selected PPDU (using `[SENSe:]BURSt:SELect`) is considered or ignored.

Parameters:

<State> ON | OFF

ON
Only the results for the selected PPDU are considered by a subsequent `TRACe<n>[:DATA]` query for "EVM vs Symbol" and "EVM vs Carrier" result displays.

OFF
"EVM vs Symbol" result display: query returns all detected PPDUs in the current capture buffer
"EVM vs Carrier" result display: query returns the statistical results for all analyzed PPDUs

*RST: OFF

Example:

```
LAY:WIND2:REPL EVSY
SENS:BURS:SEL:STAT ON
SENS:BURS:SEL 10
TRAC2:DATA? TRACE1
```

Returns the trace results for the PPDU number 10 in window 2 ("EVM vs Symbol").

TRACe<n>[:DATA] <ResultType>

This command queries current trace data and measurement results from the window previously selected using `DISPlay[:WINDow<n>]:SELect`.

As opposed to the R&S VSE base unit, the window suffix <n> is not considered in the R&S VSE WLAN application! Use the `DISPlay[:WINDow<n>]:SELect` to select the window before you query trace results!

For details see chapter 9.6.3, "Measurement Results for TRACe<n>[:DATA]? TRACE<n>", on page 188.

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 WLAN I/Q measurement (Modulation Accuracy, Flatness and Tolerance), only 1 trace per window (TRACE1) is available.

Return values:

<TraceData> For more information see tables below.

Example:

```
DISP:WIND2:SEL
TRAC? TRACE3
```

Queries the data of trace 3 in window 2.

Manual operation: See "Bitstream" on page 20
See "Constellation" on page 21
See "Constellation vs Carrier" on page 22
See "EVM vs Carrier" on page 23
See "EVM vs Symbol" on page 24
See "FFT Spectrum" on page 24
See "Group Delay" on page 25
See "Magnitude Capture" on page 26
See "PLCP Header (IEEE 802.11b, g (DSSS)" on page 26
See "PvT Full PPDU" on page 28
See "Signal Field" on page 31
See "Spectrum Flatness" on page 34

Table 9-9: 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 161. The results for the various window types are described in chapter 9.6.3, "Measurement Results for TRACe<n>[:DATA]? TRACE<n>", on page 188.

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.

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>)

9.6.3 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)

As opposed to the R&S VSE base unit, the window suffix <n> is not considered in the R&S VSE WLAN application! Use the `DISPlay[:WINDow<n>]:SELect` to select the window before you query trace results!

For details on the graphical results of these evaluation methods, see chapter 3.2, "Evaluation Methods for WLAN I/Q Measurements", on page 19.

The following table provides an overview of the main characteristics of the WLAN OFDM symbol structure in the frequency domain for various standards. The description of the TRACe results refers to these values to simplify the description.

Table 9-10: WLAN OFDM symbol structure in the frequency domain

Stan dard	CBW / MHz	N_{FFT}	N_{SD} No. of data sc	N_{SP} No. of pilot sc	Pilot subcarrier (sc)	N_{ST} No. of sc total : $=N_{SD}+N_{SP}$	N_{Null} No. of DC/ Null sc	DC / Null subcar-rier	N_{used} No. of used sc := N_{ST} + N_{Null}	N_{guard} := N_{FFT} - N_{used}	Comment
IEEE 802.11 a	5	64	48	4	{-21,-7,7,21}	52	1	{0}	53	11	IEEE Std 802.11-2012 Tab Table 18-5—Timing-related parameters
	10	64	48	4	{-21,-7,7,21}	52	1	{0}	53	11	IEEE Std 802.11-2012 Tab Table 18-5—Timing-related parameters
	20	64	48	4	{-21,-7,7,21}	52	1	{0}	53	11	IEEE Std 802.11-2012 Tab Table 18-5—Timing-related parameters
11n	20	64	52	4	{-21,-7,7,21}1)	56	1	{0}	57	7	IEEE Std 802.11-2012 Tab Table 20-6—Timing-related constants
	40	128	108	6	{-53, -25, -11, 11, 25, 53}1)	114	3	{-1,0,1}3)	117	11	IEEE Std 802.11-2012 Tab Table 20-6—Timing-related constants
11ac	20	64	52	4	{-21,-7,7,21}2	56	1	{0}	57	7	IEEE P802.11ac/D2.1, March 2012 Table 22-5—Timing-related con-stants
	40	128	108	6	{-53, -25, -11, 11, 25, 53}2)	114	3	{-1,0,1}4)	117	11	IEEE P802.11ac/D2.1, March 2012 Table 22-5—Timing-related con-stants

1) IEEE Std 802.11-2012 Section 20.3.11.10 Pilot subcarriers

2) IEEE P802.11ac/D2.1, March 2012 Section 22.3.10.10 Pilot subcarriers

3) IEEE Std 802.11-2012 equation (20-59)

