R&S®FSW-K70
Vector Signal Analysis
User Manual

ROHDE & SCHWARZ

This manual applies to the following R&S®FSW models with firmware version 1.51 and higher:

- R&S®FSW8 (1312.8000K08)
- R&S®FSW13 (1312.8000K13)
- R&S®FSW26 (1312.8000K26)

The following firmware options are described:

- R&S FSW-K70 (1313.1416.02)

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

Contents

1 Preface

1.1 About this Manual

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

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

- **Welcome to the VSA Application**
  Introduction to and getting familiar with the application

- **Typical applications**
  Example measurement scenarios in which the application is frequently used.

- **Measurements and Result Displays**
  Details on supported measurements and their result types

- **Measurement Basics**
  Background information on basic terms and principles in the context of the measurement

- **Configuration + Analysis**
  A concise description of all functions and settings available to configure measurements and analyze results with their corresponding remote control command

- **How to Perform Measurements in VSA**
  The basic procedure to perform each measurement and step-by-step instructions for more complex tasks or alternative methods

- **Measurement Examples**
  Detailed measurement examples to guide you through typical measurement scenarios and allow you to try out the application immediately

- **Optimizing and Troubleshooting the Measurement**
  Hints and tips on how to handle errors and optimize the test setup

- **Remote Commands for VSA**
  Remote commands required to configure and perform VSA measurements in a remote environment, sorted by tasks
  (Commands required to set up the environment or to perform common tasks on the instrument are provided in the main R&S FSW User Manual)
  Programming examples demonstrate the use of many commands and can usually be executed directly for test purposes

- **Annex**
  Reference material

- **List of remote commands**
  Alpahabetical list of all remote commands described in the manual

- **Index**

1.2 Documentation Overview

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

● "Getting Started" printed manual

● Online Help system on the instrument

● Documentation CD-ROM with:
  – Getting Started
  – User Manuals for base unit and options
  – Service Manual
  – Release Notes
  – Data sheet and product brochures

Online Help

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

Getting Started

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

The Getting Started manual in various languages is also available for download from the R&S website, on the R&S FSW product page at http://www2.rohde-schwarz.com/product/FSW.html.

User Manuals

User manuals are provided for the base unit and each additional (software) option.

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

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

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

All user manuals are also available for download from the R&S website, on the R&S FSW product page at http://www2.rohde-schwarz.com/product/FSW.html.

Service Manual

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

Release Notes

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

The most recent release notes are also available for download from the R&S website, on the R&S FSW product page at http://www2.rohde-schwarz.com/product/FSW.html > Downloads > Firmware.

1.3 Conventions Used in the Documentation

1.3.1 Typographical Conventions

The following text markers are used throughout this documentation:

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

1.3.2 Conventions for Procedure Descriptions

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

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

2 Welcome to the Vector Signal Analysis Application

The R&S FSW-K70 is a firmware application that adds functionality to perform Vector Signal Analysis (VSA) to the R&S FSW.

The VSA application performs vector and scalar measurements on digitally modulated single-carrier signals. To perform the measurements it converts RF signals into the complex baseband. It can also use the optional Digital Baseband interface (R&S FSW-B17 option) to analyze I/Q signals already delivered to the complex baseband.

The VSA application features:

- Flexible modulation analysis from MSK to 64QAM
- Numerous standard-specific default settings
- Various graphical, numerical and statistical evaluations and result displays
- Spectrum analyses of the measurement and error signal
- Flexible burst search for the analysis of complex signal combinations, short bursts or signal mix

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

All functions not discussed in this manual are the same as in the base unit and are described in the R&S FSW User Manual. The latest version is available for download at the product homepage (http://www2.rohde-schwarz.com/product/FSW.html).

Installation

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

2.1 Starting the VSA Application

The VSA application adds a new application to the R&S FSW.

To activate the VSA application

1. Press the MODE key on the front panel of the R&S FSW.

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

2. Select the "VSA" item.

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

The measurement is started immediately with the default settings. It can be configured in the VSA "Overview" dialog box, which is displayed when you select the "Overview" softkey from any menu (see chapter 5.3, "Configuration Overview", on page 123).

Multiple Measurement Channels and Sequencer Function

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

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

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

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

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

2.2 Understanding the Display Information

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

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

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MSRA operating mode

In MSRA operating mode, additional tabs and elements are available. A colored background of the screen behind the measurement channel tabs indicates that you are in MSRA operating mode.

For details on the MSRA operating mode see the R&S FSW MSRA User Manual.

Channel bar information

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

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

Ref Level	Reference level
Freq	Center frequency for the RF signal
Mod	Modulation type, if no standard is active (or default standard is changed)
Res Len	Result Length
SR	Symbol Rate
Att	Mechanical and electronic RF attenuation
Offset	Reference level offset
Cap Len	Capture Length (instead of result length for capture buffer display), see "Capture Length Settings" on page 152
Input	Input type of the signal source, see chapter 5.5.1, "Input Settings", on page 134
Burst	Burst search active (see "Enabling Burst Searches" on page 162)
Pattern	Pattern search active (see "Enabling Pattern Searches" on page 163)
Stat Count	Statistics count for averaging and other statistical operations, see "Statistic Count" on page 159; cannot be edited directly
Capt Count	Capture count; the current number of captures performed if several captures are necessary to obtain the number of results defined by "Statistics Count"; cannot be edited directly
SGL	The sweep is set to single sweep mode.

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

Window title bar information

For each diagram, the header provides the following information:

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

1 = Window name
2 = Result type
3 = Data source type
4 = Trace color
5 = Displayed signal for Meas&Ref data source: M (Meas) or R (Ref)
6 = Trace mode

Diagram area

The diagram area displays the results according to the selected result displays (see chapter 3, "Measurements and Result Displays", on page 15).

Diagram footer information

The diagram footer (beneath the diagram) contains the start and stop symbols or time of the evaluation range.

Status bar information

Global instrument settings, the instrument status and any irregularities are indicated in the status bar beneath the diagram. Furthermore, the progress of the current operation is displayed in the status bar.

3 Measurements and Result Displays

Various different result displays for VSA measurements are available. Which result types are available depends on the selected data source. You can define which part of the measured signal is to be evaluated and displayed.

The determined result and evaluation ranges are included in the result displays (where useful) to visualize the basis of the displayed values and traces.

For background information on the result and evaluation ranges see chapter 4.6, "Measurement Ranges", on page 111.)

3.1 Evaluation Data Sources in VSA

All data sources for evaluation available for VSA are displayed in the evaluation bar in SmartGrid mode. The data source determines which result types are available (see table 3-1).

For details on selecting the data source for evaluation see chapter 6.5, "Display and Window Configuration", on page 196.

In diagrams in the frequency domain (Spectrum transformation, see "Result Type Transformation" on page 197) the usable I/Q bandwidth is indicated by vertical blue lines.
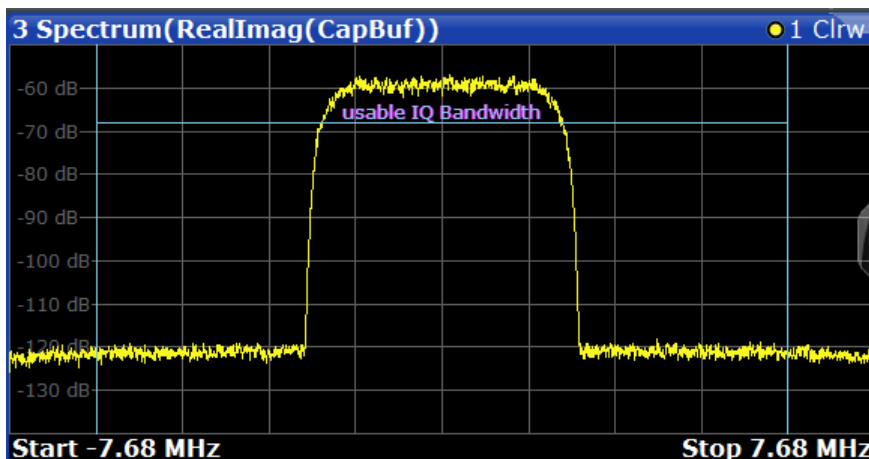
Capture Buffer

The captured I/Q data

In capture buffer result diagrams the result ranges are indicated by green bars along the time axis. The currently displayed result range is indicated by a blue bar.
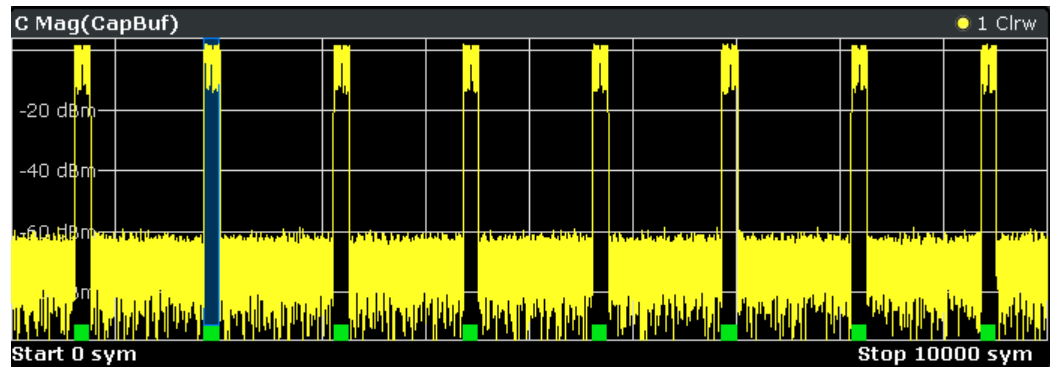
Fig. 3-1: Result ranges for a burst signal

Note: Tip: You can use the capture buffer display to navigate through the available result ranges (using Select Result Rng softkey), and analyze the individual result ranges in separate windows.

You can change the position of the result range quickly and easily by dragging the blue bar representing the result range to a different position in the capture buffer.

The default result type is "Magnitude Absolute".

The following result types are available:

* chapter 3.2.1, "Magnitude Absolute", on page 21
* chapter 3.2.7, "Real/Imag (I/Q)", on page 26
* chapter 3.2.5, "Frequency Absolute", on page 24
* chapter 3.2.13, "Vector I/Q", on page 31

SCPI command:

`LAY:ADD? '1',BEL,MTAB`(see `LAYout:ADD[:WINDow]?` on page 351)

Measurement & Reference Signal

The measurement signal or the ideal reference signal (or both)

The default result type is "Magnitude Relative".

The following result types are available:
* chapter 3.2.1, "Magnitude Absolute", on page 21
* chapter 3.2.2, "Magnitude Relative", on page 22
* chapter 3.2.3, "Phase Wrap", on page 22
* chapter 3.2.4, "Phase Unwrap", on page 23
* chapter 3.2.5, "Frequency Absolute", on page 24
* chapter 3.2.6, "Frequency Relative", on page 25
* chapter 3.2.7, "Real/Imag (I/Q)", on page 26
* chapter 3.2.8, "Eye Diagram Real (I)", on page 27

SCPI command:

`LAY:ADD? '1',BEL,REF`(see `LAYout:ADD[:WINDow]?` on page 351)

Symbols

The detected symbols (i.e. the detected bits) displayed in a table

The default result type is a hexadecimal symbol table.

Other formats for the symbol table are available, but no other result types (see chapter 3.2.16, "Symbol Table", on page 33).

SCPI command:

`LAY:ADD? '1',BEL, SYMB`(see `LAYout:ADD[:WINDow]?` on page 351)

Error Vector

The modulated difference between the complex measurement signal and the complex reference signal:

Modulation (measurement signal - reference signal)

For example: EVM = Mag(meas - ref)

The default result type is "EVM".

The following result types are available:
- chapter 3.2.17, "Error Vector Magnitude (EVM)", on page 34
- chapter 3.2.7, "Real/Imag (I/Q)", on page 26
- chapter 3.2.13, "Vector I/Q", on page 31

SCPI command:

`LAY:ADD? '1',BEL,EVEC`(see `LAYout:ADD[:WINDow]?` on page 351)

Modulation Errors

The difference between the modulated complex samples in the measurement and the modulated reference signal:

Modulation (measurement signal) - Modulation (reference signal)

For example: Magnitude Error = Mag(meas) - Mag(ref)

The default result type is "Magnitude Error".

The following result types are available:
- chapter 3.2.1, "Magnitude Absolute", on page 21
- chapter 3.2.19, "Phase Error", on page 36
- chapter 3.2.20, "Frequency Error Absolute", on page 37
- chapter 3.2.21, "Frequency Error Relative", on page 38

SCPI command:

`LAY:ADD? '1',BEL,MERR`(see `LAYout:ADD[:WINDow]?` on page 351)

Modulation Accuracy

Paraeters that characterize the accuracy of modulation.

The default result type is "Result Summary".

The following result types are available:

- chapter 3.2.22, "Result Summary", on page 39
- chapter 3.2.23, "Bit Error Rate (BER)", on page 42

The results of a modulation accuracy measurement can be checked for violation of defined limits automatically. If limit check is activated and the measured values exceed the limits, those values are indicated in red in the result summary table. If limit check is activated and no values exceed the limits, the checked values are indicated in green.

1 Result Summary		Current	Peak	Unit
*EVM *	RMS	12.59*	12.59	%
	Peak	103.31*	103.31	%
MER	RMS	18.00	18.00	dB
	Peak	-0.28	-0.28	dB
Phase Error	RMS	6.62	6.62	deg
	Peak	44.67	44.67	deg
Magnitude Error	RMS	5.04	5.04	%
	Peak	48.74	48.74	%
Carrier Frequency Error		-201.04	-201.04	Hz
Rho		0.984 404	0.984 404	
I/Q Offset		-40.15	-40.15	dB
I/Q Imbalance		-57.56	-57.56	dB
Gain Imbalance		0.01	0.01	dB
Quadrature Error		0.14	0.14	deg
Amplitude Droop		-0.000 53	0.000 005	dB/sym

SCPI command:

`LAY:ADD? '1',BEL,MACC`(see `LAYout:ADD[:WINDow]?` on page 351)

Equalizer

Filter characteristics of the equalizer used to compensate for channel distortion and parameters of the distortion itself.

The default result type is "Frequency Response Magnitude".

The following result types are available:

- chapter 3.2.24, "Impulse Response Magnitude", on page 44
- chapter 3.2.25, "Impulse Response Phase", on page 44
- chapter 3.2.26, "Impulse Response Real/Imag", on page 45
- chapter 3.2.27, "Frequency Response Magnitude", on page 45
- chapter 3.2.28, "Frequency Response Phase", on page 46
- chapter 3.2.29, "Group Delay", on page 46
- chapter 3.2.30, "Channel Frequency Response Magnitude", on page 47
- chapter 3.2.31, "Channel Group Delay", on page 48

SCPI command:

`LAY:ADD? '1',BEL,EQU`(see `LAYout:ADD[:WINDow]?` on page 351)

3.2 Result Types in VSA

The available result types for a window depend on the selected evaluation data source.

Table 3-1: Available result types depending on data source

Evaluation Data Source	Result Type	SCPI Parameter
Capture Buffer	Magnitude Absolute	MAGNitude
	Real/Imag (I/Q)	RIMag
	Frequency Absolute	FREQuency
	Vector I/Q	COMP
Meas & Ref Signal	Magnitude Absolute	MAGNitude
	Magnitude Relative	MAGNitude
	Phase Wrap	PHASe
	Phase Unwrap	UPHase
	Frequency Absolute	FREQuency
	Frequency Relative	FREQuency
	Real/Imag (I/Q)	RIMag
	Eye Diagram Real (I)	IEYE
	Eye Diagram Imag (Q)	QEYE
	Eye Diagram Frequency	FEYE
	Constellation I/Q	CONS
	Constellation I/Q (Rotated)	RCON
	Vector I/Q	COMP
	Constellation Frequency	CONF
	Vector Frequency	COVF
Symbols	Binary	-
	Octal	-
	Decimal	-
	Hexadecimal	-
Error Vector	EVM	MAGNitude
	Real/Imag (I/Q)	RIMag
	Vector I/Q	COMP
Modulation Errors	Magnitude Error	MAGNitude
	Phase Error	PHASe
	Frequency Error Absolute	FREQuency

Evaluation Data Source	Result Type	SCPI Parameter
	Frequency Error Relative	FREQuency
Modulation Accuracy	Bit Error Rate	BERate
	Result Summary	RSUM
Equalizer	Impulse Response Magnitude	MAGNitude
	Impulse Response Phase	UPHase
	Impulse Response Real/Image	RIMag
	Frequency Response Magnitude	MAGNitude
	Frequency Response Phase	UPHase
	Group Delay	GDELay
	Channel Frquency Response Magnitude	MAGNitude
	Channel Group Delay	GDELay

For details on selecting the data source and result types for evaluation see chapter 6.5, "Display and Window Configuration", on page 196.

SCPI command:

CALCulate<n>:FORMat on page 357

3.2.1 Magnitude Absolute

Magnitude of the source signal; the actual signal amplitude is displayed

$$Mag_{MEAS}(t) = |MEAS(t)|$$

with t=n·T_D and T_D=the duration of one sampling period at the sample rate defined by the display points per symbol parameter (see "Display Points/Sym" on page 198).

Available for source types:

● Capture Buffer
● Meas & Ref Signal
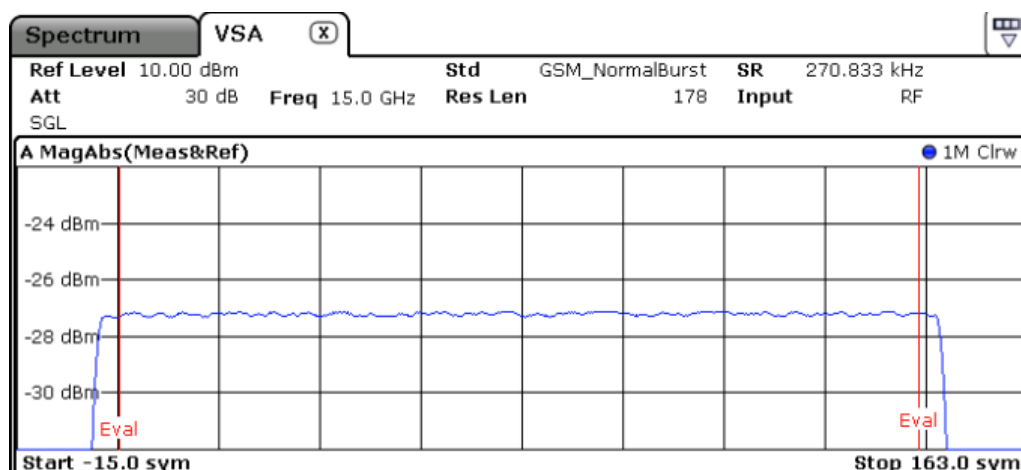
Fig. 3-2: Result display "Magnitude Absolute" for capture buffer data with normal transformation

SCPI commands:

LAY:ADD? '1',BEL,CBUF

to define the required source type (see LAYout:ADD[:WINDow]? on page 351)

CALC:FORM MAGN

to define the result type (see CALCulate<n>:FORMat on page 357)

TRAC:DATA

to query the trace results (see TRACe<n>[:DATA] on page 363)

3.2.2 Magnitude Relative

Magnitude of the source signal; the signal amplitude is scaled to the ideal reference signal

Available for source types:

● Meas & Ref Signal
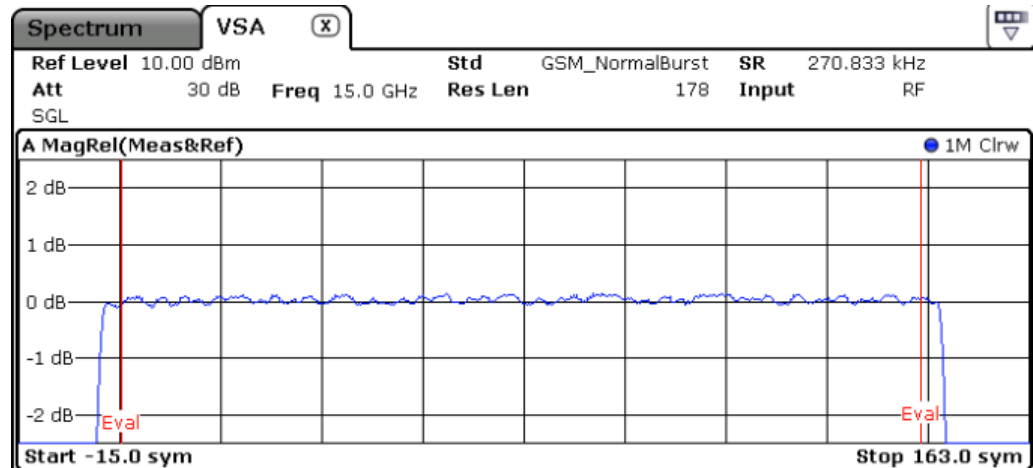
Fig. 3-3: Result display "Magnitude Relative" in normal mode

SCPI commands:

`LAY:ADD? '1',BEL,MEAS`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM MAGN`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`DISP:TRAC:Y:MODE REL`

to define relative values (see `DISPlay[:WINDow<n>]:TRACe:Y[:SCALe]:MODE` on page 360)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.3 Phase Wrap

The phase or argument of the signal; the display is limited to the phase value range of [-180°, 180°]

$$Phase_{MEAS}(t) = \angle(MEAS(t))$$

with $t = n \cdot T_D$ and T_D = the duration of one sampling period at the sample rate defined by the display points per symbol parameter (see "Display Points/Sym" on page 198).

Available for source types:

- Meas & Ref Signal
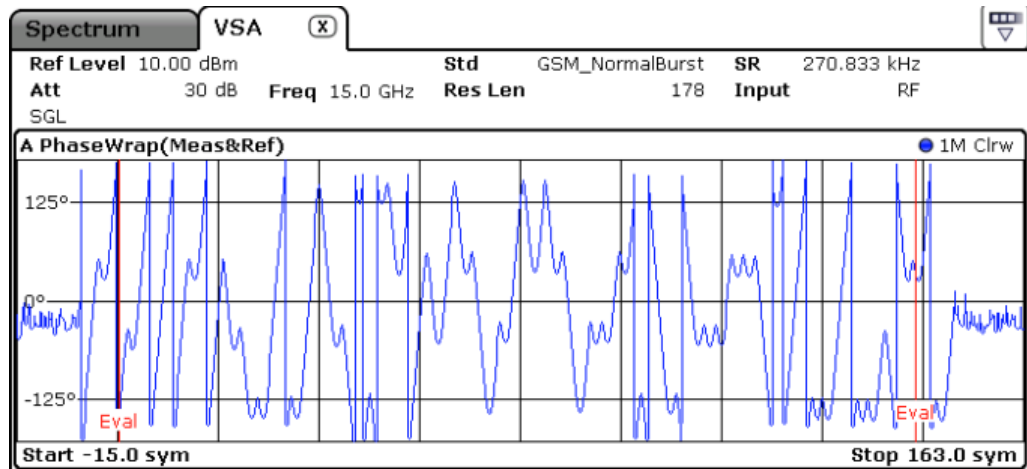
Fig. 3-4: Result display "Phase Wrap" in normal mode

SCPI commands:

`LAY:ADD? '1',BEL,REF`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM PHASe`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.4 Phase Unwrap

The phase of the signal; the display is not limited to [-180°, 180°].

Available for source types:

- Meas & Ref Signal

Fig. 3-5: Result display "Phase Unwrap" in normal mode

SCPI commands:

`LAY:ADD? '1',BEL,MEAS`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM UPHase`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.5 Frequency Absolute

The instantaneous frequency of the signal source; the absolute value is displayed in Hz.

Available for source types:

- Meas & Ref Signal
- Capture Buffer

Meas&Ref signal:

$$FREQ_{MEAS}(t) = \frac{1}{2 \cdot \pi} \frac{d}{dt} \angle MEAS(t)$$

with t=n·T_D and T_D=the duration of one sampling period at the sample rate defined by the display points per symbol parameter (see "Display Points/Sym" on page 198).

Capture buffer:

$$FREQ_{CAPT.}(t) = \frac{1}{2 \cdot \pi} \frac{d}{dt} \angle Capt(t)$$

When evaluating the capture buffer, the absolute frequency is derived from the measured phase, with T_D=the duration of one sampling period at the sample rate (see "Sample Rate" on page 153).

This measurement is mainly of interest when using the MSK or FSK modulation, but can also be used for the PSK/QAM modulations. However, since these modulations can have transitions through zero in the I/Q plane, in this case you might notice uncritical spikes. This is due to the fact that the phase of zero (or a complex value close to zero) is of limited significance, but still influences the result of the instantaneous frequency measurement.
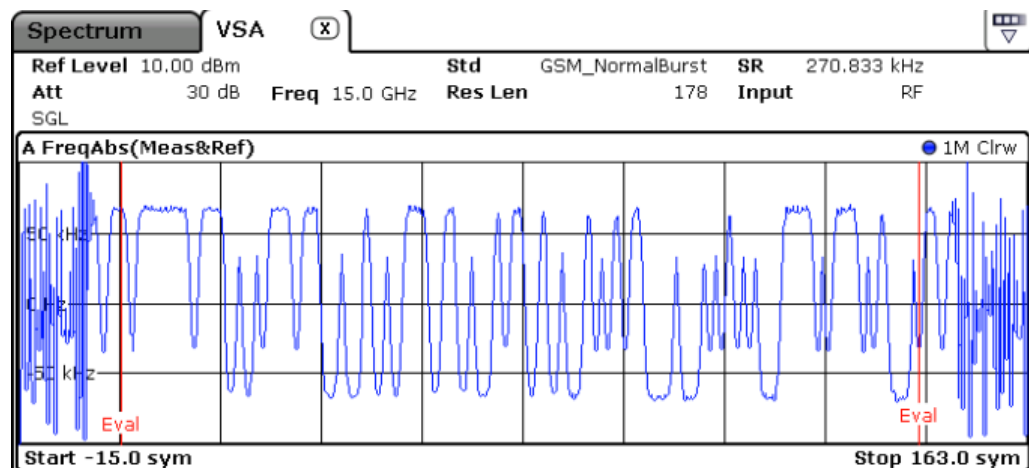
Fig. 3-6: Result display "Frequency Absolute" in normal mode

SCPI commands:

`LAY:ADD? '1',BEL,MEAS`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM FREQ`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.6 Frequency Relative

The instantaneous frequency of the signal source.

The results are normalized to the symbol rate (PSK and QAM modulated signals), the estimated FSK deviation (FSK modulated signals) or one quarter of the symbol rate (MSK modulated signals).

$$FREQ_{MEAS}(t) = \frac{1}{2 \cdot \pi} \frac{d}{dt} \angle MEAS(t)$$

with t=n·T_D and T_D=the duration of one sampling period at the sample rate defined by the display points per symbol parameter (see "Display Points/Sym" on page 198).


This measurement is mainly of interest when using the MSK or FSK modulation, but can also be used for the PSK/QAM modulations. See also the note for chapter 3.2.5, "Frequency Absolute", on page 24.

Available for source types:

- Meas & Ref Signal
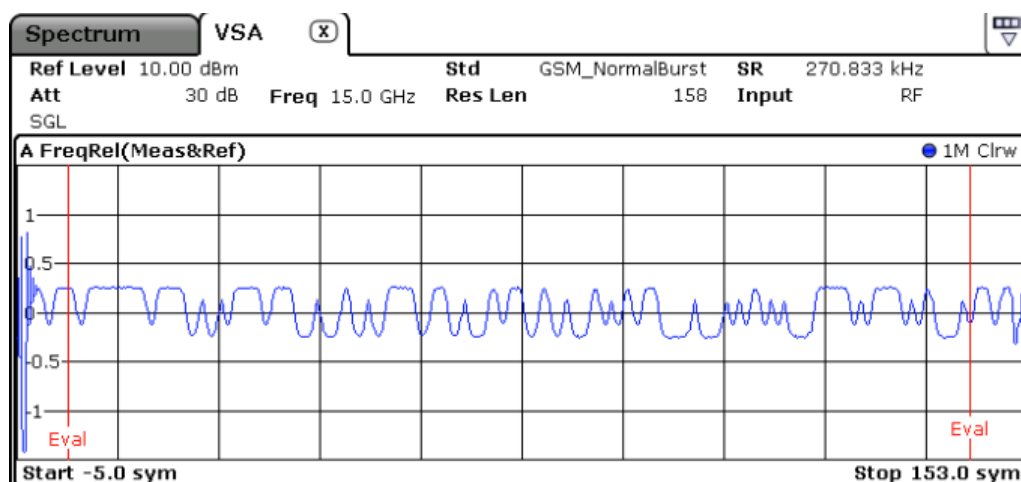
Fig. 3-7: Result display "Frequency Relative" in normal mode

SCPI commands:

`LAY:ADD? '1',BEL,MEAS`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM FREQ`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`DISP:TRAC:Y:MODE REL`

to define relative values (see `DISPlay[:WINDow<n>]:TRACe:Y[:SCALe]:MODE` on page 360)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.7 Real/Imag (I/Q)

Real and imaginary part of the measurement or reference signal in separate measurement diagrams; the x-axis (scaled in time units or symbols) is identical for both diagrams

The scaling of the capture buffer is

- relative to the current reference level if you are using the RF input
- relative to the full scale level if you are using the I/Q input

Available for source types:

- Capture Buffer
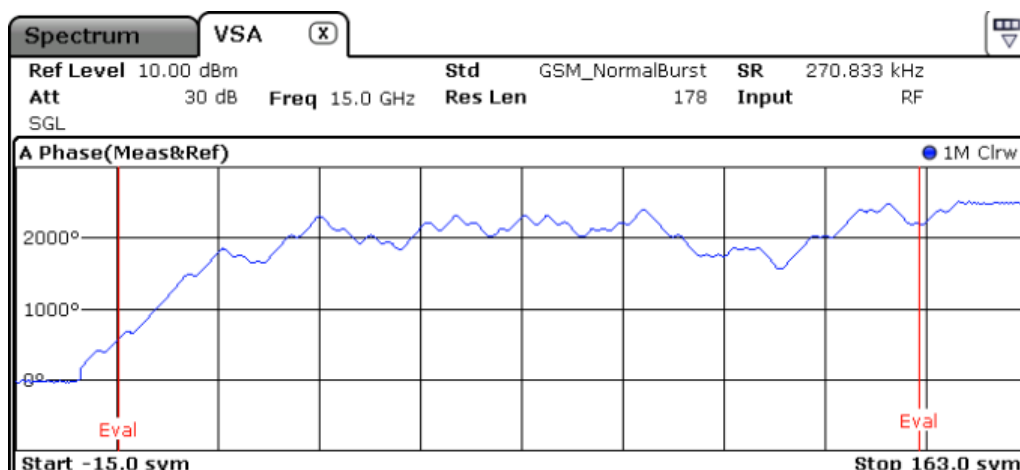- Meas & Ref Signal
- Error Vector
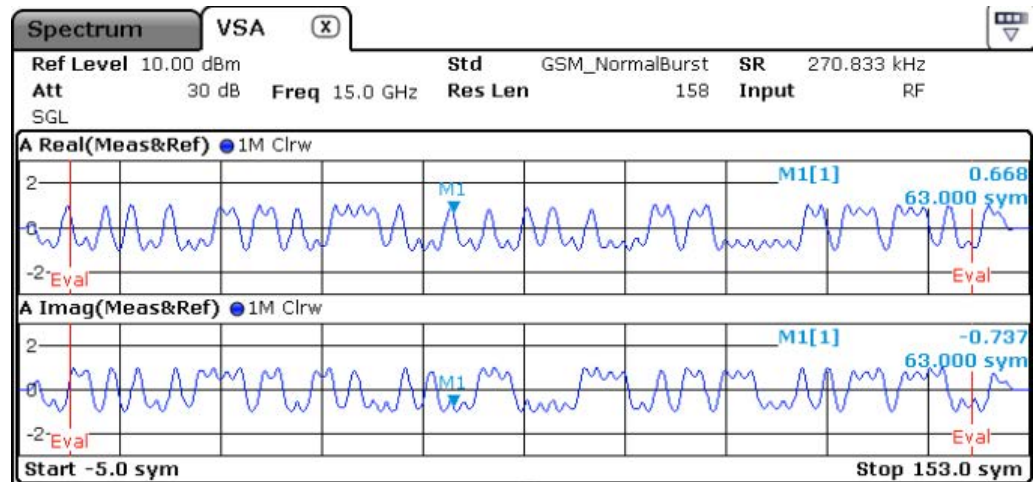
Fig. 3-8: Result display "Real/Imag (I/Q)" in normal mode

SCPI commands:

`LAY:ADD? '1',BEL,MEAS`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM RIMag`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.8 Eye Diagram Real (I)

The eye pattern of the inphase (I) channel; the x-axis value range is from -1 to +1 symbols (MSK: -2 to +2)

Available for source types:

- Meas & Ref Signal
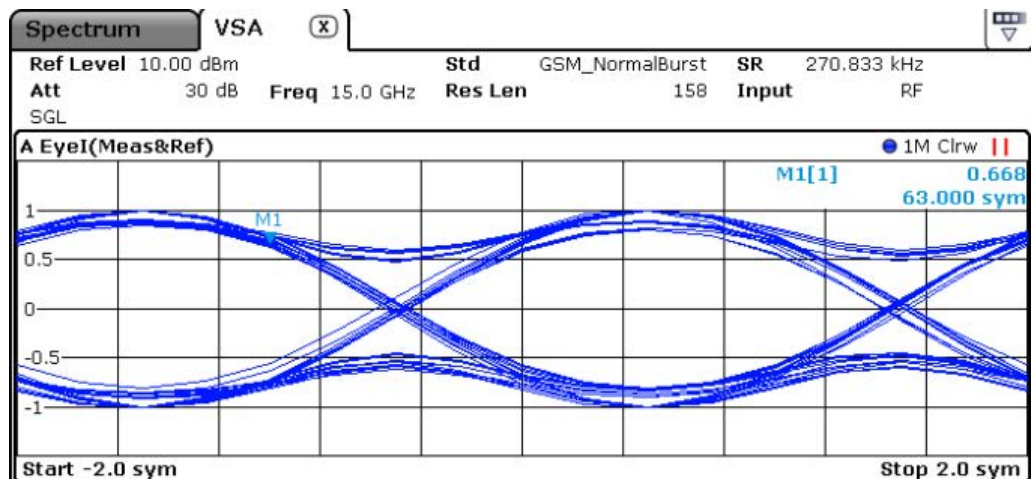
Fig. 3-9: Result display "Eye Diagram Real (I)" in normal mode

SCPI commands:

LAY:ADD? '1',BEL,MEAS

to define the required source type (see LAYout:ADD[:WINDow]? on page 351)

CALC:FORM IEYE

to define the result type (see CALCulate<n>:FORMat on page 357)

TRAC:DATA TRACE1

to query the trace results (see TRACe<n>[:DATA] on page 363)

3.2.9 Eye Diagram Imag (Q)

The eye pattern of the quadrature (Q) channel; the x-axis range is from -1 to +1 symbols (MSK: -2 to +2)

Available for source types:

- Meas & Ref Signal
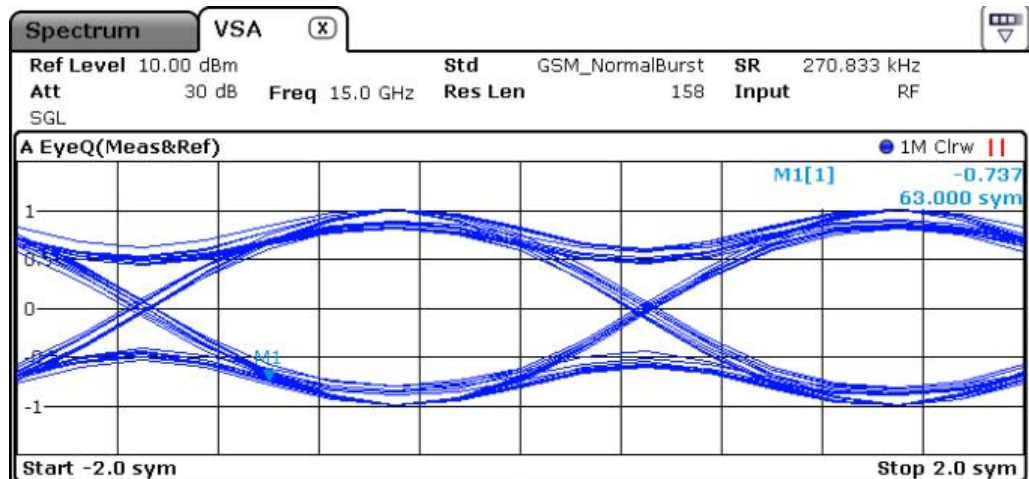
Fig. 3-10: Result display "Eye Diagram Imag (Q)" in normal mode

SCPI commands:

`LAY:ADD? '1',BEL,MEAS`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM QEYE`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.10 Eye Diagram Frequency

The eye diagram of the currently measured frequencies and/or the reference signal. The time span of the data depends on the evaluation range (capture buffer).

Available for source types:

● Meas & Ref Signal

SCPI commands:

`LAY:ADD? '1',BEL,MEAS`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM FEYE`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.11 Constellation I/Q

The complex source signal (without inter-symbol interference) as an X/Y plot; only the (de-rotated) symbol decision instants are drawn and not connected

Available for source types:

● Meas & Ref Signal

SCPI commands:

`LAY:ADD? '1',BEL,MEAS`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM CONS`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.12 Constellation I/Q (Rotated)

The complex source signal as an X/Y plot; As opposed to the common Constellation I/Q display, the symbol decision instants, *including the rotated ones*, are drawn and not connected

Available for source types:

● Meas & Ref Signal
This result type is only available for signals with a rotating modulation.
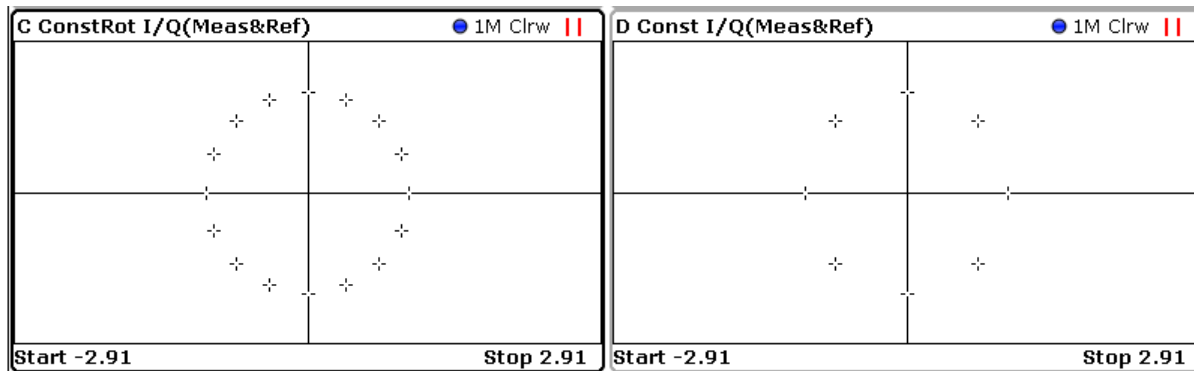
Fig. 3-11: Result display "Constellation I/Q (Rotated)" vs. common "Constellation I/Q" for 8PSK modulation

SCPI commands:

`LAY:ADD? '1',BEL,MEAS`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM RCON`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.13 Vector I/Q

The complex source signal as an X/Y plot; all available samples (as defined by the display points per symbol parameter, see "Display Points/Sym" on page 198) are drawn and connected.

The scaling of the capture buffer is:
- relative to the current reference level if you are using the RF input
- relative to the full scale level if you are using the I/Q input

Available for source types:
- Capture Buffer
- Meas & Ref Signal
- Error Vector

MSK	QPSK
B I/Q Vector(Meas&Ref) ● 1M Clrw ❚❚ M1[1] 0.715 / -0.698 103.000 sym M1 Start -2.535 Stop 2.535	B I/Q Vector(Meas&Ref) ● 1M Clrw Start -2.43 Stop 2.43
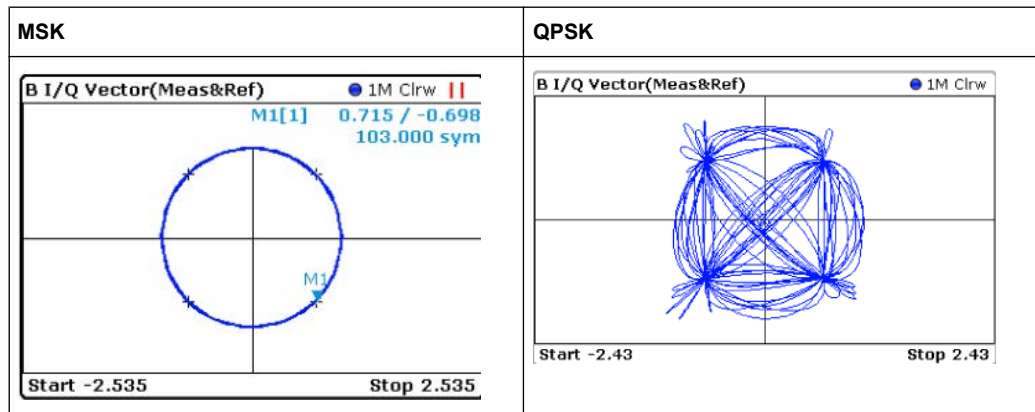
SCPI commands:

`LAY:ADD? '1',BEL,MEAS`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM COMP`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.14 Constellation Frequency

The instantenous frequency of the source signal (without inter-symbol interference) as an X/Y plot; only the symbol decision instants are drawn and not connected.

Available for source types:

● Meas & Ref Signal

C Const Freq(Meas&Ref) ● 1M Clrw

M1[1] -249.5108 kHz
9.000 sym

M1

Start -727.5 kHz Stop 727.5 kHz

SCPI commands:

`LAY:ADD? '1',BEL,MEAS`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM CONF`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.15 Vector Frequency

The instantenous frequency of the source signal as an X/Y plot; all available samples (as defined by the display points per symbol parameter (see "Display Points/Sym" on page 198)) are drawn and connected.

Available for source types:

- Meas & Ref Signal

SCPI commands:

`LAY:ADD? '1',BEL,MEAS`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM COVF`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

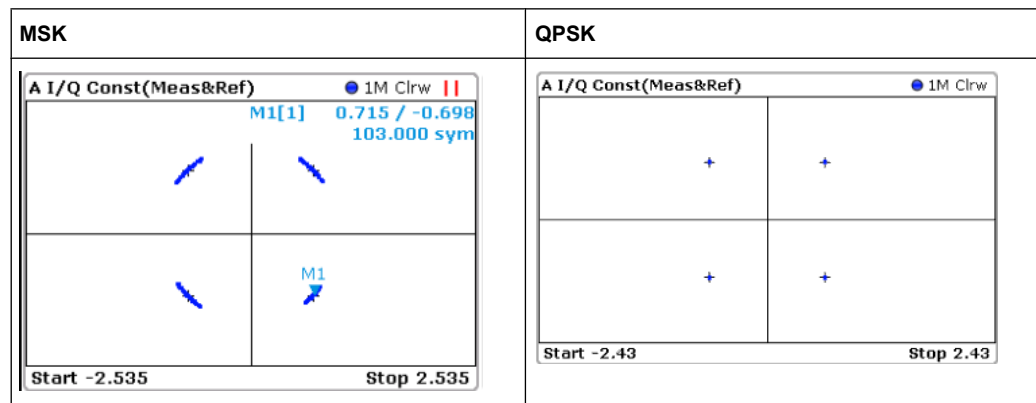to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.16 Symbol Table

Symbol numbers are displayed as a table. Each symbol is represented by an entry in the table. The symbols can be displayed in binary, octal, hexadecimal or decimal format.

Example:

Fig. 3-12: Result display for "Symbols" in binary mode

If a pattern search is active, a found pattern is indicated in the symbol table, as well.

SCPI commands:

`LAY:ADD? '1',BEL, 'XTIM:DDEM:SYMB'`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.17 Error Vector Magnitude (EVM)

Displays the error vector magnitude as a function of symbols or time.

$$EVM(t) = \frac{|EV(t)|}{C}$$

with $t = n \cdot T_D$ and T_D = the duration of one sampling period at the sample rate defined by the display points per symbol parameter (see "Display Points/Sym" on page 198).