4) IEEE P802.11ac/D2.1, March 2012 equation (22-94)

5) IEEE P802.11ac/D2.1, March 2012 equation (22-95)

6) IEEE P802.11ac/D2.1, March 2012 equation (22-96)

Stan dard	CBW / MHz	N_{FFT}	N_{SD} No. of data sc	N_{SP} No. of pilot sc	Pilot subcarrier (sc)	N_{ST} No. of sc total : $=N_{SD}+N_{SP}$	N_{Null} No. of DC/ Null sc	DC / Null subcar- rier	N_{used} No. of used sc := N_{ST} + N_{Null}	N_{guard} :=N_{FFT} - N_{used}	Comment
	80	256	234	8	{–103, –75, –39, –11, 11, 39, 75,103}[2)]	242	3	{-1,0,1}[5)]	245	11	IEEE P802.11ac/D2.1, March 2012 Table 22-5—Timing-related con- stants
	160	512	468	16	{ -231, -203, -167, -139, - 117, -89, -53, -25, 25, 53, 89, 117, 139, 167, 203, 231}[2)]	484	17	{-129, -128, -127, -5:1:5, 127, 128, 129}[6)]	501	11	IEEE P802.11ac/D2.1, March 2012 Table 22-5—Timing-related con- stants

1) IEEE Std 802.11-2012 Section 20.3.11.10 Pilot subcarriers

2) IEEE P802.11ac/D2.1, March 2012 Section 22.3.10.10 Pilot subcarriers

3) IEEE Std 802.11-2012 equation (20-59)

4) IEEE P802.11ac/D2.1, March 2012 equation (22-94)

5) IEEE P802.11ac/D2.1, March 2012 equation (22-95)

6) IEEE P802.11ac/D2.1, March 2012 equation (22-96)

9.6.3.1 Bitstream

Data is returned depending on the selected standard for which the measurement was executed (see CONFigure:STANdard on page 112):

IEEE 802.11a, ac, g (OFDM), n standard (OFDM physical layers)

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.

Standard	CBW in MHz	N_{SD} (Number of data subcarriers)	N_{SP} (Number of pilot subcarriers)	N_{ST} (Total number of subcarriers: N_{SD}+N_{SP})
IEEE 802.11 a	5	48	4	**52**
IEEE 802.11 a	10	48	4	**52**
IEEE 802.11 a	20	48	4	**52**
IEEE 802.11n	20	52	4	**56**
IEEE 802.11n	40	108	6	**114**
IEEE 802.11ac	20	52	4	**56**
IEEE 802.11ac	40	108	6	**114**
IEEE 802.11ac	80	234	8	**242**
IEEE 802.11ac	160	468	16	**484**

IEEE 802.11b and g (DSSS) standard (DSSS physical layers)

For the IEEE 802.11b and g (DSSS) standard, the data is returned in PPDU order. Each PPDU is represented as a series of bytes. For each PPDU, the first 9 or 18 bytes represent the PLCP preamble for short and long PPDU types, respectively. The next 6 bytes represent the PLCP header. The remaining bytes represent the PSDU. Data is returned in ASCII printable hexadecimal character format.

TRACE1 is used for these measurement results.

9.6.3.2 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

  $$\boldsymbol{k} \in \{-(\boldsymbol{N_{used}} - 1)/2, -(\boldsymbol{N_{used}} - 1)/2 + 1, \ldots, (\boldsymbol{N_{used}} - 1)/2\}$$

  OFDM-Symbol 1: $(I_{1,1}, Q_{1,1})$
  OFDM-Symbol 2: $(I_{2,1}, Q_{2,1})$
  …
  OFDM-Symbol N: $(I_{N,1}, Q_{N,1})$

9.6.3.3 Constellation vs Carrier

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 N_{used} subcarriers per OFDM-Symbol, until all the I and Q data for the analyzed OFDM-Symbols is exhausted.

Note that as opposed to the Constellation results, the DC/null subcarriers are included as NaNs.

N_{used} pairs of I and Q data per OFDM-Symbol

OFDM-Symbol 1: $(I_{1,1}, Q_{1,1}), (I_{1,2},Q_{1,2}), \ldots,(I_{1,Nused}, Q_{1,Nused})$

OFDM-Symbol 2: $(I_{2,1}, Q_{2,1}), (I_{2,2},Q_{2,2}),\ldots,(I_{2,Nused}, Q_{2,Nused})$

…

OFDM-Symbol N:

$(I_{N,1}, Q_{N,1}), (I_{N,2},Q_{N,2}),\ldots,(I_{N,Nused}, Q_{N,Nused})$

9.6.3.4 EVM vs Carrier

Three trace types are provided for this evaluation:

Table 9-11: Query parameter and results for EVM vs Carrier

TRACE1	The minimum EVM value - over the analyzed PPDUs - for each of the N_{used} subcarriers
TRACE2	The average EVM value - over the analyzed PPDUs - for each of the N_{used} subcarriers
TRACE3	The maximum EVM value - over the analyzed PPDUs - for each of the N_{used} subcarriers

Each EVM value is returned as a floating point number, expressed in units of dB.

Supported data formats (see `FORMat[:DATA]` on page 184): `ASCii|UINT`

Example:

For $EVM_{m,n}$: the EVM of the m-th analyzed PPDU for the subcarrier n = {1,2,…, N_{used} }

TRACE1: Minimum EVM value per subcarrier

Minimum($EVM_{1,1}$, $EVM_{2,1}$,…. $EVM_{Statistic\ Length,1}$),

//Minimum EVM value for subcarrier –(N_{used}-1)/2

Minimum($EVM_{1,2}$, $EVM_{2,2}$,…. $EVM_{Statistic\ Length,2}$),

// Minimum EVM value for subcarrier –(N_{used}-1)/2 + 1

…,

Minimum($EVM_{1,Nused}$,$EVM_{2,Nused}$,…. $EVM_{Statistic\ Length,Nused}$)

// Minimum EVM value for subcarrier +(N_{used}-1)/2

9.6.3.5 EVM vs Chip

These results are **only** available for single-carrier measurements (**IEEE 802.11b, g (DSSS)**).

Since the R&S VSE WLAN application provides two different methods to calculate the EVM, two traces are available:

TRACE1	EVM IEEE values
TRACE2	EVM Direct values

Each trace shows the EVM value as measured over the complete capture period.

The number of repeating groups that are returned is equal to the number of measured chips.

Each EVM value is returned as a floating point number, expressed in units of dBm.

Supported data formats (see `FORMat[:DATA]` on page 184): `ASCii|REAL`

9.6.3.6 EVM vs Symbol

Three traces types are available with this measurement. The basic trace types show either the minimum, mean or maximum EVM value, as measured over the complete capture period.

The number of repeating groups that are returned is equal to the number of measured symbols.

Each EVM value is returned as a floating point number, expressed in units of dBm.

Supported data formats (see `FORMat[:DATA]` on page 184): `ASCii|REAL`

TRACE1	Minimum EVM values
TRACE2	Mean EVM values
TRACE3	Maximum EVM values

These results are **not** available for single-carrier measurements (**IEEE 802.11b, g (DSSS)**).

9.6.3.7 FFT 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.

9.6.3.8 Group Delay

Currently the following trace types are provided with this measurement:

- TRACE1
  A repeating list of group delay values for each subcarrier. The number of repeating lists corresponds to the number of fully analyzed PPDUs as displayed in the current Magnitude Capture. Each group delay value is returned as a floating point number, expressed in units of seconds.
- TRACE
  All group delay values per subcarrier for each analyzed PPDU of the capture period

Example:

For $GD_{m,n}$: the group delay of the m-th analyzed PPDU for the subcarrier corresponding to n = {1,2,…, N_{used} };

`TRACE:DATA? TRACE2`

Analyzed PPDU 1:

$GD_{1,1}$, $GD_{1,2}$, …,

Analyzed PPDU 2:

$GD_{2,1}$, $GD_{2,2}$, …,

…

Analyzed PPDU N :

$GD_{N,1}$, $GD_{N,2}$, …,

9.6.3.9 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 "Input Sample Rate" on page 71 and "Capture Time" on page 71).

9.6.3.10 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.

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 184): ASCii|REAL

9.6.3.11 Signal Field

The bits are returned as read from the corresponding signal field parts in transmit order. I.e. the first transmitted bit has the highest significance and the last transmitted bit has the lowest significance.

See also "Signal Field" on page 31.

The TRAC:DATA? command returns the information as read from the signal field for each analyzed PPDU. The signal field bit sequence is converted to an equivalent sequence of hexadecimal digits for each analyzed PPDU in transmit order.

9.6.3.12 Spectrum Flatness

The spectrum flatness evaluation returns the relative power values per carrier (in dB).

Two trace types are provided for this evaluation:

Table 9-12: Query parameter and results for Spectrum Flatness

TRACE1	All spectrum flatness values per channel
TRACE2	An average spectrum flatness value for each of the 53 (or 57/117 within the IEEE 802.11 n standard) carriers

Supported data formats (FORMat:DATA): ASCii|REAL

9.7 Analysis

The following commands define general result analysis settings concerning the traces and markers in standard WLAN measurements. Currently, only one (Clear/Write) trace and one marker are available for standard WLAN measurements.

9.7.1 Markers

Markers help you analyze your measurement results by determining particular values in the diagram. Currently, only 1 marker per window can be configured for standard WLAN I/Q measurements.

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 100

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.

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.