The normalization constant C is chosen according to the EVM normalization. By default C^2 is the mean power of the reference signal.

$$C = \sqrt{\frac{1}{K} \sum_k |REF(k \cdot T)|^2}$$

and

$$T = \text{duration of symbol periods}$$

Note that $k = 0.5 \cdot n \cdot T$ for Offset QPSK with inactive Offset EVM.
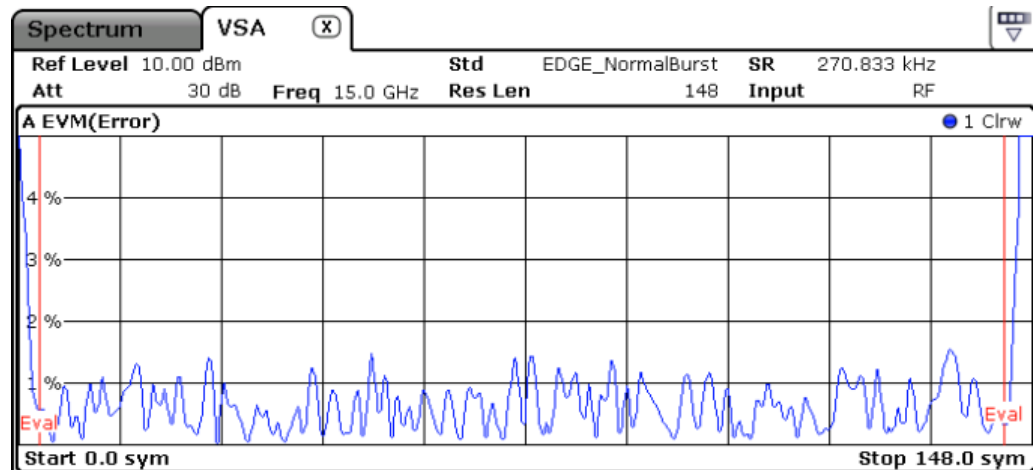
Fig. 3-13: Result display "Error Vector Magnitude" in normal mode

Available for source types:

- Error Vector

SCPI commands:

`LAY:ADD? '1',BEL,EVEC`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM MAGN`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.18 Magnitude Error

Displays the magnitude error of the measurement signal with respect to the reference signal (as a function of symbols over time)

$$MAG\_ERR(t) = MAG_{MEAS}(t) - MAG_{REF}(t)$$

with $t = n \cdot T_D$ and T_D = the duration of one sampling period at the sample rate defined by the display points per symbol parameter (see "Display Points/Sym" on page 198).
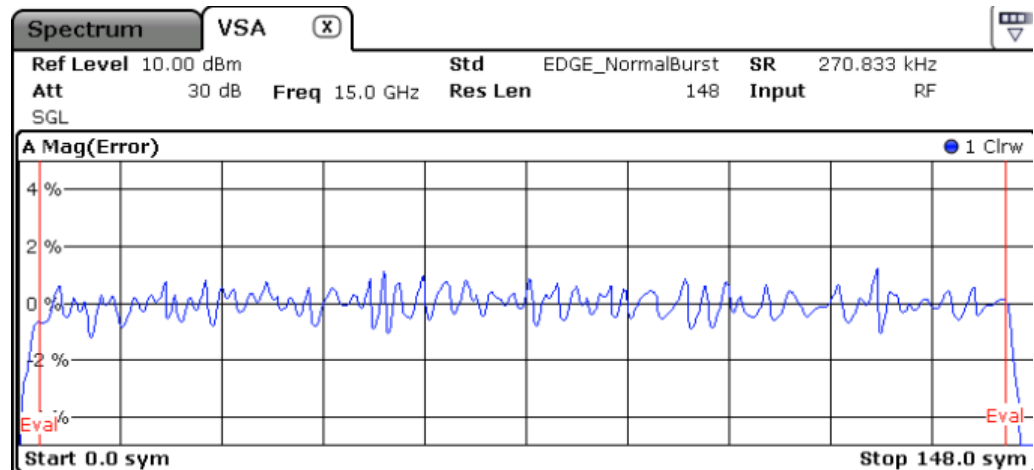
Fig. 3-14: Result display "Magnitude Error" in normal mode

Available for source types:

● Modulation Errors

SCPI commands:

`LAY:ADD? '1',BEL,MERR`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM MAGN`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.19 Phase Error

Displays the phase error of the measuremente signal with respect to the reference signal as a function of symbols over time.

$$PHASE\_ERR(t) = PHASE_{MEAS}(t) - PHASE_{REF}(t)$$

with $t = n \cdot T_D$ and T_D =the duration of one sampling period at the sample rate defined by the display points per symbol parameter (see "Display Points/Sym" on page 198).
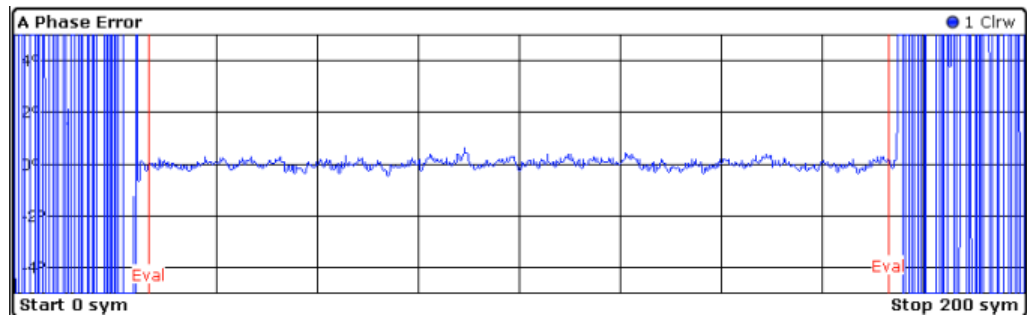
Fig. 3-15: Result display "Phase Error" in normal mode

Available for source types:

● Modulation Errors

SCPI commands:

LAY:ADD? '1',BEL,MERR

to define the required source type (see LAYout:ADD[:WINDow]? on page 351)

CALC:FORM PHAS

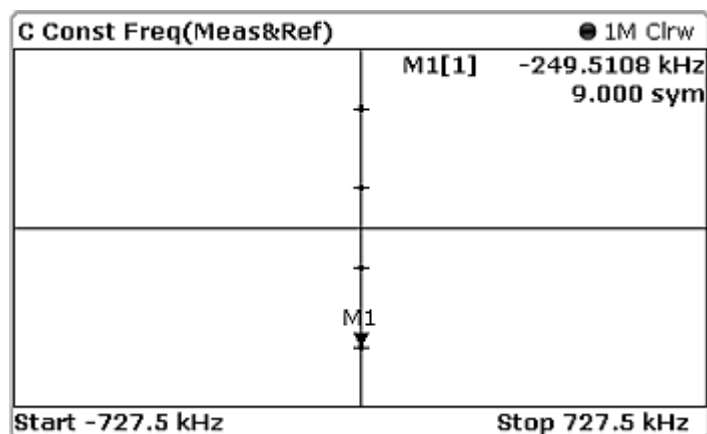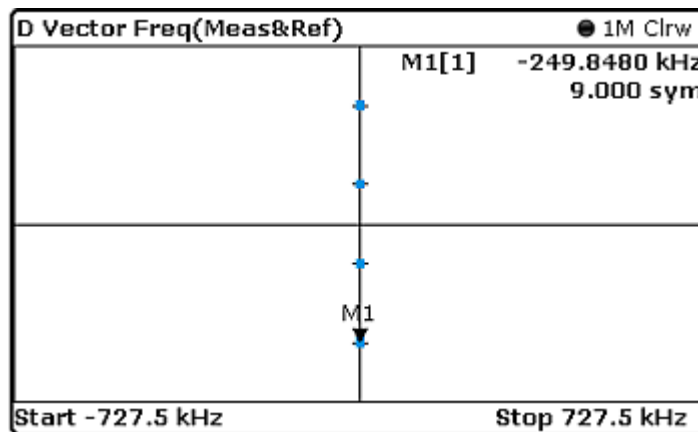to define the result type (see CALCulate<n>:FORMat on page 357)

TRAC:DATA TRACE1

to query the trace results (see TRACe<n>[:DATA] on page 363)

3.2.20 Frequency Error Absolute

Displays the error of the instantaneous frequency in Hz of the measurement signal with respect to the reference signal as a function of symbols over time.

$$FREQ\_ERR(t) = FREQ_{MEAS}(t) - FREQ_{REF}(t)$$

with $t = n \cdot T_D$ and T_D = the duration of one sampling period at the sample rate defined by the display points per symbol parameter (see "Display Points/Sym" on page 198).

Note that this measurement does not consider a possible carrier frequency offset. This has already been compensated for in the measurement signal.

This measurement is mainly of interest when using the MSK or FSK modulation, but can also be used for the PSK/QAM modulations. However, since these modulations can have transitions through zero in the I/Q plane, in this case you might notice uncritical spikes. This is due to the fact that the phase of zero (or a complex value close to zero) has in fact limited significance, but still influences the result of the current frequency measurement.
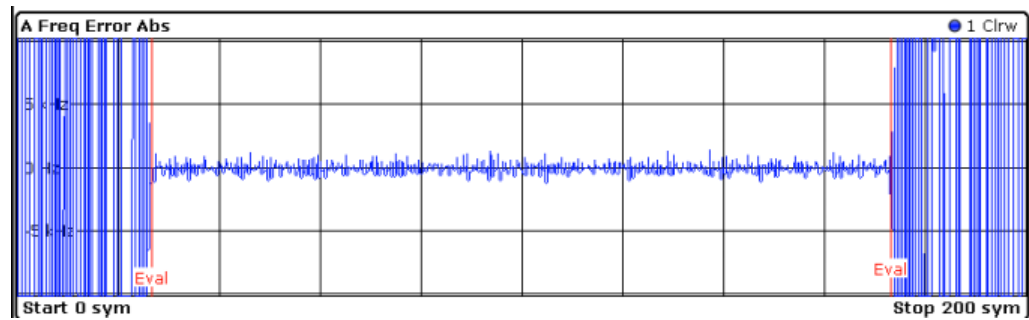
Fig. 3-16: Result display "Frequency Error Absolute" in normal mode

Available for source types:

● Modulation Errors

SCPI commands:

`LAY:ADD? '1',BEL,MERR`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM FREQ`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.21 Frequency Error Relative

Displays the error of the instantaneous frequency of the measurement signal with respect to the reference signal as a function of symbols over time.

The results are normalized to the symbol rate (PSK and QAM modulated signals), the estimated FSK deviation (FSK modulated signals) or one quarter of the symbol rate (MSK modulated signals).

$$FREQ\_ERR(t) = FREQ_{MEAS}(t) - FREQ_{REF}(t)$$

with $t = n \cdot T_D$ and T_D = the duration of one sampling period at the sample rate defined by the display points per symbol parameter (see "Display Points/Sym" on page 198).

This measurement is mainly of interest when using the MSK or FSK modulation, but can also be used for the PSK/QAM modulations. See also the note for chapter 3.2.20, "Frequency Error Absolute", on page 37.
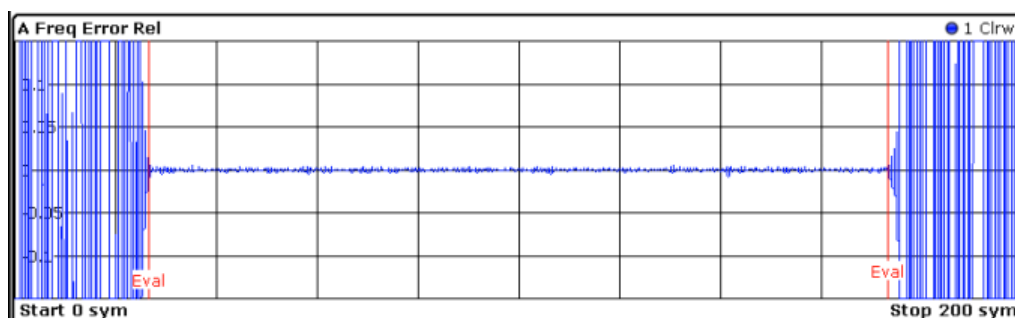
Fig. 3-17: Result display "Frequency Error Relative" in normal mode

Available for source types:

● Modulation Errors

SCPI commands:

`LAY:ADD? '1',BEL,MERR`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM FREQ`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`DISP:TRAC:Y:MODE REL`

to define relative values (see `DISPlay[:WINDow<n>]:TRACe:Y[:SCALe]:MODE` on page 360)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.22 Result Summary

The Modulation Accuracy results in a table. For details on the parameters see chapter 3.3, "Common Parameters in VSA", on page 48.

Basis of evaluation

The majority of the values that are displayed in the Result Summary are calculated over the "Evaluation Range" (see chapter 5.11, "Evaluation Range Configuration", on page 181). They are evaluated according to the setting of the Display Points/Sym parameter. For example, if "Display Points/Symbol" is "1", only the symbol instants contribute to the result displayed in the result summary.

Table 3-2: Results calculated over the evaluation range

PSK, MSK, QAM	FSK
EVM	Frequency Error
MER	Magnitude Error

PSK, MSK, QAM	FSK
Phase Error	Power
Magnitude Error	
Rho	
Power	

The following results that are based on internal estimation algorithms (see chapter 4.5, "Signal Model, Estimation and Modulation Errors", on page 96) are calculated over the "Estimation range" (see also chapter 4.5.1.2, "Estimation", on page 97).

Table 3-3: Results calculated over the estimation range

PSK, MSK, QAM	FSK
Carrier Frequency Error	FSK Deviation Error
Symbol Rate Error	Symbol Rate Error
I/Q Offset	FSK Measurement Deviation
I/Q Imbalance	Carrier Frequency Error
Gain Imbalance	Carrier Frequency Drift
Quadrature Error	
Amplitude Droop	

Current value

In the "Current" column, the value evaluation for the current evaluation is displayed. For example, the EVM Peak value in the current sweep corresponds to the peak of the trace values within the evaluation range for the current sweep (as indicated by marker 1 in figure 3-18).
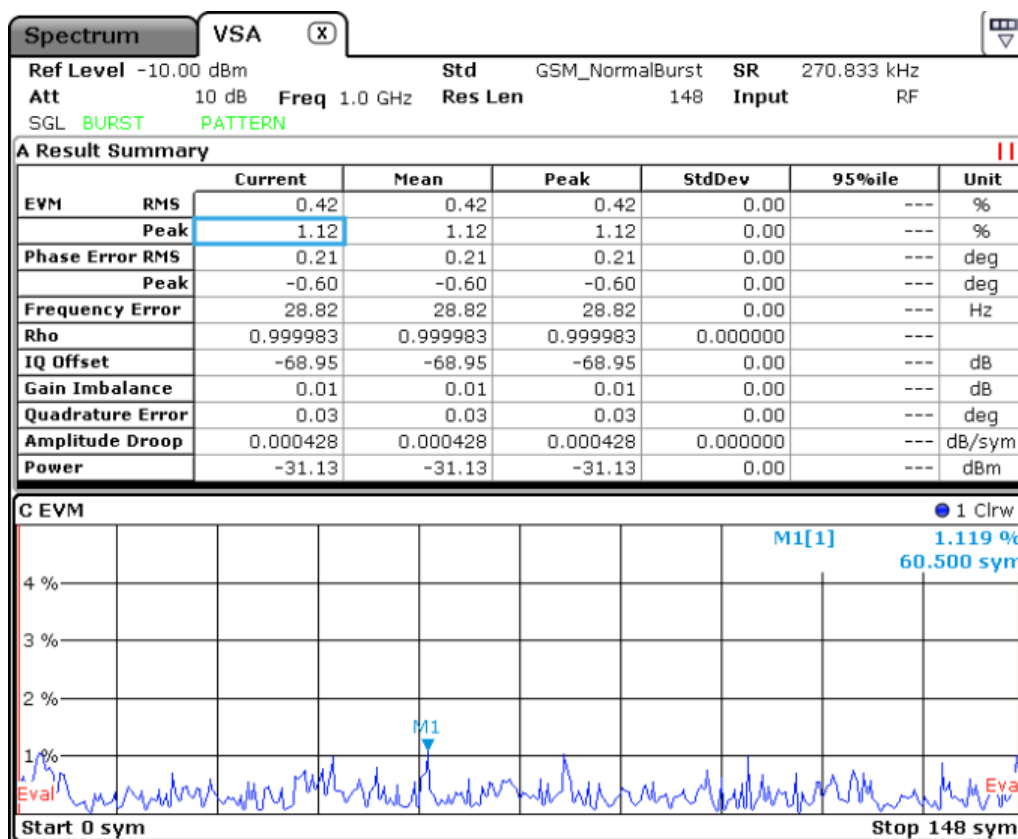
Fig. 3-18: Example for result summary with current EVM peak value marked

If you want to compare the trace values to the results of the Result Summary, make sure to match the displayed points per symbol of the trace and of the Result Summary. Refer to "Display Points/Sym" on page 198 for details.

Mean value

In the "Mean" column, the linear mean of the values that are in the "Current" column is displayed. Note that if the values are in a logarithmic representation, e.g. the I/Q Offset, the linear values are averaged.

Peak value

In the "Peak" column, the maximum value that occurred during several evaluations is displayed. Note that when the value can be positive and negative, e.g. the phase error, the maximum absolute value (maintaining its sign) is displayed. The peak value of Rho is handled differently, since its minimum value represents the worst case. In that case, the minimum value is displayed.

Standard Deviation

The value for the standard deviation is calculated on the linear values and then converted to the displayed unit.

95-percentile

The 95-percentile value is based on the distribution of the current values. Since the phase error and the magnitude error can usually be assumed to be distributed around zero, the 95-Percentile for these values is calculated based on their absolute values. Again, the Rho value is handled differently. Here, the 5-Percentile is displayed, since the lowest Rho value represents the worst case.

SCPI commands:

`LAY:ADD? '1',BEL,  MACC`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM RSUM`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

`CALC:MARK:FUNC:DDEM:STAT:<parameter>`

to query individual parameter values (see chapter 10.8.2, "Retrieving Parameter Values", on page 365

3.2.23   Bit Error Rate (BER)

A bit error rate (BER) measurement compares the transmitted bits with the determined symbol decision bits:

BER = error bits / number of analyzed bits

As a prerequisite for this measurement, the VSA application must know which bit sequences are correct, i.e. which bit sequences may occur. This knowledge must be provided as a list of possible data sequences in xml format, which is loaded in the VSA application (see chapter 4.8, "Known Data Files - Dependencies and Restrictions", on page 116).

If such a file is loaded in the application, the BER result display is available.

Available for source types:

● Modulation Accuracy

Note that this measurement may take some time, as each symbol decision must be compared to the possible data sequences one by one.

The BER measurement is an indicator for the quality of the demodulated signal. High BER values indicate problems such as:

- inadequate demodulation settings
- poor quality in the source data
- false or missing sequences in the Known Data file
- result range alignment leads to a mismatch of the input data with the defined sequences

A BER value of 0.5 means that for at least one measurement no matching sequence was found.

See also chapter 4.4.3, "Demodulation and Symbol Decisions", on page 89

B Bit Error Rate	Current	Minimum	Maximum	Accumulative
Bit Error Rate	0.000 000 000	0.000 000 000	0.461 711 705	0.003 577 107
Total # of Errors	0	0	205	216
Total # of Bits	444	444	444	59940

The following information is provided in the BER result display:

- **Bit Error Rate**: error bits / number of analyzed bits
- **Total # of Errors**: number of detected bit errors (known data compared to symbol decisions)
- **Total # of Bits**: number of analyzed bits

For each of these results, the following values are provided:

BER Result	Description
Current	Value for current result range
Minimum	Minimum "Current" value during the current measurement
Maximum	Maximum "Current" value during the current measurement
Accumulative	Total value over several measurements; for BER: Total # of Errors / Total # of Bits (similar to average function)

SCPI commands:

`LAY:ADD? '1',BEL,MACC`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM BER`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`CALC:BER?`

to query the results (see `CALCulate<n>:BERate` on page 365)

3.2.24 Impulse Response Magnitude

The impulse response magnitude of the equalizer shows the filter in the time domain.
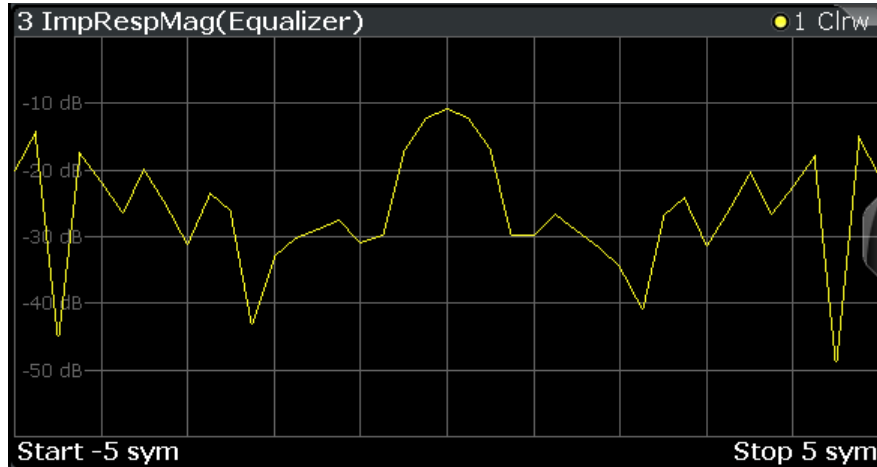
SCPI commands:

`LAY:ADD? '1',BEL,EQU`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM MAGN`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.25 Impulse Response Phase

The Impulse Response Phase is the derivation of the Impulse Response Magnitude.

SCPI commands:

`LAY:ADD? '1',BEL,EQU`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM UPH`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.26 Impulse Response Real/Imag

The Real/Imag diagram of the impulse response is a stem diagram. It displays the filter characteristics in the time domain for both the I and the Q branches individually. Using this information the equalizer is uniquely characterized and can be recreated by other applications.

SCPI commands:

`LAY:ADD? '1',BEL,EQU`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM RIM`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.27 Frequency Response Magnitude

Frequency response of the current equalizer to the input signal. Note that the frequency response of the equalizer is not a pure inverted function of the channel response, as both functions are calculated independantly. The frequency response is calculated by determining an optimal EVM for the input signal.

SCPI commands:

`LAY:ADD? '1',BEL,EQU`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM MAGN`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.28 Frequency Response Phase

The frequency response phase of the equalizer is derived from the Frequency Response Magnitude.

SCPI commands:

`LAY:ADD? '1',BEL,EQU`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM UPH`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.29 Group Delay

The group delay of the equalizer is the derivation of phase over frequency. It is a measure of phase distortion.
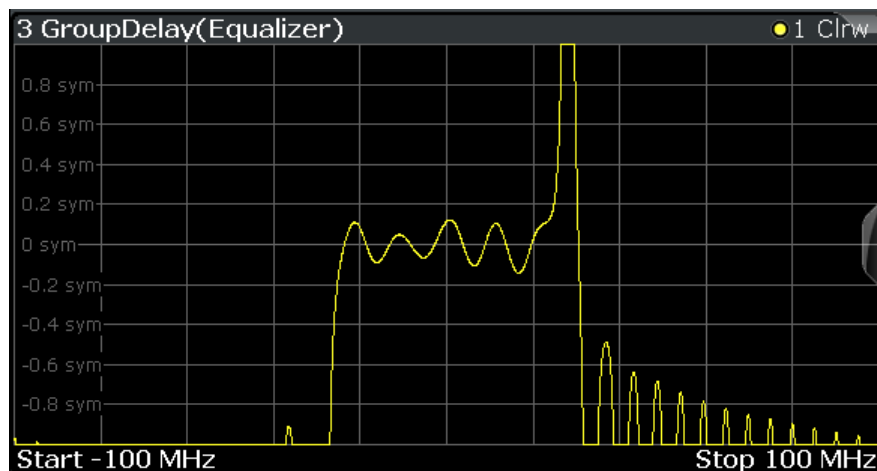
SCPI commands:

`LAY:ADD? '1',BEL,EQU`

to define the required source type (see `LAYout:ADD[:WINDow]?` on page 351)

`CALC:FORM GDEL`

to define the result type (see `CALCulate<n>:FORMat` on page 357)

`TRAC:DATA TRACE1`

to query the trace results (see `TRACe<n>[:DATA]` on page 363)

3.2.30 Channel Frequency Response Magnitude

The frequency response magnitude of the channel indicates which distortions occurred during transmission of the input signal. It is only determined if the equalizer is activated.
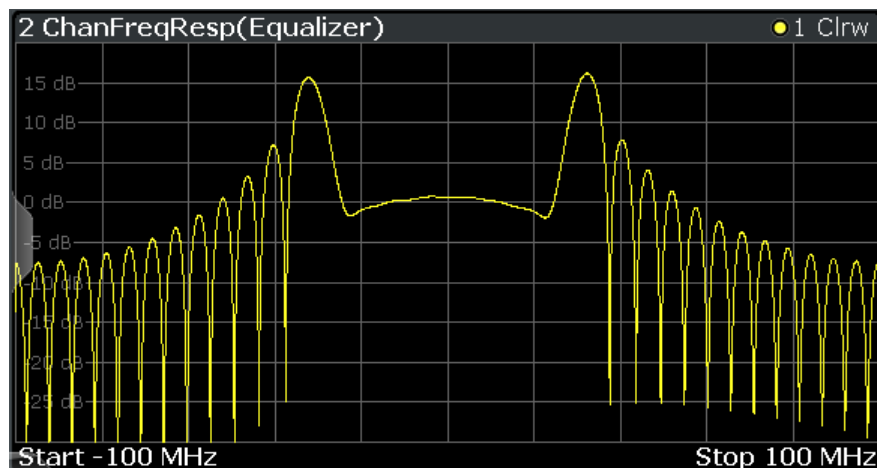
The bandwidth for which the channel transfer function can be estimated is not only limited by the usable I/Q bandwidth, but also by the bandwidth of the analyzed input signal. Areas with low reception power, e.g. at the filter edges, may suffer from less accurate estimation results.

SCPI commands:

LAY:ADD? '1',BEL,EQU

to define the required source type (see LAYout:ADD[:WINDow]? on page 351)

CALC:FORM MAGN

to define the result type (see CALCulate<n>:FORMat on page 357)

TRAC:DATA TRACE1

to query the trace results (see TRACe<n>[:DATA] on page 363)

3.2.31 Channel Group Delay

The group delay of the channel is the derivation of phase over frequency for the original input signal. It is a measure of phase distortion.
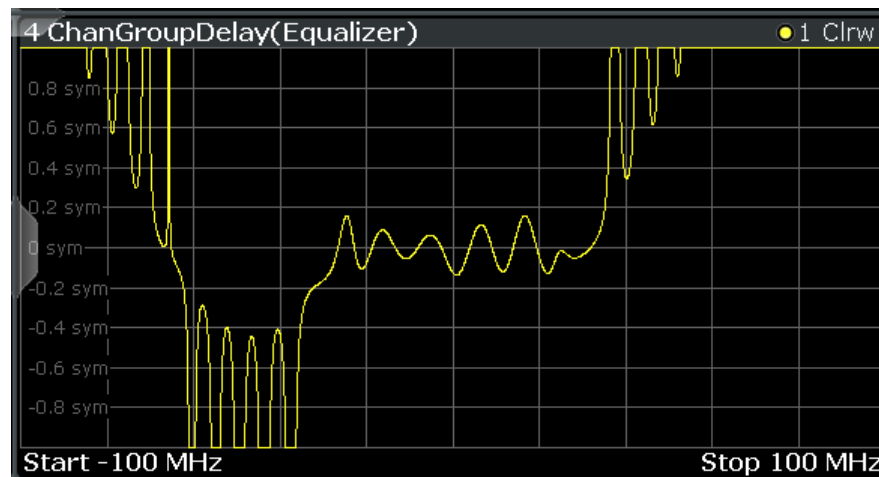
SCPI commands:

LAY:ADD? '1',BEL,EQU

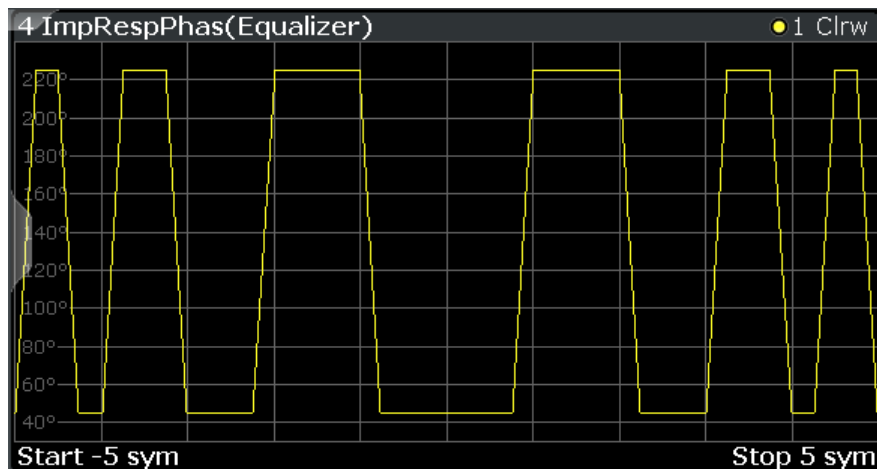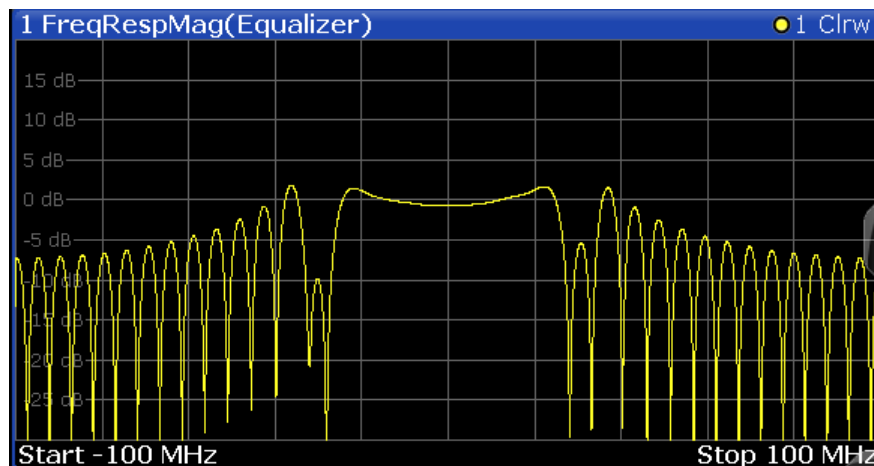to define the required source type (see LAYout:ADD[:WINDow]? on page 351)

CALC:FORM GDEL

to define the result type (see CALCulate<n>:FORMat on page 357)

TRAC:DATA TRACE1

to query the trace results (see TRACe<n>[:DATA] on page 363)

3.3 Common Parameters in VSA

Depending on the modulation type you are using, different signal parameters are determined during vector signal analysis.

Details concerning the calculation of individual parameters can be found in chapter 4.5, "Signal Model, Estimation and Modulation Errors", on page 96 and chapter A.5, "Formulae", on page 410.

Table 3-4: Parameters for PSK, QAM and MSK modulation

Parameter	Description	SCPI Parameter
EVM - RMS/Peak	Error Vector Magnitude	EVM
MER - RMS/Peak	Modulation Error Ratio	SNR
Phase Error - RMS/Peak	The phase difference between the measurement vector and the reference vector	PERR
Magnitude Error - RMS/Peak	The average (RMS) and peak magnitude error in %. The magnitude error is the difference of the measured magnitude to the magnitude of the reference signal. The magnitude error is normalized to the mean magnitude of the reference signal.	MERRor
Carrier Frequency Error	The mean carrier frequency offset in Hz	CFERror
Symbol Rate Error		SRER
Rho		RHO
I/Q Offset	Offset in the original input	OOFFset
I/Q Imbalance	Not for BPSK.	IQIMbalance
Gain Imbalance	Not for BPSK.	GIMBalance
Quadrature Error	Not for BPSK.	QERRor
Amplitude Droop	The decrease of the signal power over time in the transmitter	ADRoop
Power	The power of the measured signal	MPOWer

Table 3-5: Parameters for FSK modulation only

Parameter	Description	SCPI parameter
Frequency Error - RMS/Peak	The average (RMS) and peak frequency error in %. The frequency error is thedifference of the measured frequency and the reference frequency.The frequency error is normalized to the estimated FSK deviation.	FSK:DERRor
FSK Deviation Error	The deviation error of FSK modulated signals in Hz. The FSK deviation erroris the difference of the FSK deviation of the measured signal and the FSK referencedeviation you have set.	FDERror
FSK Meas Deviation	The estimated deviation of FSK modulated signals in Hz.	FSK:MDEViation
FSK Ref Deviation	The reference deviation you have set in Hz.	FSK:RDEViation
Carrier Frequency Drift	The mean carrier frequency drift in Hz per symbol.	FSK:CFDRift

SCPI command:

CALCulate<n>:MARKer<m>:FUNCtion:DDEMod:STATistic:<Parameter>?

4 Measurement Basics

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

For information on the basic processing of I/Q data in the R&S FSW see the R&S FSW I/Q Analyzer User Manual.

4.1 Filters and Bandwidths During Signal Processing

This section describes the used filters in vector signal analysis with an R&S FSW, as well as the bandwidth after each filter.

The relevant filters for vector signal analysis are shown in figure 4-1.
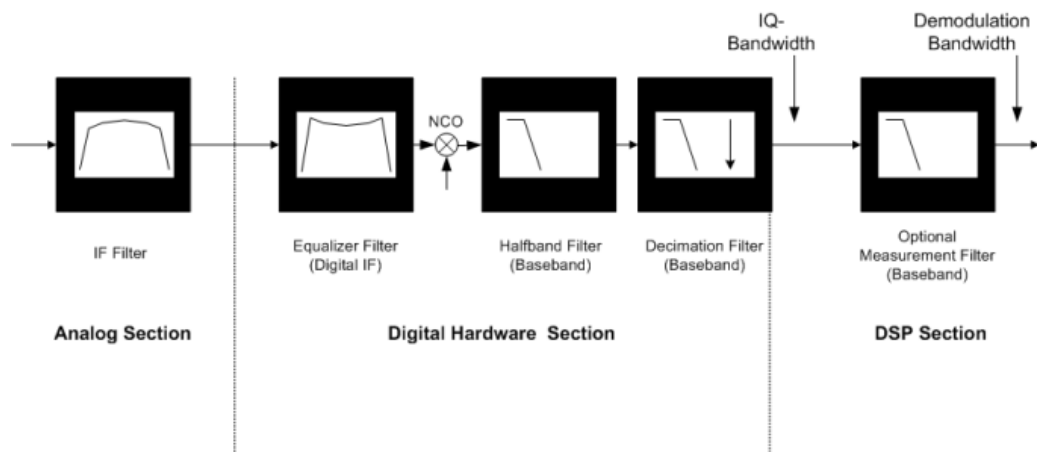
Fig. 4-1: Block diagram of bandwidth-relevant filters for vector signal analysis

- After the IF Filter (only for RF input operation): bandwidth = 40 MHz
- After the digital hardware section:
  The phase and amplitude distortions of the IF filter have been compensated for.
  Usually, the I/Q data has a usable bandwidth of about:
  0.8 * sample rate
  For details refer to chapter 4.1.1, "I/Q Bandwidth", on page 51.
  The I/Q data's sample rate and bandwidth are automatically adjusted to the set symbol rate. For most modulated signals even the smallest allowed value for the sample

rate leads to a sufficient I/Q data bandwidth. The whole spectrum of the input signal is captured, but most adjacent channels and interferers are effectively suppressed. Only for very wide signals (FSK, no TX-filter used) it can be necessary to try higher values for the sample rate (see chapter 4.2, "Sample Rate, Symbol Rate and I/Q Bandwidth", on page 57), increasing the I/Q bandwidth. The I/Q data delivered to the DSP section has no considerable amplitude or phase distortion and a suitable bandwidth.

> The "Signal Capture" dialog box ("Data Acquisition" tab) shows the sample rate and the usable I/Q bandwidth achieved for the current settings (see "Usable I/Q Bandwidth" on page 153).

● After the optional measurement filter:
  The measurement signal and the reference signal can be filtered by various measurement filters which have different bandwidths.

The filters described above are the ones that directly affect the bandwidth of the captured I/Q data and the final measurement signal and reference signal. Note, however, that several other filters are also involved in the DSP section but are not mentioned above:

● Receive filter to prevent ISI (intersymbol-interference)
● filters necessary for various estimators
● others

4.1.1 I/Q Bandwidth

The bandwidth of the I/Q data used as input for the vector signal analysis is filtered as described in chapter 4.1, "Filters and Bandwidths During Signal Processing", on page 50. Its flat, usable bandwidth (no considerable amplitude or phase distortion) depends on:

● the used sample rate, which depends on:
  – the defined "Symbol Rate" (see "Symbol Rate" on page 129)
  – the defined "Sample Rate" parameter (see "Sample Rate" on page 153
● the type of input used (digital baseband input, RF input, etc)

For details on the maximum usable bandwidth see chapter 4.2, "Sample Rate, Symbol Rate and I/Q Bandwidth", on page 57.

> The sample rate and the usable I/Q bandwidth achieved for the current settings is displayed in the "Signal Capture" dialog, see chapter 5.6.1, "Data Acquisition", on page 151.

4.1.2 Demodulation Bandwidth (Measurement Bandwidth)

Some modulation systems do not use a receive filter. In these cases special care should be taken that no interference or adjacent channels occur within the demodulation band-

width. The "Sample rate" parameter should be set to a low value (see "Sample Rate" on page 153).

Typical communication systems demand special receive or measurement filters (e.g. root-raised cosine receive filter or EDGE measurement filter).

If no such filtering is performed, care should be taken that neither interfering signals nor adjacent channels fall within the demodulation bandwidth.

4.1.3 Modulation and Demodulation Filters

Sample points are required for demodulation in the analyzer, where only information of the current symbol and none of neighbouring symbols is present (symbol points). These points are also called ISI-free points (ISI = intersymbol interference). If the transmitter does not provide an ISI-free signal after the transmit filter (**TX filter**), this condition can be fulfilled by signal-specific filtering of the analyzer input signal (**receive filter** or **Rx filter**). If an RRC (root-raised cosine) filter is used in the transmitter, an RRC filter is also required in the analyzer to obtain ISI-free points.

In many PSK systems, RRC filters are used as transmit, ISI and measurement filters. To determine the I/Q modulation error, the measurement signal must be compared with the corresponding ideal signal. For this purpose a **reference filter** is required which is calculated by the analyzer by convolving the coefficient of the transmit filter (**Tx filter**) and the **meas filter** (see figure 4-2).

If unfiltered signals have to be measured as well (e.g. to determine nonlinear signal distortions), no measurement filter is switched into the signal path and the **reference filter** is identical to the **Transmit filter** (see figure 4-2).

In the baseband block diagrams (see figure 4-2), the system-theoretical transmitter and analyzer filters are shown for PSK and QAM demodulation. For the sake of clearness, RF stages, IF filters and the filter stages of the **digital hardware section** are not shown.

For a correct demodulation, the following filters have to be accurately specified for the analyzer:

- Transmit filter: filter characteristic of transmitter
- Meas filter:
    - PSK, QAM, UserQAM, MSK:
      The I and the Q part of the measurement and the reference signal are filtered with this filter.
    - FSK:
      The instantaneous frequency of the measurement reference signal are filtered.

  In many applications, the measurement filter is identical with the ISI filter.

The receive filter (ISI filter) is configured internally depending on the transmit filter. The goal is to produce intersymbol-interference-free points for the demodulation.

The reference filter synthesizes the ideal transmitted signal (after meas filtering). It is calculated by the analyzer from the above filters (convolution operation **Transmit filter * Meas Filter**).

Typical combinations of Tx and Meas filters are shown in table 1-4; they can be set in the VSA application using "Meas filter = AUTO" (see "Using the Transmit Filter as a Measurement Filter (Auto)" on page 180). If RC (raised cosine), RRC (root-raised cosine) and Gaussian filters are used, the Alpha (RC, RRC filters) or BT (Gaussian filters) parameters must be set in addition to the filter characteristic (roll-off factor). Typically the Alpha/BT value of the measurement filter should be the same as that of the transmission filter.

4.1.4 Measurement Filters

The measurement filter can be used to filter the following two signals in the same way:

- the measurement signal (after coarse frequency, phase and timing synchronization have been achieved)
- the reference signal, i.e the I/Q symbols that have been determined in the demodulator and have already been filtered with the Transmit filter;

For FSK, the measurement filter filters the instantaneous frequency of the signal, not the I/Q signal.

For MSK, PSK, QAM and User QAM the measurement filter filters the real part and imaginary part of these signals (i.e. not the instantaneous frequency or magnitude of the signal).

The VSA application defines the error signal as the difference between the reference signal and the measurement signal. Thus, the measurement filter also shapes the spectrum of the error signal, which is used to calculate the EVM, for example.

In many applications the measurement filter is the same as the RX filter. However, unlike the measurement filter, the RX filter is not relevant for the measurement, but is only required to create the reference signal optimally.

The RX filter and the transmit filter are usually chosen such that their combination results in an **I**nter-**S**ymbol **I**nterference (ISI) free system (see figure 4-2 and figure 4-3).
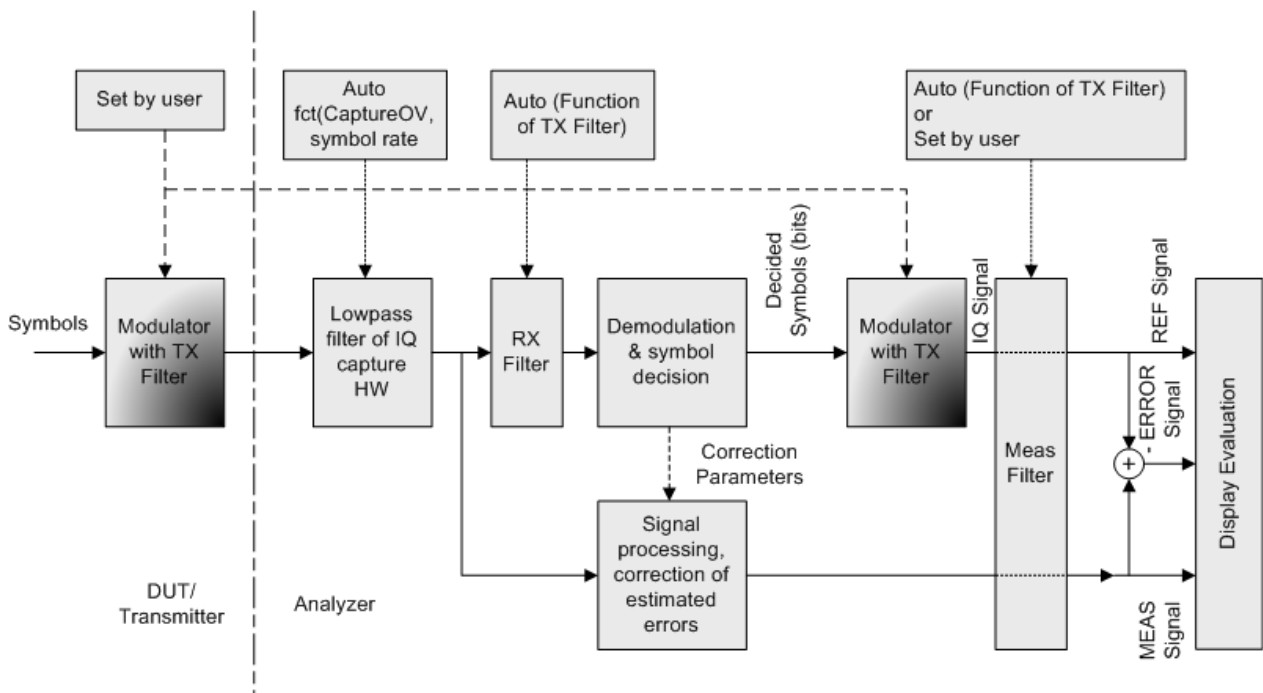
Fig. 4-2: Measurement filter in the block diagram (MSK, PSK, QAM and UserQAM)
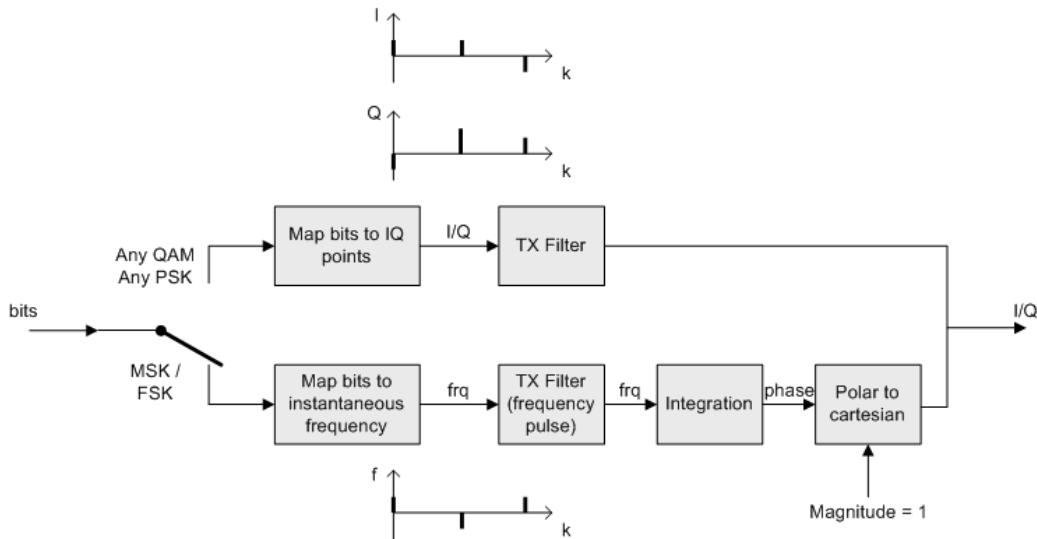
Fig. 4-3: Modulator with Transmit filter in detail

As the measurement filters of the VSA application have low-pass characteristics, they suppress high frequency distortion components in the Meas/Ref/Error signal. The errors are weighted spectrally. Thus, turning off the measurement filter can have an influence on the numeric and graphical error values. However, the measurement filter should be switched off if non-linear distortions have to be measured (they usually produce high frequency components).

Predefined measurement filters

The most frequently required measurement filters are provided by the VSA application (see chapter A.2.2, "Measurement Filters", on page 404).

The frequency response of the available standard-specific measurement filters is shown in chapter A.5.6.2, "Measurement Filter", on page 418.

4.1.5 Customized Filters

The analytical filter types RC (raised cosine), RRC (root-raised cosine) and GAUSSIAN as well as the most important standard-specific filters are already integrated in the VSA application. In addition, it is possible to use user-defined measurement and transmit filters. Customized filters may be useful for the following purposes:

●   Development of new networks and modulation methods for which no filters are defined yet.
●   Measurements of transmitter characteristics with slightly modified (e.g. shortened) transmitter filters.

An external program ("FILTWIZ") is offered to convert user-defined filters. This program generates filter files (*.vaf) which can be transferred to the analyzer with a USB device, for example. The program can be downloaded together with a detailed description as a precompiled MATLAB® file (MATLAB pcode) on the Internet, at http://www.rohde-schwarz.com (search term "FILTWIZ").
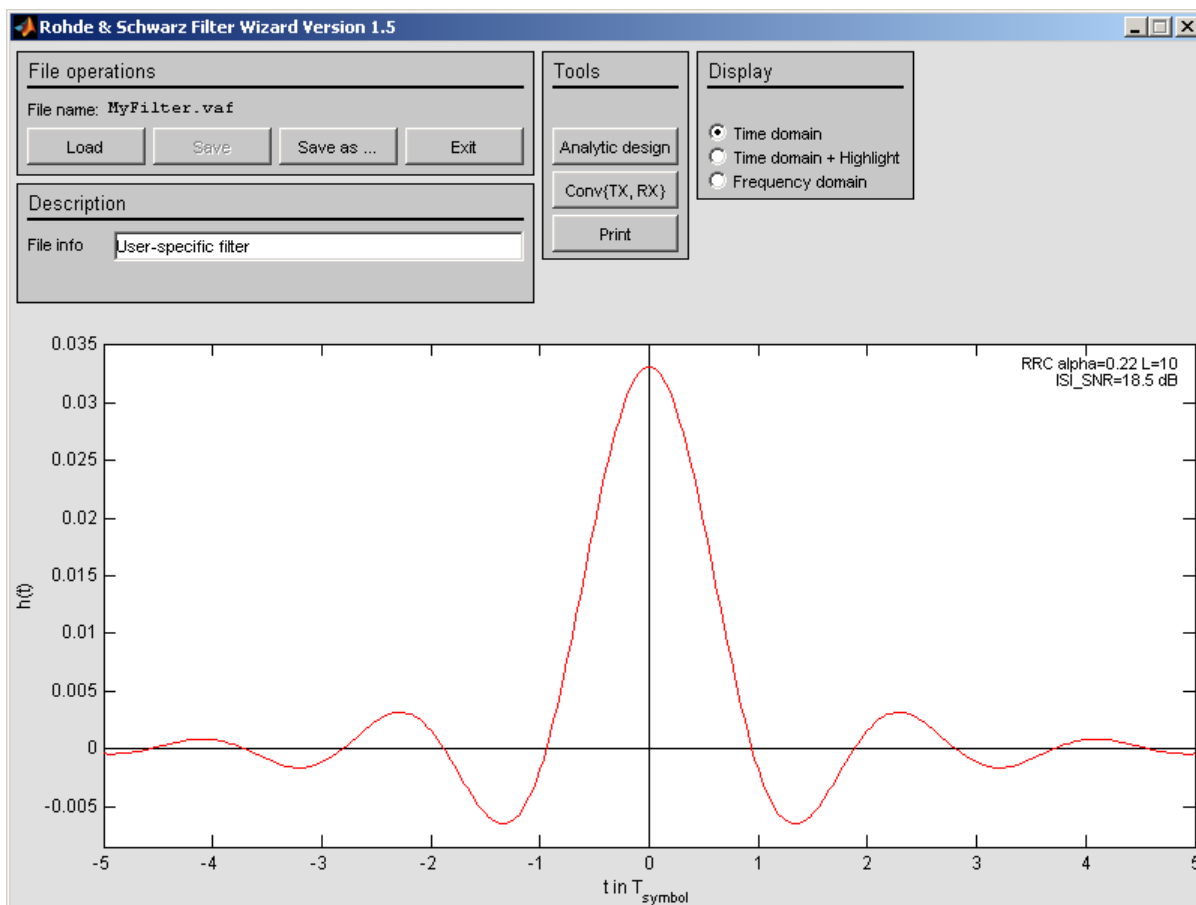
Fig. 4-4: FILTWIZ - filter tool for VSA

It is possible to load customized transmit filters and customized measurement filters. If a customized transmit filter is selected, the internal receive filter coefficients are calculated automatically on the fly.