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

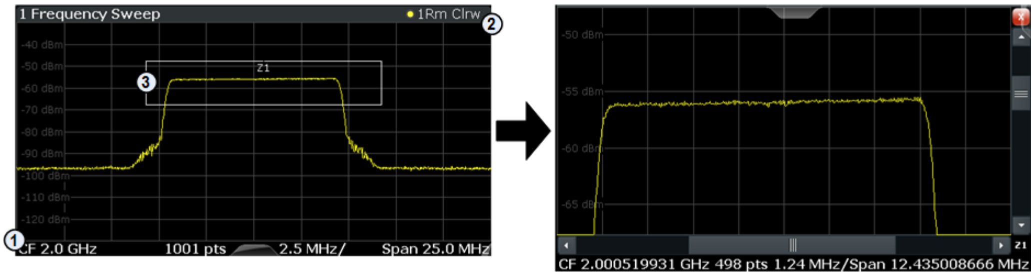
9.7.2 Zooming into the Display

9.7.2.1 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
```

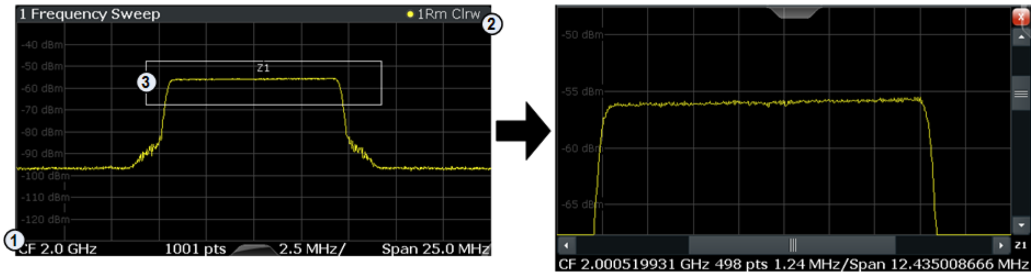
Activates the zoom mode.

9.7.2.2 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

9.8 Status Registers

The WLAN application uses the standard status registers of the R&S VSE (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 VSE status registers refer to the description of remote control basics in the R&S VSE User Manual.

*RST does not influence the status registers.

9.8.1 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 9-13: 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	This bit is not used
2	No PPDUs of REQuired type This bit is set if an I/Q measurement is performed and no PPDUs of the specified type are detected
3	GATE length too small This bit is set if gating is used in a measurement and the gate length is not set sufficiently large enough
4	PPDU count too small This bit is set if a PVT measurement is performed with gating active and there is not at least 1 PPDU within the gate lines
5	Auto level OVERload This bit is set if a signal overload is detected when an auto-level measurement is performed
6	Auto level NoSIGnal This bit is set if no signal is detected by the auto-level measurement

Bit No.	Meaning
7 - 14	These bits are not used.
15	This bit is always 0.

9.8.2 Querying the Status Registers

The following commands are required to query the status of the R&S VSE and the WLAN application.

For details on the common R&S VSE status registers refer to the description of remote control basics in the R&S VSE User Manual.

9.8.2.1 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

9.8.2.2 Reading Out the EVENt Part

STATus:OPERation[:EVENt]?
STATus:QUEStionable[:EVENt]?
STATus:QUEStionable:ACPLimit[:EVENt]? <ChannelName>
STATus:QUEStionable:LIMit<n>[:EVENt]? <ChannelName>
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

9.8.2.3 Reading Out the CONDition Part

STATus:OPERation:CONDition?
STATus:QUEStionable:CONDition?
STATus:QUEStionable:ACPLimit:CONDition? <ChannelName>
STATus:QUEStionable:LIMit<n>:CONDition? <ChannelName>
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

9.8.2.4 Controlling the ENABle Part

STATus:OPERation:ENABle <SumBit>
STATus:QUEStionable:ENABle <SumBit>
STATus:QUEStionable:ACPLimit:ENABle <SumBit>,<ChannelName>
STATus:QUEStionable:LIMit<n>:ENABle <SumBit>,<ChannelName>
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.

9.8.2.5 Controlling the Negative Transition Part

STATus:OPERation:NTRansition <SumBit>
STATus:QUEStionable:NTRansition <SumBit>
STATus:QUEStionable:ACPLimit:NTRansition <SumBit>,<ChannelName>
STATus:QUEStionable:LIMit<n>:NTRansition <SumBit>,<ChannelName>
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.

9.8.2.6 Controlling the Positive Transition Part

STATus:OPERation:PTRansition <SumBit>
STATus:QUEStionable:PTRansition <SumBit>
STATus:QUEStionable:ACPLimit:PTRansition <SumBit>,<ChannelName>
STATus:QUEStionable:LIMit<n>:PTRansition <SumBit>,<ChannelName>
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.

9.9 Commands for Compatibility

The following commands are provided only for compatibility to remote control programs from WLAN applications on previous signal analyzers. For new remote control programs use the specified alternative commands.

The `CONF:BURS:<ResultType>:IMM` commands used in former R&S Signal and Spectrum Analyzers to change the result display are still supported for compatibility reasons; however they have been replaced by the `LAY:ADD:WIND` commands in the R&S VSE (see chapter 9.5, "Configuring the Result Display", on page 157). 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.

[SENSe:]DEMod:FORMat:BANalyze:BTYPe <PPDUType>

This remote control command specifies the type of PPDU to be analyzed. Only PPDUs of the specified type take part in measurement analysis.

Parameters:

<PPDUType>

'LONG'
Only long PLCP PPDUs are analyzed.
Available for IEEE 802.11b, g.

'SHORT'
Only short PLCP PPDUs are analyzed.
Available for IEEE 802.11b, g.

'MM20'
IEEE 802.11n, Mixed Mode, 20 MHz sample rate
Note that this setting is maintained for compatibility reasons only. Use the specified commands for new remote control programs (see `[SENSe:]DEMod:FORMat:BANalyze:BTYPe:AUTO:TYPE` on page 143 and `[SENSe:]BANDwidth:CHANnel:AUTO:TYPE` on page 140).
For new programs use:
`[SENSe:]DEMod:FORMat:BANalyze:BTYPe:AUTO:TYPE MMIX`
`[SENSe:]BANDwidth:CHANnel:AUTO:TYPE MB20`

'GFM20'
IEEE 802.11n Green Field Mode, 20 MHz sample rate
Note that this setting is maintained for compatibility reasons only. Use the specified commands for new remote control programs (see `[SENSe:]DEMod:FORMat:BANalyze:BTYPe:AUTO:TYPE` on page 143 and `[SENSe:]BANDwidth:CHANnel:AUTO:TYPE` on page 140).
For new programs use:
`[SENSe:]DEMod:FORMat:BANalyze:BTYPe:AUTO:TYPE MGRF`
`[SENSe:]BANDwidth:CHANnel:AUTO:TYPE MB20`

Manual operation: See "PPDU Format" on page 90

TRIGger[:SEQuence]:MODE <Source>

Defines the trigger source.

Note that this command is maintained for compatibility reasons only. Use the `TRIGger[:SEQuence]:SOURce` on page 130 commands for new remote control programs.

This command configures how triggering is to be performed.

Parameters:

<Source> IMMediate | EXTernal | VIDeo | RFPower | IFPower | TV | AF | AM | FM | PM | AMRelative | LXI | TIME | SLEFt | SRIGht | SMPX | SMONo | SSTereo | SRDS | SPILot | BBPower | MASK | PSENsor | TDTRigger | IQPower | EXT2 | EXT3

9.10 Programming Examples (R&S VSE WLAN application)

This example demonstrates how to configure a WLAN 802.11 measurement in a remote environment.

9.10.1 Measurement 1: Measuring Modulation Accuracy for WLAN 802.11n Standard

This example demonstrates how to configure a WLAN IQ measurement for a signal according to WLAN 802.11n standard in a remote environment.