Note that this is different to the R&S FSQ-K70, where it is necessary to also transfer a user receive filter.

If you upload a customized transmit filter and leave the measurement filter set to "automatic", the internally calculated receive filter will be used as measurement filter. Note that this filter is not necessarily suitable for your specific signal. The filter is optimized such that the intersymbol interference is low. Hence, you will probably be able to see a clear eye diagram and an Vector I/Q diagram with a recognizable constellation. However, a filter that has low intersymbol interference *might* lead to noise enhancement, which is commonly undesirable for a measurement filter. In order to avoid noise enhancement, it is recommended that you:

- a) design your own measurement filter and upload it as a user filter
- b) select a suitable measurement filter from the list

Transferring filter files to the R&S FSW

You can transfer the (`.vaf`) filter files to the R&S FSW using a USB memory device.

4.2 Sample Rate, Symbol Rate and I/Q Bandwidth

The "Symbol Rate" defined in the "Signal Description" settings determines how many symbols are captured and demodulated during a certain measurement time. However, for each symbol more than one sample may be captured, so that the sample rate may be higher than the symbol rate.

The "Sample Rate" parameter in the "Data Acquisition" settings defines the **number of samples to capture per symbol** (not to be confused with the estimation points per symbol or display points per symbol, see chapter 4.7, "Display Points vs Estimation Points per Symbol", on page 115). The resulting sample rate (depending on the "Symbol Rate") is indicated behind the parameter.

The number of samples to capture per symbol was referred to as the **"Capture Oversampling"** value in previous R&S signal and spectrum analyzers.

The resulting sample rate, also referred to as the user or output sample rate, is the rate at which the I/Q data is demodulated and analyzed. The sample rate also affects the demodulation (measurement) bandwidth (see also chapter 4.2.1, "Sample Rate and Maximum Usable I/Q Bandwidth for RF Input", on page 58). If the bandwidth is too narrow, the signal is not displayed completely. If the bandwidth is too wide, interference from outside the actual signal to be measured can distort the result. Thus, for signals with a large frequency spectrum (e.g. FSK modulated signals), a higher sample rate may be necessary.

(For further details, see chapter 4.1, "Filters and Bandwidths During Signal Processing", on page 50.)

For an indication of the required sample rate, view the "Real/Imag (I/Q)" display of the capture buffer with a "Spectrum" transformation. If the complete signal is displayed and fills the width of the display, the selected value is suitable.
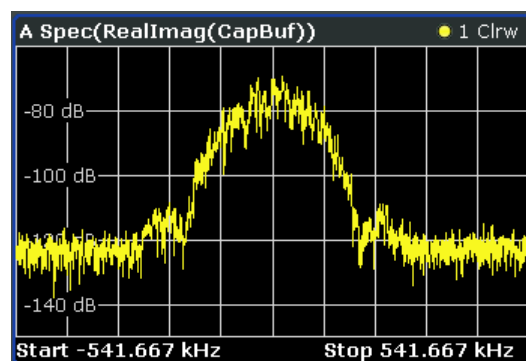
Fig. 4-5: Determining the I/Q bandwidth: Real/Imag (I/Q) display of the capture buffer with a spectrum transformation

If the signal is cut off, increase the sample rate; if it is too small, decrease the sample rate (by changing the "Symbol Rate" defined in the "Signal Description" settings, or the "Sample Rate" parameter in the "Data Acquisition" settings).

As described above, the sample rate is determined by the number of samples to capture per symbol. Thus, the maximum sample rate depends on the maximum number of symbols to be captured (the **symbol rate**) and vice versa. The maximum sample rate for the R&S FSW is 10 GHz (see chapter 4.2.1, "Sample Rate and Maximum Usable I/Q Bandwidth for RF Input", on page 58). Thus, the maximum symbol rate is:

Table 4-1: Maximum symbol rate depending on sample rate parameter

Sample rate parameter	Max. symbol rate
4* symbol rate	2500 MSymbols
8* symbol rate	1250 MSymbols
16* symbol rate	625 MSymbols
32* symbol rate	312.5 MSymbols

4.2.1 Sample Rate and Maximum Usable I/Q Bandwidth for RF Input

Within the usable I/Q bandwidth range, the analog IF filter of the R&S FSW is equalized in regard to amplitude characteristic and group delay (provided that the R&S FSW is aligned). In consequence, signals within this bandwidth range are hardly distorted at all (provided the R&S FSW is not overloaded).

For the I/Q data acquisition, digital decimation filters are used internally. 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.

Bandwidth extension options

The maximum usable I/Q bandwidth provided by the R&S FSW in the basic installation can be extended by additional options. These options can either be included in the initial installation (B-options) or updated later (U-options). The maximum bandwidth provided by the individual option is indicated by its number, e.g. B80 extends the bandwidth to 80 MHz.

Note that the U-options as of U40 always require all lower-bandwidth options as a prerequisite, while the B-options already include them.

Max. usable I/Q BW	Required B-option	Required U-option(s)
10 MHz	-	-
28 MHz	B28	U28

Max. usable I/Q BW	Required B-option	Required U-option(s)
40 MHz	B40	U28+U40 **or** B28+U40
80 MHz	B80	U28+U40+U80 **or** B28+U40+U80 **or** B40+U80
160 MHz	B160	U28+U40+U80+U160 **or** B28+U40+U80+U160 **or** B40+U80+U160 **or** B80+U160

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.

Relationship between sample rate and usable I/Q bandwidth

Up to the maximum bandwidth, the following rule applies:

*Usable I/Q bandwidth = 0.8 * Output sample rate*

> **MSRA operating mode**
>
> In MSRA operating mode, the MSRA Master is restricted to a sample rate of 200 MHz.

The figure 4-6 shows the maximum usable I/Q bandwidths depending on the output sample rates.

R&S FSW without additional bandwidth extension options

sample rate: 100 Hz - 10 GHz

maximum I/Q bandwidth: 10 MHz

Sample rate	Maximum I/Q bandwidth
100 Hz to 10 MHz	proportional up to maximum 10 MHz
10 MHz to 10 GHz	10 MHz

R&S FSW with options B28 or U28 (I/Q Bandwidth Extension):

sample rate: 100 Hz - 10 GHz

maximum bandwidth: 28 MHz

Sample rate	Maximum I/Q bandwidth
100 Hz to 35 MHz	proportional up to maximum 28 MHz
35 MHz to 10 GHz	28 MHz

R&S FSW with option B40 or U40 (I/Q Bandwidth Extension):

sample rate: 100 Hz - 10 GHz

maximum bandwidth: 40 MHz

Sample rate	Maximum I/Q bandwidth
100 Hz to 50 MHz	proportional up to maximum 40 MHz
50 MHz to 10 GHz	40 MHz

R&S FSW with option B80 or U80 (I/Q Bandwidth Extension):

sample rate: 100 Hz - 10 GHz

maximum bandwidth: 80 MHz

Sample rate	Maximum I/Q bandwidth
100 Hz to 100 MHz	proportional up to maximum 80 MHz
100 MHz to 10 GHz	80 MHz

R&S FSW with activated option B160 or U160 (I/Q Bandwidth Extension):

sample rate: 100 Hz - 10 GHz

maximum bandwidth: 160 MHz

Sample rate	Maximum I/Q bandwidth
100 Hz to 10 GHz	proportional up to maximum 1600 MHz
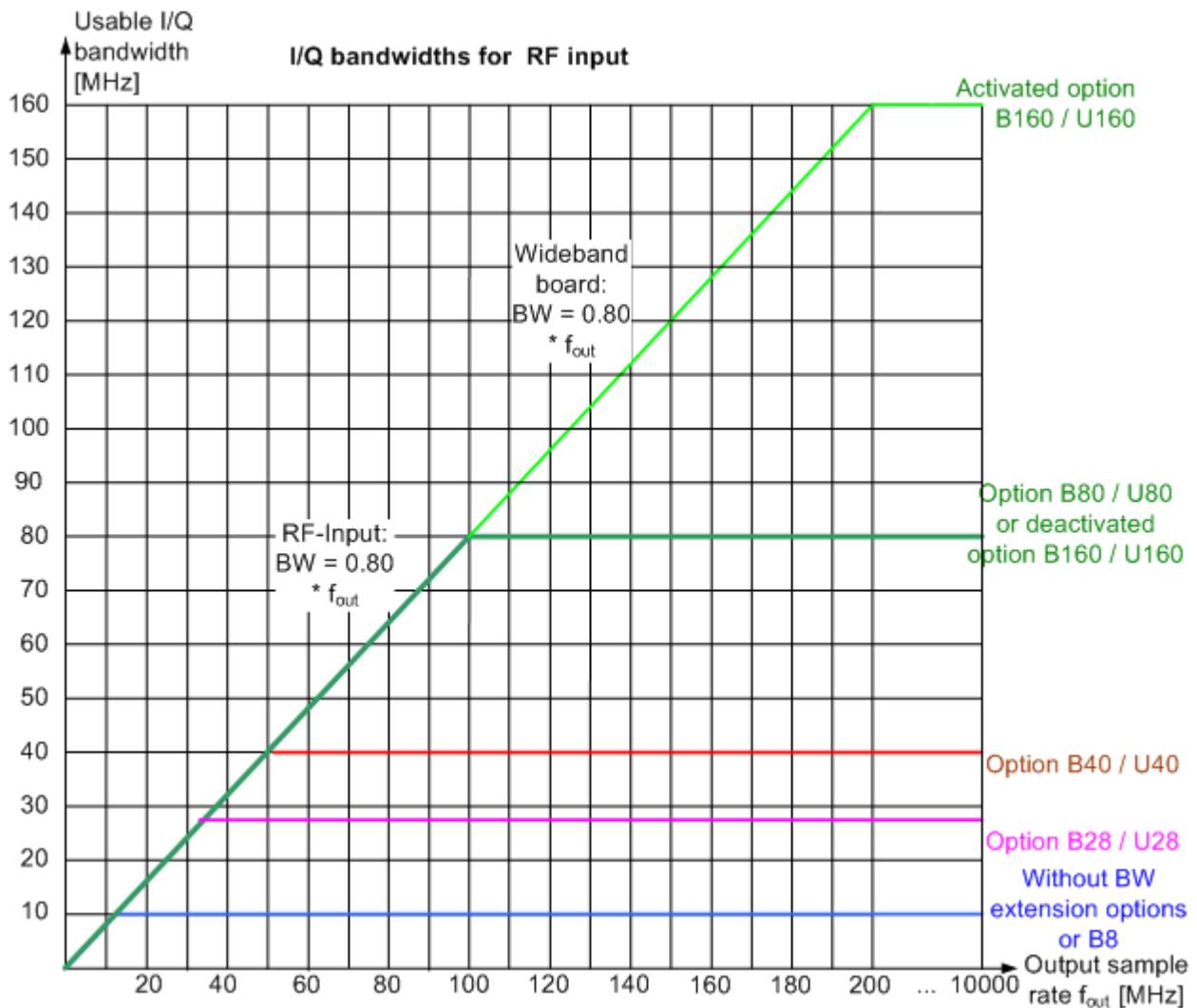
Fig. 4-6: Relationship between maximum usable I/Q bandwidth and output sample rate

4.2.2 Sample Rates and Bandwidths for Digital I/Q Data

Definitions

● **Clock rate**: the rate at which data is physically transmitted between the R&S FSW and the connected instrument; both instruments must be able to process data at this rate; the clock rate of the R&S FSW at the output connector is 100 MHz

● **Input sample rate (ISR)**: the sample rate of the useful data provided by the connected instrument to the digital input

● (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 sent to the digital output

- **Usable I/Q (Analysis) bandwidth**: the bandwidth range in which the signal remains unchanged by the digital decimation filter and thus remains undistorted; this range can be used for accurate analysis by the R&S FSW

SlowI/Q measurements

"SlowI/Q" measurements are measurements where the user-defined sample rate exceeds the rate used to transfer valid samples. In the R&S FSW, the user-defined sample rate may exceed 10 GHz for "SlowI/Q" measurements. This happens, for example, when an analog signal is sampled by external hardware, e.g. an oscilloscope, with a sample rate larger than 10 GHz, is stored there in a memory temporarily and then read from the memory and transmitted to the R&S FSW at a slower rate than it was sampled. In this case, make sure the input sample rate is defined corrrespondingly for the connected instrument (see "Input Sample Rate" on page 137).

The following table describes the restrictions for digital in- and output:

Table 4-2: Restrictions for digital in- and output

Parameter	Minimum	Maximum
Record length	2 complex samples	220*1024*1024 complex samples
Input sample rate (ISR)	100 Hz	10 GHz
Sample Rate (SR) Digital input active: Digital output active:	 Max(100 Hz; ISR/8388608) 100 Hz	 Max[200 MHz; Min(10 GHz; 2*ISR)] 100 MHz
Usable I/Q bandwidth (Digital input and filter active)	Min(0.8*SR; 0.8*ISR)	

Bandwidths

Depending on the sample rate, the following bandwidths are available:
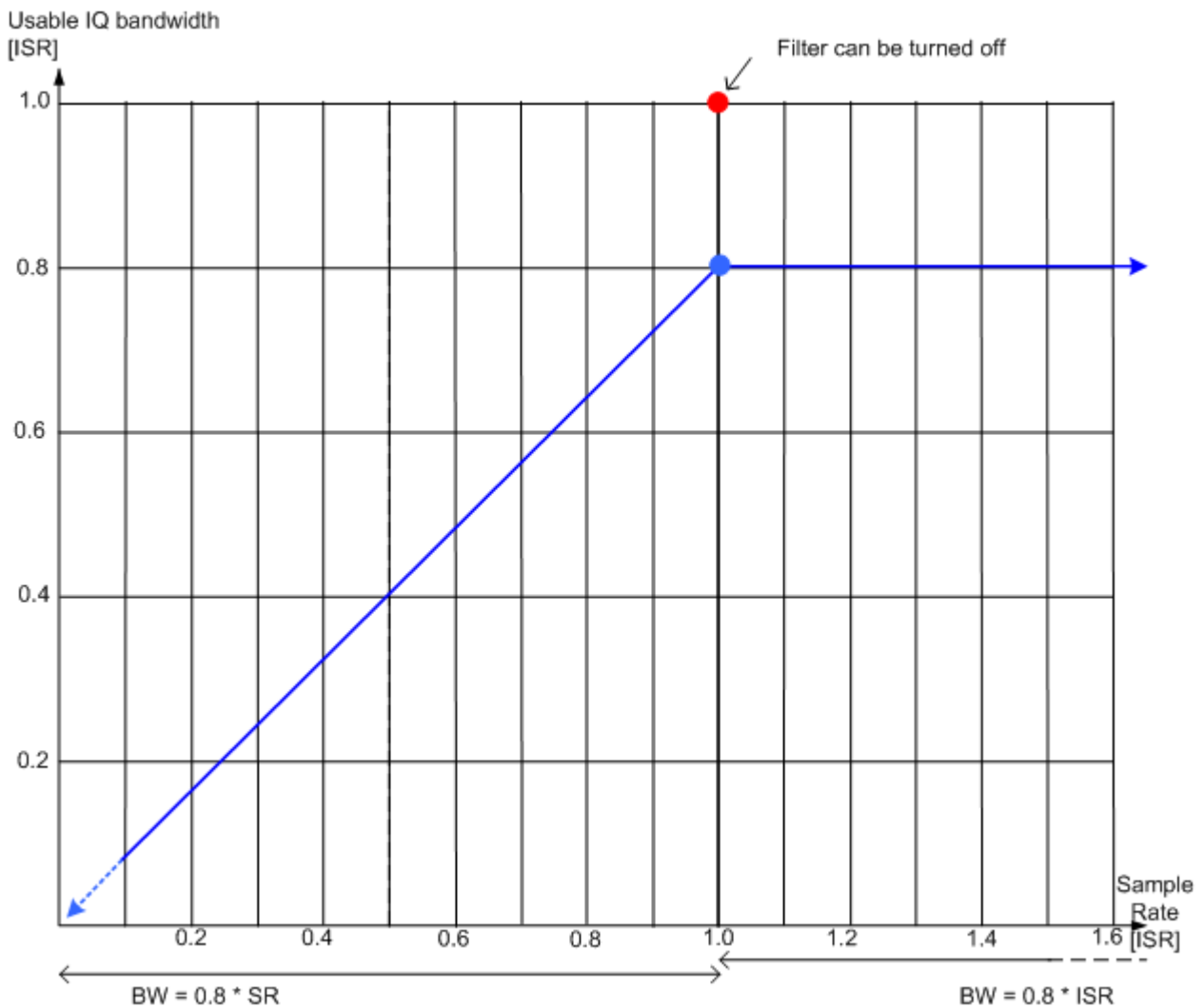
Fig. 4-7: Bandwidths depending on sample rate for active digital input

4.3 Symbol Mapping

Mapping or symbol mapping means that symbol numbers are assigned to constellation points or transitions in the I/Q plane (e.g. PSK and QAM).

In the analyzer, the mapping is required to decode the transmitted symbols from the sampled I/Q or frequency/time data records.

The mappings for all standards used in the analyzer and for all employed modulation modes are described in the following. Unless indicated otherwise, symbol numbers are specified in hexadecimal form (MSB at the left).

4.3.1 Phase Shift Keying (PSK)

With this type of modulation, the information is represented by the absolute phase position of the received signal at the decision points. All transitions in the I/Q diagram are possible. The complex constellation diagram is shown. The symbol numbers are entered in the diagram according to the mapping rule.

BPSK (NATURAL)
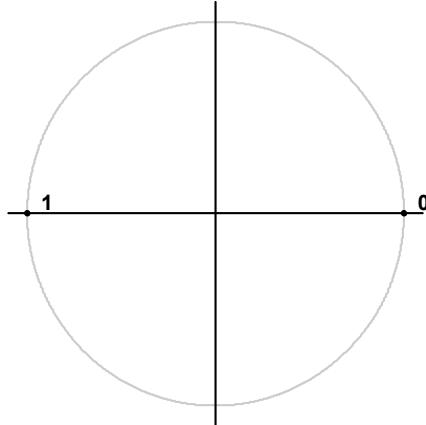
Fig. 4-8: Constellation diagram for BPSK including the symbol mapping

QPSK
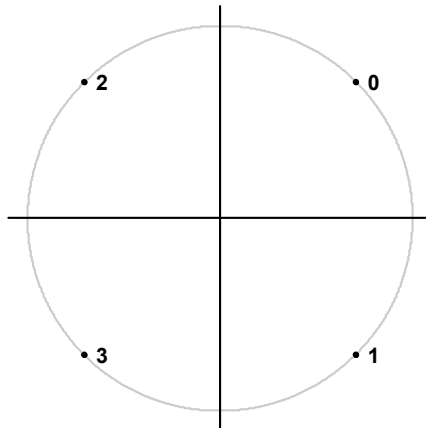
Fig. 4-9: Constellation diagram for QPSK including the symbol mapping for CDMA2000 FWD and DVB S2
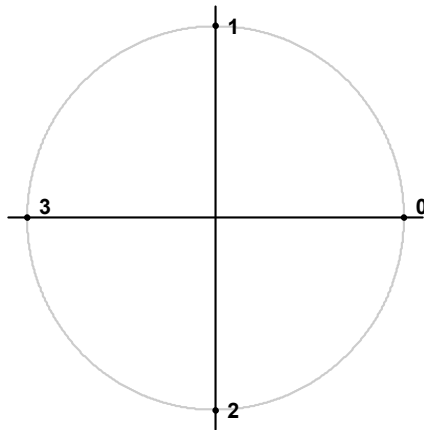
Fig. 4-10: Constellation diagram for QPSK (GRAY) including the symbol mapping
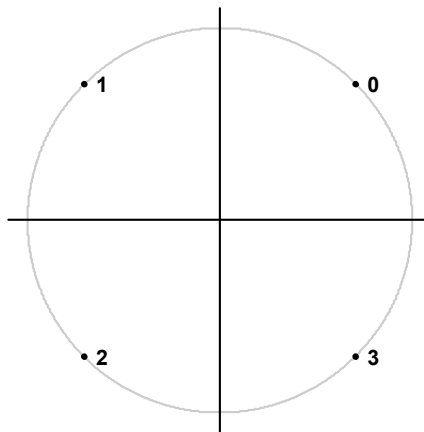
Fig. 4-11: Constellation diagram for QPSK (NATURAL) including the symbol mapping
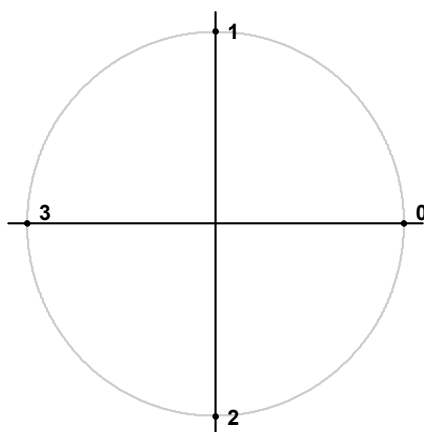
Fig. 4-12: Constellation diagram for QPSK including the symbol mapping for WCDMA

8PSK
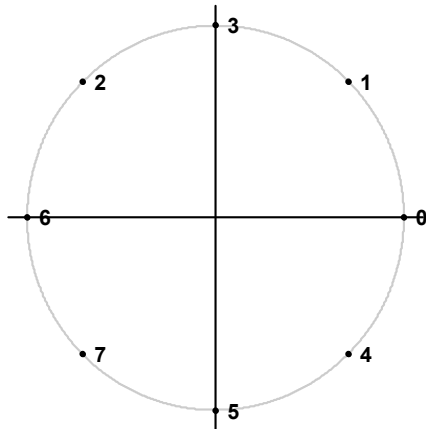
Fig. 4-13: Constellation diagram for 8PSK (GRAY) including the symbol mapping
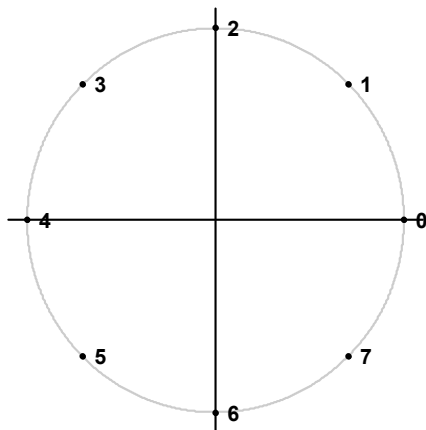
Fig. 4-14: Constellation diagram for 8PSK (NATURAL) including the symbol mapping
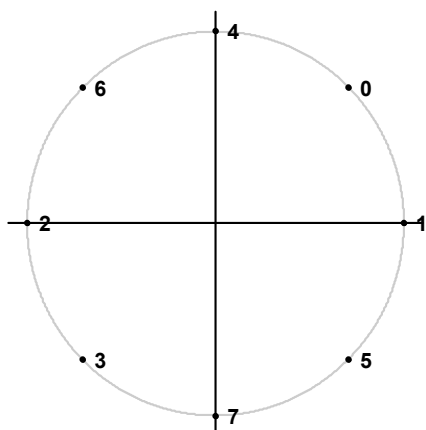
Fig. 4-15: Constellation diagram for 8PSK including the symbol mapping for DVB S2

4.3.2 Rotating PSK

A rotating PSK modulation is basically a PSK modulation in which additional phase shifts occur. These phase shifts depend on the symbol number, e.g. for a π/4-QPSK, the third symbol has an additional phase offset of (3-1)*π/4. This offset has the same effect as a rotation of the basic system of coordinates by the offset angle after each symbol.

The method is highly important in practical applications because it prevents signal transitions through the zeros in the I/Q plane. This reduces the dynamic range of the modulated signal and the linearity requirements for the amplifier.

In practice, the method is used for 3π/8-8PSK, for example, and (in conjunction with phase-differential coding) for π/4-DQPSK.

Symbol mapping

The logical constellation diagram for 3π/8-8PSK comprises 8 points that correspond to the modulation level (see figure 4-16). A counter-clockwise offset (rotation) of 3π/8 is inserted after each symbol transition.
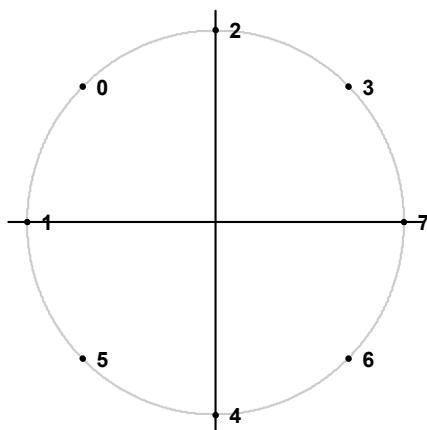
Fig. 4-16: Constellation diagram for 3π/8 8PSK before rotation including the symbol mapping for EDGE
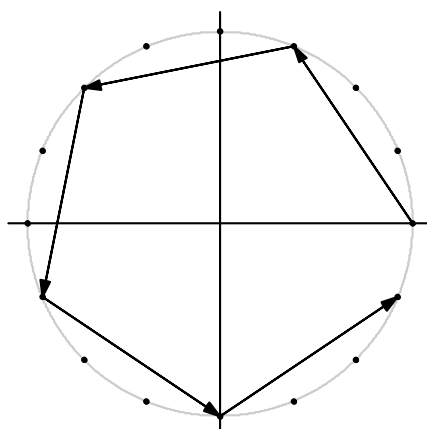
Fig. 4-17: I/Q symbol stream after 3π/8 rotation in I/Q plane if the symbol number "7" is transmitted six times in a row
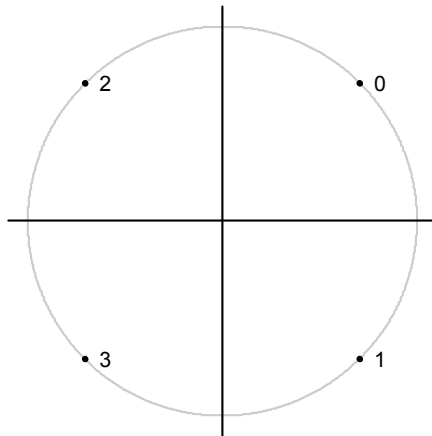
Fig. 4-18: Constellation diagram for 3π/4 QPSK including the symbol mapping for EDGE
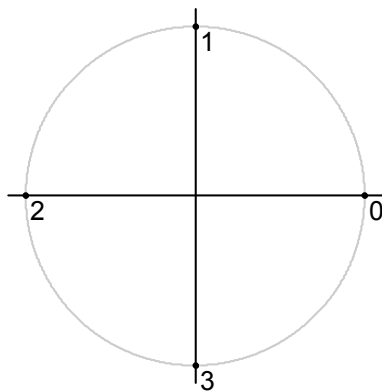
Fig. 4-19: Constellation diagram for π/4 QPSK (Natural) including the symbol mapping

4.3.3   Differential PSK

With differential PSK, the information is represented in the phase shift between two consecutive decision points. The absolute position of the complex sample value at the decision point does not carry information.

In the physical constellation diagram, the constellation points at the symbol decision points obtained after ISI-free demodulation are shown (as with common PSK methods). This diagram corresponds to the display on the analyzer. The position of the constellation points is standard-specific. For example, some QPSK standards define the constellation points on the diagonals, while other standards define the coordinate axes.

In table 4-3, the symbols are assigned to phase shifts. The QPSK (INMARSAT) mapping corresponds to simple QPSK with phase-differential coding.

Tables table 4-4 and table 4-5 show two types of differential 8PSK modulation.

Differential coding according to VDL is shown in table 4-6. It can be used for modulation types with 3 bits/symbol, e.g. 8PSK.

Other types of modulation using differential coding method are described in chapter 4.3.4, "Rotating Differential PSK Modulation", on page 70.
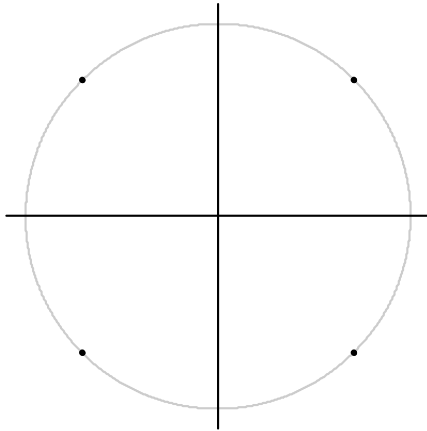
Fig. 4-20: Constellation diagram for DQPSK (INMARSAT and NATURAL) including the symbol mapping

Table 4-3: DQPSK (INMARSAT)

Logical symbol mapping				
Modulation symbol (binary indication: MSB, LSB)	00	01	10	11
Phase shift	0°	-90°	+90°	180°
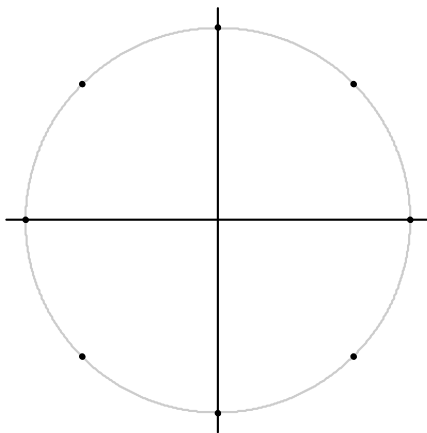
Fig. 4-21: Constellation diagram for D8PSK including the symbol mapping for APCO25, APCO25 Phase 2, GRAY, NATURAL and TETRA

Table 4-4: D8PSK (NATURAL)

Logical symbol mapping								
Modulation symbol (binary indication: MSB, LSB)	000	001	010	011	100	101	110	111
Phase shift	0°	45°	90°	135°	180°	225°	270°	315°

Table 4-5: D8PSK (GRAY)

Logical symbol mapping								
Modulation symbol (binary indication: MSB, LSB)	000	001	010	011	100	101	110	111
Phase shift	0°	45°	135°	90°	270°	315°	225°	180°

Table 4-6: D8PSK (VDL)

Logical symbol mapping								
Modulation symbol (binary indication: MSB, LSB)	000	001	010	011	100	101	110	111
Phase shift	0°	45°	135°	90°	315°	270°	180°	225°

4.3.4 Rotating Differential PSK Modulation

Phase-differential modulation is frequently combined with an additional phase shift (e.g. π/4 DQPSK = π/4 phase shift modulation + differential modulated 4PSK).

The logical mapping diagram corresponds to the diagram for DPSK.

The physical constellation diagram shows the symbol decision points obtained after ISI-free demodulation.
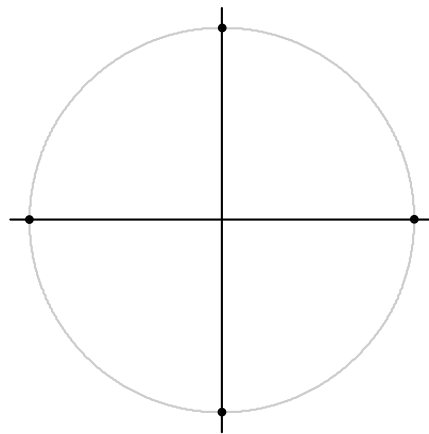
Fig. 4-22: Constellation diagram for π/4 DQPSK including the symbol mapping for APCO25 Phase 2, NADC, NATURAL, PDC, PHS, TETRA and TFTS; the π/4 rotation is already compensated for

Table 4-7: π/4 DQPSK (NADC, PDC, PHS, TETRA)

Logical symbol mapping				
Modulation symbol (binary indication: MSB, LSB)	00	01	10	11
Phase shift	0°+45°	90°+45°	-90°+45°	-180°+45°

Table 4-8: π/4 DQPSK (TFTS)

Logical symbol mapping				
Modulation symbol (binary indication: MSB, LSB)	00	01	10	11
Phase shift	-180°+45°	90°+45°	-90°+45°	0°+45°

Table 4-9: π/4 DQPSK (Natural)

Logical symbol mapping				
Modulation symbol (binary indication: MSB, LSB)	00	01	10	11
Phase shift	0°+45°	90°+45°	-180°+45°	-90°+45°

Table 4-10: π/4 DQPSK (APCO25 and APCO25Phase2)

Logical symbol mapping				
Modulation symbol (binary indication: MSB, LSB)	00	01	10	11
Phase shift	0°+45°	90°+45°	-90°+45°	-180°+45°

4.3.5 Offset QPSK

Offset QPSK differs from "normal" QPSK in the fact that the Q component is delayed by half a symbol period against the I component in the time domain. Hence, the symbol time instants of the I and the Q component do not coincide. The concept of Offset QPSK is illustrated in the diagrams below.

Derivation of OQPSK

Table 4-11: I/Q diagram and constellation diagram
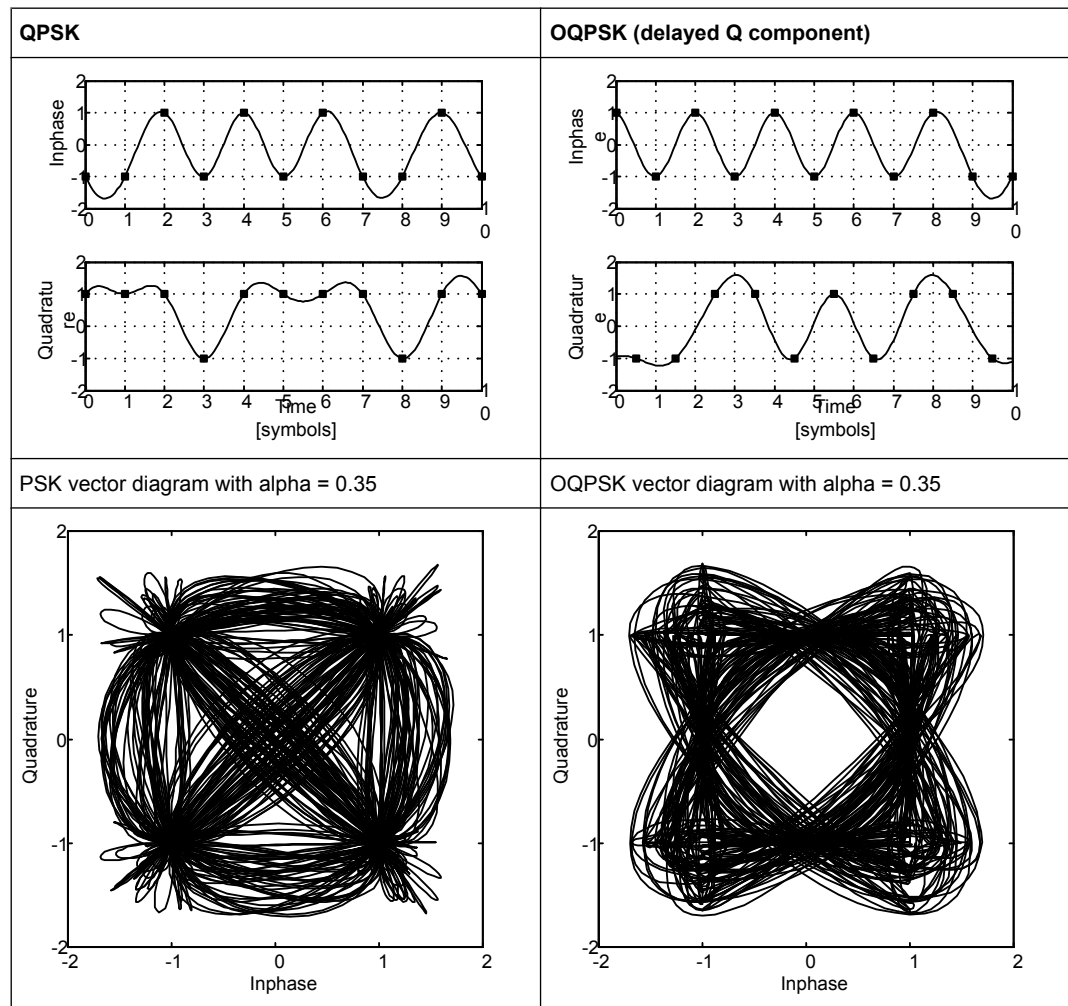
Offset QPSK reduces the dynamic range of the modulated signal (with respect to "normal" QPSK) and, therefore, the demands on amplifier linearity by avoiding zero crossings.

A distinction is made in the analyzer display:

In the Vector I/Q result display of the measurement (or reference) signal, the time delay is not compensated for. The display corresponds to the physical diagram shown in (table 4-11)

In the Constellation I/Q result display of the measurement (or reference) signal, the time delay is compensated for. The display corresponds to the logical mapping as in figure 4-23.

OQPSK
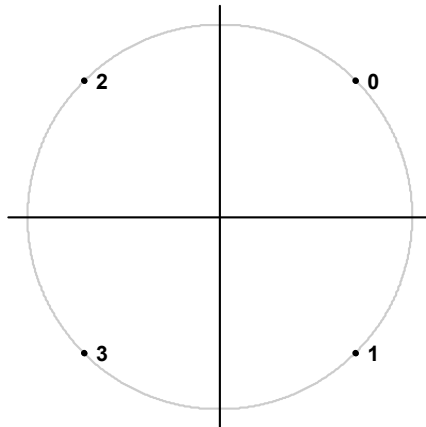
Fig. 4-23: Constellation diagram for OQSK (GRAY) including the symbol mapping

4.3.6 Frequency Shift Keying (FSK)

To illustrate symbol mappings for FSK modulations, the symbol numbers are marked in the logical mapping diagram versus the instantaneous frequency. An instantaneous frequency of zero in the baseband corresponds to the input frequency of the analyzer.

2FSK (NATURAL)

With 2FSK, the symbol decision is made by a simple frequency discriminator:
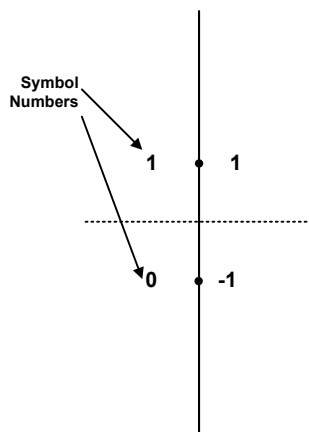
Fig. 4-24: Constellation diagram for 2FSK (NATURAL) including the logical symbol mapping

4FSK

With 4FSK, the symbol decision is made by a frequency discriminator with 3 decision thresholds (-2/3; 0; +2/3) normalized to the FSK reference deviation.
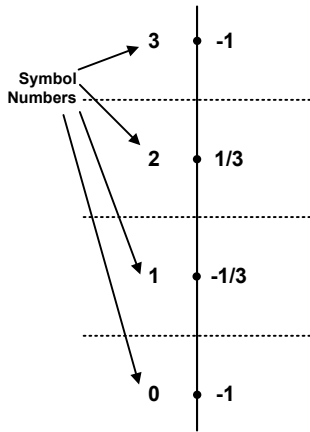
Fig. 4-25: Constellation diagram for 4FSK (NATURAL) including the logical symbol mapping
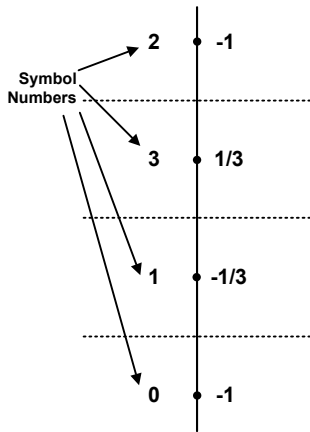
Fig. 4-26: Constellation diagram for 4FSK (GRAY) including the logical symbol mapping
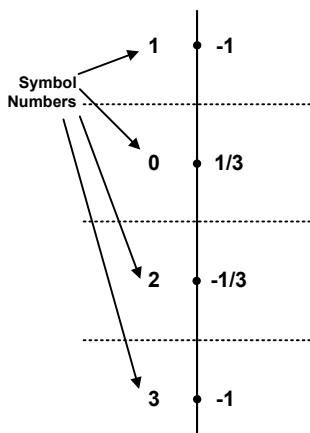
Fig. 4-27: Constellation diagram for 4FSK for APCO C4FM and APCO Phase 2 including the logical symbol mapping

8FSK (NATURAL)
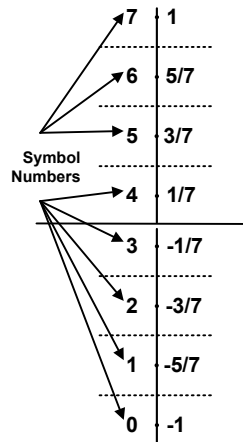
Fig. 4-28: Constellation diagram for 8FSK (NATURAL) including the logical symbol mapping

4.3.7 Minimum Shift Keying (MSK)

MSK modulation causes modulation-dependent phase shifts of +/- 90° which can be shown in an Constellation I/Q diagram. As with PSK, demodulation is performed by evaluation of the phase positions.

Table 4-12: MSK (NATURAL)

Logical symbol mapping		
Modulation symbol (binary indication: MSB, LSB)	0	1
Phase shift	-90°	+90°

Table 4-13: MSK (GSM)

Logical symbol mapping		
Modulation symbol (binary indication: MSB, LSB)	0	1
Phase shift	+90°	-90°
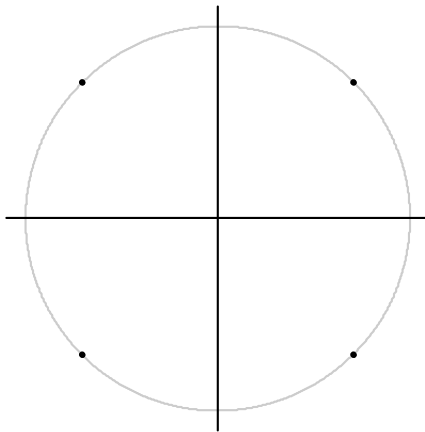
Fig. 4-29: MSK (for GSM and NATURAL) and DMSK Constellation Diagram including the symbol mapping

Similar to PSK, differential coding can also be used with MSK. In this case, too, the information is represented by the transition of two consecutive symbols. The block diagram of the coder is shown below.
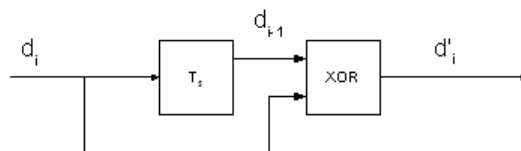
Fig. 4-30: DMSK: differential encoder in the transmitter

d_i input symbol {0;1} of differential encoder

d_{i-1} input symbol delayed by the symbol period Ts

d'_i output symbol {0;1} of differential encoder

The logical symbol mapping is then performed on the XOR-coded bitstream d'.

4.3.8 Quadrature Amplitude Modulation (QAM)

In the case of QAM the information is represented by the signal amplitude and phase.

The symbols are arranged in a square constellation in the I/Q plane.

To ensure reliable demodulation, symbol numbers should be distributed evenly with respect to the symbol alphabet.

As a rule of thumb, the **result length** should correspond to at least 8 times the modulation order. For example, with 64 QAM, a result length of at least 8*64 = 512 symbols should be used.

QAM Mappings

The following QAM mappings are obtained from the mapping of the 1st quadrant, which is always rotated by π/2 for the subsequent quadrants and supplemented by a (GRAY-coded) prefix for each quadrant.

Table 4-14: Derivation of QAM mappings
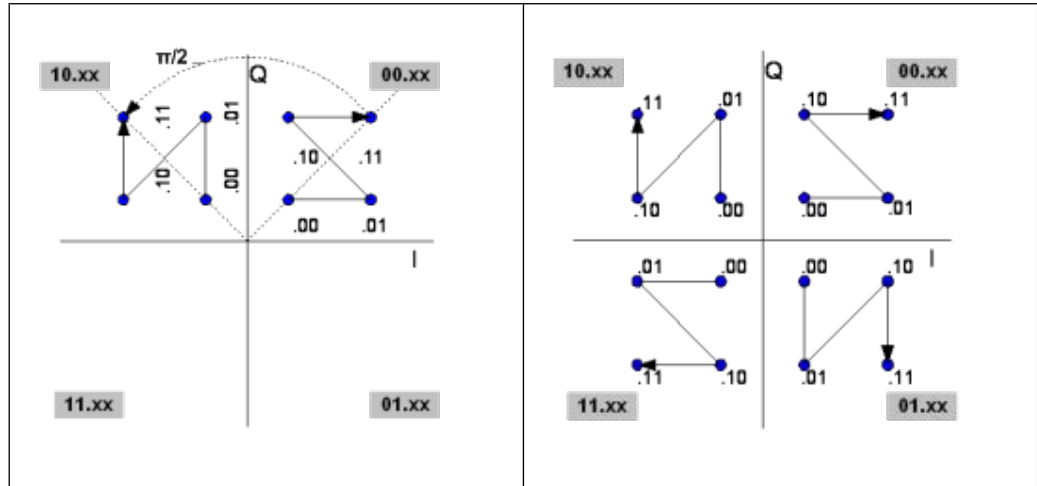
In the following diagrams, the symbol mappings are indicated in hexadecimal and binary form.

Fig. 4-31: Constellation diagram for 16QAM (GRAY) including the logical symbol mapping (hexadecimal and binary)

• B	• 9	• 1	• 3	• 1011	• 1001	• 0001	• 0011
• A	• 8	• 0	• 2	• 1010	• 1000	• 0000	• 0010
• E	• C	• 4	• 6	• 1110	• 1100	• 0100	• 0110
• F	• D	• 5	• 7	• 1111	• 1101	• 0101	• 0111
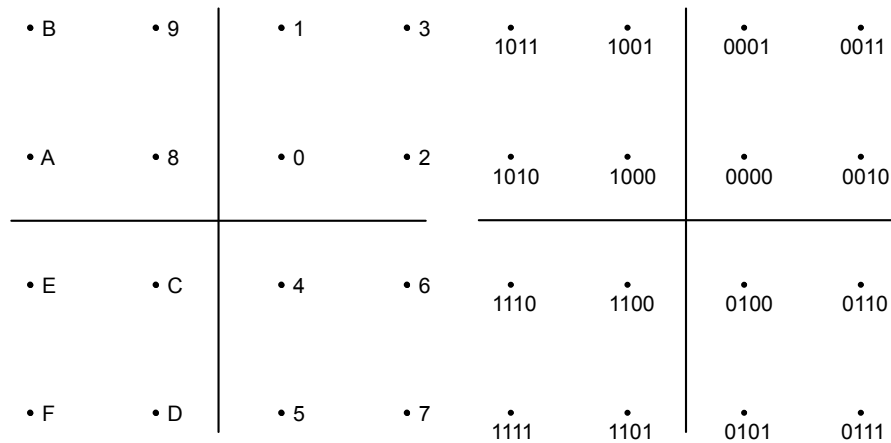
Fig. 4-32: Constellation diagram for 16QAM including the logical symbol mapping for EDGE (hexadecimal and binary)
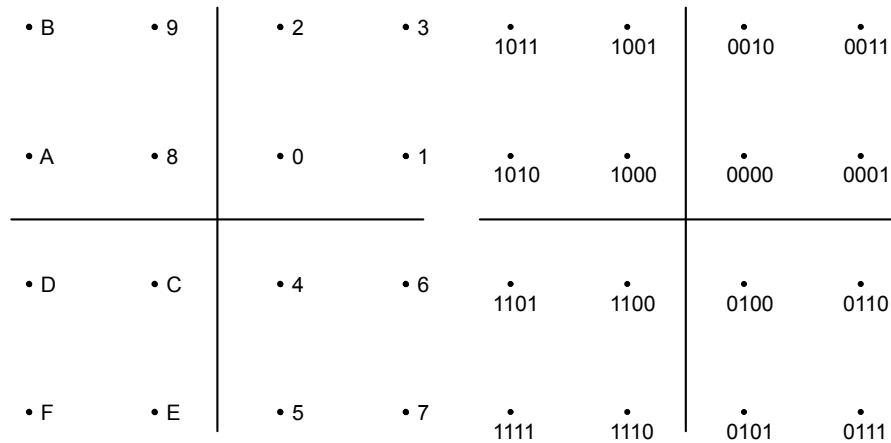
• B	• 9	• 2	• 3	• 1011	• 1001	• 0010	• 0011
• A	• 8	• 0	• 1	• 1010	• 1000	• 0000	• 0001
• D	• C	• 4	• 6	• 1101	• 1100	• 0100	• 0110
• F	• E	• 5	• 7	• 1111	• 1110	• 0101	• 0111

Fig. 4-33: Constellation diagram for 16QAM including the logical symbol mapping for DVB-C (hexadecimal and binary)

	• 17	• 13	• 06	• 02				• 10111	• 10011	• 00110	• 00010	
• 12	• 15	• 11	• 04	• 05	• 07		• 10010	• 10101	• 10001	• 00100	• 00101	• 00111
• 16	• 14	• 10	• 00	• 01	• 03		• 10110	• 10100	• 10000	• 00000	• 00001	• 00011
• 1B	• 19	• 18	• 08	• 0C	• 0E		• 11011	• 11001	• 11000	• 01000	• 01100	• 01110
• 1F	• 1D	• 1C	• 09	• 0D	• 0A		• 11111	• 11101	• 11100	• 01001	• 01101	• 01010
	• 1A	• 1E	• 0B	• 0F				• 11010	• 11110	• 01011	• 01111	
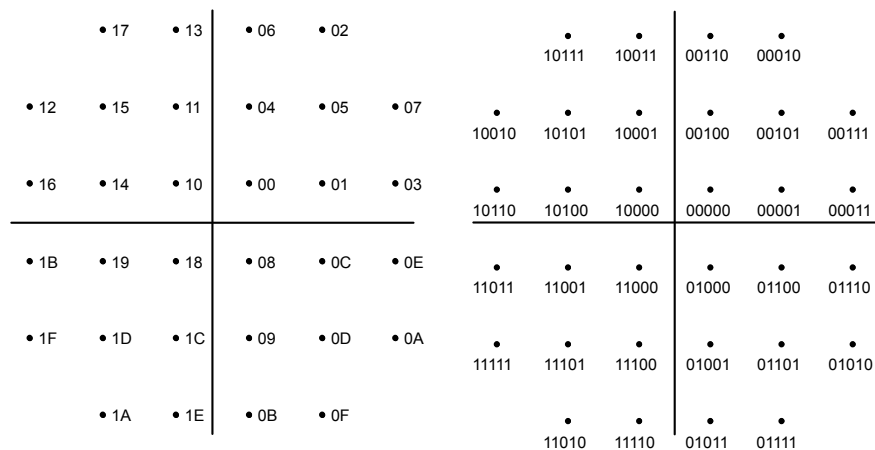
Fig. 4-34: Constellation diagram for 32QAM including the logical symbol mapping for DVB-C (hexadecimal and binary)

• 2C	• 2E	• 26	• 24	• 08	• 09	• 0D	• 0C
• 2D	• 2F	• 27	• 25	• 0A	• 0B	• 0F	• 0E
• 29	• 2B	• 23	• 21	• 02	• 03	• 07	• 06
• 28	• 2A	• 22	• 20	• 00	• 01	• 05	• 04
• 34	• 35	• 31	• 30	• 10	• 12	• 1A	• 18
• 36	• 37	• 33	• 32	• 11	• 13	• 1B	• 19
• 3E	• 3F	• 3B	• 3A	• 15	• 17	• 1F	• 1D
• 3C	• 3D	• 39	• 38	• 14	• 16	• 1E	• 1C

• 001000	• 001001	• 001101	• 001100
• 001010	• 001011	• 001111	• 001110
• 000010	• 000011	• 000111	• 000110
• 000000	• 000001	• 000101	• 000100
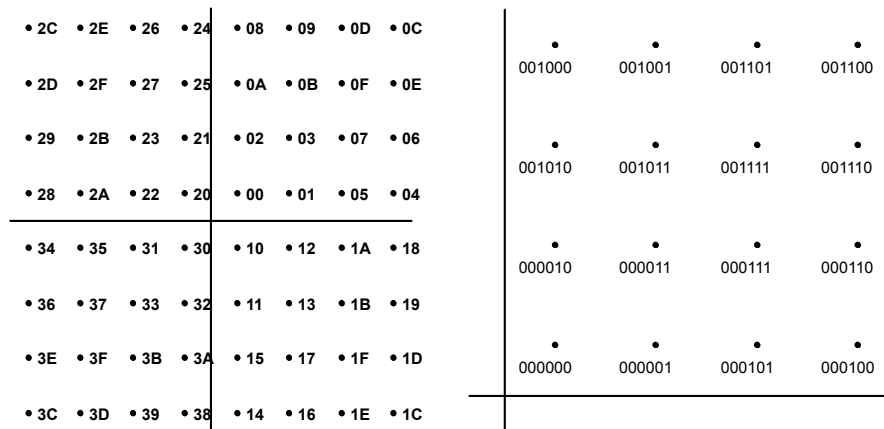
Fig. 4-35: Constellation diagram for 64QAM including the logical symbol mapping for DVB-C (hexadec-imal and binary); the binary form shows the upper right section of the diagram only.

• 0011010	• 0011011	• 0001011	• 0001010		
• 0011000	• 0011001	• 0001001	• 0001000		
• 0010000	• 0010001	• 0010101	• 0010100	• 0011100	• 0011101
• 0010010	• 0010011	• 0010111	• 0010110	• 0011110	• 0011111
• 0000010	• 0000011	• 0000111	• 0000110	• 0001110	• 0001111
• 0000000	• 0000001	• 0000101	• 0000100	• 0001100	• 0001101

• 1A	• 1B	• 0B	• 0A		
• 18	• 19	• 09	• 08		
• 10	• 11	• 15	• 14	• 1C	• 1D
• 12	• 13	• 17	• 16	• 1E	• 1F
• 02	• 03	• 07	• 06	• 0E	• 0F
• 00	• 01	• 05	• 04	• 0C	• 0D
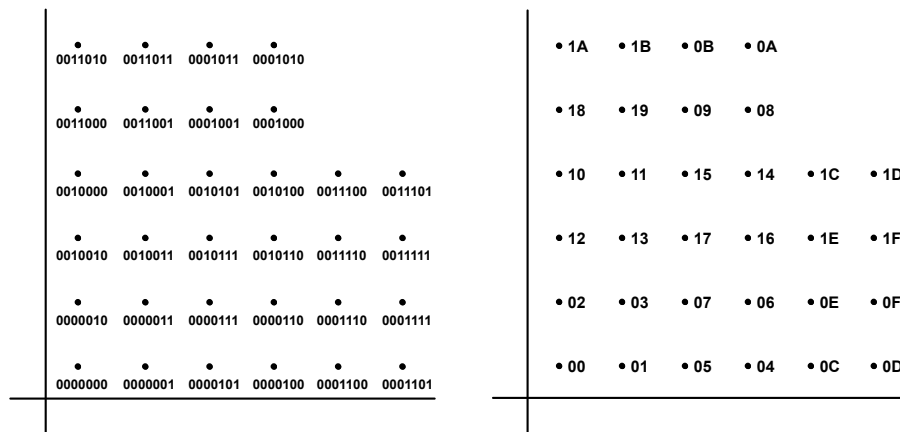
Fig. 4-36: Constellation diagram for 128QAM including the logical symbol mapping (hexadecimal and binary); the figure shows the upper right sections of the diagram only

• 20	• 21	• 25	• 24	• 34	• 35	• 31	• 30
• 22	• 23	• 27	• 26	• 36	• 37	• 33	• 32
• 2A	• 2B	• 2F	• 2E	• 3E	• 3F	• 3B	• 3A
• 28	• 29	• 2D	• 2C	• 3C	• 3D	• 39	• 38
• 08	• 09	• 0D	• 0C	• 1C	• 1D	• 19	• 18
• 0A	• 0B	• 0F	• 0E	• 1E	• 1F	• 1B	• 1A
• 02	• 03	• 07	• 06	• 16	• 17	• 13	• 12
• 00	• 01	• 05	• 04	• 14	• 15	• 11	• 10
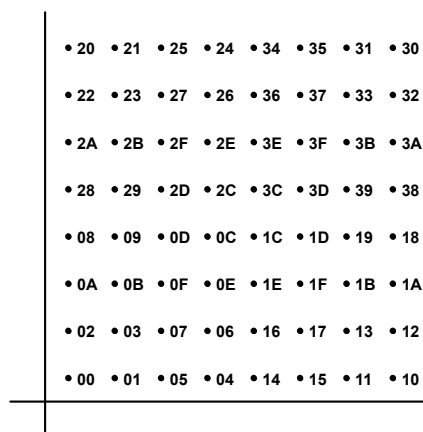
Fig. 4-37: Constellation diagram for 256QAM including the logical symbol mapping (hexadecimal); the figure shows the upper right section of the diagram only
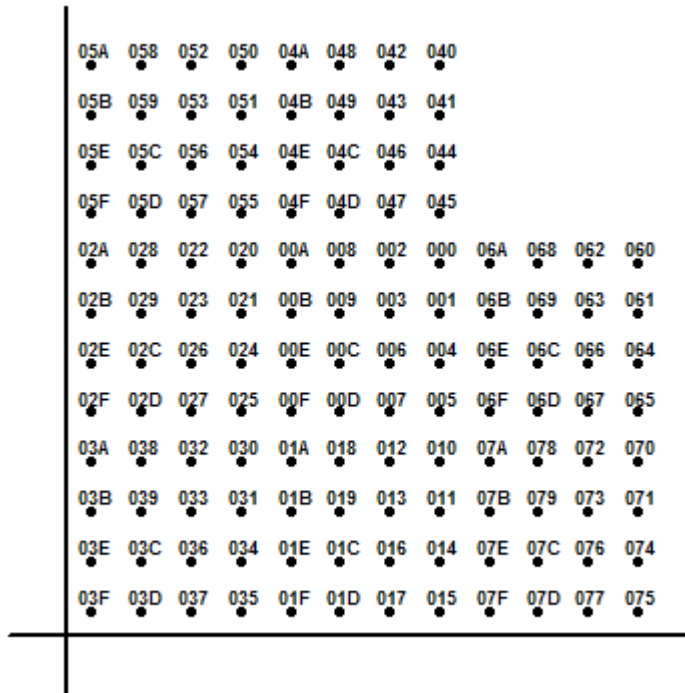
Fig. 4-38: Constellation diagram for 512QAM including the logical symbol mapping (hexadecimal); the figure shows the upper right section of the diagram only
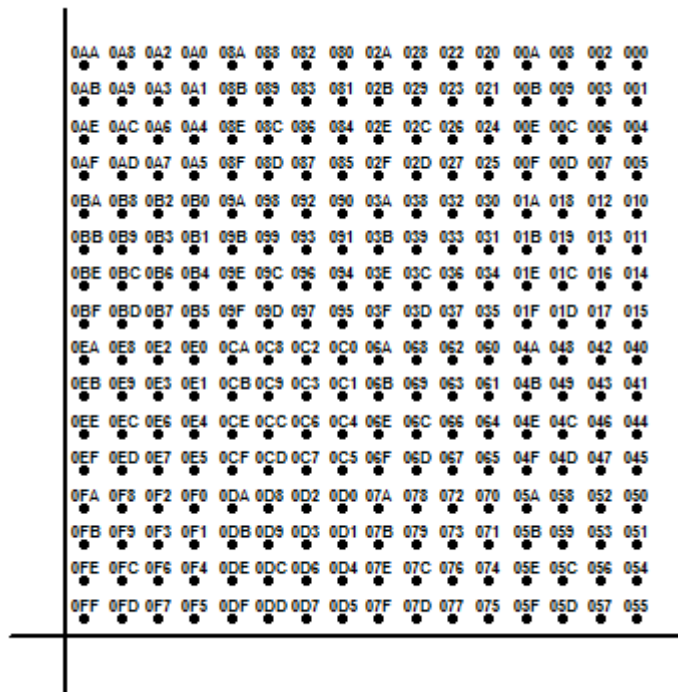
Fig. 4-39: Constellation diagram for 1024QAM including the logical symbol mapping (hexadecimal); the figure shows the upper right section of the diagram only

4.3.9 ASK

2ASK (OOK)

ASK stands for Amplitude Shift Keying, 2ASK (binary) is often also referred to as "On Off Keying" (OOK). With this type of modulation, the information is solely represented by the absolute amplitude of the received signal at the decision points.
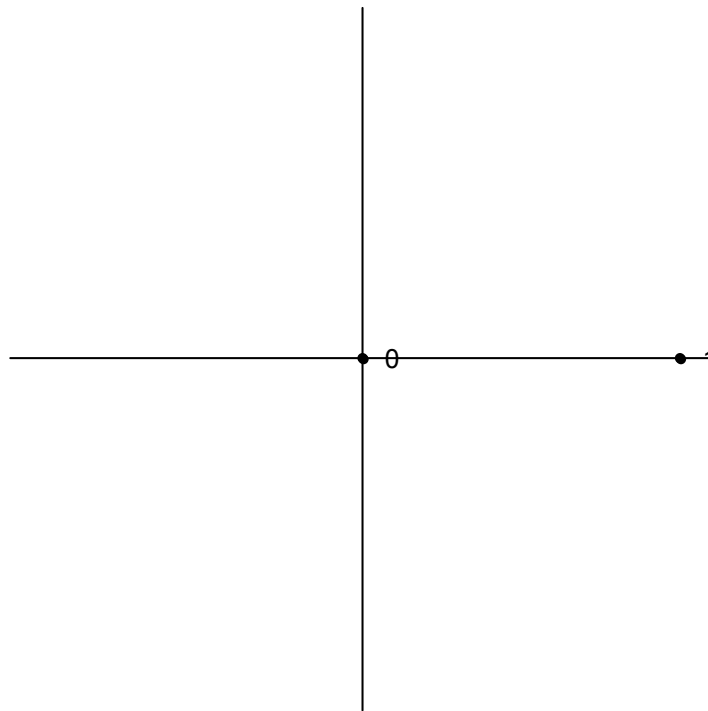
Fig. 4-40: Constellation diagram for 2ASK

4ASK

4ASK is a 4-ary Amplitude Shift Keying mapping type. With this type of modulation, the information is solely represented by the absolute amplitude of the received signal at the decision points.
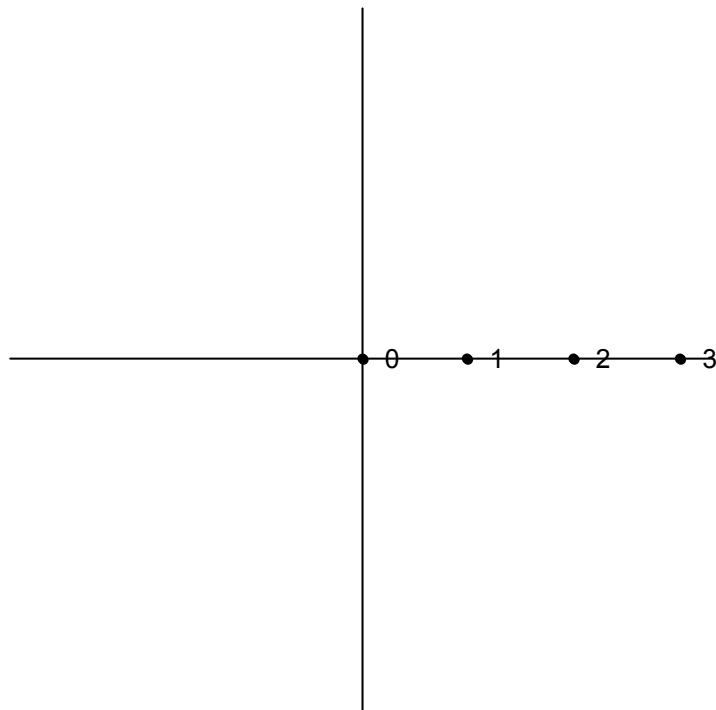
Fig. 4-41: Constellation diagram for 4ASK

4.3.10 APSK

With Amplitude Phase Shift Keying (APSK) modulation, the information is represented by the signal amplitude and the signal phase.

16APSK
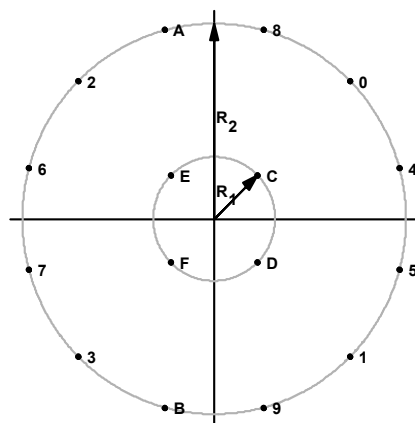
Fig. 4-42: Constellation diagram for 16APSK including the logical symbol mapping for DVB-S2

For DVB-S2 16APSK mappings, the ratio of the outer circle radius to the inner circle radius (γ = R2/R1) depends on the utilized code rate and complies with figure 4-42.

Table 4-15: Optimum constellation radius ratio γ (linear channel) for 16APSK

Code Rate	Modulation / coding spectral efficiency	γ
2/3	2.66	3.15
3/4	2.99	2.85
4/5	3.19	2.75
5/6	3.32	2.70
8/9	3.55	2.60
9/10	3.59	2.57

32APSK

For DVB-S2 32APSK mappings, the ratio of the middle circle radius to the inner circle radius (γ_1 = R2/R1) and the ratio of the outer circle radius to the inner circle radius (γ_2 depend on the utilized code rate and comply with table 4-16.

Table 4-16: Optimum constellation radius ratios γ_1 and γ_2 (linear channel) for 32APSK

Code Rate	Modulation / coding spectral efficiency	γ_1	γ_2
2/3	3.74	2.84	5.27
3/4	3.99	2.72	4.87
4/5	4.15	2.64	4.64
5/6	4.43	2.54	4.33
8/9	4.49	2.53	4.30

4.3.11 User-defined Modulation

In addition to the modulation types defined by the standards, modulation (including symbol mappings) can also be defined according to user requirements. In this case, the mapping is defined and stored in a specific format (`*.vam` file format) and then loaded to the VSA application. Modulation files in `.vam` format can be defined using a mapping wizard ("mapwiz"), an auxiliary tool provided by R&S via Internet free of charge. This tool is a precompiled MATLAB® file (MATLAB pcode). To download the tool together with a detailed description see http://www.rohde-schwarz.com (search term "mapwiz").

4.4   Overview of the Demodulation Process
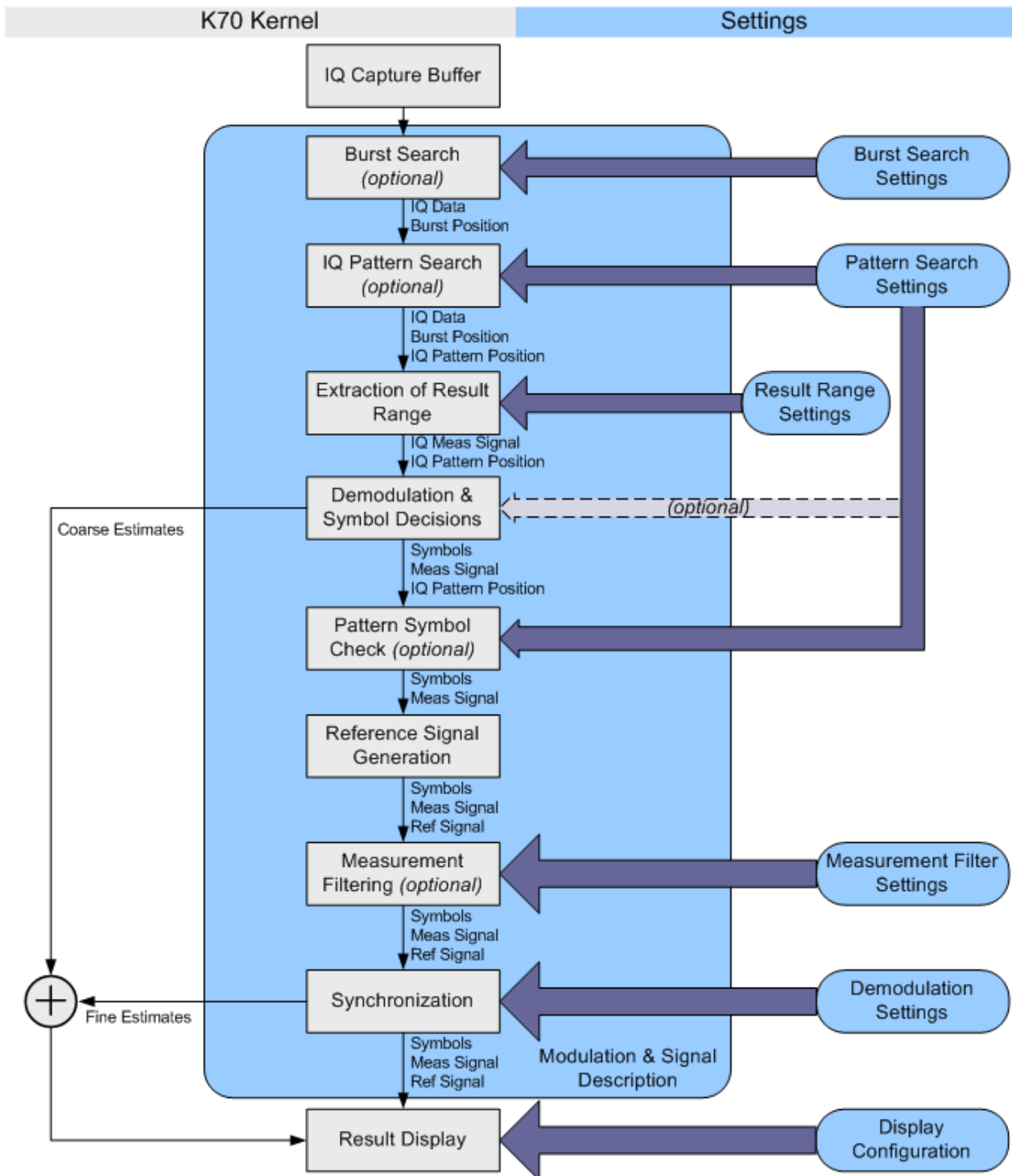
Fig. 4-43: Demodulation stages of the vector signal analysis option

The figure 4-43 provides an overview of the demodulation stages of the vector signal analysis option. The function blocks of the signal processing kernel can be found at the left (in grey) and their appropriate settings at the right (in blue).

A more detailed description of the most important stages is given in the following sections.

Burst Search

In this stage, the capture buffer is searched for bursts that comply with the signal description. The search itself can be switched on or off via the "Burst Search" dialog (see "Enabling Burst Searches" on page 162). A list of the detected bursts is passed on to the next processing stage.

I/Q Pattern Search

The "I/Q Pattern Search" is performed on the capture buffer. This means the VSA application modulates the selected pattern according to the transmit filter (Tx filter) and the modulation scheme. Subsequently, it searches the capture buffer for this I/Q pattern, i.e. the I/Q waveform of the pattern. It is assumed that patterns can only appear within bursts, i.e. the I/Q pattern search range is limited to the bursts detected by the burst search stage. If the burst search is switched off, the whole capture buffer is searched for the I/Q pattern. A list of all detected I/Q patterns is passed on to the next processing stage. It is important to note that the VSA application can only search for one pattern at a time.

The pattern search can be switched on or off via the "Pattern Search" dialog (see "Enabling Pattern Searches" on page 163).

Extraction of Result Range

The result range can be aligned to a burst, a pattern or simply the start of the capture buffer (see "Reference" on page 170). Within this stage, the result range is cut from the capture buffer starting at a point that is specified by the user, e.g. the start of a detected burst. The VSA application automatically takes into account filter settling times by making the internal buffers sufficiently longer than the selected result range.

Demodulation & Symbol Decisions

This stage operates on the extracted result range and aims at making the correct symbol decisions. Within this stage, a coarse synchronization of the carrier frequency offset, the carrier phase, the scaling and the timing takes place. Furthermore, an automatically selected internal receive filter (Rx filter) is used in order to remove the inter-symbol interference as effectively as possible. The outputs of this stage are the (coarsely) synchronized measurement signal and the symbol decisions (bits). The symbol decisions are later used for the "Pattern Symbol Check" stage and for the "Reference Signal Generation" stage.

Pattern Symbol Check

The "I/Q Pattern Search" stage can only detect whether the similarity between the I/Q pattern and the capture buffer exceeds a certain threshold and, in this way, find the most likely positions where a pattern can be found.

Within this stage, the VSA application checks whether the pattern symbols (bits) really coincide with the symbol decisions at the pre-detected position. E.g. if one out of 20 symbols does not coincide, the "I/Q Pattern Search" stage might detect this I/Q pattern, but the "Pattern Symbol Check" stage will decline it.

Note that this stage is only active if the pattern search is switched on.

Reference Signal Generation

The ideal reference signal is generated based on the detected symbols and the specifications of the signal model, i.e. the modulation scheme and the transmit filter (Tx filter).

Measurement Filtering

Both the measurement signal and the reference signal are filtered with the specified measurement filter.

Synchronization

In this stage, the measurement signal and the reference signal are correlated. For PSK, QAM and MSK modulated signals, an estimation algorithm is used in order to obtain estimates for the signal amplitude, signal timing, carrier frequency error, phase error, I/Q offset, gain imbalance, quadrature error and the amplitude droop. Alternatively, it is possible to disable the estimation algorithm.

For FSK modulated signals, estimates for the signal amplitude, signal timing, carrier frequency error, FSK deviation error and the carrier frequency drift are calculated. The measurement signal is subsequently corrected with these estimates. Compensation for FSK deviation error and carrier frequency drift can be enabled or disabled.

For more information on synchronization see

- chapter 4.5.1.2, "Estimation", on page 97
- chapter 5.9.2, "Advanced Demodulation (Synchronization)", on page 175

Result Display

The selected measurement results are displayed in the window(s). Configuration of the windows can be performed via the "Window Configuration" dialog (see chapter 6.5, "Display and Window Configuration", on page 196).

4.4.1 Burst Search

The burst search is performed only if it is switched on. Otherwise, this stage is skipped. It is recommended that you switch the burst search on if the signal is bursted. This ensures that all internal estimators are operated in time ranges where the burst power ramping is up.

In order to eliminate amplitude variations caused by noise or the modulation itself, the instantaneous power of the whole capture buffer is computed and then a moving average filter is applied. The length of this filter is automatically determined with the help of the user settings.

The filtered power of the capture buffer is subsequently compared to an automatically chosen threshold and the rising and falling edges of bursts are identified. With the help of the detected edges and some further processing, it is possible to decide whether the burst "candidates" comply with the user settings.

All bursts must have a length between ("Min Burst Length" – "Search Tolerance") and ("Max Burst Length" + "Search Tolerance") to be accepted. See "Burst Settings" on page 132 and chapter 5.7.1, "Burst Search", on page 161 for a more detailed description of these parameters.
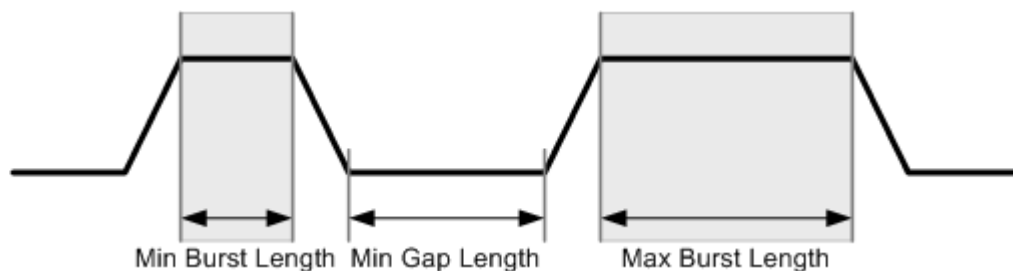
Fig. 4-44: Burst Search parameters

You can influence the robustness of the burst search directly by entering the correct minimum gap length, minimum burst length and maximum burst length (see "Burst Settings" on page 132 and "Min Gap Length" on page 162). Refer to figure 4-44 for an illustration of the three parameters.

The detected bursts in the capture buffer for the current burst search settings are indicated by blue lines in the preview area of the "Burst Search" configuration dialog box (see chapter 5.7.1, "Burst Search", on page 161).
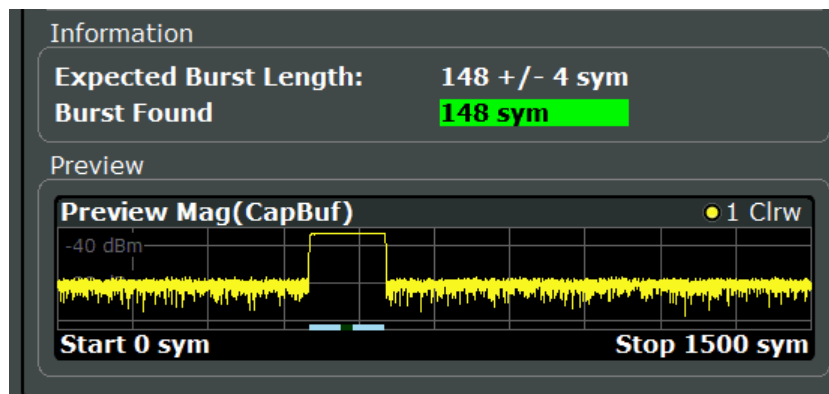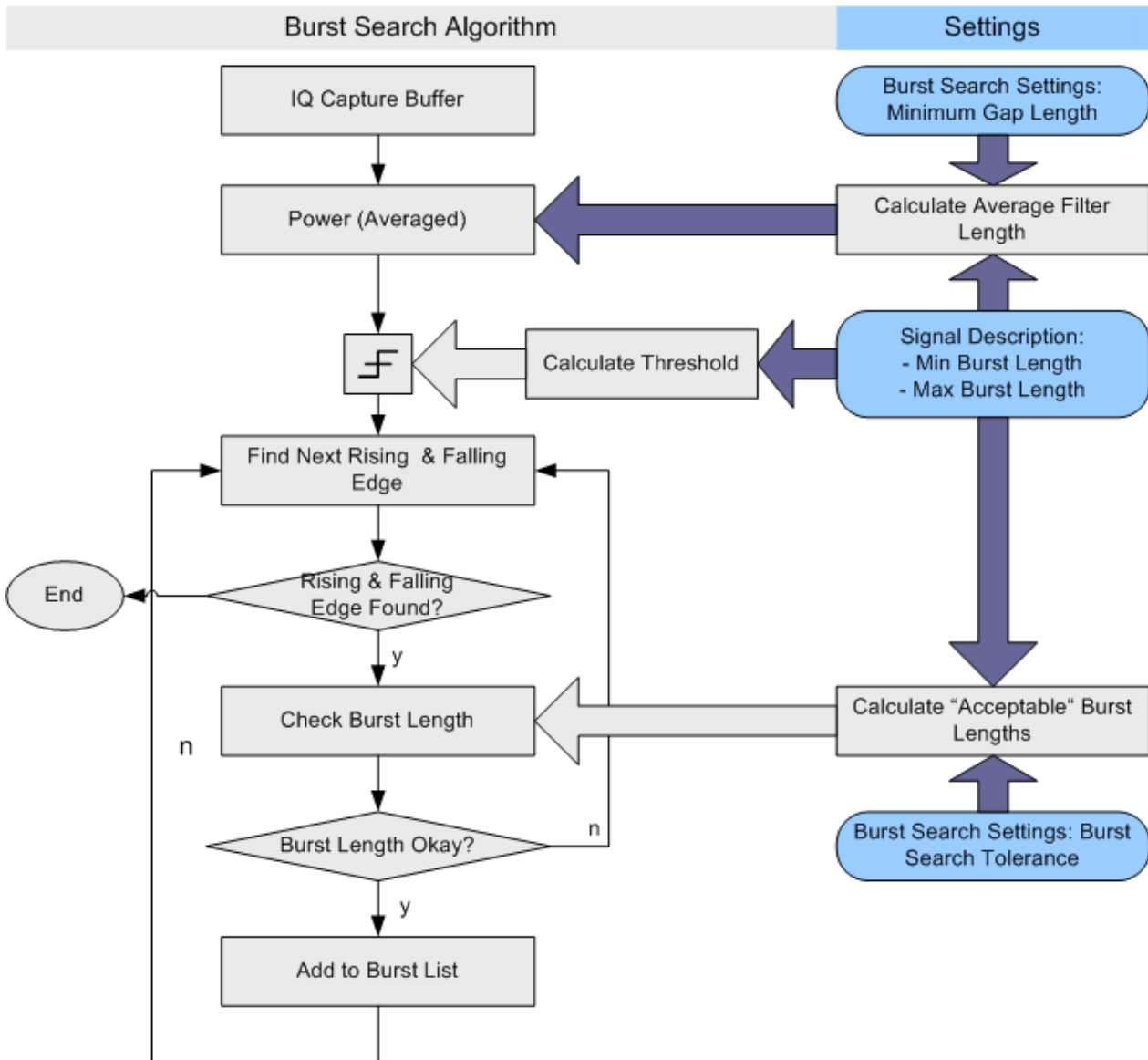
Fig. 4-45: Burst search algorithm

4.4.2   I/Q Pattern Search

The I/Q pattern search is performed only if it is switched on. Otherwise, this stage is skipped. The main benefit of the I/Q pattern search is that it enables an alignment of the result range to the pattern. Furthermore, this stage can function as a filter: If the burst search and I/Q pattern search are switched on, and the parameter "Meas Only If Pattern Symbols Correct" is set to true, only bursts with the correct pattern are demodulated (see "Meas only if Pattern Symbols Correct" on page 164).

During the I/Q pattern search stage, the capture buffer is searched for an I/Q pattern by trying different time and frequency hypotheses. The I/Q pattern is generated internally, based on the specified symbol number of the pattern and the signal description (i.e.

modulation scheme and transmit filter). The I/Q pattern search can also be referred to as the I/Q waveform. An I/Q pattern is considered detected if the correlation metric, i.e. the correlation value between the ideal I/Q pattern and capture buffer, exceeds a specified "I/Q Correlation Threshold" (see "I/Q Correlation Threshold" on page 164.)

If the burst search is switched on, the I/Q pattern search only searches the I/Q pattern in bursts previously detected by the burst search. Furthermore, it only finds the first I/Q pattern within each burst. If the burst search is switched off, the I/Q pattern search searches for the I/Q pattern in the entire capture buffer.

The first detected pattern in the capture buffer for the current pattern search settings is indicated by a green line in the preview area of the "Pattern Search" configuration dialog box (see chapter 5.7.2, "Pattern Search", on page 163).

Predefined Patterns

Common standards usually have predefined pattern lists with standard specific patterns. Patterns required for the current measurement can be selected from this list. This list can be extended by patterns that are already available in the instrument. Newly created patterns can also be added to the list.

4.4.3 Demodulation and Symbol Decisions

This stage operates on the result range and aims to make the correct symbol decisions. The algorithm is illustrated in figure 4-46 using the example of a QPSK modulation. After timing and scaling recovery, a frequency offset and phase offset estimator is employed.

After this coarse synchronization, the VSA application makes symbol decisions, i.e. recovers which symbols were transmitted by the device under test (DUT).

Typically, the employed estimators are "non-data-aided" (NDA) estimators. This means that they operate on an unknown data sequence. Since the local oscillators (LO) of the transmitter (device under test) and the receiver (R&S FSW) are normally not coupled, their phase offset with respect to each other is unknown. The unknown transmission delay between DUT and R&S FSW adds a further unknown phase offset.

Due to this unknown phase offset, the result of the demodulation can be ambiguous with respect to the absolute phase position because of the rotational symmetry of e.g. a PSK constellation. For example, in the case of non-differential QPSK modulation, the measurement signal, the reference signal and the decided I/Q symbols may have a constant phase offset of {0, π/2, π, or 3π/2}. This offset can only be detected and eliminated if a pattern was successfully detected at symbol level (see also chapter 4.4.4, "Pattern Symbol Check", on page 92).

If modulation types are used where the information is represented by the phase transition, e.g. differential PSK or MSK, the absolute phase position is not an issue. Thus, the ambiguity of the starting phase does not have an influence on the symbol decisions.

If the measurement signal contains a known pattern, it is also possible to use a "data-aided" (DA) estimator at this stage. This means that the estimator operates on a known data sequence, i.e. the pattern. If the signal contains a pattern, it is possible to choose between the above-described non-data-aided estimator and the data-aided estimator with the setting "Coarse Synchronization: Pattern". If the data-aided estimator is employed, the phase ambiguitiy can be resolved at this stage.
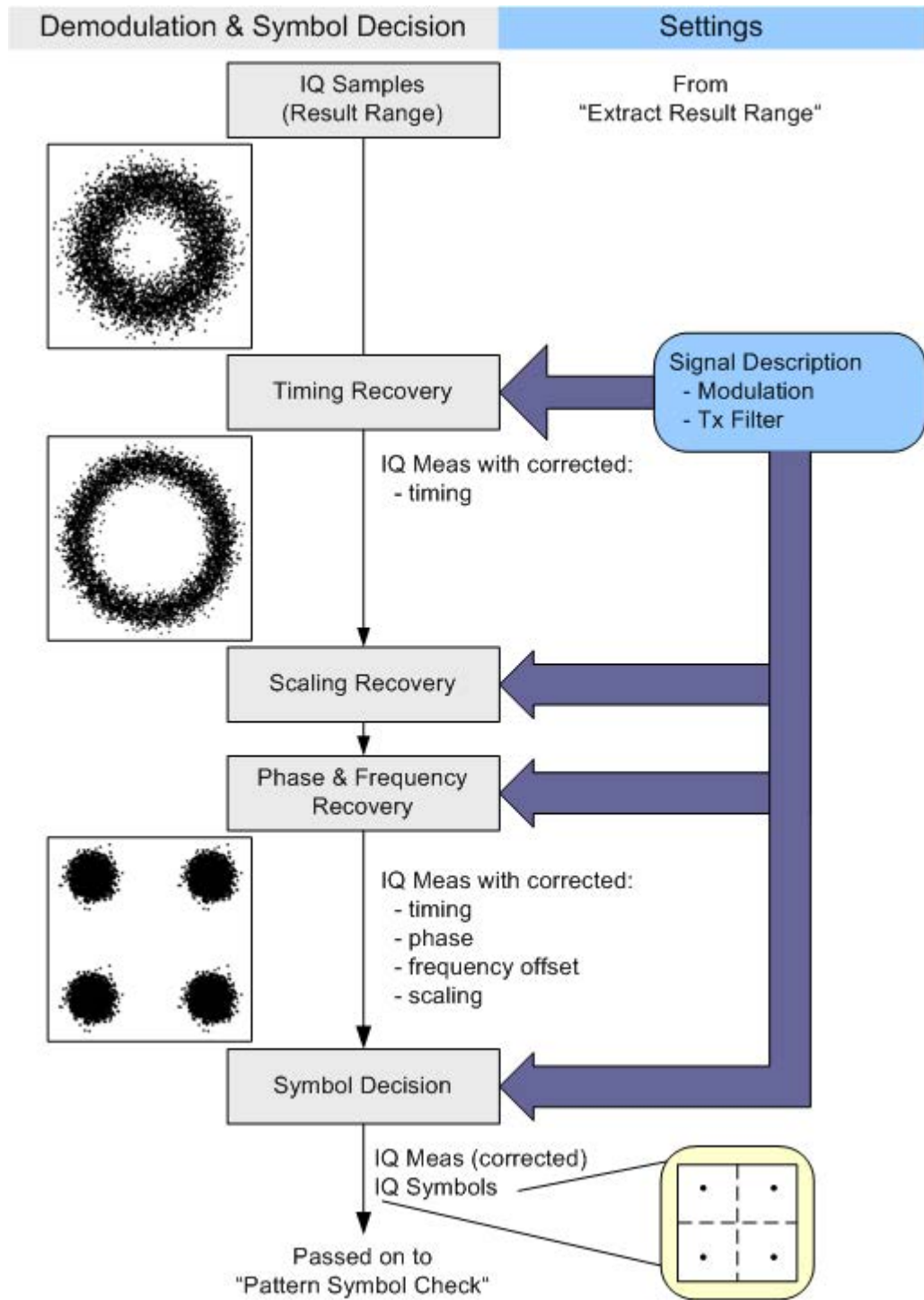
Fig. 4-46: Demodulation and Symbol Decision algorithm

4.4.4 Pattern Symbol Check

This stage performs a bit-by-bit comparison between the selected pattern and the demodulated bits. It is important to note that this comparison is only performed at positions that have been identified by the I/Q pattern search as possible pattern positions. The algorithm and a simple example are illustrated in figure 4-47.

First, the pattern candidate bits are extracted from the whole bitstream calculated by the "Demodulation & Symbol Decisions" stage. This means that the symbol stream is cut at the position that has been detected by the I/Q Pattern Search as the start of the pattern. The extracted sequence is then compared to the selected pattern.

If the demodulation has been ambiguous with respect to the absolute phase position, the extracted sequence needs to be compared to all possible rotated versions of the selected pattern. For example, in the case of QPSK modulation, the rotational symmetry has the order four, i.e. there are four pattern hypotheses. If the extracted sequence coincides with one of the hypotheses, the pattern is declared as "found" and the absolute phase corresponding to the appropriate hypothesis is passed on. Both the symbol decisions and the I/Q measurement signal are then rotated with this pattern phase (for the whole result range), thus resolving the phase ambiguity.

For more information refer to:

- chapter 4.4.3, "Demodulation and Symbol Decisions", on page 89
- chapter 4.4.2, "I/Q Pattern Search", on page 88
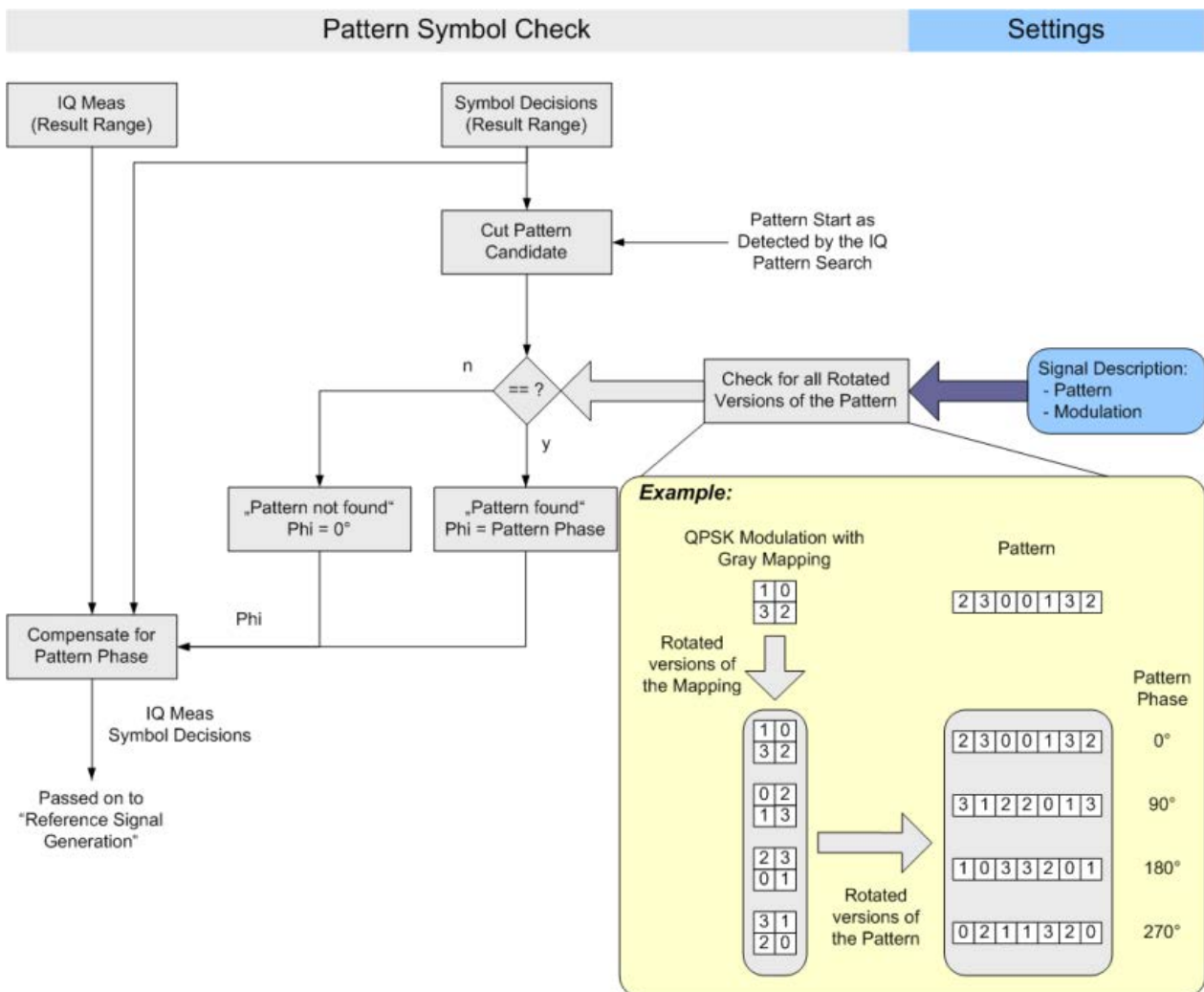
Fig. 4-47: Pattern Symbol Check algorithm

4.4.5 The Equalizer

A possible source of high modulation errors of the DUT with PSK and QAM signals is a non-flat frequency response or ripple in frequency response within the modulation bandwidth.