```
//---------- Preparing the application ------------
// Preset the instrument
*RST
// Enter the WLAN option K91n
INSTrument:SELect WLAN
// Switch to single sweep mode and stop sweep
INITiate:CONTinuous OFF;:ABORt

//---------- Configuring the result display ------------
// Activate following result displays:
// 1: Magnitude Capture (default, upper left)
// 2: Result Summary Detailed (below Mag Capt)
// 3: Result Summary Global (default, lower right)
// 4: EVM vs Carrier (next to Mag Capt)

LAY:REPL '2',RSD
LAY:ADD:WIND? '1',RIGH,EVC
//Result: '4'

//---------- Signal description ------------
//Use measurement standard IEEE 802 11n
CONF:STAN 6
//Center frequency is 13.25 GHz
FREQ:CENT 13.25GHZ

//---------- Configuring Data Acquisition ---------------------
//Each measurement captures data for 10 ms.
SWE:TIME 10ms
//Set the input sample rate for the captured I/Q data to 20MHz
TRAC:IQ:SRAT 20MHZ
// Number of samples captured per measurement: 0.01s * 20e6 samples per second
// = 200 000 samples
//Include effects from adjacent channels - switch off filter
BAND:FILT OFF

//---------- Synchronization -----------------
```

```
//Improve performance - perform coarse burst search initially
SENS:DEM:TXAR ON
//Minimize the intersymbol interference - FFT start offset determined automatically
SENS:DEM:FFT:OFFS AUTO

//---------- Tracking and channel estimation -----------------
//Improve EVM accuracy - estimate channel from preamble and payload
SENS:DEM:CEST ON
//Use pilot sequence as defined in standard
SENS:TRAC:PIL STAN
//Disable all tracking and compensation functions
SENS:TRAC:LEV OFF
SENS:TRAC:PHAS OFF
SENS:TRAC:TIME OFF

//---------- Demodulation ------------
//Define a user-defined logical filter to analyze:
SENS:DEM:FORM:BCON:AUTO OFF
//all PPDU formats
SENS:DEM:FORM:BAN:BTYP:AUTO:TYPE ALL
//20MHZ channel bandwidth
SENS:BAND:CHAN:AUTO:TYPE MB20
//an MCS Index '1'
SENS:DEM:FORM:MCS:MODE MEAS
SENS:DEM:FORM:MCS 1
//STBC field = '1'
CONF:WLAN:STBC:AUTO:TYPE M1
//Ness = 1
CONF:WLAN:EXT:AUTO:TYPE M1
//short guard interval length (8 samples)
CONF:WLAN:GTIM:AUTO ON
CONF:WLAN:GTIM:AUTO:TYPE MS

//---------- Evaluation range settings -----------------
//Calculate statistics over 10 PPDUs
SENS:BURS:COUN:STAT ON
SENS:BURS:COUN 10
//Determine payload length from HT signal
CONF:WLAN:PAYL:LENG:SRC HTS
//Payload length: 8-16 symbols
SENS:DEM:FORM:BAN:SYMB:EQU OFF
SENS:DEM:FORM:BAN:SYMB:MIN 8
SENS:DEM:FORM:BAN:SYMB:MAX 16

//---------- Measurement settings --------------------
//Define units for EVM and Gain imbalance results
UNIT:EVM PCT
UNIT:GIMB PCT

//---------- Defining Limits -----------------------
```

```
//Define non-standard limits for demonstration purposes
//and return to standard limits later.
//Query current limit settings:
CALC:LIM:BURS:ALL?
//Set new limits:
//Average CF error: 5HZ
//max CF error: 10HZ
//average symbol clock error: 5
//max symbol clock error: 10
//average I/Q offset: 5
//maximum I/Q offset: 10
//average EVM all carriers: 0.1%
//max EVM all carriers: 0.5%
//average EVM data carriers: 0.1%
//max EVM data carriers: 0.5%
//average EVM pilots: 0.1%
//max EVM pilots: 0.5%
CALC:LIM:BURS:ALL 5,10,5,10,5,10,0.1,0.5,0.1,0.5,0.1,0.5

//---------- Performing the Measurements -----
// Run 10 (blocking) single measurements
INITiate:IMMediate;*WAI

//---------- Retrieving Results -------------
//Query the I/Q data from magnitude capture buffer for first ms
// 200 000 samples per second -> 200 samples
TRACe1:IQ:DATA:MEMory? 0,200
//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? 201,400
//Note: result will be too long to display in IECWIN, but is stored in log file


//Select window 4 (EVM vs carrier)
DISP:WIND4:SEL
//Query the current EVM vs carrier trace
TRAC: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 carriers
FETC:BURS:EVM:ALL:AVER?
//Query the result of the EVM limit check for all carriers
CALC:LIM:BURS:ALL:RES?

//Return to standard-defined limits
CALC:LIM:BURS:ALL
//Query the result of the EVM limit check for all carriers again
CALC:LIM:BURS:ALL:RES?