This could be caused by the DUT's:

●   Analog filter sections
●   Digital filter sections, if a shortened filter length is used
●   Digital arithmetic sections, if a shortened bit-length is used
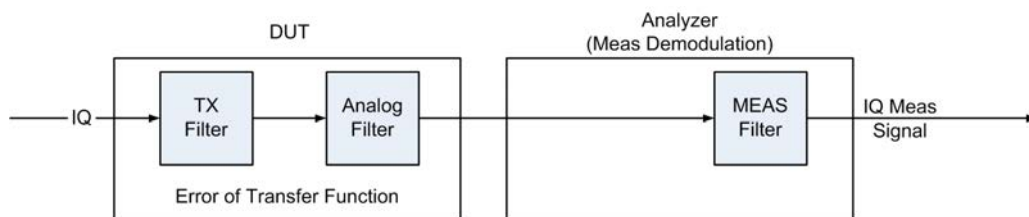
Fig. 4-48: General processing in the modulation- and demodulation stages

An equalizer filter with a reverse frequency response characteristic is able to compensate less distorted frequency responses in order to improve the modulation analysis results (see figure 4-49).
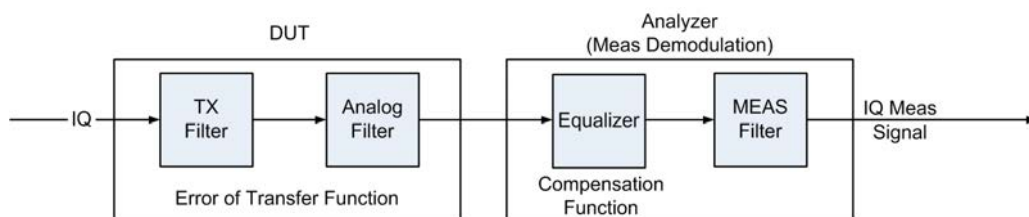
Fig. 4-49: Compensation of the transfer function's error by inserting an equalizer in the receive path

For small distortions the reference signal can be determined correctly without pre-equalization. The equalizer can be calculated by comparing the reference signal and the measured signal and is only applied to the measured signal. This is referred to as **normal equalizer mode**. Note that the resulting equalizer function is not simply the inverted distortion function.

For more complex distortions the reference signal might not be determined correctly due to wrong symbol decisions. Despite the resulting imperfect equalizer calculation, the estimated equalizer is often good enough to improve the reference signal creation in the succeeding sweep. Thus, the new equalizer is improved successively. This processing mode of the equalizer is called **tracking mode**. After only few sweeps, the results are sufficiently accurate and the learning phase is completed. Then the equalizer can be used without additional calculations as long as the input signal remains stable. If an unstable input has led to an unusable equalizer filter, reset the equalizer with the "Reset" button.
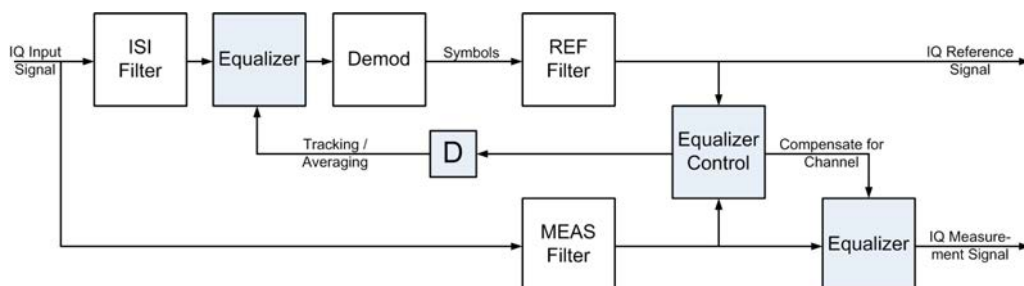
Fig. 4-50: An equalizer filter can be activated in the reference and measurement signal path. The filter coefficients are determined in such a way that the error vector magnitude (EVM) is minimized.

The result range used for equalizer calculation might be quite short leading to unstable equalizer impulse responses. For time-invariant channels the estimation length can be

extended using **Averaging mode**. In this case, the statistics from *all* previously determined reference signals and measurement signals are averaged to determine the current equalizer function. Thus, the results of previous sweeps are continuously considered to calculate the current equalizer values. Averaging is only restarted when the instrument is switched off or when the user manually resets the equalizer. Obviously, this method requires a stable input signal for the entire duration of the measurement, as otherwise the current equalizer is distorted by previous results.

This process requires extended calculation time so that the measurement update rate of the instrument decreases distinctly. When the distortions are compensated sufficiently, this averaging process can be stopped. The current filter is **frozen**, that means it is no longer changed.

Keep in mind that in Tracking and Averaging mode for sweep counts > 1 repeated analysis of past result ranges might lead to differing readings.

The equalizer algorithm is limited to PSK and QAM modulation schemes, as the optimization criterion of the algorithm is based on minimizing the mean square error vector magnitude. Thus it cannot be used for FSK modulation.

User-defined equalizers

Instead of tracking equalizer values repeatedly for different input signals, you can store existing values to a file and load them again later. This is useful if signals from the same input source are measured frequently. In this case, you only have to perform a calculation once and can use the same equalizer filter again and again.

Filter length

The length of the equalizer can be defined in symbols. The longer the equalizer the higher the resolution in the frequency domain is and the more distortion can be compensated. The shorter the filter length, the less calculation time is required during the equalizer's tracking or averaging phase.

Estimation points per symbol

You can define how many sample points are used for the equalizer calculation at each symbol ("Estimation points per symbol", see chapter 4.7, "Display Points vs Estimation Points per Symbol", on page 115). Typically, this is one point per symbol (= **symbol rate**) or a factor of 2.

Channel EVM

The equalizer not only compensates for distortions in the measurement signal, but also improves the accuracy of the estimated ideal reference signal. Thus, it is usually recommendable to enable the equalizer once you have analyzed the original input signal on the R&S FSW. By default, the error results are calculated using the compensated values if the equalizer is enabled. However, you can disable the compensation for channel results in order to analyze the actual error values obtained from the distorted channel.

4.5   Signal Model, Estimation and Modulation Errors

This section describes the signal and error models used within the VSA application. The estimation algorithms used to quantify specific modulation errors are then outlined. The descriptions vary depending on the modulation type.

4.5.1   PSK, QAM and MSK Modulation

4.5.1.1   Error Model
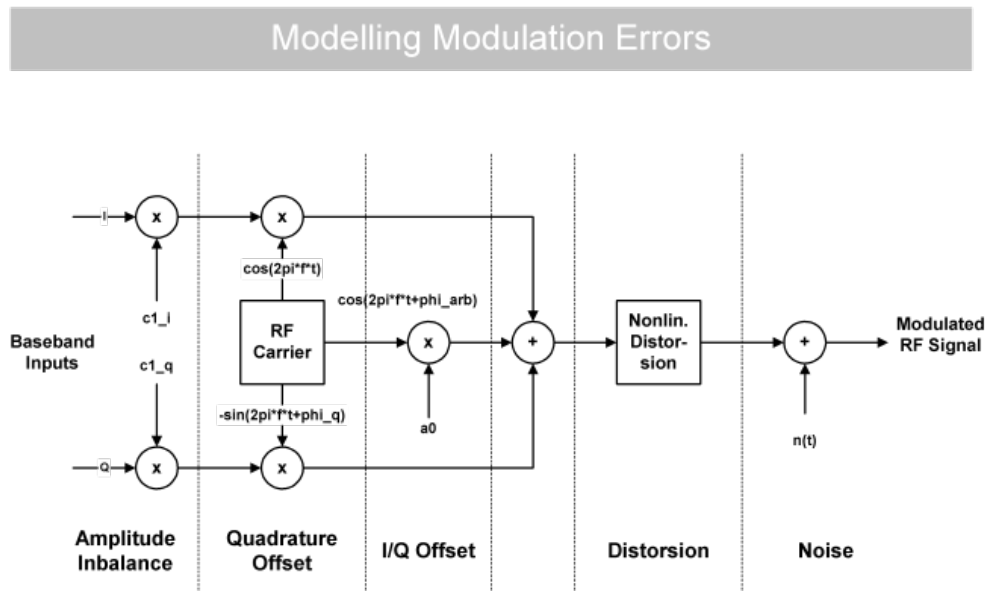
Fig. 4-51: Modelling Modulation Errors

The measured signal model for PSK, QAM and MSK modulation is shown in figure 4-51 and can be expressed as:

$$MEAS(t) = \left(g_I \cdot REF_I(t-\tau) + c_I + j \cdot \left(g_Q \cdot REF_Q(t-\tau) + c_Q \right) e^{j \cdot \vartheta} \right) e^{j \cdot (2\pi f_0 t + \varphi) - \alpha t} + n(t)$$

where:

REF$_I$(t) and REF$_Q$(t): the inphase and quadrature component of the reference signal

g$_I$ and g$_Q$: the effects of the gain imbalance

c$_I$ and c$_Q$: the effects of an I/Q offset

ϑ: the quadrature error

α: the amplitude droop

f$_0$: the carrier frequency offset

φ: the carrier phase offset

τ: the timing offset

n(t): a disturbing additive noise process of unknown power

4.5.1.2 Estimation

The VSA application includes two synchronization stages. The first stage has already been described in the context of the "Demodulation & Symbol Decisions" block (see chapter 4.4.3, "Demodulation and Symbol Decisions", on page 89).

The second stage is realized within the "Synchronization" block. Here, the measurement signal is matched to the reference signal by minimizing the mean square of the error vector magnitude. This is done by selecting the optimum parameter vector $\hat{x}$:

$$\hat{x} = \arg \min_{x} \left\{ \sum_{t} \left| MEAS(t) - REF(t, \tilde{x}) \right|^2 \right\}$$

The minimization takes place at the sample instants specified by the Estimation Points/ Sym parameter, i.e.

$$t = n \cdot T_E$$

with T$_E$: the sampling period used for estimation

Subsequently, the measurement signal is corrected with the determined parameter vector. Note that with a subset of the parameters, you can enable or disable correction (see chapter 5.9.1, "Demodulation - Compensation", on page 172).

Estimation ranges

The "estimation ranges" are determined internally according to the signal description:

- For continuous signals, the estimation range corresponds to the entire result range, since it can then be assumed that the signal consists of valid modulated symbols at all time instants.
- For bursted signals, the estimation range corresponds to the overlapping area of the detected burst and the "Result Range". Furthermore, the Run-In/Run-Out ranges (see "Burst Settings" on page 132) are explicitly excluded from the estimation range.

In the special case that the signal is indicated as a "burst signal", but is so highly distorted that the burst search cannot detect a burst, the estimation range corresponds to the pattern and (if an offset of the pattern is indicated) the useful part of the burst from its start to the pattern start.

4.5.1.3   Modulation Errors

Error vector (EV)
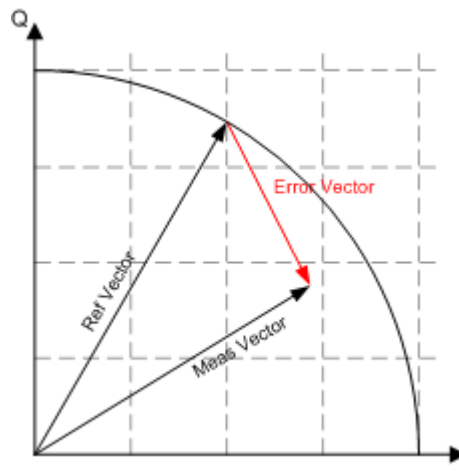
Fig. 4-52: Modulation error: error vector

The error vector is the difference between the measurement signal vector (Meas vector) and the reference signal vector (Ref vector).

Error Vector Magnitude (EVM)
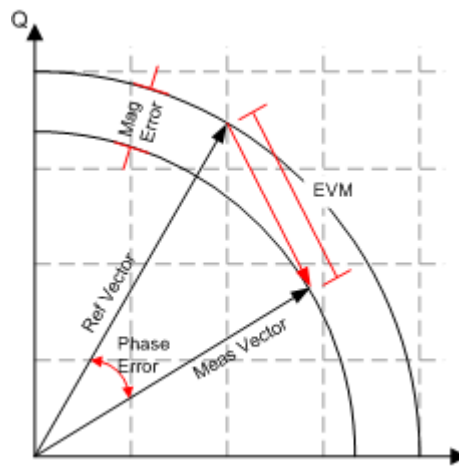
Fig. 4-53: Modulation error: EVM, magnitude error, phase error

The magnitude of the error vector in the diagram is specified as the error vector magnitude (EVM). It is commonly normalized to the mean reference power. The EVM should not be confused with the magnitude error, see below.

Magnitude Error

The magnitude error is defined as the difference between the measurement vector magnitude and the reference vector magnitude (see figure 4-53).

Phase Error
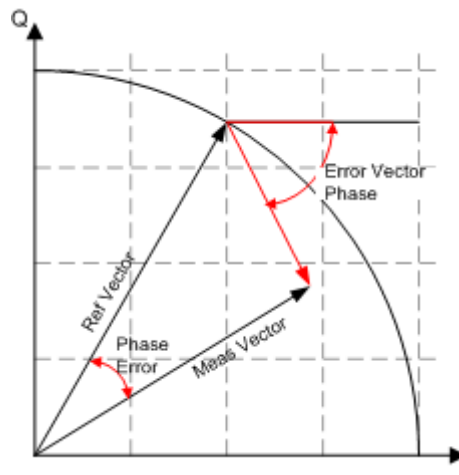
Fig. 4-54: Modulation error: Phase error, error vector phase

The phase error is the phase difference between the measurement vector and the reference vector.

$$PHASE\_ERR(t) = PHASE_{MEAS}(t) - PHASE_{REF}(t)$$

This measurement parameter is of great importance for MSK modulation measurements.

The phase error should not be confused with the error vector phase. The error vector phase is the absolute phase of the error vector (see figure 4-54).

The effects of the different modulation errors in the transmitter on the result display of the analyzer are described in the next topics. All diagrams show the equivalent, complex baseband signal.

Modulation Error Ratio (MER)

The modulation error ratio (MER) is closely related to EVM:

$$MER = -20 \cdot \log_{10}(EVM)$$

where the EVM is normalized to the mean reference power.

I/Q Offset (Origin Offset)
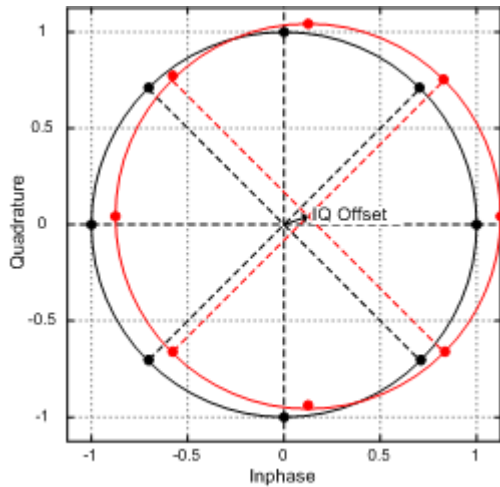
Fig. 4-55: Effect of an I/Q or origin offset after demodulation and error compensation

The effect of an I/Q offset in the transmitter is shown in figure 4-55.

The I/Q offset can be compensated for if the corresponding option is selected in the demodulation settings. In this case, the offset does not affect the EVM.

Example:

The following figures compare the results for a compensated I/Q offset of 2.5% and a non-compensated offset.

I/Q Offset compensated for	I/Q Offset NOT compensated for
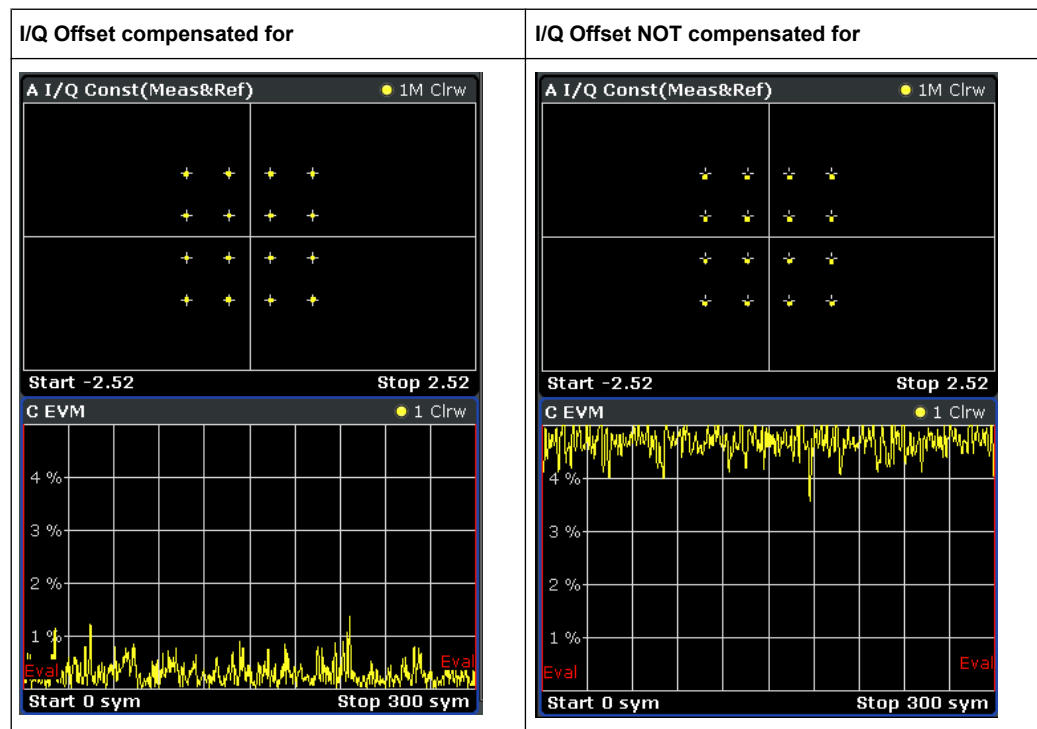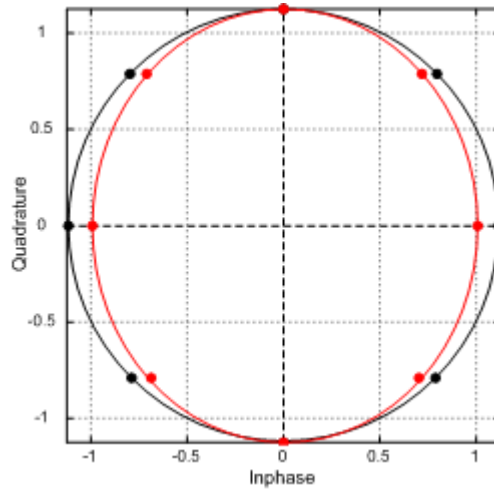
Gain Imbalance

Fig. 4-56: Effect of gain imbalance

The gain difference in the I and Q channels during signal generation in the transmitter is referred to as gain imbalance. The effect of this error on the constellation diagram and the unit circle are shown in figure 4-56. In the example, the gain in the I channel is slightly reduced which causes a distortion of coordinates in the I direction. The unit circle of the ideal constellation points has an elliptic shape.

The gain imbalance can be compensated for if the corresponding option is selected in the demodulation settings. In this case, the imbalance does not affect the EVM.

Note that the gain imbalance is not estimated (and cannot be compensated for) in a BPSK signal.

Preconditions for Gain Imbalance and Quadrature Error measurements

The distortions "gain imbalance" and "quadrature error" can only be measured without ambiguity, if the following two conditions are fullfilled:

● a pattern is detected
● the modulation is a non-differential, non-rotating QAM or PSK

Otherwise, only the measurement parameter "I/Q Imbalance", which is a combination of the gain imbalance and the quadrature error, is significant.

Quadrature Error
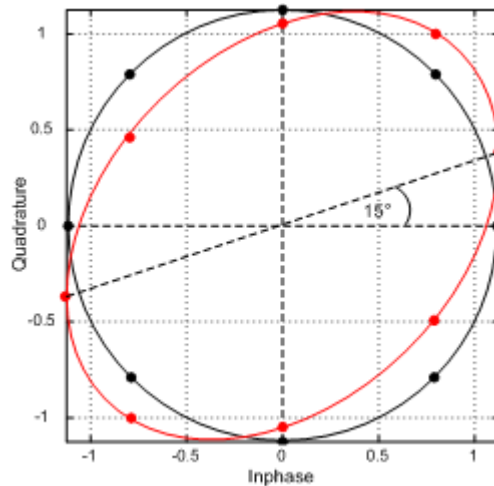
Fig. 4-57: Effect of Quadrature Error

The quadrature error is another modulation error which is shown in figure 4-57.

In this diagram, the I and Q components of the modulated carrier are of identical amplitude but the phase between the two components deviates from 90°.

This error also distorts the coordinates. In the example in figure 4-57, the Q-axis is shifted.

Note that the quadrature error is not estimated (and cannot be compensated for) in a BPSK signal.

I/Q Imbalance

The effect of quadrature error and gain imbalance are combined to form the error parameter I/Q imbalance.

$$B_{[lin]} = \frac{\left| g_I - g_Q \cdot e^{j\theta} \right|}{\left| g_I + g_Q \cdot e^{j\theta} \right|}$$

where g_I and g_Q are the gain of the inphase and the quadrature component and θ represents the quadrature error.

The I/Q imbalance can be compensated for if the corresponding option is selected in the demodulation settings. In this case, the I/Q imbalance does not affect the EVM.

Note that the I/Q imbalance is not estimated (and cannot be compensated for) in a BPSK signal.

Amplitude Droop

The decrease of the signal power over time in the transmitter is referred to amplitude droop.
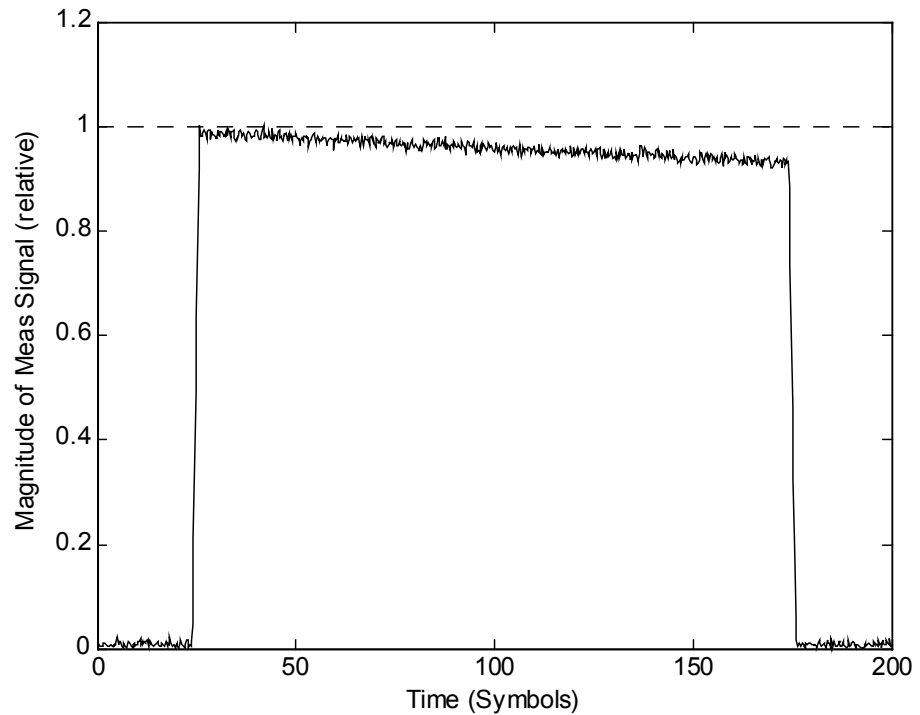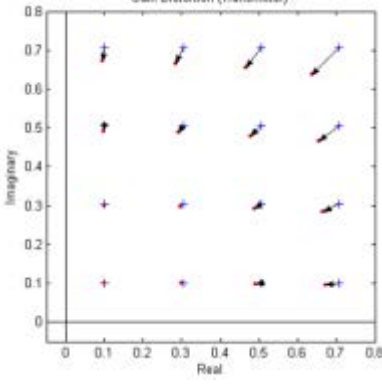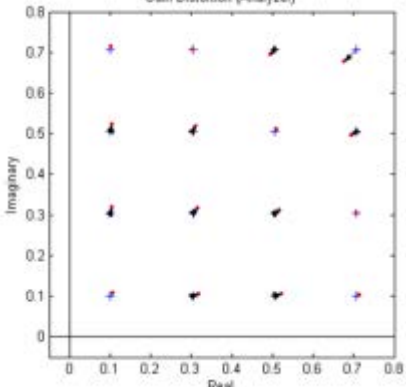
Fig. 4-58: Effect of amplitude droop

Gain Distortion

Table 4-17: Effect of nonlinear amplitude distortions

Nonlinear distortions: amplitude distortion (transmitter)	Amplitude distortion (analyzer)

The effect of nonlinear amplitude distortions on a 64QAM signal are illustrated in table 4-17 (only the first quadrant is shown). The transfer function is level-dependent: the highest effects occur at high input levels while low signal levels are hardly affected. The signal is scaled in the analyzer so that the average square magnitude of the error vector is minimized. The second column shows the signal after scaling.

Table 4-18: Amplitude transfer functions

Amplitude transfer function (transmitter)	Amplitude transfer function (analyzer)
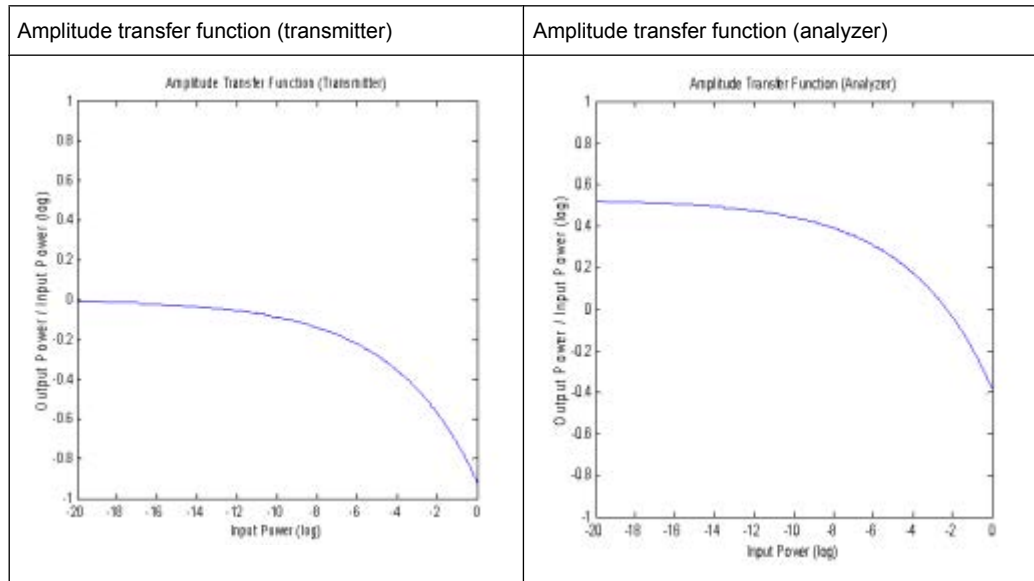
A logarithmic display of the amplitude transfer functions is shown in table 4-18. The analyzer trace is shifted against the transmitter trace by this scale factor.

Phase Distortion

Table 4-19: Effect of nonlinear phase distortions

Nonlinear distortions: phase distortion (transmitter)	Phase distortion (analyzer)
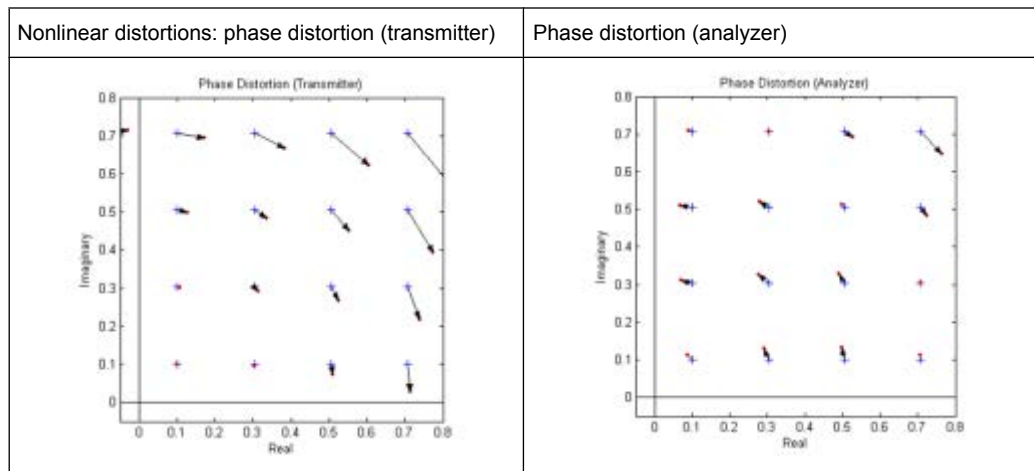
The effect of nonlinear phase distortions on a 64QAM signal is illustrated in table 4-19 (only the first quadrant is shown). The transfer function is level-dependent: the highest effects occur at high input levels while low signal levels are hardly affected. These effects are caused, for instance, by saturation in the transmitter output stages. The signal is scaled in the analyzer so that the average square magnitude of the error vector is minimized. The second column shows the signal after scaling.

Table 4-20: Phase transfer functions

Nonlinear distortions: phase distortion (transmitter)	Phase distortions (analyzer)
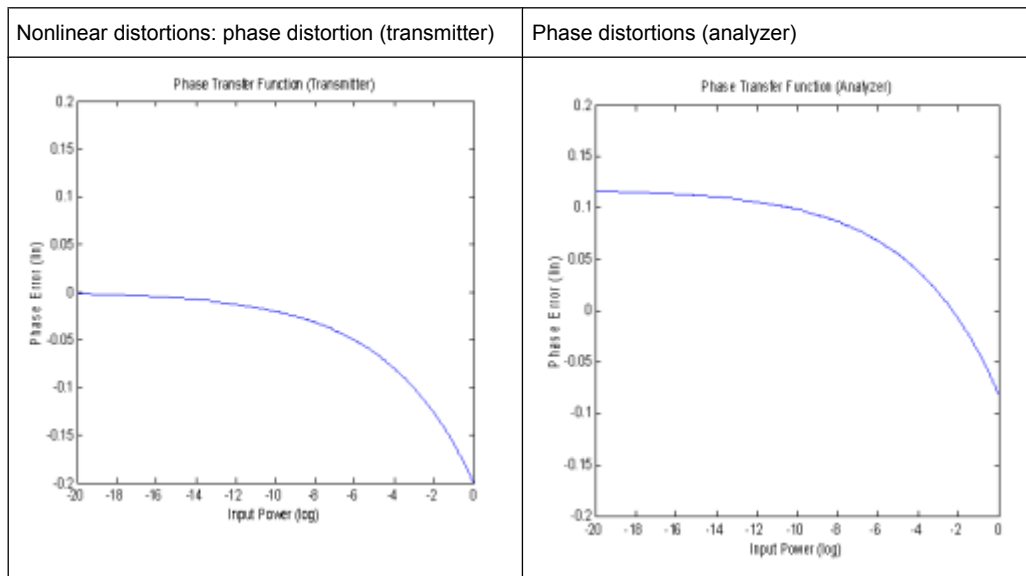
A logarithmic display of the phase transfer functions is shown in table 4-20. The analyzer trace is shifted by the phase described above as against the transmitter trace.

Noise
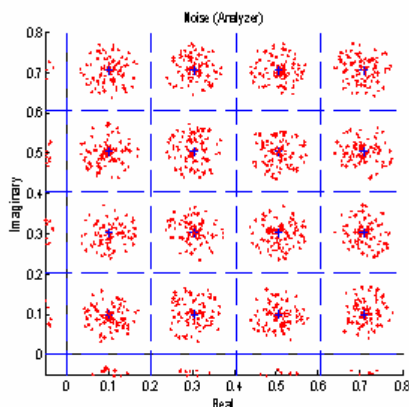
Fig. 4-59: Additive noise

A 64QAM signal with additive noise is shown in figure 4-59 (only the first quadrant is shown). The symbol decision thresholds are also shown.

The noise signal forms a "cloud" around the ideal symbol point in the constellation diagram. Exceeding the symbol decision boundaries leads to wrong symbol decisions and increases the bit error rate.

Similar displays are obtained in case of incorrect transmitter filter settings. When an incorrect filter is selected, crosstalk occurs between neighbouring symbol decision points instead of the ISI-free points. The effect increases the more the filtering deviates from actual requirements.

The two effects described cannot be distinguished in the Constellation I/Q diagram but in statistical and spectral analyses of the error signal.

Channel (transmission) distortion

During transmission, disturbances in the transmission channel may cause distortions in the input signal at the R&S FSW. Such influences are included in the EVM calculation. However, if the ideal (reference) signal can be estimated with suffcent accuracy by the R&S FSW (e.g. using the equalizer), the channel distortions can be compensated for and deducted from the EVM.

4.5.2 FSK Modulation

Signal Model

Frequency shift keying (FSK) involves the encoding of information in the frequency of a transmitted signal. As opposed to other modulation formats such as PSK and QAM, the FSK process is a non-linear transformation of the transmitted data into the transmitted waveform.

A sequence of symbols {s_i} are modulated using a "frequency pulse" *g(t)* to form the instantaneous frequency of the transmitted complex baseband waveform, denoted by $f_{REF}(t)$ and defined as:

$$f_{REF}(t) = h \cdot \sum_i s_i g(t - i \cdot T)$$

where f_{Symb}=1/T is the symbol rate and *h* is a scaling factor, termed the modulation index. The transmitted (or reference) FSK signal is formed by frequency modulation of the instantaneous frequency:

$$REF(t) = e^{j \cdot 2 \cdot \pi \cdot \int_{\infty}^{t} f_{REF}(u) du} = e^{j \cdot \varphi_{REF}(t)}$$

where $\varphi_{REF}(t)$ denotes the phase of the transmitted waveform. In the VSA application a continuous phase FSK signal is assumed, which is ensured by the integral in the expression for *REF(t)*. A graphical depiction of the reference waveform generation is shown below in figure 4-60.
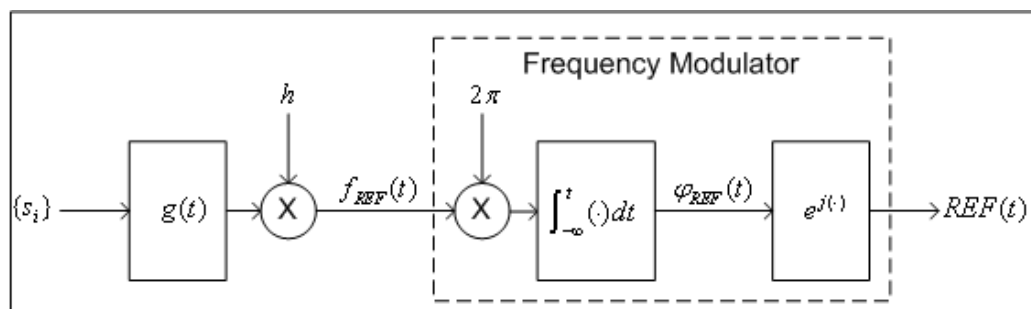
Fig. 4-60: Reference complex baseband FSK signal generation

Reference Deviation

The transmitted symbols {s_i} are assumed to be chosen from a finite and real-valued constellation of *M* values; *{$\varsigma_1, \varsigma_2, ..., \varsigma_M$}*. The maximum absolute constellation point is denoted by ς_{MAX}. The maximum phase contribution of a data symbol is given by:

$$\phi_{MAX} = 2 \cdot \pi \cdot h \cdot \varsigma_{MAX} \int_{-\infty}^{\infty} g(t) \cdot dt$$

The reference deviation of the FSK signal is defined as:

$$\Lambda_{REF} = \frac{\phi_{MAX}}{2 \cdot \pi \cdot T} = \frac{1}{T} h \cdot \varsigma_{MAX} \int_{-\infty}^{\infty} g(t) \cdot dt$$

In the VSA application the frequency pulse filter is normalized such that:

$$\int_{-\infty}^{\infty} g(t) \cdot dt = \frac{1}{2}$$

The constellation for *M* FSK is assumed to be *{±1, ±3, ..., ±(M-1)}*, which implies ς_{MAX} = M-1. The expression for the reference deviation in terms of the modulation index is therefore given by:

$$\Lambda_{REF} = \frac{1}{2} \cdot h \cdot (M - 1) \cdot f_{Symb}$$

The above formula provides the necessary calculation for measurement of an FSK signal with known symbol rate and modulation index.

Calculation examples:

The GSM standard describes the transmission of binary data using MSK (i.e. 2FSK) modulation with a modulation index of *h=1/2* at a symbol rate of 270.8333 KHz. The reference deviation is therefore given by:

$$\Lambda_{REF} = \frac{1}{2} \cdot \left(\frac{1}{2}\right) \cdot (2 - 1) \cdot (270.8333\,\text{kHz}) = 67.7083\,\text{kHz}$$

The APCO Project 25 standard (phase 2) defines a H-CPM signal (i.e. 4FSK) with a modulation index of *h=1/3* and a symbol rate of 6 KHz. The reference deviation is:

$$\Lambda_{REF} = \frac{1}{2} \cdot \left(\frac{1}{3}\right) \cdot (4 - 1) \cdot (6\,\text{kHz}) = 3\,\text{kHz}$$

4.5.2.1 Error Model

The FSK measurement model used assumes that signal distortions in both the magnitude and phase/frequency are present, as well as additive noise. The measured signal model is expressed as:

$$MEAS(t) = A_{DIST}(t) \cdot e^{j \cdot \varphi_{DIST}(t)} + n(t)$$

with

$n(t)$ is a disturbing additive noise process of unknown power,

$A_{DIST}(t)$ is the distorted magnitude model and

$\varphi^{DIST(t)}$ is the distorted phase model.

The magnitude model is given by:

$$A_{DIST}(t) = K \cdot e^{-\alpha \cdot t}$$

with

K is a constant scaling factor which can be interpreted as the system gain and

α is the amplitude droop in Nepers per second.

The phase model is given by:

$$\varphi_{DIST}(t) = B \cdot \varphi_{REF}(t - \tau) + C \cdot t + \frac{1}{2} D \cdot t^2 + \phi$$

with

B is a scaling factor which results in a reference deviation error,

C is a carrier frequency offset in radians per second,

D is a frequency drift in radians per second per second,

τ is a timing offset in seconds and

ϕ is a phase offset in radians.

For the above phase model, an equivalent frequency distortion model may be expressed as:

$$f_{DIST}(t) = B \cdot f_{REF}(t - \tau) + f_0 + f_d \cdot t$$

with

B is the scaling factor which results in a reference deviation error,

$f_0 = C/(2 \cdot \pi)$ is a carrier frequency offset in Hz,

$f_0 = D/(2 \cdot \pi)$ is a frequency drift in Hz per second and

τ is the timing offset in seconds.

The measured signal model in terms of the instantaneous frequency and all distortion parameters is given by:

$$MEAS(t) = K \cdot e^{-\alpha \cdot t} \cdot e^{j \cdot \phi} \cdot e^{j \cdot 2 \cdot \pi \cdot \left[B \cdot \int_{-\infty}^{t} f_{REF}(u - \tau) du + f_0 \cdot t + \frac{1}{2} f_d \cdot t^2 \right]} + n(t)$$

4.5.2.2 Estimation

The estimation of the distortion parameters listed previously is performed separately for the magnitude and phase/frequency distortions, as illustrated in figure 4-61. It is noted that the estimation of the timing offset is performed only on the frequency of the signal, as the reference magnitude is assumed to be constant over the estimation range. For details on the estimation range, see "Estimation ranges" on page 97.
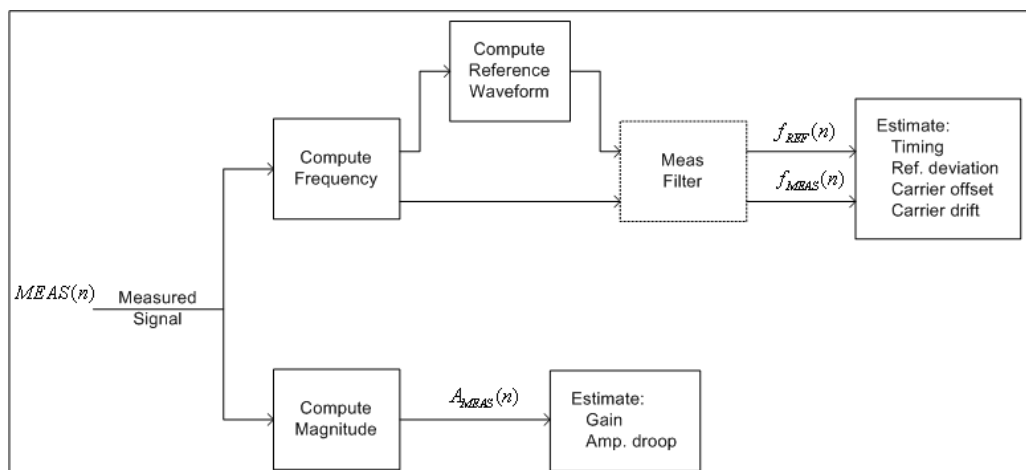
Fig. 4-61: FSK Estimation Strategy

In figure 4-61 *MEAS(n)* denotes the sampled (complex baseband) measured signal waveform. The magnitude samples are denoted $A_{MEAS}(n)$, while the instantaneous frequency samples of the measured and reference signals are denoted by $f_{MEAS}(n)$ and $f_{REF}(n)$ respectively. The dashed outline of the "Meas Filter" block indicates that this operation is optionally (de-) activated based on the corresponding user settings (see "Type" on page 180).

For the estimation of the magnitude parameters, the following least-squares criterion is minimized:

$$C_{MAG}(K,\alpha) = \sum_n \left| A_{MEAS}(n) - K \cdot e^{-\alpha \cdot n \cdot T_E} \right|^2$$

with respect to the model parameters K and α, where T_E denotes the sampling period used for estimation (see "Estimation Points/Sym" on page 177).

For estimation of the frequency parameters, the following least-squares criterion is minimized:

$$C_{FREQ}(B, f_0, f_d, \tau) = \sum_n \left| f_{MEAS}(n) - \left[B \cdot f_{REF}(n; \tau) + f_0 + f_d \cdot n \cdot T_E \right] \right|^2$$

with respect to the model parameters B, f_0, f_d and τ. The term denotes the reference instantaneous frequency with a (possibly fractional) delay of samples.

For FSK modulation the default sampling period used for estimation is the capture sampling period.

4.5.2.3   Modulation Errors

A 2FSK signal is generated using a GMSK frequency pulse. Examples of carrier drift and reference deviation are shown in figure 4-62 and figure 4-63, respectively.

Carrier frequency drift

A carrier frequency drift is modeled as a linear change in the carrier frequency with respect to time. The effect of carrier drift on the instantaneous frequency of an FSK signal is illustrated in figure 4-62.
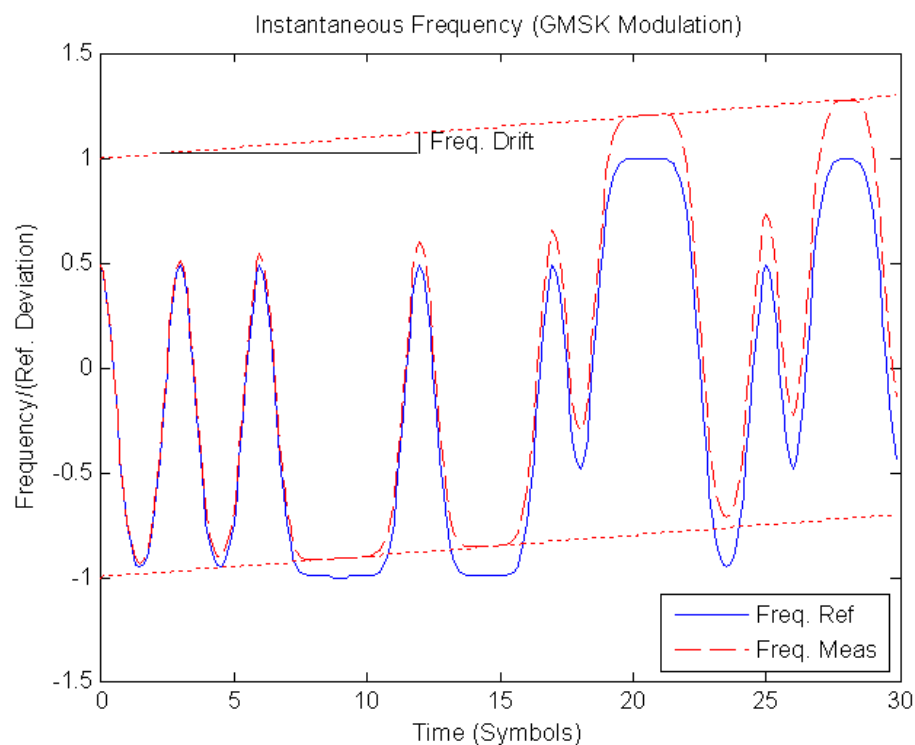
Fig. 4-62: The reference and distorted instantaneous frequency of a GMSK signal with a carrier frequency drift

FSK deviation error

The FSK deviation error is the difference between the measured frequency deviation and the reference frequency deviation as entered by the user (see "FSK Ref Deviation (FSK only)" on page 129). The evidence of a deviation error in the instantaneous frequency of an FSK signal is demonstrated in figure 4-63.
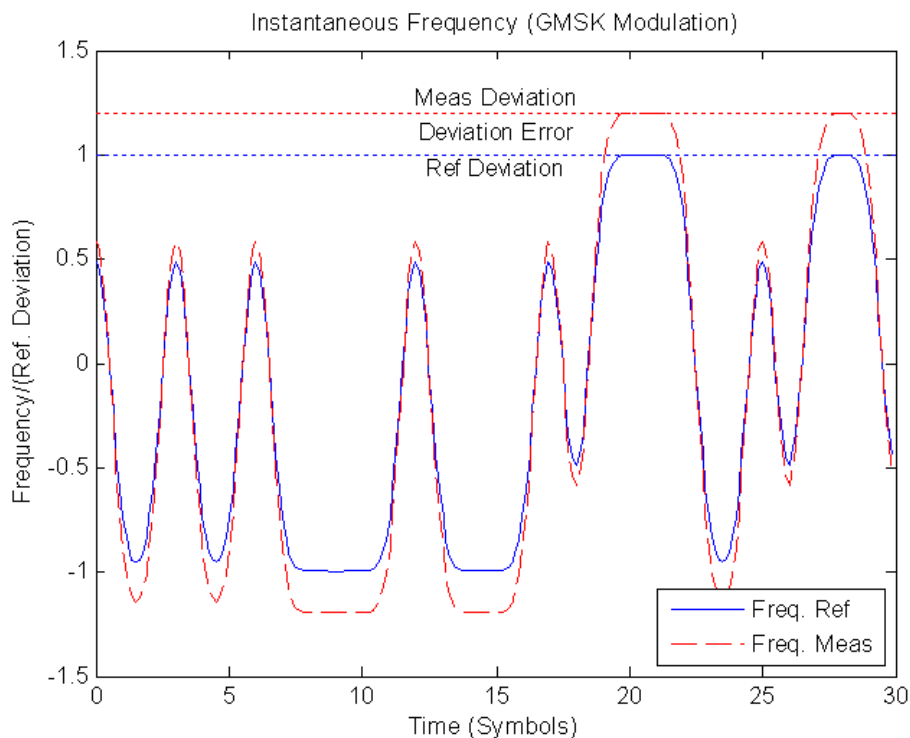
Fig. 4-63: The reference and measured instantaneous frequency of a GMSK signal with reference deviation error

4.6 Measurement Ranges

The VSA application contains three measurement ranges that need to be set by the user:

- **Capture Buffer Length**
  The length of the capture buffer specifies how many data points are captured during a single VSA measurement.
  For example, if you want to measure a bursted signal, it is recommended that you make the capture length long enough to ensure that in each capture buffer at least one entire burst is included.