//---------- 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'
```

A Annex: Reference

A.1 Menu Reference

Most functions in the R&S VSE are available from the menus.

A.1.1 Common R&S VSE Menus

The following menus provide **basic functions for all applications**:

A.1.1.1 File Menu

The "File" menu includes all functionality directly related to any file operations, printing or setting up general parameters.

For a description of these functions see the "Data Management" chapter in the R&S VSE User Manual.

Menu item	Correspond-ing icon in toolbar	Description
Save		Saves the current software configuration to a file
Recall		Recalls a saved software configuration from a file
Save IQ Recording	-	Saves the recorded I/Q data from a measurement channel to a file
Recall IQ Recording	-	Loads the recorded I/Q data from a file
Measurement Group >	-	Configures measurement channels and groups
> New Group	-	Inserts a new group in the measurement sequence
> New Measurement Channel	-	Inserts a new channel in the selected group
> Replace Measure-ment Channel	-	Replaces the currently selected channel by the selected applica-tion.
> Delete Current Mea-surement Channel	-	Deletes the currently selected channel.

Menu item	Correspond-ing icon in toolbar	Description
> Measurement Group Setup	-	Displays the "Measurement Group Setup" tool window.
Instruments >	-	Configures instruments to be used for input to the R&S VSE soft-ware
> New	-	Creates a new instrument configuration
> Search	-	Searches for connected instruments in the network
> Delete All	-	Deletes all current instrument configurations
> Setup	-	Hides or displays the "Instrument" tool window
Preset >	-	Restores stored settings
> All	-	Restores the default software configuration globally for the entire software
> All & Delete Instru-ments		Restores the default software configuration globally for the entire software and deletes all instrument configurations
> Selected Channel	-	Restores the default software configuration for an individual channel
> Reset VSE Layout	-	Restores the default layout of windows, toolbars etc. in the R&S VSE software
Preferences >	-	Configures global software settings
> General	-	
> Displayed Items	-	Hides or shows individual screen elements
> Theme & Color	-	Configures the style of individual screen elements
> Network & Remote	-	Configures the network settings and remote access to or from other devices
> Recording	-	Configures general recording parameters
Print	-	Opens "Print" dialog to print selected measurement results
Exit	-	Closes the R&S VSE software

A.1.1.2 Window Menu

The "Window" menu allows you to hide or show individual windows.

For a description of these functions see the "Controlling Instruments and Capturing Data" chapter in the R&S VSE User Manual.

Menu item	Correspond-ing icon in toolbar	Description
Player...	-	Displays the "Player" tool window to recall I/Q data recordings
Instrument Setup...	-	Displays the "Instruments" window to configure input instruments

Menu item	Correspond-ing icon in toolbar	Description
Measurement Group Setup...	-	Displays the "Measurement Group Setup" window to configure a measurement sequence
New Window >		Inserts a new result display window for the selected measure-ment channel
Channel Infos >	-	Displays the channel bar with global channel information for the selected meausrement channel
Active Windows >	-	Selects a result display as the active window; the corresponding channel is also activated
Configure Selected Result Window	-	Displays the "Window Configuration" dialog box to configure result-specific settings

A.1.1.3 Help Menu

The "Help" menu provides access to help, support and licensing functions.

For a description of these functions see the "Basic Operations" and "General Software Settings" chapters in the R&S VSE User Manual.

Menu item	Correspond-ing icon in toolbar	Description
Help	?	Opens the Online help window
License	-	Licensing, version and options information
Support	-	Support functions
Register VSE	-	Attempts to create an email with the default mail program (if available) to the Rohde & Schwarz support address for registra-tion.
Online Support	-	Opens the default web browser and attempts to establish an Internet connection to the Rohde & Schwarz product site.
About	-	Software version information

A.1.2 WLAN I/Q Measurements Menus

The following menus are only available if a WLAN I/Q measurement channel is selected.

A.1.2.1 Input & Output Menu

The "Input & Output" menu provides functions to configure the input source, frontend parameters and output settings for the measurement.

This menu is application-specific.

Table 1-1: "Input" menu items for WLAN I/Q Measurements

Menu item	Description
Amplitude	chapter 5.3.4, "Amplitude Settings", on page 68
Scale	
Frequency	chapter 5.3.3, "Frequency Settings", on page 66
Trigger	chapter 5.4.2, "Trigger Settings", on page 72
Input Source	chapter 5.3.1, "Input Source Settings", on page 60
Output Source	chapter 5.3.2, "Output Settings", on page 64

A.1.2.2 Meas Setup Menu

The "Meas Setup" menu provides access to most measurement-specific settings, as well as bandwidth, sweep and auto configuration settings, and the configuration "Overview" window.

This menu is application-specific.

Table 1-2: "Meas Setup" menu items for WLAN I/Q Measurements

Menu item	Description
Signal Description	chapter 5.2, "Signal Description", on page 59
Input/Frontend	chapter 5.3, "Input, Output, and Frontend Settings", on page 60
Signal Capture	chapter 5.4, "Signal Capture (Data Acquisition)", on page 71
Synch/OFDM-Demod	chapter 5.5, "Synchronization and OFDM Demodulation", on page 77
Tracking/Channel Estimation	chapter 5.6, "Tracking and Channel Estimation", on page 78
Demod	chapter 5.7, "Demodulation", on page 80
Evaluation Range	chapter 5.8, "Evaluation Range", on page 94
ResultConfig	chapter 5.9, "Result Configuration", on page 99
Meas Settings	chapter 3, "WLAN I/Q Measurement and Results", on page 11
Overview	chapter 5.1, "Configuration Overview", on page 57

A.1.2.3 Trace Menu

The "Trace" does not contain any functions for WLAN I/Q measurements, traces are generally not configurable.

A.1.2.4 Marker Menu

The "Marker" menu provides access to marker-specific functions.

This menu is application-specific.

Table 1-3: "Marker" menu items for WLAN I/Q Measurements

Menu item	Corresponding icon in toolbar	Description
Marker 1	-	
Marker to Trace	-	

A.1.2.5 Limits Menu