- **Result Range**
  The result range defines the symbols from the capture buffer that are to be demodulated and analyzed together.
  For example, bursted signals have intervals between the bursts that are not of interest when analyzing peaks or overshoots. Thus, the result range usually coincides with the range of the capture buffer in which the burst is located.

- **Evaluation Range**
  The evaluation range defines the symbols from the result range that are to be included in the evaluation of specific parameters, e.g. error vectors.

For example, while you may want to display the ramps of a burst and thus include them in the result range, they do not contribute to the error vectors or power levels. Thus, you would not include them in the evaluation range.
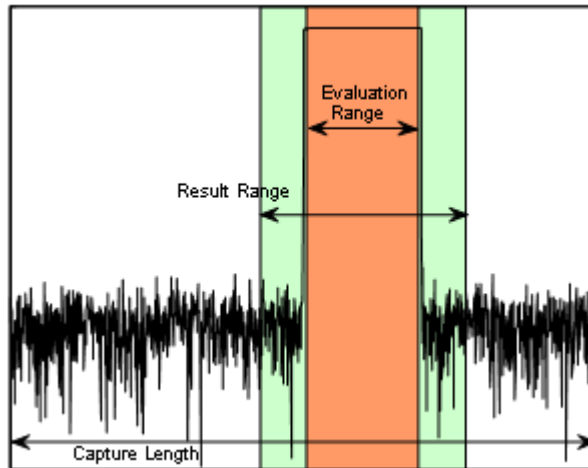
Fig. 4-64: Schematic overview of Capture Length, Result Range, and Evaluation Range

The determined result and evaluation ranges are included in the result displays (where useful) to visualize the basis of the displayed values and traces.

4.6.1 Result Range

The result range defines the symbols from the capture buffer that are to be demodulated and analyzed together.

In some cases, the data in the capture buffer contains parts that are not relevant for the evaluation task at hand. Thus, you can exclude them from the result range (see chapter 5.8, "Result Range Configuration", on page 169).

Result range display

The result ranges are indicated by green bars along the time axis of the capture buffer result diagrams.
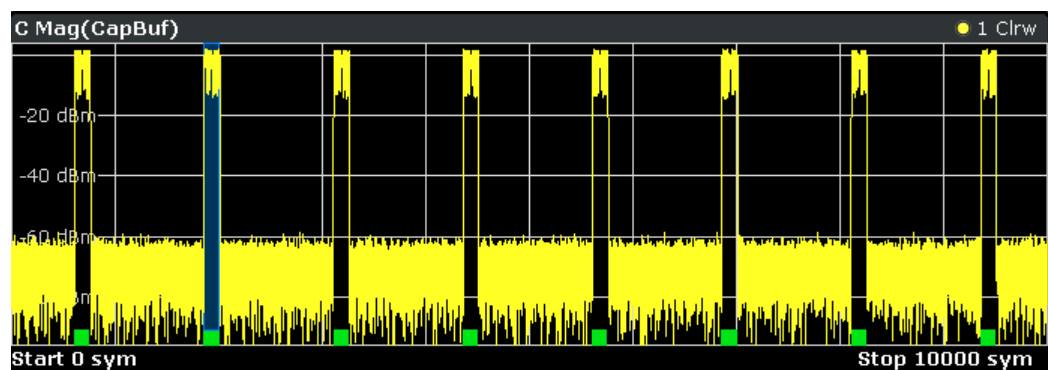
Fig. 4-65: Result ranges for a burst signal

Result displays whose source is not the capture buffer are based on a single result range, such as the "EVM vs. Time" display or the data in the "Current" column of the Result Summary. In this case, you can use the capture buffer display to navigate through the available result ranges (Select Result Rng softkey), and analyze the individual result ranges in separate windows. The currently displayed result range is indicated by a blue bar in the capture buffer display.

You can change the position of the result range quickly and easily by dragging the blue bar representing the result range to a different position in the capture buffer.

Continuous and discrete result ranges

Depending on the type of signal and your result range definition, the result ranges may be continuous or discrete. Bursted signals commonly have several discrete result ranges at the bursts, with intervals during the noise periods which should not be included in the results (see figure 4-65).

Continuous signals, on the other hand, have result ranges that cover the entire or a specific part of the capture buffer without intervals.
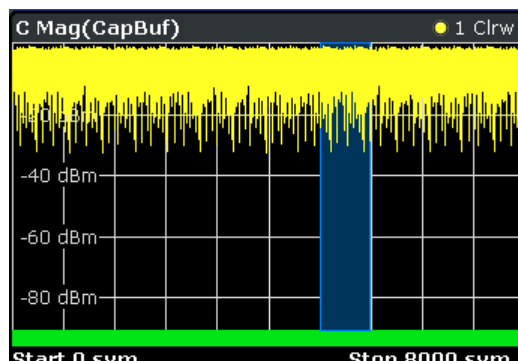
Fig. 4-66: Result ranges for a continuous signal

Result Range Length

The result range length is defined by the number of symbols that are to be demodulated. All traces over time are displayed over the result range. For example, if you have a burst of 100 symbols and you define the result length as 200 symbols, you can examine the burst ramps in detail (by selecting the alignment "Burst - Center").

The maximum result length depends on the CPU board (indicated in "SETUP > System Info > Hardware Info"):

FMR-7: 10000 symbols

FMR-9: 20000 symbols

Result Range Alignment

By defining the number of the symbol which marks the beginning of the alignment reference source (burst, capture buffer or pattern), you can define an offset of the x-axis (in addition to the one defined for the signal structure, see "Offset" on page 133).

For example, if you align the result to the center of the pattern and set the "Symbol Number at Pattern Start" to "0", you can easily find the pattern start in the EVM measurement simply by moving a marker to the symbol number "0".

When you define the "Symbol Number at <Reference> Start" remember to take the offset defined for the signal structure into consideration (see "Offset" on page 133). If you define an offset of the pattern with respect to the useful part of the burst in the signal description and align the result to the pattern, the "Symbol Number at Pattern Start" refers to the first symbol of the useful part of the burst, not the first symbol of the pattern.

Run-In / Run-Out Time

The parameter Run-In/-Out can be used to influence the range over which the EVM is minimized. The (internal) synchronization range is the overlapping area of the result range and the burst excluding its Run-In/-Out areas. Hence, this parameter also allows for demodulation of bursts with mixed modulations, e.g. Bluetooth, because it can be used to explicitly exclude symbols from influencing the synchronization.

Useful length

The burst excluding its Run-In/-Out areas is sometimes referrred to as the "useful part". The minimum length of the useful part (= Min Length - Run-In - Run-Out) must be ≧10.

4.6.2 Evaluation Range

In some scenarios, the result range contains symbols that are not supposed to be considered for the EVM or other calculated parameters that are displayed in the Result Summary.

For example, while you may want to display the ramps of a burst and thus include them in the result range, they do not contribute to the error vectors or power levels. Thus, you would not include them in the evaluation range. (See also chapter 8.3.4, "Evaluating the Rising and Falling Edges", on page 233).

The evaluation range is always equal to or smaller than the result range and defines:

● The range over which traces that do not have a time axis are displayed, e.g. polar diagrams

● The range over which the following parameters are calculated for the Result Summary: EVM, MER, Phase Error, Magnitude Error, Power

Evaluation range display

In all displays over time, except for capture buffer displays, the evaluation range is indicated by red lines.
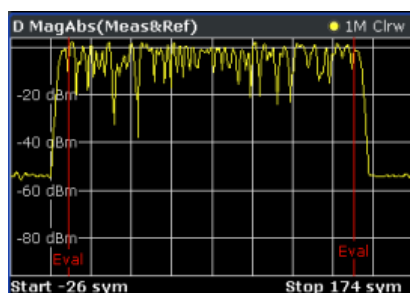
Fig. 4-67: Evaluation lines in absolute magnitude diagram

In symbol tables, the evaluated symbols are indicated by red square brackets.

In other result displays that are based on the evaluation range only, two red vertical lines are displayed in the diagram header to indicate a limited evaluation basis.

4.7 Display Points vs Estimation Points per Symbol

Estimation points per symbol

During synchronization, the measurement signal is matched to the reference signal and various signal parameters are calculated, as well as the optional equalizer. You can define how many sample points are used for this calculation at each symbol. Typically, this is one point per symbol (= **symbol rate**) or a factor of 4 (= **sample rate**).

Display points per symbol

The number of points per symbol used for calculation may vary from the number of points used to display the results of the calculation. If more points per symbol are selected than the defined sample rate, the additional points are interpolated for the display. The more points are displayed per symbol, the more detailed the trace becomes, as illustrated in figure 4-68.
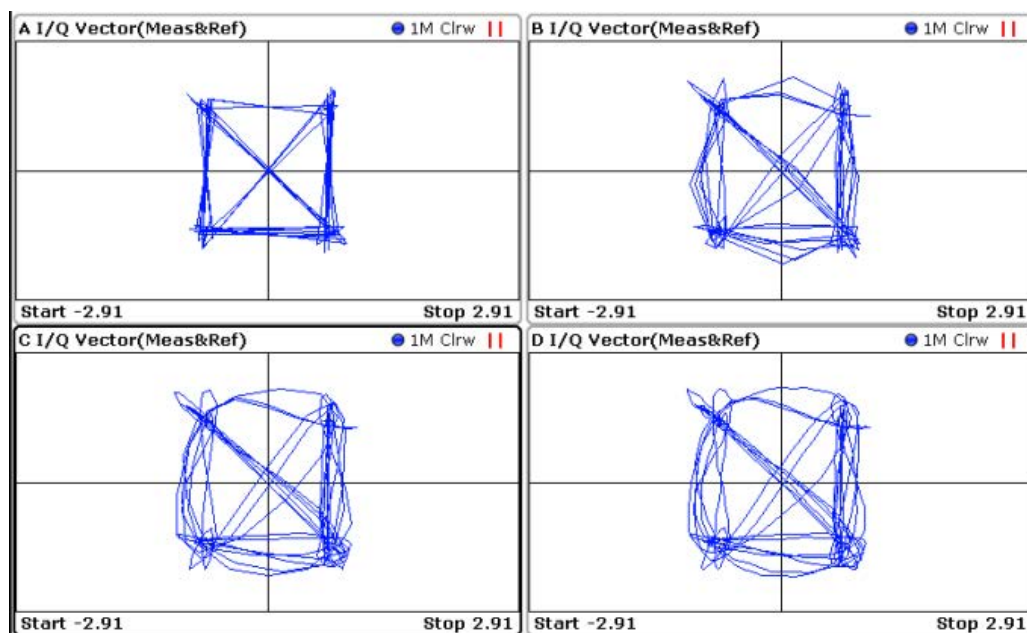
Fig. 4-68: Result display with different numbers of points per symbol: window A = 1; window B = 2; window C = 4; window D = 16;

The displayed points per symbol also determine how many values are returned when the trace data is queried by a remote command (see `TRACe<n>[:DATA]` on page 363).

For results based on the **capture buffer**, one display point is displayed for each sample taken, i.e. the display points per symbol are always identical to the sample rate.

For the "Result Summary", the number of display points corresponds to the estimation points per symbol. (By default, 1 for QAM and PSK modulated signals and the sample rate for MSK and FSK modulated signals.) This value also controls which samples are considered for the peak and RMS values and the power result.

For all other result displays, the default number of displayed points per symbol is identical to the sample rate.

4.8 Known Data Files - Dependencies and Restrictions

For various vector signal analysis functions the measured signal is compared to a defined ideal reference signal. The more precise the reference signal, the more precise the results become. In the best case, the possible data sequences within the signal to analyze are known in advance and can be used to compare the measured data to. This is similar to defining a pattern for the entire result range. Thus, a falsely estimated reference signal (due to false symbol decisions) is avoided and does not influence the error calculation.

You can load xml files containing the possible sequences to the VSA application and use them to compare the measured data to. In particular, you can use known data for the following functions:

- Fine synchronization during the demodulation process (see figure 4-43 and "Fine Synchronization" on page 178)

- Calculation of the Bit Error Rate (BER), see chapter 3.2.23, "Bit Error Rate (BER)", on page 42

For details on working with Known Data files see chapter 7.2.3, "How to Manage Known Data Files", on page 208.

The syntax for Known Data files is described in chapter A.4, "Known Data File Syntax Description", on page 408.

When you use Known Data files as a reference, some dependencies to other settings and restrictions for other functions apply.

Modulation Order

The "Modulation Order" selected in the "Modulation" settings in the VSA application must correspond to the modulation order value specified in the xml file (<ModulationOrder> element).

Demodulation

Demodulation using synchronization to the Known Data may increase the measurement duration, as each detected symbol must be compared to each possible sequence in the data file.

Result Length

The "Result Length" specified in the "Result Range" dialog box in the VSA application must be identical to the length of the specified symbol sequences in the xml file (<Result-Length> element).

Result Range Alignment

- **Bursted signals**
  When you align the result range to a bursted signal, due to the uncertainty of the burst search, the determined result range might start up to 2 symbols before or after the actual burst. However, an offset of only one symbol has the effect that none of the predefined symbol sequences in the Known Data file will be found. To avoid this, try one of the following:
  – Align the result range to a pattern instead of the burst.

  – Use a precise external trigger and align the result range to the capture buffer. This requires a very precise trigger timing, otherwise the result range start may be incorrect again.

- **Continuous signals**
  For continuous signals without a pattern, the result range is aligned randomly. Thus, a very large number of possible sequences must be predefined.
  Use a precise external trigger and align the result range to the capture buffer. This requires a very precise trigger timing, otherwise the result range start may be incorrect again.

4.9 VSA in MSRA Operating Mode

The R&S FSW VSA application can also be used to analyze data in MSRA operating mode.

In MSRA operating mode, only the MSRA Master actually captures data; the MSRA applications receive an extract of the captured data for analysis, referred to as the **application data**. For the R&S FSW VSA application in MSRA operating mode, the application data range is defined by the same settings used to define the signal capture in Signal and Spectrum Analyzer mode. In addition, a capture offset can be defined, i.e. an offset from the start of the captured data to the start of the application data for vector signal analysis. The "Capture Buffer" displays show the application data of the VSA application in MSRA mode.

Data coverage for each active application

Generally, if a signal contains multiple data channels for multiple standards, separate applications are used to analyze each data channel. Thus, it is of interest to know which application is analyzing which data channel. The MSRA Master display indicates the data covered by each application, restricted to the channel bandwidth used by the corresponding standard, by vertical blue lines labeled with the application name. Since the VSA application supports several standards and the standard used by the currently analyzed data is not known, the "Symbol Rate" defined in the "Signal Description" settings is used to approximate the channel bandwidth.

Analysis interval

However, the individual result displays of the application need not analyze the complete data range. The data range that is actually analyzed by the individual result display is referred to as the **analysis interval**.

In the R&S FSW VSA application the analysis interval is automatically determined according to the evaluation range or result range settings, as in Signal and Spectrum Analyzer mode. The currently used analysis interval (in seconds, related to capture buffer start) is indicated in the window header for each result display.

Exception: Equalizer

In the "Equalizer" displays do not indicate the analysis interval in MSRA mode.

For details on the MSRA operating mode see the R&S FSW MSRA User Manual.

5 Configuration

Using the VSA application you can perform vector signal analysis measurements using predefined standard setting files, or independently of digital standards using user-defined measurement settings. Such settings can be stored for recurrent use.

Thus, configuring VSA measurements requires one of the following tasks:

- Selecting an existing standard settings file and, if necessary, adapting the measurement settings to your specific requirements.
- Configuring the measurement settings and, if necessary, storing the settings in a file.

VSA application

VSA measurements require a special application on the R&S FSW, which you activate using the MODE key on the front panel.

When you switch the application of a measurement channel to VSA the first time, a set of parameters is passed on from the currently active application (see chapter 5.1, "Default Settings for Vector Signal Analysis", on page 120). After initial setup, the parameters for the measurement channel are stored upon exiting and restored upon re-entering the channel. Thus, you can switch between applications quickly and easily.

When you activate a measurement channel for the VSA application, a VSA measurement for the input signal is started automatically with the default configuration. The "VSA" menu is displayed and provides access to the most important configuration functions.

Automatic refresh of preview and visualization in dialog boxes after configuration changes

The R&S FSW supports you in finding the correct measurement settings quickly and easily - after each change in settings in dialog boxes, the preview and visualization areas are updated immediately and automatically to reflect the changes. Thus, you can see if the setting is appropriate or not before accepting the changes.

Importing and Exporting I/Q Data

The I/Q data to be evaluated in VSA can not only be measured by the VSA application itself, it can also be imported to the application, provided it has the correct format. Furthermore, the evaluated I/Q data from the VSA application can be exported for further analysis in external applications.

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

For details on importing and exporting I/Q data see the R&S FSW User Manual.

5.1 Default Settings for Vector Signal Analysis

When you switch the application of a measurement channel to VSA the first time, a set of parameters is passed on from the currently active application:

- center frequency and frequency offset
- reference level and reference level offset
- attenuation
- signal source and digital I/Q input settings
- input coupling
- YIG filter state

After initial setup, the parameters for the measurement channel are stored upon exiting and restored upon re-entering the channel. Thus, you can switch between applications quickly and easily.

Apart from these settings, the following default settings are activated directly after a measurement channel has been set to VSA, or after a Preset Channel:

Table 5-1: Default settings for VSA channels

Parameter	Value
Digital standard	3G_WCDMA
Sweep mode	CONTINUOUS
Trigger settings	FREE RUN
Trigger offset	0
Modulation	QPSK, WCDMA mapping
Transmit filter	RRC, α=0.22
Measurement filter	= Transmit filter
Signal type	Continuous, no pattern
Symbol rate	3.84 MHz
Sample rate	4* Symbol rate (=15.36 MHz)
Capture length	8000 symbols
Usable I/Q Bandwidth	12.228 MHz
Result length	800 symbols

Parameter	Value
Result Range alignment	Left at capture buffer start
Evaluation range	Entire result range
Demodulation	Compensation for I/Q offset and amplitude droop
	Estimation points per symbol: auto (1)
Evaluations	Window 1: Constellation I/Q (Meas & Ref)
	Window 2: Result Summary
	Window 3: Magnitude absolute (Capture buffer)
	Window 4: Symbol table (hexadecimal)
Display points per symbol	= Sample rate (4)

Apart from the "Preset Channel" function (see "Preset Channel" on page 125), the following functions are available to restore factory settings to the VSA application (via softkeys in the MEAS menu):

Restore Factory Settings
Opens a submenu that allows you to restore all standards and pattern settings on the instrument to the values predefined by Rohde & Schwarz available at the time of delivery.

Restore Standard Files ← Restore Factory Settings
Restores the standards predefined by Rohde & Schwarz available at the time of delivery.

Note that this function will overwrite customized standards that have the same name as predefined standards.

SCPI command:
[SENSe:]DDEMod:FACTory[:VALue] on page 265

Restore Pattern Files ← Restore Factory Settings
Restores the pattern files predefined by Rohde&Schwarz available at the time of delivery.

SCPI command:
[SENSe:]DDEMod:FACTory[:VALue] on page 265

5.2 Configuration According to Digital Standards

Various predefined settings files for common digital standards are provided for use with the VSA application. In addition, you can create your own settings files for user-specific measurements.

For an overview of predefined standards and settings see chapter A.1, "Predefined Standards and Settings", on page 398. For detailed instructions see chapter 7.1, "How to Perform VSA According to Digital Standards", on page 201

Digital standard settings are available via the "Digital Standards" softkey in the MEAS menu.

Digital Standards

Opens a file selection dialog to manage predefined measurement settings for conventional mobile radio standards.

Selecting the Storage Location - Drive/ Path/ Files ← **Digital Standards**

Select the storage location of the settings file on the instrument or an external drive.

The "Drive" indicates the internal (C:) or any connected external drives (e.g. a USB storage device).

The "Path" contains the drive and the complete file path to the currently selected folder.

The "Files" list contains all subfolders and files of the currently selected path.

The default storage location for the standards files is: `C:/FSW/vsa/Standards` or (for user-defined standards) `C:/FSW/user/vsa/Standards`.

New Folder ← **Digital Standards**

Creates a new folder in the file system in which you can save the settings file.

File Name ← **Digital Standards**

Contain the name of the data file without the path or extension.

By default, the name of a settings file consists of a base name followed by an underscore. Multiple files with the same base name are extended by three numbers, e.g. `limit_lines_005`.

For details on the file name and location see the "Data Management" topic in the R&S FSW User Manual.

Comment ← **Digital Standards**

An optional description for the data file. A maximum of 60 characters can be displayed.

SCPI command:

`[SENSe:]DDEMod:STANdard:COMMent` on page 266

Load Standard ← **Digital Standards**

Loads the selected measurement settings file.

Note: When you load a standard, the usage of a known data file, if available, is automatically deactivated.

SCPI command:

[SENSe:]DDEMod:PRESet[:STANdard] on page 265

Save Standard ← Digital Standards
Saves the current measurement settings for a specific standard as a file with the defined name.

SCPI command:

[SENSe:]DDEMod:STANdard:SAVE on page 267

Save Standard ← Digital Standards
Saves the current measurement settings for a specific standard as a file with the defined name.

SCPI command:

[SENSe:]DDEMod:STANdard:SAVE on page 267

Delete Standard ← Digital Standards
Deletes the selected standard. Standards predefined by Rohde & Schwarz can also be deleted. A confirmation query is displayed to avoid unintentional deletion of the standard.

Note: Restoring predefined standard files. The standards predefined by Rohde & Schwarz available at the time of delivery can be restored using the "Restore Standards" softkey.
(See "Restore Standard Files" on page 121).

SCPI command:

[SENSe:]DDEMod:STANdard:DELete on page 266

Restore Standard Files ← Digital Standards
Restores the standards predefined by Rohde & Schwarz available at the time of delivery.

Note that this function will overwrite customized standards that have the same name as predefined standards.

SCPI command:

[SENSe:]DDEMod:FACTory[:VALue] on page 265

5.3 Configuration Overview

Throughout the measurement channel configuration, an overview of the most important currently defined settings is provided in the "Overview". The "Overview" is displayed when you select the "Overview" icon, which is available at the bottom of all softkey menus.
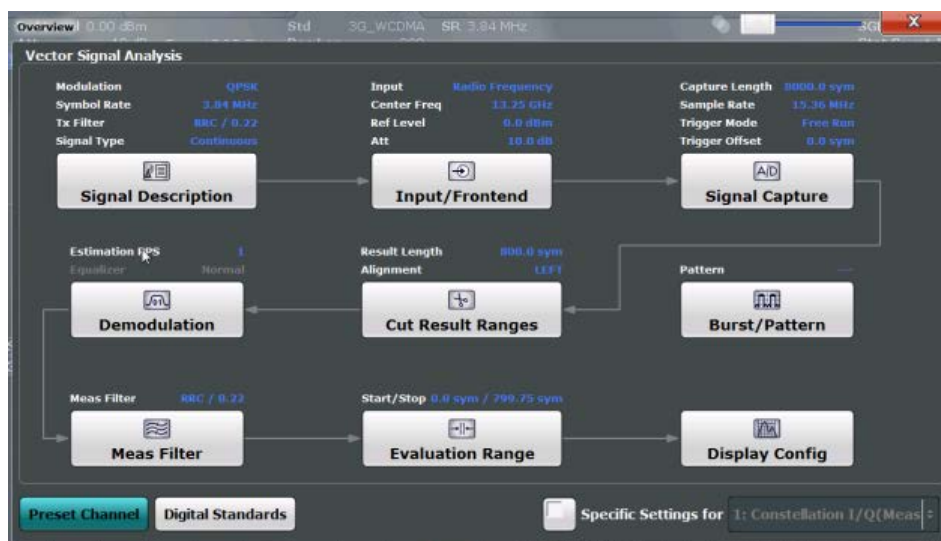
In addition to the main measurement settings, the "Overview" provides quick access to the main settings dialog boxes. The individual configuration steps are displayed in the order of the data flow. Thus, you can easily configure an entire measurement channel from input over processing to output and analysis by stepping through the dialog boxes as indicated in the "Overview".

In particular, the "Overview" provides quick access to the following configuration dialog boxes (listed in the recommended order of processing):

1. Signal Description
   See chapter 5.4, "Signal Description", on page 126

2. Input and Frontend Settings
   See chapter 5.5, "Input and Frontend Settings", on page 134

3. Signal Capture (including Triggering)
   See chapter 5.6, "Signal Capture", on page 151

4. Burst/Pattern Configuration
   See chapter 5.7, "Burst and Pattern Configuration", on page 160

5. Result Range Definition
   See chapter 5.8, "Result Range Configuration", on page 169

6. Demodulation Settings
   See chapter 5.9, "Demodulation Settings", on page 171

7. Measurement Filter Settings
   See chapter 5.10, "Measurement Filter Settings", on page 179

8. Evaluation Range Definition
   See chapter 5.11, "Evaluation Range Configuration", on page 181

9. Display Configuration
   The "Display Config" button is only available in the general overview, not in the window-specific overview (see "Specifics for" on page 125).

See chapter 6.5, "Display and Window Configuration", on page 196

10. Analysis
    See chapter 6, "Analysis", on page 185

To configure settings

► Select any button in the "Overview" to open the corresponding dialog box.
  Select a setting in the channel bar (at the top of the measurement channel tab) to change a specific setting.

For step-by-step instructions on configuring VSA measurements, see chapter 7, "How to Perform Vector Signal Analysis", on page 201.

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

Note that the PRESET key on the front panel restores all measurements **in all measurement channels** on the R&S FSW to their default values!

See chapter 5.1, "Default Settings for Vector Signal Analysis", on page 120 for details.

SCPI command:
SYSTem:PRESet:CHANnel[:EXECute] on page 264

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.

Enable the "Specifics for" option.

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

The indicated data flow is updated for the selected data source.

If the "Specifics for" option is not enabled, the overview displays the default data flow and the general settings independantly of the selected window.

Note: The "Display Config" button is only available in the general overview, not in the window-specific overview.

Digital Standards
Opens a file selection dialog to manage predefined measurement settings for conventional mobile radio standards. See chapter 5.2, "Configuration According to Digital Standards", on page 121

5.4 Signal Description

The signal description provides information on the expected input signal, which optimizes burst and pattern detection and allows for the application to calculate an ideal reference signal. The signal description consists of information on the used modulation and on the signal's structure.

5.4.1 Modulation

The "Modulation" settings contain modulation and transmit filter settings. A live preview of the Constellation I/Q trace using the currently defined settings is displayed at the bottom of the dialog box to visualize the changes to the settings. The preview area is not editable directly.

The modulation settings vary depending on the selected modulation type; in particular, FSK modulation provides some additional settings.

The "Modulation" settings are displayed when you select the "Signal Description" button in the "Overview" or the "Signal Description" softkey in the main VSA menu.
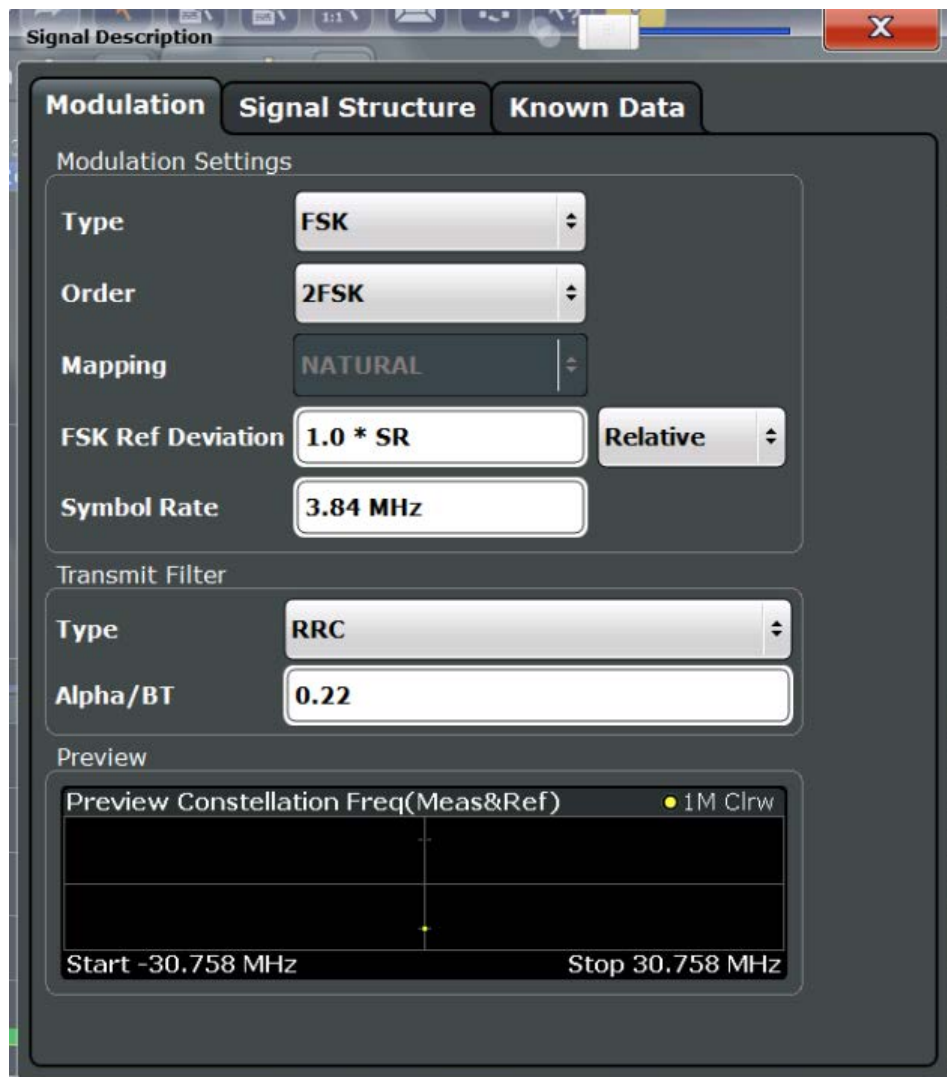
Fig. 5-1: Signal modulation settings for FSK modulation

Modulation Type

Defines the modulation type of the vector signal. The following types are available:

- PSK
- MSK
- QAM

- FSK
- ASK
- APSK
- User Modulation
  Uses the selected user-defined modulation loaded from a file.

For more information on these modulation types see chapter 4.3, "Symbol Mapping", on page 63.

SCPI command:

[SENSe:]DDEMod:FORMat on page 270

Load User Modulation ← Modulation Type

This function is only available if the modulation type "User Modulation" is selected.

Opens a file selection dialog box to select the file that contains the user-defined modulation (*.vam file).

For details on user-defined modulation files see chapter 4.3.11, "User-defined Modulation", on page 83.

SCPI command:

SENS:DDEM:FORM UQAM (see [SENSe:]DDEMod:FORMat on page 270)

[SENSe:]DDEMod:USER:NAME on page 275

Modulation Order

Depending on the Modulation Type, various orders of modulation are available:

Type	Available orders		
PSK	BPSK	3Pi/4-QPSK	Pi/8-D8PSK
	QPSK	8PSK	DQPSK
	Offset QPSK	3Pi/8-8PSK	Pi/4-DQPSK
	Pi/4-QPSK	D8PSK	
MSK	MSK	DMSK	
QAM	16QAM	-Pi/4-32QAM	256QAM
	Pi/4-16QAM	64QAM	512QAM
	32QAM	128QAM	1024QAM
FSK	2FSK	4FSK	8FSK

Type	Available orders		
ASK	2ASK	4ASK	
APSK	16APSK	32APSK	

SCPI command:
PSK:
`[SENSe:]DDEMod:PSK:FORMat` on page 272
`[SENSe:]DDEMod:PSK:NSTate` on page 272
`[SENSe:]DDEMod:QPSK:FORMat` on page 273
MSK: `[SENSe:]DDEMod:MSK:FORMat` on page 271
QAM:
`[SENSe:]DDEMod:QAM:FORMat` on page 272
`[SENSe:]DDEMod:QAM:NSTate` on page 273
FSK: `[SENSe:]DDEMod:FSK:NSTate` on page 270
ASK: `[SENSe:]DDEMod:ASK:NSTate` on page 269
APSK: `[SENSe:]DDEMod:APSK:NSTate` on page 269

FSK Ref Deviation (FSK only)
The FSK Reference Deviation sets the deviation to the reference frequency.

In case of 2FSK, it indicates the distance from the reference frequency to the positive / negative deviation frequency and in case of 4FSK, the distance to the outer positive/ negative deviation frequency.

To set the deviation as a multiple of the symbol rate (x*SR), select "Relative" mode. To set the deviation as an absolute value in Hz, select "Absolute" mode.

Note that this parameter is available only for FSK modulated signals.

SCPI command:
`CALCulate<n>:FSK:DEViation:REFerence[:VALue]` on page 268
`CALCulate<n>:FSK:DEViation:REFerence:RELative` on page 268

Modulation Mapping
The available mapping types depend on the Modulation Type and Modulation Order.

For more information on the modulation mapping, refer to chapter 4.3, "Symbol Mapping", on page 63

SCPI command:
`[SENSe:]DDEMod:MAPPing[:VALue]` on page 271
`[SENSe:]DDEMod:MAPPing:CATalog?` on page 271

Symbol Rate
The symbol rate also determines the I/Q bandwidth of the data recording and demodulation. You can change the default rate by entering a value in Hz.

The minimum symbol rate is 25 Hz. The maximum symbol rate depends on the defined Sample Rate (see chapter 4.2, "Sample Rate, Symbol Rate and I/Q Bandwidth", on page 57).

SCPI command:

[SENSe:]DDEMod:SRATe on page 274

Transmit Filter Type

Defines the type of transmit filter

An overview of available transmit filters is provided in chapter A.2.1, "Transmit Filters", on page 404.

For more information on transmit filters see chapter 4.1.3, "Modulation and Demodulation Filters", on page 52.

SCPI command:

[SENSe:]DDEMod:TFILter:NAME on page 275

To define the name of the transmit filter to be used.

[SENSe:]DDEMod:TFILter[:STATe] on page 275

To switch off the transmit filter.

[SENSe:]DDEMod:TFILter:USER on page 275

To select a user-defined filter.

Load User Filter ← Transmit Filter Type

Opens a file-selection dialog box to select the user-defined transmit filter to be used.

Note: If a user-defined transmit filter is selected and the measurement filter is defined automatically (see "Using the Transmit Filter as a Measurement Filter (Auto)" on page 180), a Low-ISI measurement filter according to the selected user filter is calculated and used.

For details see chapter 4.1.5, "Customized Filters", on page 55.

For detailed instructions on working with user-defined filters see chapter 7.2.1, "How to Select User-Defined Filters", on page 204.

SCPI command:

[SENSe:]DDEMod:TFILter:USER on page 275

[SENSe:]DDEMod:TFILter:NAME on page 275

Alpha/BT

Defines the roll-off factor (Alpha) or the filter bandwidth (BT).

The roll-off factor and filter bandwidth for transmit filter is available for RC, RRC, Gauss and GMSK filter.

SCPI command:

[SENSe:]DDEMod:TFILter:ALPHa on page 274

5.4.2 Signal Structure

The "Signal Structure" settings describe the expected input signal and determine which settings are available for configuration. You can define a pattern to which the instrument can be synchronized, thus adapting the result range.

A visualization of the currently defined signal structure is displayed at the bottom of the dialog box.

The "Signal Structure" settings are displayed when you select the "Signal Description" button in the "Overview" or the "Signal Description" softkey in the main VSA menu and then switch to the "Signal Structure" tab.
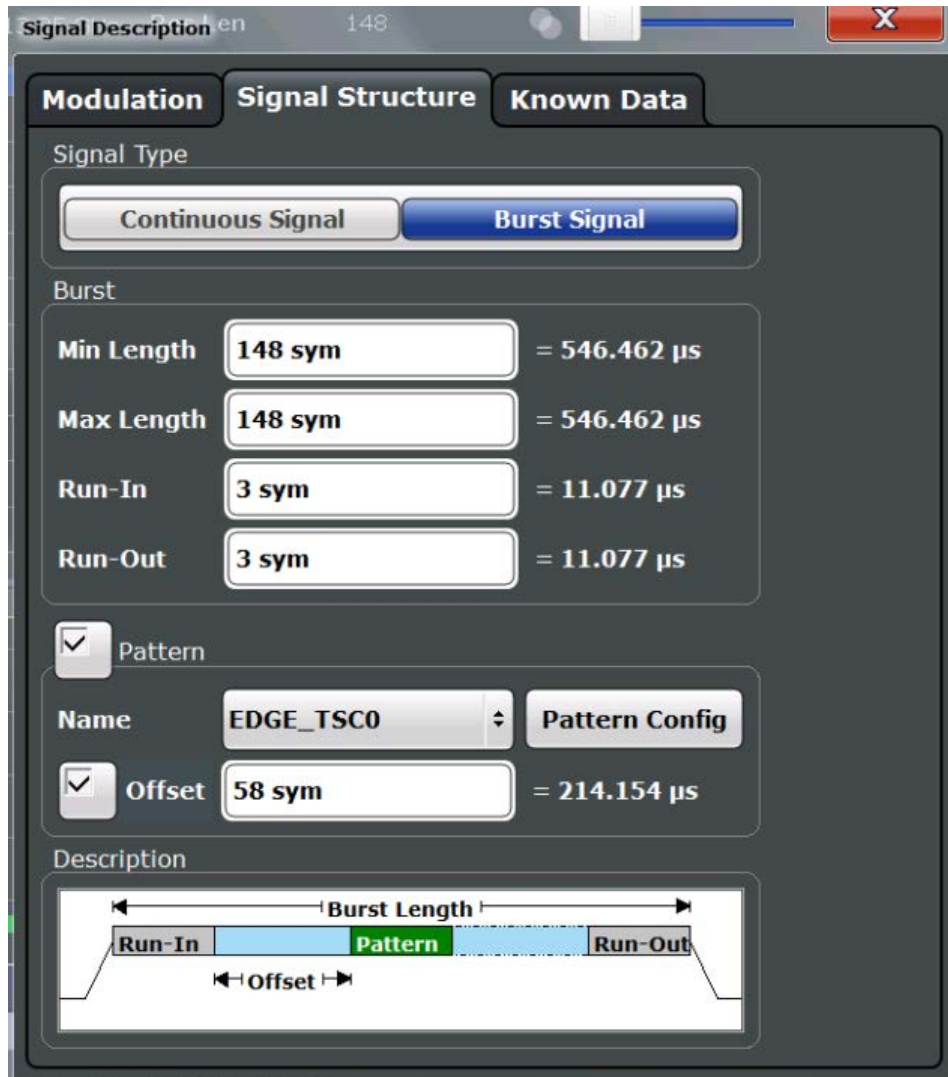
Signal Type
Determines whether the signal is continuous or contains bursts.

SCPI command:
[SENSe:]DDEMod:SIGNal[:VALue] on page 278

Burst Settings
For bursts, further settings are available.

Min Length / Max Length ← Burst Settings
Shortest and longest expected burst length in symbols (≦15000). The symbols are converted to seconds for reference.

SCPI command:
[SENSe:]DDEMod:SEARch:BURSt:LENGth:MAXimum on page 276
[SENSe:]DDEMod:SEARch:BURSt:LENGth[:MINimum] on page 276

Run-In ← Burst Settings
The number of symbols before the signal is assumed to have valid modulated symbols.

The symbols are converted to seconds for reference.

SCPI command:
[SENSe:]DDEMod:SEARch:BURSt:SKIP:RISing on page 277

Run-Out ← Burst Settings
The number of symbols before the falling edge that do not necessarily need to have a valid modulation.

The symbols are converted to seconds for reference.

SCPI command:
[SENSe:]DDEMod:SEARch:BURSt:SKIP:FALLing on page 277

Pattern Settings
If the signal is expected to have a specific pattern, enable the "Pattern" option to define the pattern settings.

Note: The pattern search itself must be enabled separately in the "Pattern Search Settings", see "Enabling Pattern Searches" on page 163. By default, the pattern search is active if the signal description contains a pattern.

Name ← Pattern Settings
Specifies the pattern name from the list of defined patterns. You can also configure new patterns, see chapter 5.7.3, "Pattern Configuration", on page 164.

SCPI command:
[SENSe:]DDEMod:SIGNal:PATTern on page 278

Pattern Configuration ← Pattern Settings
Displays the "Pattern Configuration" dialog box (see chapter 5.7.3, "Pattern Configuration", on page 164).

Offset ← Pattern Settings

The offset of the pattern is defined with respect to the start of the useful part of the burst (see "Useful length" on page 114). If the position of the pattern within the burst is known, it is recommended that you define the offset. That will accelerate the pattern search and enhance the accuracy of the burst search.

SCPI command:

[SENSe:]DDEMod:STANdard:SYNC:OFFSet:STATe on page 278
[SENSe:]DDEMod:STANdard:SYNC:OFFSet[:VALue] on page 278

5.4.3   Known Data

The "Known Data" settings allow you to load a file that describes the possible data sequences in the input signal (see chapter 7.2.3, "How to Manage Known Data Files", on page 208).

Additional information provided by the loaded file is displayed at the bottom of the dialog box. This information is not editable directly.

The "Known Data" settings are displayed when you select the "Signal Description" button in the "Overview" or the "Signal Description" softkey in the main VSA menu and then switch to the "Known Data" tab.
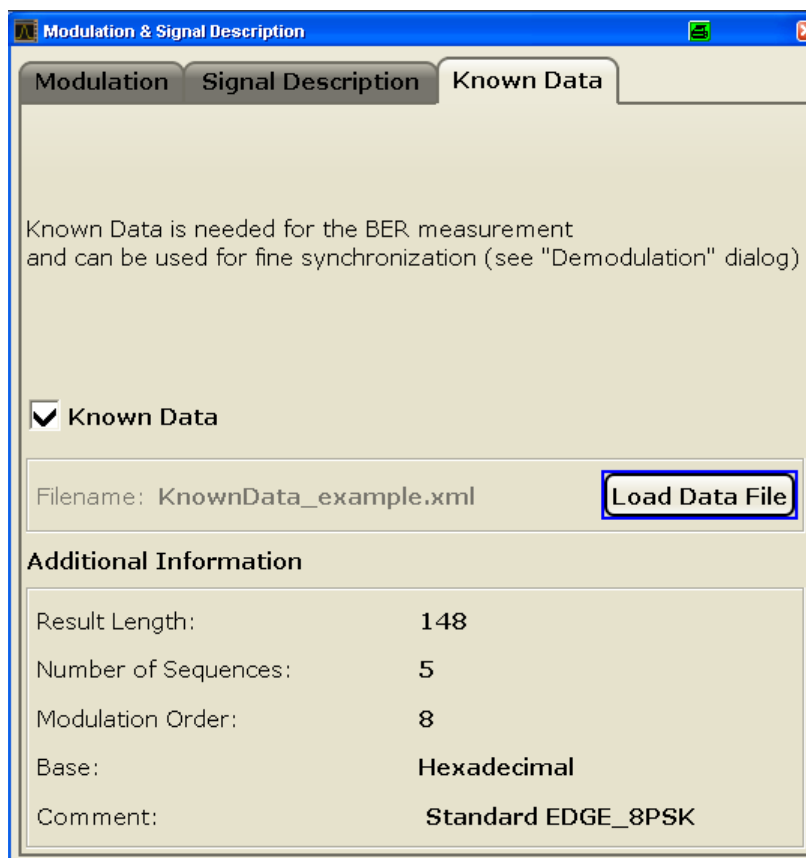
Known Data

Activates or deactivates the use of the loaded data file (if available). When deactivated, the additional information from the previously loaded data file is removed. Any references to the known data in the "Demodulation" dialog box are replaced by the default parameter values (see chapter 5.9.2, "Advanced Demodulation (Synchronization)", on page 175).

Note: When a standard is loaded, the use of a Known Data file is automatically deactivated.

SCPI command:
[SENSe:]DDEMod:KDATa:STATe on page 318

Load Data File

If Known Data is activated, this function displays a file selection dialog box to select the xml file that contains the known data. Once a file has been selected, any additional information provided by the file is displayed at the bottom of the dialog box.

SCPI command:
[SENSe:]DDEMod:KDATa[:NAME] on page 318

5.5   Input and Frontend Settings

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

The frequency and amplitude settings represent the "frontend" of the measurement setup.

5.5.1   Input Settings

Input settings can be configured via the INPUT/OUTPUT key, in the "Input" dialog box.

Some settings are also available in the "Amplitude" tab of the "Amplitude" dialog box.

5.5.1.1   Radio Frequency Input

The default input source for the R&S FSW is the radio frequency. If no additional options are installed, this is the only available input source.
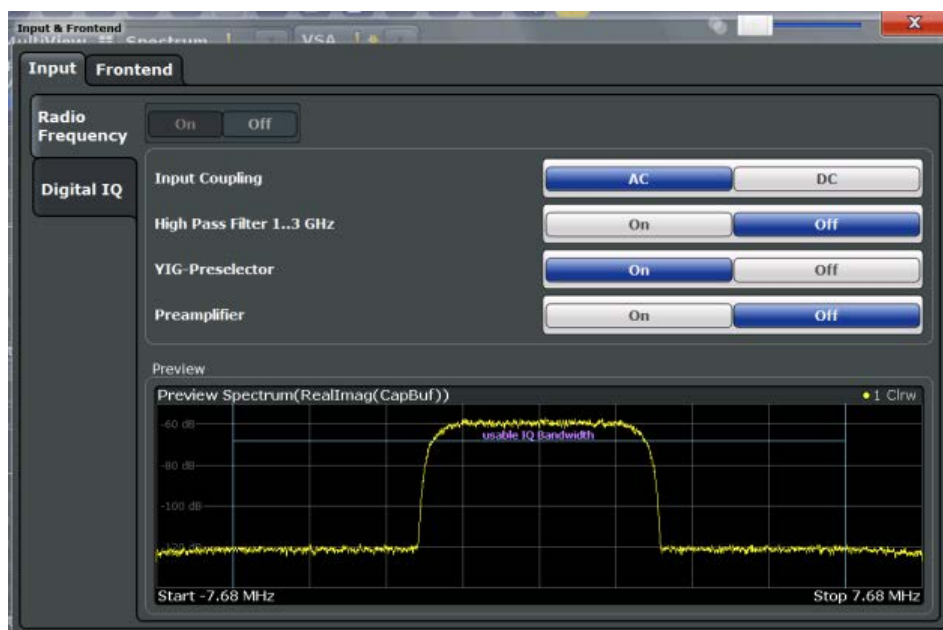
Radio Frequency State

Activates input from the RF INPUT connector.

SCPI command:

INPut:SELect on page 280

Input Coupling

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

This function is not available for input from the Digital Baseband Interface (R&S FSW-B17).

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.

SCPI command:

INPut:COUPling on page 279

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 R&S FSW in order to measure the harmonics for a DUT, for example.

This function requires option R&S FSW-B13.

(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.)

SCPI command:

INPut:FILTer:HPASs[:STATe] on page 280

YIG-Preselector

Activates or deactivates the YIG-preselector.

An internal YIG-preselector at the input of the R&S FSW ensures that image frequencies are rejected. However, this is only possible for a restricted bandwidth. In order to use the maximum bandwidth for signal analysis you can deactivate the YIG-preselector at the input of the R&S FSW, which may lead to image-frequency display.

Note that the YIG-preselector is active only on frequencies greater than 8 GHz. Therefore, switching the YIG-preselector on or off has no effect if the frequency is below that value.

INPut:FILTer:YIG[:STATe] on page 280

Preamplifier (option B24)

If option R&S FSW-B24 is installed, a preamplifier can be activated for the RF input signal.

This function is not available for input from the Digital Baseband Interface (R&S FSW-B17).

For R&S FSW 26 models, the input signal is amplified by 30 dB if the preamplifier is activated.

For R&S FSW 8 or 13 models, the following settings are available:

"Off"   Deactivates the preamplifier.

"15 dB"   The RF input signal is amplified by about 15 dB.

"30 dB"   The RF input signal is amplified by about 30 dB.

SCPI command:

INPut:GAIN:STATe on page 288

INPut:GAIN[:VALue] on page 287

5.5.1.2 Digital I/Q Input Settings

The following settings and functions are available to provide input via the Digital Baseband Interface (R&S FSW-B17) in the applications that support it.

They can be configured via the INPUT/OUTPUT key, in the "Input" dialog box.

Digital I/Q Input State

Enables or disable the use of the "Digital IQ" input source for measurements. "Digital IQ" is only available if the Digital Baseband Interface (R&S FSW-B17) is installed.

SCPI command:

INPut:SELect on page 280

Input Sample Rate

Defines the sample rate of the digital I/Q signal source. This sample rate must correspond with the sample rate provided by the connected device, e.g. a generator.

If "Auto" is selected, the sample rate is adjusted automatically by the connected device.

The allowed range is from 100 Hz to 10 GHz.

SCPI command:

INPut:DIQ:SRATe on page 284

INPut:DIQ:SRATe:AUTO on page 284

Full Scale Level

The "Full Scale Level" defines the level and unit that should correspond to an I/Q sample with the magnitude "1".

If "Auto" is selected, the level is automatically set to the value provided by the connected device.

SCPI command:

INPut:DIQ:RANGe[:UPPer] on page 283

INPut:DIQ:RANGe[:UPPer]:UNIT on page 284

INPut:DIQ:RANGe:AUTO on page 283

Adjust Reference Level to Full Scale Level
If enabled, the reference level is adjusted to the full scale level automatically if any change occurs.

SCPI command:

INPut:DIQ:RANGe:COUPling on page 283

Connected Instrument
Displays the status of the Digital Baseband Interface connection.

If an instrument is connected, the following information is displayed:

- Name and serial number of the instrument connected to the Digital Baseband Interface
- Used port
- Sample rate of the data currently being transferred via the Digital Baseband Interface
- Level and unit that corresponds to an I/Q sample with the magnitude "1" (Full Scale Level), if provided by connected instrument

SCPI command:

INPut:DIQ:CDEVice on page 282

DigIConf
Starts the optional R&S DigIConf application. This softkey is available in the In-/Output menu, but only if the optional software is installed.

Note that R&S DigIConf requires a USB connection (not LAN!) from the R&S FSW to the R&S EX-IQ-BOX in addition to the Digital Baseband Interface (R&S FSW-B17) connection. R&S DigIConf version 2.20.360.86 Build 170 or higher is required.

To return to the R&S FSW application, press any key on the front panel. The R&S FSW application is displayed with the "Input/Output" menu, regardless of which key was pressed.

For details on the R&S DigIConf application, see the "R&S®EX-IQ-BOX Digital Interface Module R&S®DigIConf Software Operating Manual".

Note: If you close the R&S DigIConf window using the "Close" icon, the window is minimized, not closed.
If you select the "File > Exit" menu item in the R&S DigIConf window, the application is closed. Note that in this case the settings are lost and the EX-IQ-BOX functionality is no longer available until you restart the application using the "DigIConf" softkey in the R&S FSW once again.

5.5.2 Frontend Settings

Frontend settings affect the signal power or error levels.

To configure the Frontend settings select "Input/Frontend" from the "Overview", then switch to the "Frontend" tab.
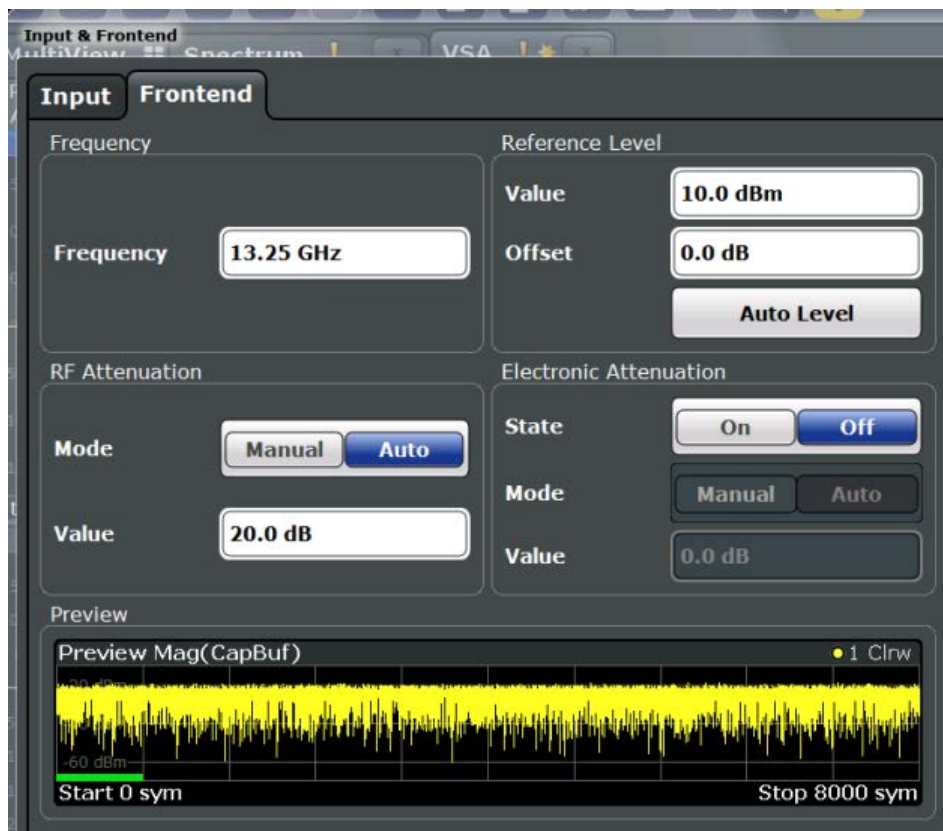
Center
Defines the normal center frequency of the signal. The allowed range of values for the center frequency depends on the frequency span.

span > 0: $span_{min}/2 \leq f_{center} \leq f_{max} - span_{min}/2$

f_{max} and $span_{min}$ are specified in the data sheet.

SCPI command:
[SENSe:]FREQuency:CENTer on page 285

Reference Level
Defines the expected maximum reference level. Signal levels above this value may not be measured correctly, which is indicated by the "IFOVL" status display.

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

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

Note that the "Reference Level" value ignores the Shifting the Display (Offset). It is important to know the actual power level the R&S FSW must handle.

SCPI command:
DISPlay[:WINDow<n>]:TRACe:Y[:SCALe]:RLEVel on page 286

Shifting the Display (Offset) ← Reference Level

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 FSW 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 FSW 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 FSW increases the displayed power values) , a negative value indicates an external gain (R&S FSW decreases the displayed power values).

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

SCPI command:
DISPlay[:WINDow<n>]:TRACe:Y[:SCALe]:RLEVel:OFFSet on page 287

Setting the Reference Level Automatically (Auto Level) ← Reference Level

Automatically determines the optimal reference level for the current input data. At the same time, the internal attenuators and the preamplifier are adjusted so the signal-to-noise ratio is optimized, while signal compression, clipping and overload conditions are minimized.

In order to do so, a level measurement is performed to determine the optimal reference level.

You can change the measurement time for the level measurement if necessary (see "Changing the Automatic Measurement Time (Meastime Manual)" on page 183).

SCPI command:
[SENSe:]ADJust:LEVel on page 326

RF Attenuation

Defines the mechanical attenuation for RF input.

This function is not available for input from the R&S Digital Baseband Interface (option R&S FSW-B17).

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 the optimum RF attenuation is always used. It is the default setting. By default and when Using Electronic Attenuation (Option B25) is not available, mechanical attenuation is applied.

This function is not available for input from the **Digital Baseband Interface (R&S FSW-B17)**.

In "Manual" mode, you can set the RF attenuation in 1 dB steps (down to 0 dB, also using the rotary knob). 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.

SCPI command:

`INPut:ATTenuation` on page 288

`INPut:ATTenuation:AUTO` on page 289

Using Electronic Attenuation (Option B25)

If option R&S FSW-B25 is installed, 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.

This function is not available for input from the Digital Baseband Interface (R&S FSW-B17).

Note: Electronic attenuation is not available for stop frequencies (or center frequencies in zero span) >13.6 GHz.

In "Auto" mode, RF attenuation is provided by the electronic attenuator as much as possible to reduce the amount of mechanical switching required. Mechanical attenuation may provide a better signal-to-noise ratio, however.

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

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

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.

SCPI command:

`INPut:EATT:STATe` on page 290

`INPut:EATT:AUTO` on page 290

`INPut:EATT` on page 289

5.5.3 Frequency Settings

Frequency settings for the input signal can be configured via the "Frequency" dialog box, which is displayed when you do one of the following:

- Select the FREQ key and then the "Frequency Config" softkey.
- Select the "Frequency" tab in the "Input Settings" dialog box

Center

Defines the normal center frequency of the signal. The allowed range of values for the center frequency depends on the frequency span.

span > 0: $span_{min}/2 ≤ f_{center} ≤ f_{max} – span_{min}/2$

f_{max} and $span_{min}$ are specified in the data sheet.

SCPI command:

[SENSe:]FREQuency:CENTer on page 285
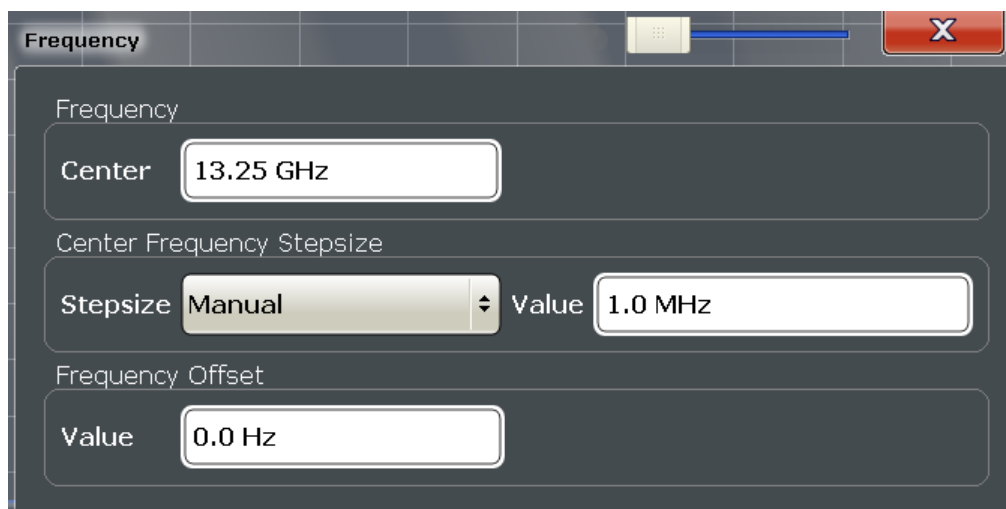
Center Frequency Stepsize

Defines the step size of the center frequency. The step size can be set to a predefined value, or it can be manually set to a user-defined value.

"Auto"   The step size is set to the default value:

- using the rotary knob: 100 kHz

- using the arrow keys: 1 MHz

"Manual"   Defines a user-defined step size for the center frequency. Enter the step size in the "Value" field.

SCPI command:

[SENSe:]FREQuency:CENTer:STEP:AUTO on page 285

[SENSe:]FREQuency:CENTer:STEP on page 285

Frequency Offset

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

This parameter has no effect on the R&S FSW 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.

SCPI command:

[SENSe:]FREQuency:OFFSet on page 286

5.5.4 Amplitude and Vertical Axis Configuration

Amplitude and scaling settings allow you to configure the vertical (y-)axis display and for some result displays also the horizontal (x-)axis.

5.5.4.1 Amplitude Settings

Amplitude settings affect the signal power or error levels.

To configure the amplitude settings select the AMPT key and then the "Amplitude Config" softkey.
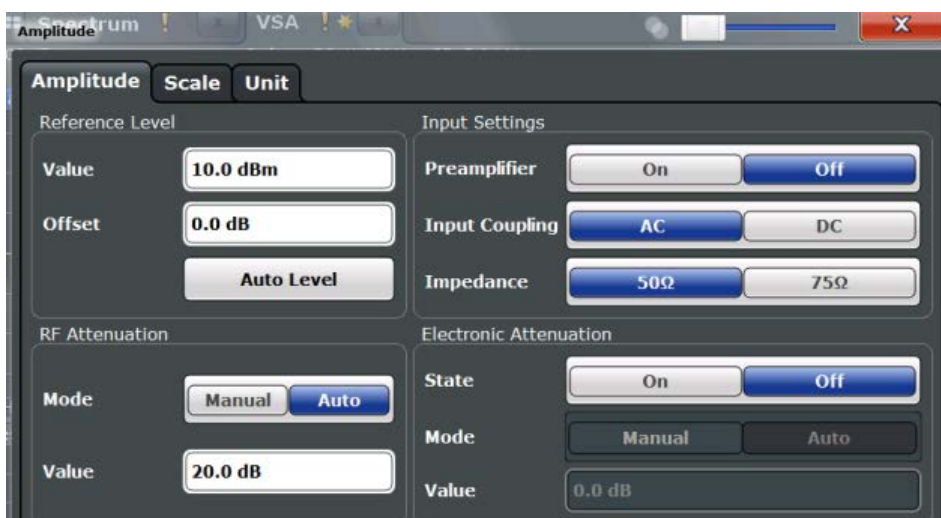
> Note that amplitude settings are not window-specific, as opposed to the scaling and unit settings.

Reference Level

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

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

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

Note that the "Reference Level" value ignores the Shifting the Display (Offset). It is important to know the actual power level the R&S FSW must handle.

SCPI command:
DISPlay[:WINDow<n>]:TRACe:Y[:SCALe]:RLEVel on page 286

Shifting the Display (Offset) ← Reference Level

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 FSW 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 FSW 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 FSW increases the displayed power values) , a negative value indicates an external gain (R&S FSW decreases the displayed power values).

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

SCPI command:
DISPlay[:WINDow<n>]:TRACe:Y[:SCALe]:RLEVel:OFFSet on page 287

Setting the Reference Level Automatically (Auto Level) ← Reference Level

Automatically determines the optimal reference level for the current input data. At the same time, the internal attenuators and the preamplifier are adjusted so the signal-to-noise ratio is optimized, while signal compression, clipping and overload conditions are minimized.

In order to do so, a level measurement is performed to determine the optimal reference level.

You can change the measurement time for the level measurement if necessary (see "Changing the Automatic Measurement Time (Meastime Manual)" on page 183).

SCPI command:
[SENSe:]ADJust:LEVel on page 326

Input Settings

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

For information on other input settings see chapter 5.5.1, "Input Settings", on page 134.

Preamplifier (option B24) ← Input Settings

If option R&S FSW-B24 is installed, a preamplifier can be activated for the RF input signal.

This function is not available for input from the Digital Baseband Interface (R&S FSW-B17).

For R&S FSW 26 models, the input signal is amplified by 30 dB if the preamplifier is activated.

For R&S FSW 8 or 13 models, the following settings are available:

"Off"   Deactivates the preamplifier.

"15 dB"   The RF input signal is amplified by about 15 dB.

"30 dB"   The RF input signal is amplified by about 30 dB.

SCPI command:

INPut:GAIN:STATe on page 288

INPut:GAIN[:VALue] on page 287

Input Coupling ← Input Settings

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

This function is not available for input from the Digital Baseband Interface (R&S FSW-B17).

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.

SCPI command:

INPut:COUPling on page 279

RF Attenuation

Defines the mechanical attenuation for RF input.

This function is not available for input from the R&S Digital Baseband Interface (option R&S FSW-B17).

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 the optimum RF attenuation is always used. It is the default setting. By default and when Using Electronic Attenuation (Option B25) is not available, mechanical attenuation is applied.

This function is not available for input from the **Digital Baseband Interface (R&S FSW-B17)**.

In "Manual" mode, you can set the RF attenuation in 1 dB steps (down to 0 dB, also using the rotary knob). 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.

SCPI command:

INPut:ATTenuation on page 288

INPut:ATTenuation:AUTO on page 289

Using Electronic Attenuation (Option B25)
If option R&S FSW-B25 is installed, 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.

This function is not available for input from the Digital Baseband Interface (R&S FSW-B17).

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

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

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

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.

SCPI command:

INPut:EATT:STATe on page 290

INPut:EATT:AUTO on page 290

INPut:EATT on page 289

5.5.4.2 Scaling

Depending on the type of display (time, spectrum or statistics), various scaling functions are available to adapt the result display to the current data.

Note that scaling settings are window-specific, as opposed to the amplitude settings.

The scaling settings are displayed when you select the AMPT key and then the "Scale Config" softkey.
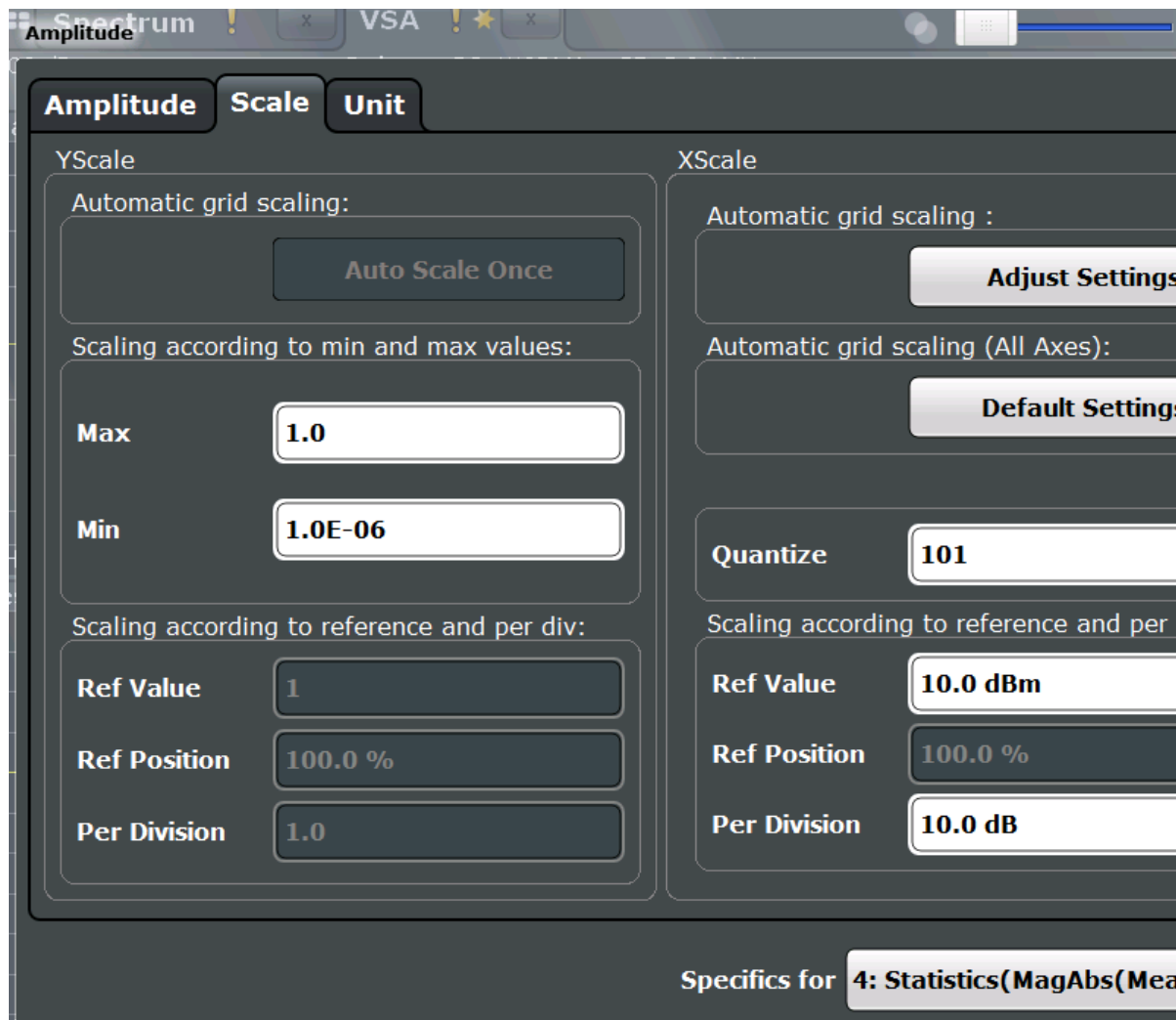
For details on the different methods to configure the scaling see chapter 7.3.1, "How to Change the Display Scaling", on page 213.

A visualization of the diagram scaling with the current settings is displayed at the right side of the dialog box.

Auto Scale Once/Auto Scale Window
If enabled, both the x-axis and y-axis are automatically adapted to the current measurement results (only once, not dynamically) in the selected window.

To adapt the range of all screens together, use the Auto Scale All function.

SCPI command:
DISPlay[:WINDow<n>]:TRACe:Y[:SCALe]:AUTO ONCE on page 324

Defining Min and Max Values
Indicates the current range borders according to the current settings (for information only).

For statistical evaluations only: defines the displayed range using minimum and maximum values.

Values in the range *1e⁻⁹ < value < 0.1* are allowed. The y-axis unit is defined via the "Y-Axis Unit" on page 151 setting. The distance between max and min value must be at least one decade.

SCPI command:
CALCulate<n>:STATistics:SCALe:Y:UPPer on page 292
CALCulate<n>:STATistics:SCALe:Y:LOWer on page 292

Configuring a Reference Point and Divisions
Defines the displayed range using a reference point and the size of the divisions.

Y-Axis Reference Value ← Configuring a Reference Point and Divisions
Defines a reference value on the y-axis in the current unit. The y-axis is adapted so that the reference value is displayed at the "Y-Axis Reference Position" on page 148.

SCPI command:
DISPlay[:WINDow<n>]:TRACe:Y[:SCALe]:RVALue on page 294

Y-Axis Reference Position ← Configuring a Reference Point and Divisions
Defines the position of the Y-Axis Reference Value on the y-axis. The position is defined as a percentage value, where 0 % refers to the bottom edge, 100 % refers to the top edge of the screen. The y-axis is adapted so that the reference value is displayed at the reference position.

SCPI command:
DISPlay[:WINDow<n>]:TRACe:Y[:SCALe]:RPOSition on page 294

Range per Division ← Configuring a Reference Point and Divisions
Defines the value range to be displayed per division. Since the display consists of 10 divisions by default, the displayed range is:

Range = 10 * <Range per Division>

Note: If fewer divisions are displayed (e.g. because the window is reduced in height), the range per division is increased in order to display the same result range in the smaller window. In this case, the per division value does not correspond to the actual display.

SCPI command:

DISPlay[:WINDow<n>]:TRACe:Y[:SCALe]:PDIVision on page 294

X-Axis Scaling

For statistics, a histogram is displayed. For these diagrams, the x-axis can be configured, as well.

Adjust Settings ← X-Axis Scaling

Adjusts the x-axis scaling to the occurring statistical values.

SCPI command:

CALCulate<n>:STATistics:SCALe:AUTO ONCE on page 291

Default Settings ← X-Axis Scaling

Resets the x- and y-axis scalings to their preset values for the current measurement window.

SCPI command:

CALCulate<n>:STATistics:PRESet on page 291

Quantize ← X-Axis Scaling

Defines the number of bars to be displayed in the graph, i.e. the granularity of classifications.

SCPI command:

CALCulate<n>:STATistics:SCALe:X:BCOunt on page 291

X-Axis Reference Value ← X-Axis Scaling

Defines a reference value on the x-axis in the current unit.

SCPI command:

DISPlay[:WINDow<n>]:TRACe<t>:X[:SCALe]:RVALue on page 293

X-Axis Reference Position ← X-Axis Scaling

Defines the position of the X-Axis Reference Value on the x-axis. The position is defined as a percentage value, where 0 % refers to the beginning (left side), 100 % refers to the end (right side) of the diagram. The x-axis is adapted so that the reference value is displayed at the reference position.

SCPI command:

DISPlay[:WINDow<n>]:TRACe<t>:X[:SCALe]:RPOSition on page 293

Range per Division ← X-Axis Scaling

Defines the value range to be displayed per division on the x-axis. Since the display consists of 10 divisions by default, the displayed range is:

*Range = 10 * <Range per Division>*

Note: If fewer divisions are displayed (e.g. because the window is reduced in width), the range per division is increased in order to display the same result range in the smaller window. In this case, the per division value does not correspond to the actual display.

SCPI command:

DISPlay[:WINDow<n>]:TRACe<t>:X[:SCALe]:PDIVision on page 293

5.5.4.3 Units

You can configure the units for both axes of the diagrams.

The unit settings are displayed when you do one of the following:

● Select "Input/Frontend" from the "Overview" and then switch to the "Unit" tab.
● Select the AMPT key and then the "Unit Config" softkey.
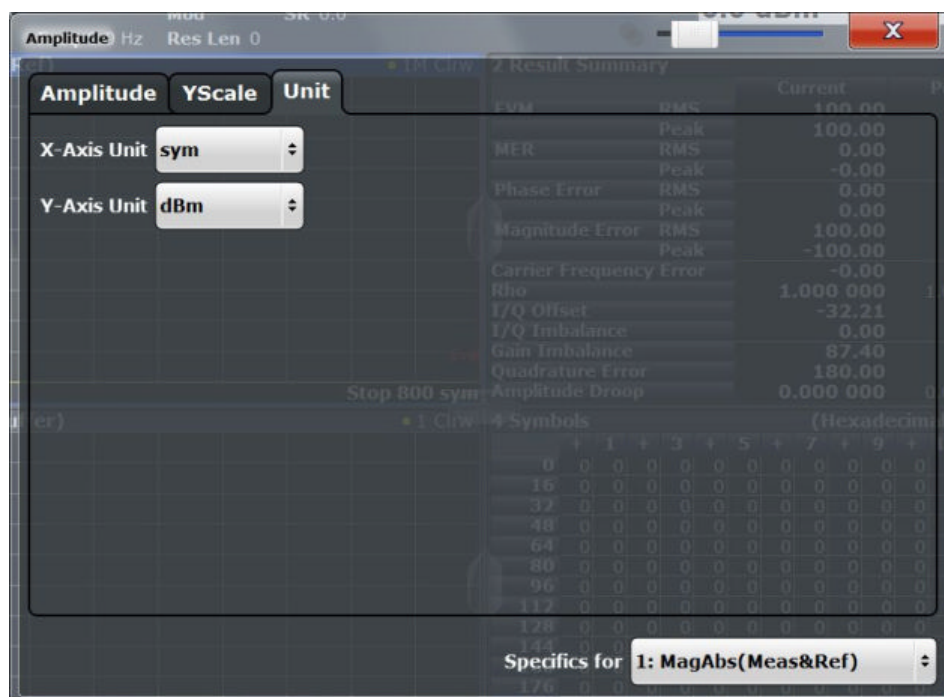
Note that unit settings are window-specific, as opposed to the amplitude settings.

X-Axis Unit

Defines the unit of the x-axis in the current result diagram.

SCPI command:

CALCulate<n>:X:UNIT:TIME on page 292

Y-Axis Unit

Defines the unit of the y-axis in the current result diagram.

SCPI command:

`DISPlay[:WINDow<n>]:TRACe:Y:SPACing` on page 294

For phase diagrams: `CALCulate<n>:UNIT:ANGLe` on page 292

For statistics: `CALCulate<n>:STATistics:SCALe:Y:UNIT` on page 292

5.6 Signal Capture

The "Signal Capture" settings define how much, how and when data is captured from the input signal.

The "Signal Capture" settings are displayed when you select the "Signal Capture" button from the "Overview" or the "Signal Capture" softkey from the main VSA menu.

5.6.1 Data Acquisition

The "Data Acquisition" settings define how much and how data is captured from the input signal.

A live preview of the signal in the capture buffer with the current settings is displayed in the preview area at the bottom of the dialog box. The preview area is not editable directly.

The "Data Acquisition" settings are displayed when you select the "Signal Capture" button from the "Overview" or the "Signal Capture" softkey from the main VSA menu.
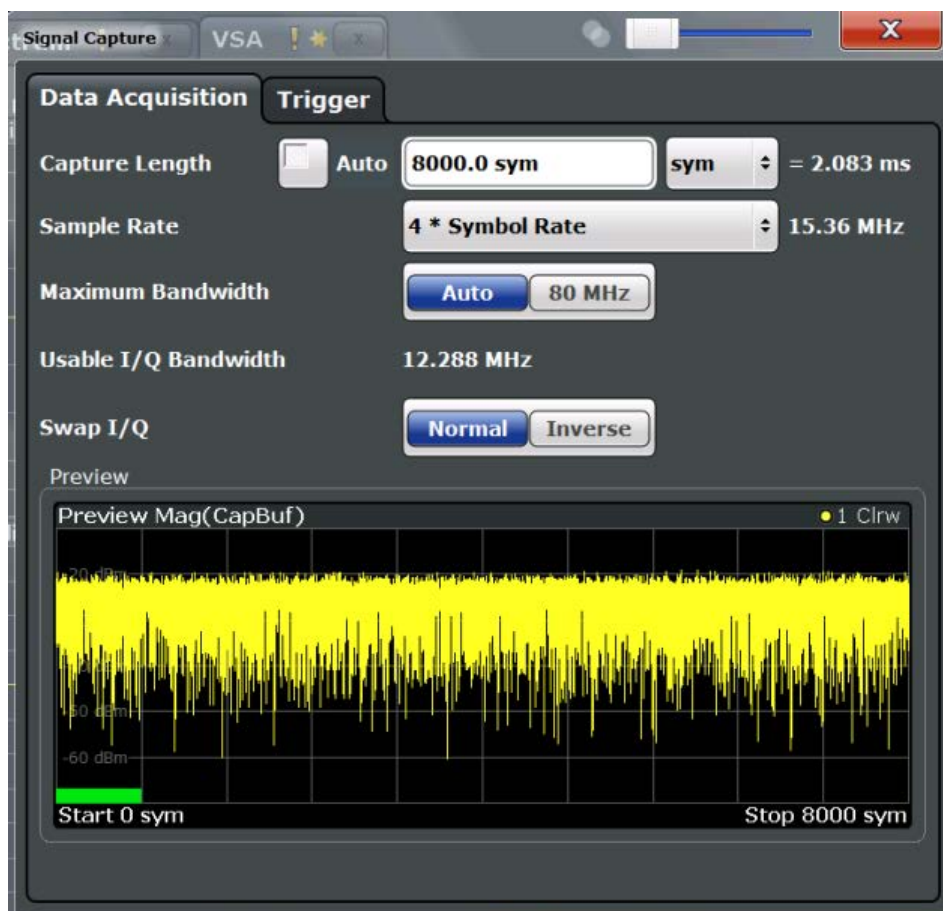
MSRA operating mode

In MSRA operating mode, only the MSRA Master channel actually captures data from the input signal. The data acquisition settings for the VSA application in MSRA mode define the **application data extract** and **analysis interval**.

For details on the MSRA operating mode see the R&S FSW MSRA User Manual.

Capture Length Settings

The capture length defines how many symbols are captured during each measurement.

Enable the "Auto" option to define the capture length automatically according to the burst and pattern length settings and the statistics count. Thus, a minimal capture length is used, which improves performance.

If the capture length is not defined automatically, enter the number of symbols or seconds to be captured and select the used unit. The defined number is converted to the alternative unit (seconds/symbols) for reference.

SCPI command:

[SENSe:]DDEMod:RLENgth:AUTO on page 296

[SENSe:]DDEMod:RLENgth[:VALue] on page 296

Sample Rate

Defines the number of samples to capture per symbol. The sample rate in MHz is indicated for reference. This parameter affects the demodulation bandwidth and thus the usable I/Q bandwidth.

The maximum sample rate depends on the defined Symbol Rate (see chapter 4.2, "Sample Rate, Symbol Rate and I/Q Bandwidth", on page 57).

For details on selecting the suitable sample rate, see chapter 4.2, "Sample Rate, Symbol Rate and I/Q Bandwidth", on page 57.

SCPI command:

[SENSe:]DDEMod:PRATe on page 296

Maximum Bandwidth

Defines the maximum bandwidth to be used by the R&S FSW for I/Q data acquisition. This setting is only available if the bandwidth extension option R&S FSW-B160 / U160 is installed. Otherwise the maximum bandwidth is determined automatically.

For details on the maximum bandwidth see chapter 4.2.1, "Sample Rate and Maximum Usable I/Q Bandwidth for RF Input", on page 58.

"80 MHz"   Restricts the analysis bandwidth to a maximum of 80 MHz. The bandwidth extension option R&S FSW-B160 / U160 is deactivated.

"Auto"   (Default) Up to an analysis bandwidth of 80 MHz (or a sample rate of 100 MHz), the maximum bandwidth is set to 80 MHz. For larger bandwidths or sample rates, the bandwidth extension option R&S FSW-B160 / U160 is activated, thus allowing for a sample rate of up to 10 GHz. Note that using the bandwidth extension may cause more spurious effects.

SCPI command:

TRACe:IQ:WBANd[:STATe] on page 297

Usable I/Q Bandwidth

Shows the usable I/Q bandwidth which depends on the selected sample rate. For details see chapter 4.2, "Sample Rate, Symbol Rate and I/Q Bandwidth", on page 57.

This information is provided for reference only.

Note:

In diagrams in the frequency domain (Spectrum transformation, see "Result Type Transformation" on page 197) the usable I/Q bandwidth is indicated by vertical blue lines.

Swap I/Q

Specifies whether the I and Q values of the signal are swapped. Swapping I and Q inverts the sideband.

"Normal"   Normal sideband, I+j*Q

"Inverse"   I and Q are exchanged, inverted sideband, Q+j*I

SCPI command:
[SENSe:]DDEMod:SBANd on page 297

5.6.2 Trigger Settings

The trigger settings define the beginning of a measurement.

Trigger settings can be configured via the TRIG key or in the "Trigger" dialog box, which is displayed when you select the "Trigger" button in the "Overview".
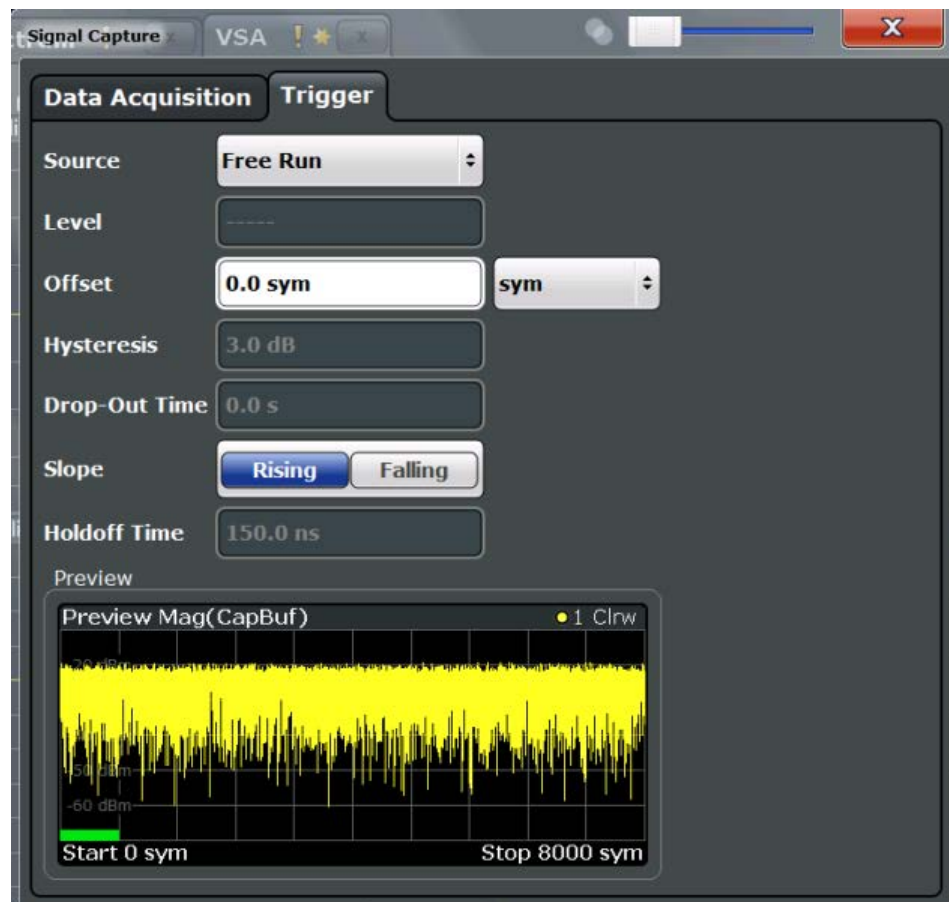
The TRIGGER INPUT/OUTPUT connectors on the R&S FSW can only be used for input in the VSA application, for use as external triggers. No configuration settings are available for trigger input.

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

MSRA operating mode

In MSRA operating mode, only the MSRA Master channel actually captures data from the input signal. Thus, no trigger settings are available in the VSA application in MSRA operating mode. However, a **capture offset** can be defined with a similar effect as a trigger offset. It defines an offset from the start of the captured data (from the MSRA Master) to the start of the application data for vector signal analysis. (See Capture Offset.)

For details on the MSRA operating mode see the R&S FSW MSRA User Manual.

Trigger Source

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

SCPI command:

TRIGger[:SEQuence]:SOURce on page 301

Free Run ← Trigger Source

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

SCPI command:

TRIG:SOUR IMM, see TRIGger[:SEQuence]:SOURce on page 301

External Trigger 1/2/3 ← Trigger Source

Data acquisition starts when the TTL signal fed into the specified input connector (on the front or rear panel) meets or exceeds the specified trigger level.

(See "Trigger Level" on page 156).

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

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

"External Trigger 1"

      Trigger signal from the TRIGGER INPUT connector on the front panel.

"External Trigger 2"

Trigger signal from the TRIGGER INPUT/OUTPUT connector on the front panel.

Note: in VSA, trigger output is not supported, thus the connector is always configured for input.

"External Trigger 3"

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

Note: in VSA, trigger output is not supported, thus the connector is always configured for input.

SCPI command:

`TRIG:SOUR EXT, TRIG:SOUR EXT2, TRIG:SOUR EXT3`

See `TRIGger[:SEQuence]:SOURce` on page 301

IF Power ← Trigger Source

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

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

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

The trigger threshold depends on the defined trigger level, as well as on the RF attenuation and preamplification. For details on available trigger levels and trigger bandwidths see the data sheet.

This trigger source is only available for RF input.

SCPI command:

`TRIG:SOUR IFP`, see `TRIGger[:SEQuence]:SOURce` on page 301

Baseband Power ← Trigger Source

Defines triggering on the baseband power (for digital input via the Digital Baseband Interface R&S FSW-B17).

This trigger source is only available if "Digital IQ" is selected as the input source for the measurement (see "Digital I/Q Input State" on page 137).

SCPI command:

`TRIG:SOUR BBP`, see `TRIGger[:SEQuence]:SOURce` on page 301

IQ Power ← Trigger Source

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" setting for data acquisition (see "Usable I/Q Bandwidth" on page 153).

SCPI command:

`TRIG:SOUR IQP`, see `TRIGger[:SEQuence]:SOURce` on page 301

Trigger Level

Defines the trigger level for the specified trigger source.

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

SCPI command:

TRIGger[:SEQuence]:LEVel:IFPower on page 300

TRIGger[:SEQuence]:LEVel:IQPower on page 300

TRIGger[:SEQuence]:LEVel[:EXTernal<port>] on page 300

TRIGger[:SEQuence]:LEVel:BBPower on page 300

Trigger Offset

Defines the time offset between the trigger event and the start of the sweep.

The time may be entered in s or in symbols.

offset > 0:	Start of the sweep is delayed
offset < 0:	Sweep starts earlier (pre-trigger)
	Only possible for zero span (e.g. I/Q Analyzer application) and gated trigger switched off
	Maximum allowed range limited by the sweep time:
	pretrigger$_{max}$ = sweep time
	When using the Digital Baseband Interface (R&S FSW-B17), the maximum range is limited by the number of pretrigger samples. (See table 4-2)

SCPI command:

TRIGger[:SEQuence]:HOLDoff[:TIME] on page 299

Hysteresis

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

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

SCPI command:

TRIGger[:SEQuence]:IFPower:HYSTeresis on page 299

Drop-Out Time

Defines the time the input signal must stay below the trigger level before triggering again.

SCPI command:

TRIGger[:SEQuence]:DTIMe on page 298

Slope

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.

SCPI command:

TRIGger[:SEQuence]:SLOPe on page 301

Trigger Holdoff

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

SCPI command:

TRIGger[:SEQuence]:IFPower:HOLDoff on page 299

Capture Offset

This setting is only available for applications in **MSRA operating mode**. It has a similar effect as the trigger offset in other measurements: it defines the time offset between the capture buffer start and the start of the extracted application data. The offset must be a positive value, as the application can only analyze data that is contained in the capture buffer.

SCPI command:

[SENSe:]MSRA:CAPTure:OFFSet on page 302

5.6.3 Sweep Settings

The sweep settings define how often data from the input signal is acquired and then evaluated. They are configured via the SWEEP key.

Continuous Sweep/RUN CONT

After triggering, starts the measurement and repeats it continuously until stopped. This is the default setting.

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

Note: Sequencer. If the Sequencer is active, the "Continuous Sweep" softkey only controls the sweep mode for the currently selected channel; however, the sweep mode only has an effect the next time the Sequencer activates that channel, and only for a channel-defined sequence. In this case, a channel in continuous sweep mode is swept repeatedly. Furthermore, the RUN CONT key on the front panel controls the Sequencer, not individual sweeps. RUN CONT starts the Sequencer in continuous mode.

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

SCPI command:

INITiate:CONTinuous on page 327

Single Sweep/ RUN SINGLE

After triggering, starts the number of evaluations set in "Statistics Count". The measurement stops after the defined number of evaluations has been performed.

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

Note: Sequencer. If the Sequencer is active, the "Single Sweep" softkey only controls the sweep mode for the currently selected channel; however, the sweep mode only has an effect the next time the Sequencer activates that channel, and only for a channel-defined sequence. In this case, a channel in single sweep mode is swept only once by the Sequencer.

Furthermore, the RUN SINGLE key on the front panel controls the Sequencer, not individual sweeps. RUN SINGLE starts the Sequencer in single mode.

If the Sequencer is off, only the evaluation for the currently displayed measurement channel is updated.

SCPI command:

INITiate[:IMMediate] on page 328

Continue Single Sweep

After triggering, repeats the number of evaluations set in "Statistics Count", without deleting the trace of the last measurement.

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

SCPI command:

INITiate:CONMeas on page 327

### Refresh (non-MSRA mode)

Repeats the evaluation of the data currently in the capture buffer without capturing new data. This is useful after changing settings, for example filters, patterns or evaluation ranges.

SCPI command:

INITiate:REFMeas on page 329

Statistic Count

Defines the number of measurements to be considered for statistical evaluations. The behavior depends on the active sweep mode.
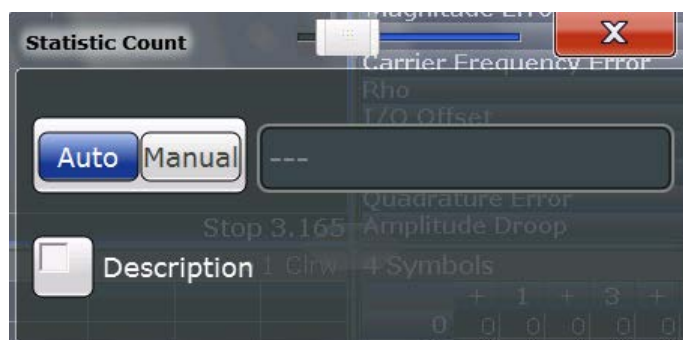
Activate "Description" to display a visualization of the behavior of the current settings.

Note: If the "Statistic Count" is set to *1*, trace averaging is not performed; Max Hold and Min Hold, however, remain active, unlike in the Spectrum application.

"Auto"　　　　　In single sweep mode: captures the I/Q data once and evaluates it
　　　　　　　　In continuous sweep mode: captures I/Q data continuously; for each evaluation, the average is calculated over the last 10 capture sets (moving average)

"Manual"　　　　In single sweep mode: captures I/Q data until the defined number of evaluations have been performed
　　　　　　　　In continuous sweep mode: captures I/Q data continuously; if trace averaging is selected, the average is calculated over the defined number of capture sets (moving average);

SCPI command:
[SENSe:]SWEep:COUNt[:VALue] on page 303

Select Result Rng
Selects the result range from the capture buffer that you want to evaluate.

This function is available in single sweep mode only.

By default, the application shows the results over all result ranges that have been captured in the signal capturing process and are in the R&S FSW's memory. By selecting a range number, you can evaluate a specific result range, e.g. a particular burst.

The range depends on the number of result ranges you have captured previously.

For more information refer also to chapter 4.6, "Measurement Ranges", on page 111.

SCPI command:
[SENSe:]DDEMod:SEARch:MBURst:CALC on page 303

Refresh
This function is only available if the Sequencer is deactivated and only for **MSRA applications**.

The data in the capture buffer is re-evaluated by the currently active application only. The results for any other applications remain unchanged.

This is useful, for example, after evaluation changes have been made or if a new sweep was performed from another application; in this case, only that application is updated automatically after data acquisition.

SCPI command:
INITiate:REFResh on page 329

5.7　Burst and Pattern Configuration

Information on known patterns and bursts in the captured signal improve the accuracy of the determined ideal reference signal, and calculation of the signal parameters becomes quicker.

For details on burst and patterns see chapter 4.4, "Overview of the Demodulation Process", on page 84.

5.7.1 Burst Search

The "Burst Search" settings define when a burst is detected in the evaluated signal.

A live preview of the capture buffer with the current settings is displayed in the preview area at the bottom of the dialog box. The blue lines below the trace indicate the detected bursts. The preview area is not editable directly.

The "Burst Search" settings are displayed when you select the "Burst/Pattern" button in the "Overview" or the "Burst/Pattern Search" softkey in the main VSA menu.

Enabling Burst Searches

Enables or disables burst searches. If "Auto" is selected, burst search is enabled only if the signal structure defines a bursted signal (in the "Signal Structure" tab of the "Modulation & Signal Description" dialog box, see "Signal Type" on page 132).