The "Limits" menu does not contain any functions for WLAN I/Q measurements.

A.2 Reference of Toolbar Functions

Common functions can be performed via the icons in the toolbars.

Individual toolbars can be hidden or displayed.

Hiding and displaying a toolbar

1. Right-click any toolbar or the menu bar.

   A context menu with a list of all available toolbars is displayed.

2. Select the toolbar you want to hide or display.

   A checkmark indicates that the toolbar is currently displayed.

   The toolbar is toggled on or off.

Note that some icons are only available for specific applications. Those functions are described in the individual application's User Manual.

General toolbars

The following functions are generally available for all applications:

"Main" toolbar

For a description of these functions see the R&S VSE Base Software User Manual.

Table 1-4: Functions in the "Main" toolbar

Icon	Description
	Overview: Displays the configuration overview for the current measurement channel
	Save: Saves the current software configuration to a file
	Recall: Recalls a saved software configuration from a file
	Save I/Q recording: Stores the recorded I/Q data to a file
	Recall I/Q recording: Loads recorded I/Q data from a file
	Print immediately: prints the current display (screenshot) as configured
	Add Window: Inserts a new result display window for the selected measurement channel

"Control" toolbar

For a description of these functions see the R&S VSE Base Software User Manual.

Table 1-5: Functions in the "Control" toolbar

Icon	Description
IQ Analyzer	Selects the currently active channel
	Capture: performs the selected measurement
	Pause: temporarily stops the current measurement
	Continuous: toggles to continuous measurement mode for next capture
	Single: toggles to single measurement mode for next capture
	Record: performs the selected measurement and records the captured data and results
	Refresh: Repeats the evaluation of the data currently in the capture buffer without capturing new data (VSA application only).

"Help" toolbar

For a description of these functions see the R&S VSE Base Software User Manual.

Table 1-6: Functions in the "Help" toolbar

Icon	Description
	Help (+ Select): allows you to select an object for which context-specific help is displayed (not available in standard Windows dialog boxes or measurement result windows)
	Help: displays context-sensitive help topic for currently selected element

Application-specific toolbars

The following toolbars are application-specific; not all functions shown here may be available in each application:

"Zoom" toolbar

For a description of these functions see the R&S VSE Base Software User Manual.

Table 1-7: Functions in the "Zoom" toolbar

Icon	Description
	Normal mouse mode: the cursor can be used to select (and move) markers in a zoomed display
	Zoom mode: displays a dotted rectangle in the diagram that can be expanded to define the zoom area
	Multiple zoom mode: multiple zoom areas can be defined for the same diagram
	Zoom off: displays the diagram in its original size

Table 1-8: Functions in the "Marker" toolbar

Icon	Description
	Place new marker
	Select marker
	Marker type "normal"
	Marker type "delta"
	Global peak
	Absolute peak (Currently only for GSM application)
	Next peak to the left
	Next peak to the right
	Next peak up (for spectrograms only: search in more recent frames)
	Next peak down (for spectrograms only: search in previous frames)
	Global minimum
	Next minimum left
	Next minimum right
	Next min up (for spectrograms only: search in more recent frames)

Icon	Description
	Next min down (for spectrograms only: search in previous frames)
CF	Set marker value to center frequency
REF	Set reference level to marker value
	All markers off
	Marker search configuration
	Marker configuration

Table 1-9: Functions in the "AutoSet" toolbar

Icon	Description
AUTO LEVEL	Auto level
AUTO FREQ	Auto frequency
	Auto trigger (R&S VSE GSM application only)
	Auto frame (R&S VSE GSM application only)
	Auto search (R&S VSE 3GPP FDD application only)
	Auto scale (R&S VSE 3GPP FDD + Pulse applications only)
	Auto scale all (R&S VSE 3GPP FDD + Pulse applications only)
AUTO ALL	Auto all
	Configure auto settings

A.3 Sample Rate and Maximum Usable I/Q Bandwidth for RF Input

Definitions

- **Input sample rate (ISR)**: the sample rate of the useful data provided by the device connected to the input of the instrument in use
- (User, Output) **Sample rate (SR)**: the sample rate that is defined by the user (e.g. in the "Data Aquisition" dialog box in the "I/Q Analyzer" application) and which is used as the basis for analysis or output
- **Usable I/Q (Analysis) bandwidth**: the bandwidth range in which the signal remains undistorted in regard to amplitude characteristic and group delay; this range can be used for accurate analysis by the R&S VSE

- **Record length**: Number of I/Q samples to capture during the specified measurement time; calculated as the measurement time multiplied by the sample rate

For the I/Q data acquisition, digital decimation filters are used internally in the instrument in use. The passband of these digital filters determines the *maximum usable I/Q bandwidth*. In consequence, signals within the usable I/Q bandwidth (passband) remain unchanged, while signals outside the usable I/Q bandwidth (passband) are suppressed. Usually, the suppressed signals are noise, artifacts, and the second IF side band. If frequencies of interest to you are also suppressed, you should try to increase the output sample rate, since this increases the maximum usable I/Q bandwidth.

As a rule, the usable I/Q bandwidth is proportional to the output sample rate. Yet, when the I/Q bandwidth reaches the bandwidth of the analog IF filter (at very high output sample rates), the curve breaks.

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A.3.1 Relationship Between Sample Rate,Record Length, and Usable I/Q Bandwidth

In the R&S VSE software, the usable I/Q bandwidth is proportional to the output sample rate:

*Usable I/Q bandwidth = 0.8 * Output sample rate*

The maximum record length, that is, the maximum number of samples that can be captured, depends on the sample rate of the instrument in use or provided by the input file.

*Record length = Measurement time * sample rate*

List of Remote Commands (WLAN)

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