SCPI command:

[SENSe:]DDEMod:SEARch:BURSt:AUTO on page 304

Measuring only if burst was found

If enabled, measurement results are only displayed (and are only averaged) if a valid burst has been found. When measuring bursted signals that are averaged over several measurements, it is recommended that you enable this option so that erroneous measurements do not affect the result of averaging.

SCPI command:

[SENSe:]DDEMod:SEARch:BURSt:MODE on page 305

Burst Configuration

The conditions under which a burst is detected in the captured data can be configured either manually or automatically according to the defined signal structure settings (see "Burst Settings" on page 132.

SCPI command:

[SENSe:]DDEMod:SEARch:BURSt:CONFigure:AUTO on page 304

Search Tolerance ← Burst Configuration

Defines the number of symbols that may differ from the burst length without influencing the burst detection. A search tolerance of 5, for example, with a minimum and maximum burst length of 100, will detect bursts that are 95 to 100 symbols long. (The minimum and maximum burst length is defined in the Signal Structuresettings

Note: Due to the fact that the VSA does not have knowledge of the ramp length, there is an uncertainty in the burst search algorithm. Thus, setting this parameter to "0" will result in a failed burst search for most signals.

SCPI command:

[SENSe:]DDEMod:SEARch:BURSt:TOLerance on page 305

Min Gap Length ← Burst Configuration

Represents the minimum distance (in symbols) between adjacent bursts. The default value is 1 symbol in order to make sure that the burst search finds bursts that are very close to each other. However, in case the capture buffer does not contain very close bursts, it is recommended that you increase the value. This makes the burst search faster and also more robust for highly distorted signals.

Note that this parameter only influences the robustness of the burst search. It should not be used to explicitly exclude certain bursts from the measurement. For example, setting the minimum gap length to 100 symbols does not ensure that the burst search does not find bursts that have a very small gap.

SCPI command:

[SENSe:]DDEMod:SEARch:BURSt:GLENgth[:MINimum] on page 305

5.7.2 Pattern Search

The "Pattern Search" settings define when a pattern is detected in the evaluated signal.

A live preview of the capture buffer with the current settings is displayed in the preview area at the bottom of the dialog box. The preview area is not editable directly.

The "Pattern Search" settings are displayed when you select the "Burst/Pattern" button in the "Overview" or the "Burst/Pattern Search" softkey in the main VSA menu and then switch to the "Pattern Search" tab.

Enabling Pattern Searches
Enables or disables pattern searches. If "Auto" is selected, pattern search is enabled only if the signal structure defines a pattern in the signal (in the "Signal Structure" tab of the "Modulation & Signal Description" dialog box, see "Pattern Settings" on page 132).

SCPI command:
[SENSe:]DDEMod:SEARch:SYNC:STATe on page 307
[SENSe:]DDEMod:SEARch:SYNC:AUTO on page 306

I/Q Correlation Threshold

The I/Q correlation threshold decides whether a match is accepted or not during a pattern search (see also chapter 4.4.2, "I/Q Pattern Search", on page 88). If the parameter is set to 100%, only I/Q patterns that match totally with the input signal are found. This is only the case for infinite SNR.

If the threshold "Auto" option is enabled, the default value of 90% is used. As long as the pattern is found, there is no need to change this parameter. However, if the pattern is very short (approximately < 10 symbols) or if the signal is highly distorted, tuning this parameter helps the pattern search to succeed. To define a threshold manually, disable the "Auto" option.

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:IQCThreshold on page 306

[SENSe:]DDEMod:SEARch:PATTern:CONFigure:AUTO on page 306

Meas only if Pattern Symbols Correct

If enabled, measurement results are only displayed (and are only averaged) if a valid pattern has been found. When measuring signals that contain a pattern and are averaged over several measurements, it is recommended that you enable this option so that erroneous measurements do not affect the result of averaging.

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:MODE on page 307

Selected Pattern for Search

Indicates which of the patterns that are assigned to the current standard is selected and will be searched for.

The selected pattern is indicated for information only and cannot be edited here, only in the "Signal Structure" settings, see "Name" on page 132).

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:SELect on page 307

Pattern Found

Indicates whether a pattern was found in the currently captured data.

5.7.3   Pattern Configuration

For common signal standards, the patterns to be searched for in the captured signal are predefined in the VSA application. In addition, new patterns can be defined and assigned to a signal standard manually.

Patterns are configured in the "Advanced Pattern Settings" dialog box which is displayed when you do one of the following:

● Select the "Pattern Config" softkey in the main VSA menu.

● In the "Signal Description" dialog box, switch to the "Signal Structure" tab and select the "Pattern Config" button.

Standard Patterns

The "Standard Patterns" are the patterns assigned to the currently selected standard.
You can add existing patterns to the standard or remove patterns already assigned to
the standard.
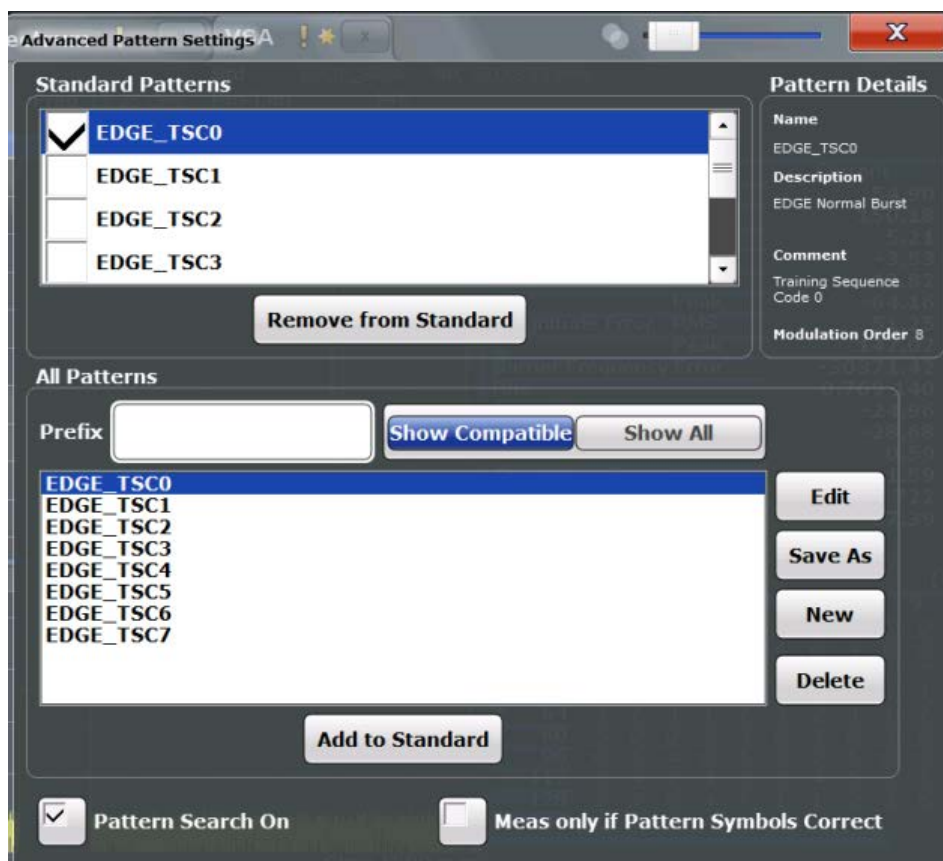
Removing patterns from a standard

Removes the assignment of the selected patterns to the standard. The patterns are
removed from the "Standard Patterns" list, but not deleted.

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:PATTern:REMove on page 310

Adding patterns to a standard

Adds the selected patterns in the list of available patterns ("All Patterns") to the list of assigned patterns ("Standard Patterns").

For details see "To add a predefined pattern to a standard" on page 205.

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:PATTern:ADD on page 310

Displaying available patterns

The "All Patterns" list contains the patterns available in the VSA application.

You can assign available patterns to the selected standard, edit existing or define new patterns. For details on managing standard patterns, see chapter 7.2.2.3, "How to Manage Patterns", on page 207

The list can be filtered using the following functions:

Prefix ← Displaying available patterns

Shows only patterns that contain the specified prefix.

Show Compatible/ Show All ← Displaying available patterns

Shows only patterns that are compatible to the selected modulation mode or all patterns (regardless of the selected standard).

Edit

Opens the "Edit Pattern" dialog box to edit the pattern definition. See chapter 5.7.4, "Pattern Definition", on page 167.

For details on defining a pattern, see example "Defining a pattern" on page 207.

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:NAME on page 309

[SENSe:]DDEMod:SEARch:SYNC:COMMent on page 308

[SENSe:]DDEMod:SEARch:SYNC:DATA on page 309

[SENSe:]DDEMod:SEARch:SYNC:TEXT on page 310

Save As

Saves a copy of an existing pattern under a new name.

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:COPY on page 308

New

Opens the "Pattern" dialog box to create a new pattern definition. See chapter 5.7.4, "Pattern Definition", on page 167.

For details on defining a pattern, see chapter 7.2.2.2, "How to Define a New Pattern", on page 206.

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:NAME on page 309

[SENSe:]DDEMod:SEARch:SYNC:COMMent on page 308

[SENSe:]DDEMod:SEARch:SYNC:DATA on page 309

[SENSe:]DDEMod:SEARch:SYNC:TEXT on page 310

Delete

Deletes the selected patterns. Any existing assignments to other standards are removed.

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:DELete on page 308

Pattern details

Pattern details for the currently focussed pattern are displayed at the upper right-hand side of the dialog box. You can refer to these details, for example, when you want to add a new pattern to the standard and want to make sure you have selected the correct one.

Pattern Search On

If enabled, the VSA application searches for the selected pattern. This setting is identical to the setting in the "Pattern Search" dialog box (see "Enabling Pattern Searches" on page 163).

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:STATe on page 307

Meas only if Pattern Symbols Correct

If enabled, measurement results are only displayed (and are only averaged) if a valid pattern has been found. When measuring signals that contain a pattern and are averaged over several measurements, it is recommended that you enable this option so that erroneous measurements do not affect the result of averaging.

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:MODE on page 307

5.7.4 Pattern Definition

New patterns can be defined and then assigned to a standard. Patterns are defined in the "New Pattern" dialog box which is displayed when you select the "New" button in the "Advanced Pattern Settings" dialog box.

For details on defining a pattern, see chapter 7.2.2.2, "How to Define a New Pattern", on page 206.

Name

Pattern name that will be displayed in selection list

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:NAME on page 309

Description

Optional description of the pattern which is displayed in the pattern details

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:TEXT on page 310

Mod. order

The order of modulation, e.g. 8 for an 8-PSK.

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:NSTate on page 309

Symbols

The pattern definition is a symbol table consisting of one or more symbols. The number of symbols is indicated as the "Size" to the left of the symbol table.

A scrollbar beneath the input area alows you to scroll through the table for long patterns. The numbers beneath the scrollbar indicate the sequential number of the following symbols, from left to right:

- the first symbol
- the currently selected symbol
- the last symbol

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:DATA on page 309

Symbol format ← Symbols

Defines the format in which each symbol is defined: hexadecimal, decimal or binary

Adding symbols ← Symbols

Adds a new symbol in the symbol table to the left of the currently selected symbol.

Removing symbols ← Symbols

Removes the currently selected symbol in the symbol table.

Comment

Optional comment for the pattern, displayed in the pattern details (kept for compatibility with FSQ)

SCPI command:

[SENSe:]DDEMod:SEARch:SYNC:COMMent on page 308

5.8 Result Range Configuration

The result range determines which part of the capture buffer, burst or pattern is displayed. For more information, see chapter 4.6, "Measurement Ranges", on page 111.

A visualization of the result display with the current settings is displayed in the visualization area at the bottom of the dialog box.

The result range settings are displayed when you select the "Cut Result Ranges" button in the "Overview" or the "Range Settings" softkey in the main VSA menu.
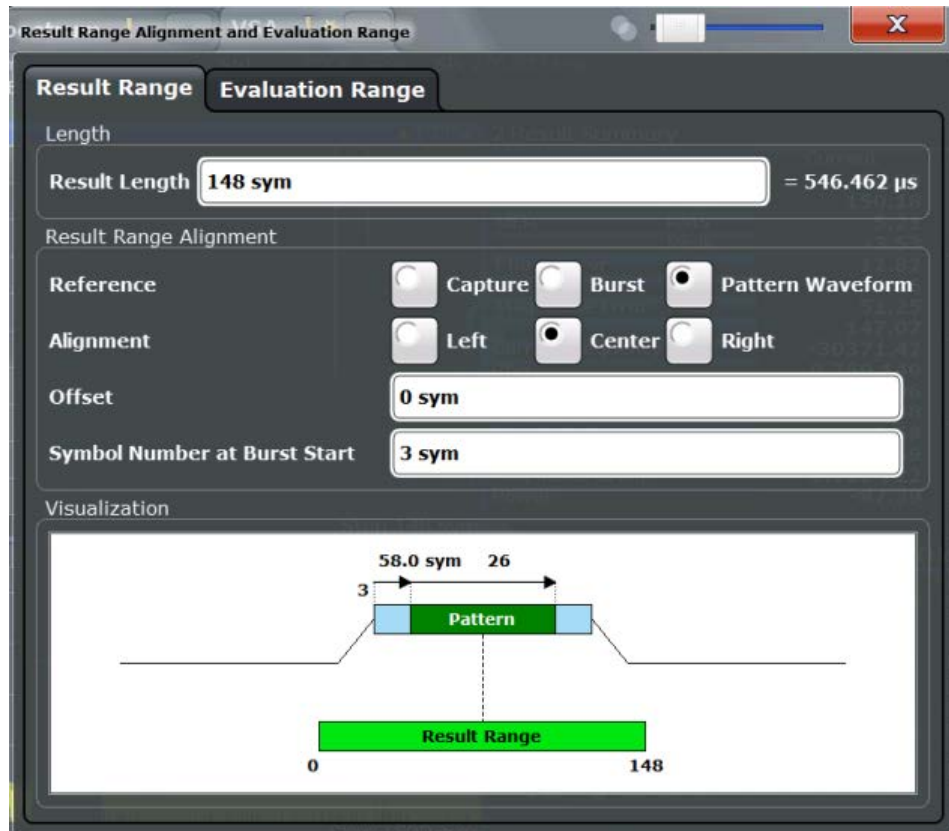
Result Length

Defines the number of symbols that are to be demodulated. All traces over time are displayed over the result range.

SCPI command:

[SENSe:]DDEMod:TIME on page 312

Reference

Defines the reference for the result range alignment.

The result of the current setting is displayed in the visualization area of the dialog box.

"Capture"   the capture buffer

"Burst"   the detected burst

"Pattern"   the detected pattern

SCPI command:

CALCulate<n>:TRACe<t>:ADJust[:VALue] on page 311

Alignment

Defines the type of alignment of the result range to the reference source. The result of the current setting is displayed in the visualization area of the dialog box.

SCPI command:

CALCulate<n>:TRACe<t>:ADJust:ALIGnment[:DEFault] on page 310

Offset

Defines the offset of the result range to the alignment reference. The result of the current setting is displayed in the visualization area of the dialog box.

Note: Note the following restrictions to this parameter:

● An offset < 0 is not possible if you align the result range to the left border of the capture buffer.
● An offset that moves the pattern outside the result range is not allowed. For example, if you align the result to the left border of the pattern, only offsets ≦ 0 are allowed. Otherwise, you would never be able to find the pattern within the result range.

SCPI command:

CALCulate<n>:TRACe<t>:ADJust:ALIGnment:OFFSet on page 311

Symbol Number at <Reference> Start

Defines the number of the symbol which marks the beginning of the alignment reference source (burst, capture buffer or pattern). The result of the current setting is displayed in the visualization area of the dialog box.

In effect, this setting defines an offset of the x-axis (in addition to the one defined for the signal structure, see "Offset" on page 133).

Note: When you define the "Symbol Number at <Reference> Start" remember to take the offset defined for the signal structure into consideration (see "Offset" on page 133). The "Symbol Number at Pattern Start" refers to the first symbol of the pattern offset, not the first symbol of the pattern.

SCPI command:

DISPlay[:WINDow<n>]:TRACe<t>:X[:SCALe]:VOFFset on page 312

5.9 Demodulation Settings

During demodulation of the vector signal some undesired effects that may occur during transmission can be compensated for. Furthermore, you can influence the synchronization process.

5.9.1 Demodulation - Compensation

> Note that compensation for all the listed distortions can result in lower EVM values.

Demodulation settings are displayed when you select the "Demodulation" button in the "Overview" or the "Demod/Meas Filter" softkey in the main VSA menu.

A live preview of the constellation with the current settings is displayed in the preview area at the bottom of the dialog box. The preview area is not editable directly.

Demodulation settings depend on the used modulation.
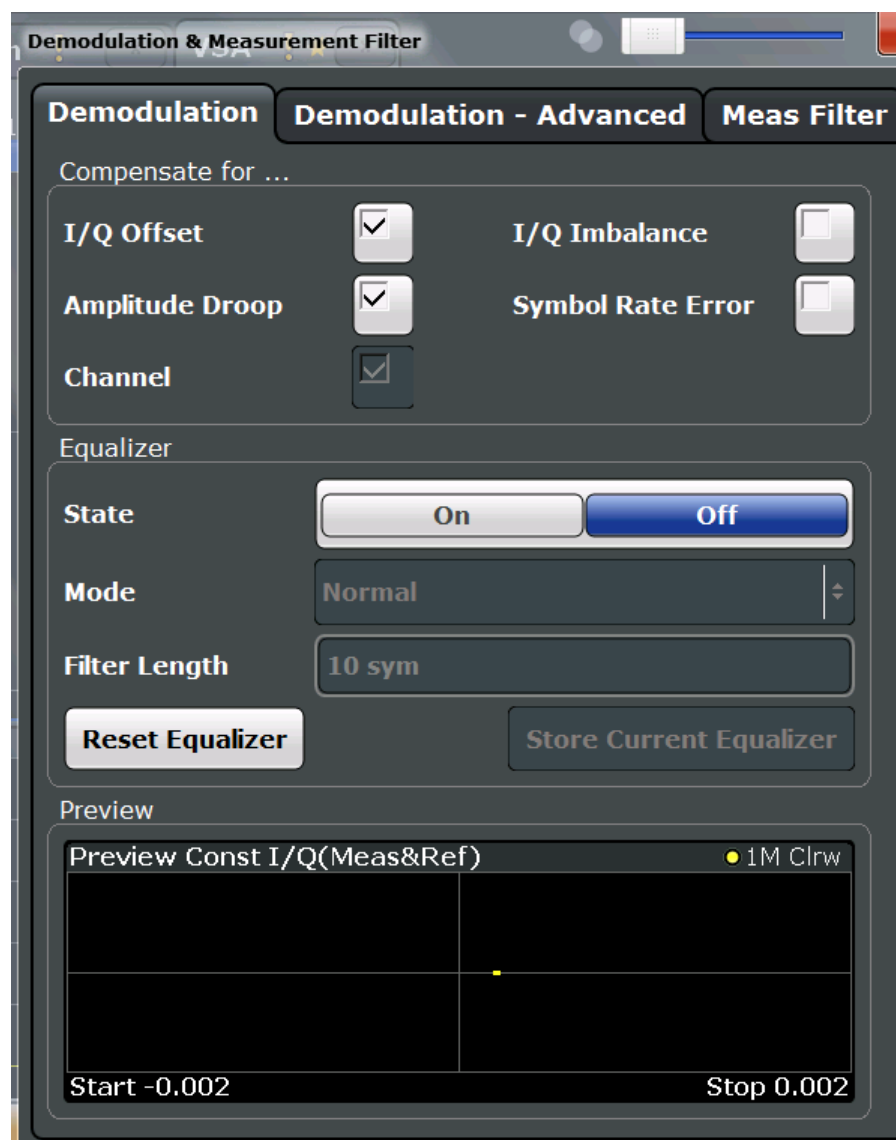
Fig. 5-2: Demodulation settings for PSK, MSK and QAM modulation
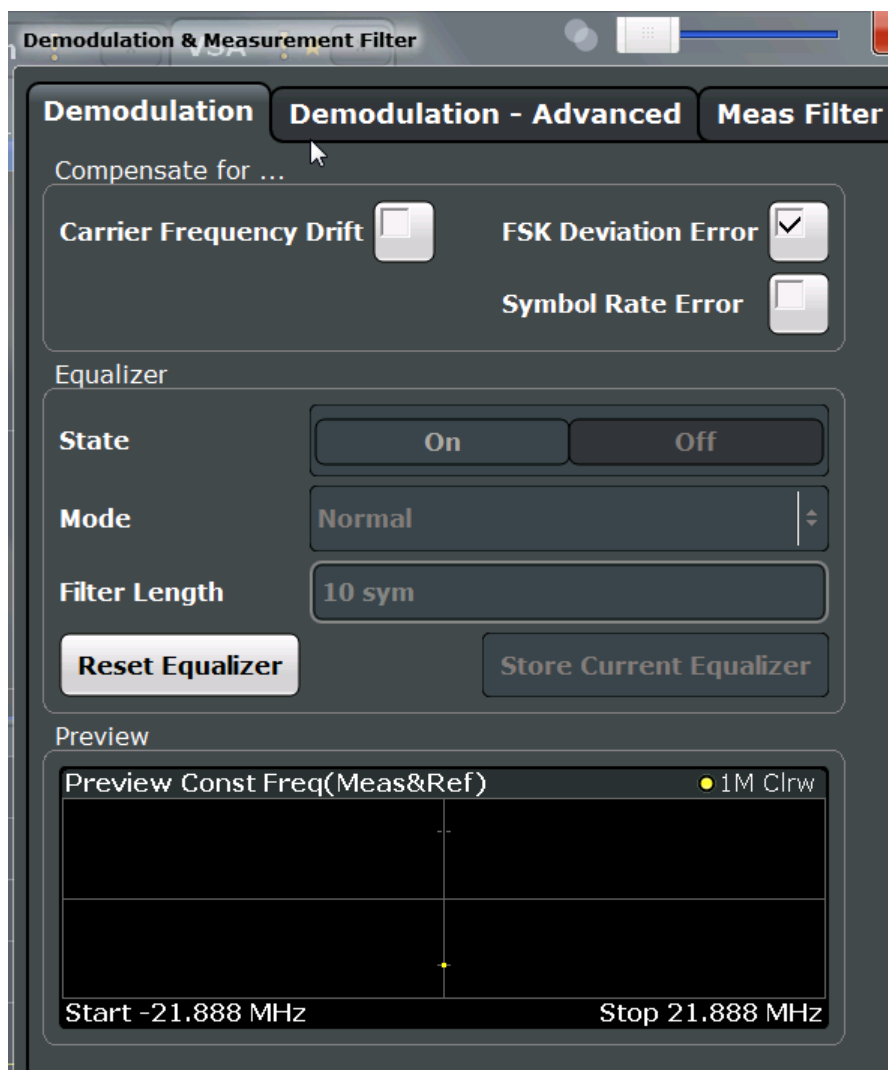
Fig. 5-3: Demodulation settings for FSK modulation

Compensate for...   (PSK, MSK, ASK, QAM)

If enabled, compensation for various effects is taken into consideration during demodulation. Thus, these distortions are not shown in the calculated error values.

Note: Note that compensation for all the listed distortions can result in lower EVM values.

- I/Q Offset (default: on)
- I/Q Imbalance

- Amplitude Droop (default: on)
- Symbol Rate Error
- Channel (default: on)
  Note that channel distortion can only be determined if the equalizer is on (see "State" on page 174). Thus, compensation can only be disabled if the equalizer is on.
  By default, channel compensation is enabled to improve accuracy of the error results. If compensation is disabled, the EVM is calculated from the original input signal with channel distortions.

For details on these effects see chapter 4.5.1.3, "Modulation Errors", on page 98.

SCPI command:

[SENSe:]DDEMod:NORMalize:IQOFfset on page 319

[SENSe:]DDEMod:NORMalize:IQIMbalance on page 319

[SENSe:]DDEMod:NORMalize:ADRoop on page 318

[SENSe:]DDEMod:NORMalize:SRERror on page 320

[SENSe:]DDEMod:NORMalize:CHANnel on page 319

Compensate for...   (FSK)

If enabled, compensation for various effects is taken into consideration during demodulation. Thus, these distortions are not shown in the calculated error values.

- Carrier Frequency Drift
- FSK Deviation Error
- Symbol Rate Error

For details on these effects see chapter 4.5.2.3, "Modulation Errors", on page 110.

SCPI command:

[SENSe:]DDEMod:NORMalize:CFDRift on page 319

[SENSe:]DDEMod:NORMalize:FDERror on page 319

[SENSe:]DDEMod:NORMalize:SRERror on page 320

Equalizer Settings

The equalizer can compensate for a distorted transmission of the input signal or improve accuracy in estimating the reference signal.

For details see chapter 4.4.5, "The Equalizer", on page 93.

State ← Equalizer Settings

Activates or deactivates the equalizer to compensate for a distorted channel.

SCPI command:

[SENSe:]DDEMod:EQUalizer[:STATe] on page 317

Mode ← Equalizer Settings

Defines the operating mode of the equalizer.

"Normal"   Determines the filter values from the difference between the ideal (reference) signal and the measured signal. Normal mode is sufficient for small distortions and performance remains high.

"Tracking"	The results of the equalizer in the previous sweep are considered to calculate the new filter until adaquate results are obtained. This "learning" effect allows for powerful removement of larger distortions within a minimum of sweeps. During the tracking phase calculation of the equalizer requires additional processing time.
"Freeze"	The filter is no longer changed, the current equalizer values are used for subsequent sweeps.
"User"	A user-defined equalizer loaded from a file is used.
"Averaging"	The results of the equalizer in all previous sweeps (since the instrument was switched on or the equalizer was reset) are considered to calculate the new filter. To start a new averaging process, select the Reset Equalizer button. Calculation of the equalizer requires additional processing time.

SCPI command:
[SENSe:]DDEMod:EQUalizer:MODE on page 315

Filter Length ← **Equalizer Settings**
Defines the length of the equalizer in symbols. The longer the equalizer, the more accurate the filter becomes and the more distortion can be compensated. However, this requires extended calculation time. The shorter the filter length, the less calculation time is required during the equalizer's tracking or averaging phase.

SCPI command:
[SENSe:]DDEMod:EQUalizer:LENGth on page 314

Reset Equalizer ← **Equalizer Settings**
Deletes the data of the currently selected equalizer. After deletion, averaging and tracking starts anew.

This is useful in the rare case that calculation takes a wrong symbol decision into consideration and distorts the signal such that the original signal can no longer be determined.

SCPI command:
[SENSe:]DDEMod:EQUalizer:RESet on page 316

Store/Load Current Equalizer ← **Equalizer Settings**
Saves the current equalizer results to a file, or loads a user-defined equalizer.

The equalizer Mode must be set to USER in order to load a file.

SCPI command:
[SENSe:]DDEMod:EQUalizer:SAVE on page 316
[SENSe:]DDEMod:EQUalizer:LOAD on page 315

5.9.2 Advanced Demodulation (Synchronization)

You can influence the synchronization process and calculation of error values during demodulation.

Advanced demodulation settings are displayed when you select the "Demodulation" button in the "Overview" or the "Demod/Meas Filter" softkey in the main VSA menu and then switch to the "Demodulation - Advanced" tab.

A live preview of the constellation with the current settings is displayed in the preview area at the bottom of the dialog box. The preview area is not editable directly.
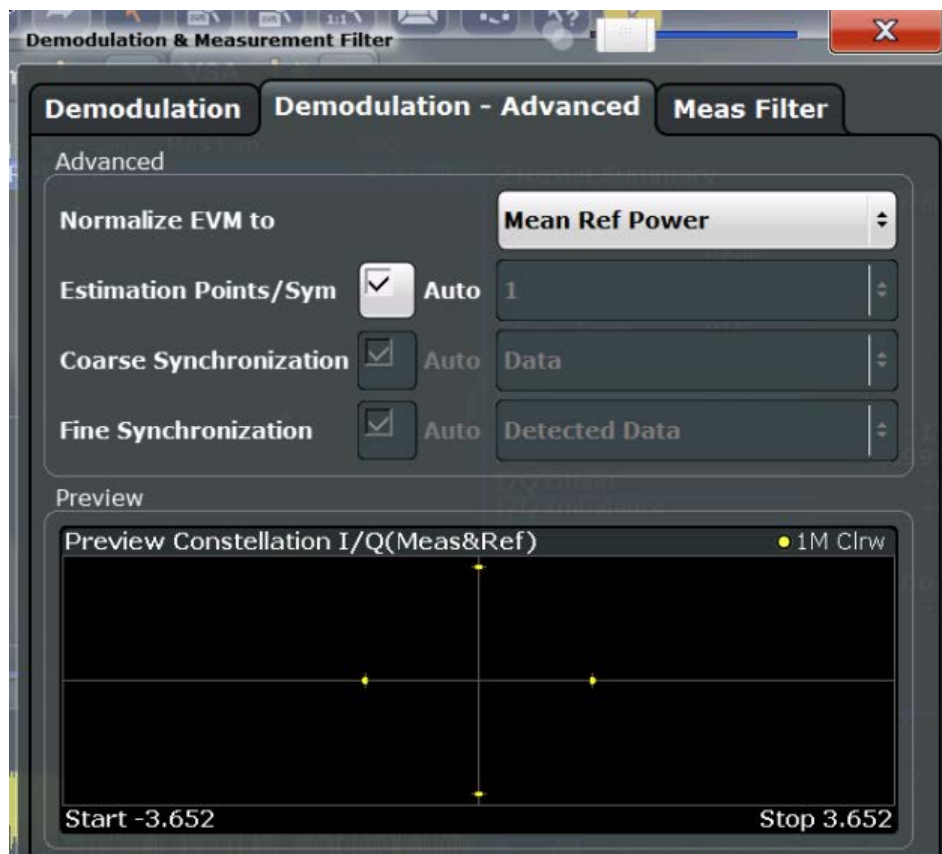
Normalize EVM to
Normalizes the EVM to the specified power value.

This setting is not available for MSK or FSK modulation.

- **Max Ref Power**
  Maximum power of the reference signal at the symbol instants.
- **Mean Ref Power**
  mean power of the reference signal at the symbol instants.
- **Mean Constellation Power**
  Mean expected power of the measurement signal at the symbol instants
- **Max Constellation Power**

The maximum expected power of the measurement signal at the symbol instants

SCPI command:

[SENSe:]DDEMod:ECALc[:MODE] on page 313

Estimation Points/Sym

During synchronization, the measurement signal is matched to the reference signal and various signal parameters are calculated. You can define how many sample points are used for this calculation at each symbol.

For more information on estimation points per symbol see chapter 4.7, "Display Points vs Estimation Points per Symbol", on page 115.

You can set the estimation points manually or let the VSA application decide how many estimation points to use.

If automatic mode is enabled, the VSA application uses the following settings, depending on the modulation type:

Modulation	Est. Points
PSK, QAM	1
Offset QPSK	2
FSK, MSK	Capture Oversampling

For manual mode, the following settings are available:

"1"   the estimation algorithm takes only the symbol time instants into account

"2"   two points per symbol instant are used (required for Offset QPSK)

"Capture Over-sampling"   the number of samples per symbol defined in the signal capture settings is used (see "Sample Rate" on page 153), i.e. all sample time instants are weighted equally

SCPI command:

[SENSe:]DDEMod:EPRate:AUTO on page 314

[SENSe:]DDEMod:EPRate[:VALue] on page 314

Coarse Synchronization

It is not only possible to check whether the pattern is part of the signal, but also to use the pattern for synchronization, in order to obtain the correct reference signal.

For details on synchronization see chapter 4.4, "Overview of the Demodulation Process", on page 84.

If "Auto" mode is selected, the detected data is used. In manual mode you can select one of the following settings:

"Data"   (Default): the detected data is used for synchronization, i.e. unknown symbols
                Use this setting if no pattern is available or if the pattern is short or does not have suitable synchronization properties, e.g. a pattern that consists of only one repeated symbol.

"Pattern"   Known symbols from a defined pattern are used for synchronization
                   Depending on the signal, using the pattern can speed up your mea-
                   surement considerably and make it more robust against high carrier
                   frequency offsets.
                   Make sure that the pattern is suitable for synchronization, e.g. a GSM
                   pattern.

SCPI command:
[SENSe:]DDEMod:SEARch:PATTern:SYNC:AUTO on page 320
[SENSe:]DDEMod:SEARch:PATTern:SYNC[:STATe] on page 320

Fine Synchronization

In addition to the coarse synchronization used for symbol decisions, a fine synchroniza-
tion is available to calculate various results from the reference signal, e.g. the EVM.
However, when the signal is known to have a poor transmission quality or has a high
noise level, false symbol decisions are more frequent, which may cause spikes in the
EVM results.

To improve these calculations the reference signal can be estimated from a smaller area
that includes a known symbol sequence in the input signal. In this case, the results for
the limited reference area are more precise, at the cost of less accurate results outside
this area. Thus, the result range should be set to the length of the reference area. The
reference area can be defined either using a pattern or using a known data sequence
from a Known Data file. If no predefined data sequences are available for the signal, the
detected data is used by default.

If "Auto" mode is selected and a Known Data file has been loaded and activated for use,
the known data sequences are used. Otherwise, the detected data is used.

Note: You can define a maximum symbol error rate (SER) for the known data in reference
to the evaluated data. If the SER of the known data exceeds this limit, the default syn-
chronization using the detected data is performed.

"Known Data"   The reference signal is defined as the data sequence from the loaded
                   Known Data file that most closely matches the measured data.

"Pattern"   The reference signal is estimated from the defined pattern.

"Detected   (Default) The reference signal is estimated from the detected data.
Data"

SCPI command:
[SENSe:]DDEMod:FSYNc:AUTO on page 317
[SENSe:]DDEMod:FSYNc[:MODE] on page 317
[SENSe:]DDEMod:FSYNc:RESult? on page 317

If SER ≤

This setting is only available if "Known Data" is selected for "Fine Synchronization". You can define a maximum symbol error rate for the known data in reference to the evaluated data. Thus, if a wrong file was mistakenly loaded or the file proves to be unsuitable, it is not used for synchronization. Otherwise the results would be strongly distorted. If the SER of the known data exceeds this limit, the default synchronization using the detected data is performed.

SCPI command:

[SENSe:]DDEMod:FSYNc:LEVel on page 317

Offset EVM

The offset EVM is only available for Offset QPSK modulated signals.

Unlike QPSK modulation, the Q component of Offset QPSK modulation is delayed by half a symbol period against the I component in the time domain. The symbol time instants of the I and the Q component therefore do not coincide.

The offset EVM controls the calculation of all results that are based on the error vector. It affects the EVM, Real/Imag and Vector I/Q result displays as well as the EVM results in the Result Summary (EVM and MER).

You can configure the way the VSA application calculates the error vector results.

If "Offset EVM" is disabled, the VSA application substracts the measured signal from the reference signal to calculate the error vector. This method results in the fact that the error vector contains two symbol instants per symbol period: one that corresponds to the I component and one that corresponds to the Q component.

If "Offset EVM" is enabled, however, the VSA application compensates the delay of the Q component with respect to the I component in the measurement signal as well as the reference signal **before** calculating the error vector. That means that the error vector contains only one symbol instant per symbol period.

SCPI command:

[SENSe:]DDEMod:ECALc:OFFSet on page 313

5.10 Measurement Filter Settings

The measurement filter can be used to filter both the measured signal and the reference signal, and thus the error vector. You can configure the measurement filter to be used.

For more information on measurement filters see chapter 4.1.4, "Measurement Filters", on page 53.

Measurement filter settings are displayed when you select the "Meas Filter" button in the "Overview" or the "Demod/Meas Filter" softkey in the main VSA menu and then switch to the "Meas Filter" tab.

A live preview of the constellation with the current settings is displayed in the preview area at the bottom of the dialog box. The preview area is not editable directly.
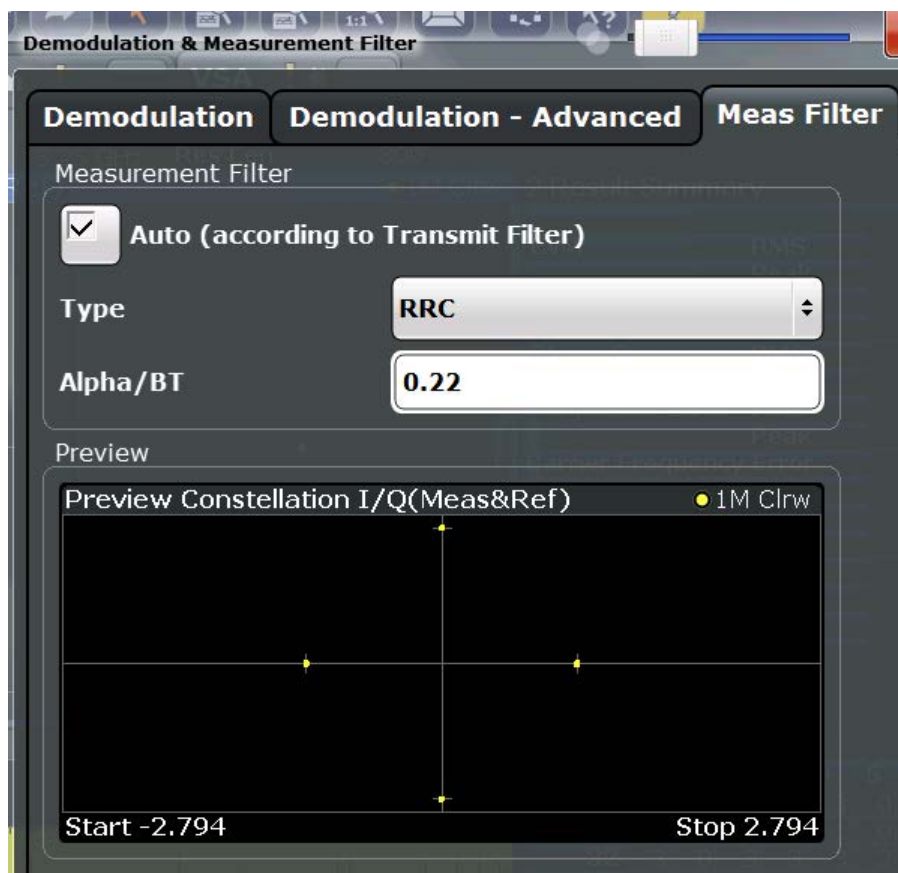
Using the Transmit Filter as a Measurement Filter (Auto)

If the "Auto" option is enabled, the measurement filter is defined automatically depending on the transmit filter specified in the "Modulation" settings (see "Transmit Filter Type" on page 130).

Note: If a user-defined transmit filter is selected and the measurement filter is defined automatically, a Low-ISI measurement filter according to the selected user filter is calculated and used.

SCPI command:

[SENSe:]DDEMod:MFILter:AUTO on page 321

Type

Defines the measurement filter type, if the Using the Transmit Filter as a Measurement Filter (Auto) setting is not enabled.

"<Predefined Filter>"	An overview of available measurement filters is provided in chapter A. 2.2, "Measurement Filters", on page 404.

"User"	User-defined filter.
	Define the filter using the Load User Filter function or the `[SENSe:]DDEMod:MFILter:USER` command.
	For more information on user-defined filters see chapter 4.1.5, "Customized Filters", on page 55.
"None"	No measurement filter is used.

SCPI command:

`[SENSe:]DDEMod:MFILter[:STATe]` on page 321

To turn off the measurement filter.

`[SENSe:]DDEMod:MFILter:USER` on page 322

To use a user-defined filter.

`[SENSe:]DDEMod:MFILter:NAME` on page 321

To define the name of the measurement filter.

Load User Filter ← Type

Opens a file-selection dialog box to select the user-defined measurement filter to be used.

This setting is only available if "User" is selected as the "Filter Type".

For detailed instructions on working with user-defined filters see chapter 7.2.1, "How to Select User-Defined Filters", on page 204.

SCPI command:

`[SENSe:]DDEMod:MFILter:USER` on page 322

Alpha/BT ← Type

Defines the roll-off factor (Alpha) or the filter bandwidth (BT).

The roll-off factor or filter bandwidth are available for RC, RRC and Gauss filters.

If the measurement mode is automatically selected according to the transmit filter, this setting is identical to the "Alpha/BT" value in the modulation settings (see "Alpha/BT" on page 130).

SCPI command:

Measurement filter: `[SENSe:]DDEMod:MFILter:ALPHa` on page 321

Transmit filter: `[SENSe:]DDEMod:TFILter:ALPHa` on page 274

5.11 Evaluation Range Configuration

The evaluation range defines which range of the result is to be evaluated - either the entire result range or only a specified part of it. The calculated length of the specified range is indicated beneath the entries.

A visualization of the evaluation range (in relation to the result range) with the current settings is displayed at the bottom of the dialog box. The green bar below the trace indicates the defined result range, indented red lines indicate defined start and stop symbols (see "Evaluation range display" on page 114). The visualization is not editable directly.

The evaluation range settings are displayed when you select the "Evaluation Range" button in the "Overview" or the "Range Settings" softkey in the main VSA menu and then switch to the "Evaluation Range" tab.
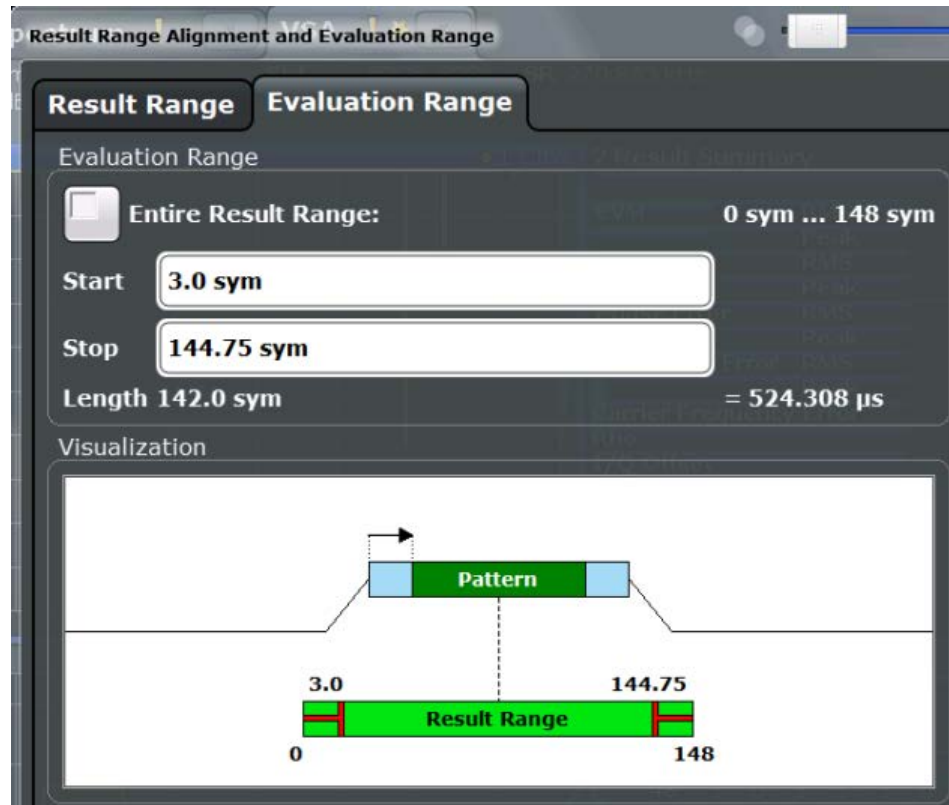
For details on the evaluation range see

For an example on setting the evaluation range see

Evaluating the Entire Result Range
If enabled, the entire result range is evaluated.

If disabled, you can define a specific part of the result range to be evaluated.

SCPI command:
CALCulate<n>:ELIN<startstop>:STATe on page 322

Start / Stop
Defines the symbol in the result range at which evaluation is started and stopped. The start and stop symbols themselves are included in the evaluation range.

Note: Note that the start and stop values are defined with respect to the x-axis including an optional offset defined via the Symbol Number at <Reference> Start parameter.

SCPI command:

CALCulate<n>:ELIN<startstop>[:VALue] on page 323

5.12 Adjusting Settings Automatically

Some settings can be adjusted by the R&S FSW automatically according to the current measurement settings. In order to do so, a measurement is performed. The duration of this measurement can be defined automatically or manually.

To activate the automatic adjustment of a setting, select the corresponding function in the AUTO SET menu or in the configuration dialog box for the setting, where available.

Setting the Reference Level Automatically (Auto Level)
Automatically determines the optimal reference level for the current input data. At the same time, the internal attenuators and the preamplifier are adjusted so the signal-to-noise ratio is optimized, while signal compression, clipping and overload conditions are minimized.

In order to do so, a level measurement is performed to determine the optimal reference level.

You can change the measurement time for the level measurement if necessary (see "Changing the Automatic Measurement Time (Meastime Manual)" on page 183).

SCPI command:

[SENSe:]ADJust:LEVel on page 326

Resetting the Automatic Measurement Time (Meastime Auto)
Resets the measurement duration for automatic settings to the default value.

SCPI command:

[SENSe:]ADJust:CONFigure:DURation:MODE on page 324

Changing the Automatic Measurement Time (Meastime Manual)
This function allows you to change the measurement duration for automatic setting adjustments. Enter the value in seconds.

SCPI command:

[SENSe:]ADJust:CONFigure:DURation:MODE on page 324

[SENSe:]ADJust:CONFigure:DURation on page 324

Upper Level Hysteresis

When the reference level is adjusted automatically using the Setting the Reference Level Automatically (Auto Level) function, the internal attenuators and the preamplifier are also adjusted. In order to avoid frequent adaptation due to small changes in the input signal, you can define a hysteresis. This setting defines an upper threshold the signal must exceed (compared to the last measurement) before the reference level is adapted automatically.

SCPI command:

[SENSe:]ADJust:CONFigure:HYSTeresis:UPPer on page 325

Lower Level Hysteresis

When the reference level is adjusted automatically using the Setting the Reference Level Automatically (Auto Level) function, the internal attenuators and the preamplifier are also adjusted. In order to avoid frequent adaptation due to small changes in the input signal, you can define a hysteresis. This setting defines a lower threshold the signal must fall below (compared to the last measurement) before the reference level is adapted automatically.

SCPI command:

[SENSe:]ADJust:CONFigure:HYSTeresis:LOWer on page 325

Auto Scale Once/Auto Scale Window

If enabled, both the x-axis and y-axis are automatically adapted to the current measurement results (only once, not dynamically) in the selected window.

To adapt the range of all screens together, use the Auto Scale All function.

SCPI command:

DISPlay[:WINDow<n>]:TRACe:Y[:SCALe]:AUTO ONCE on page 324

Auto Scale All

Adapts the x-axis and y-axis to the current measurement values (only once, not dynamically) in all measurement windows.

SCPI command:

DISPlay[:WINDow<n>]:TRACe<t>:Y[:SCALe]:AUTO:ALL on page 324

6 Analysis

General result analysis settings concerning the trace, markers, windows etc. can be configured via the "Analysis" button in the "Overview". They are identical to the analysis functions in the base unit except for the special window functions.

Window-specific configuration

The settings in the "Analysis" dialog box are specific to the selected window. Thus, the "Analysis" button is only available in the "Overview" if the "Specifics for" option is enabled. To configure the settings for a different VSA window, select the window outside the displayed dialog box, or select the window from the "Specifics for" selection list in the dialog box.
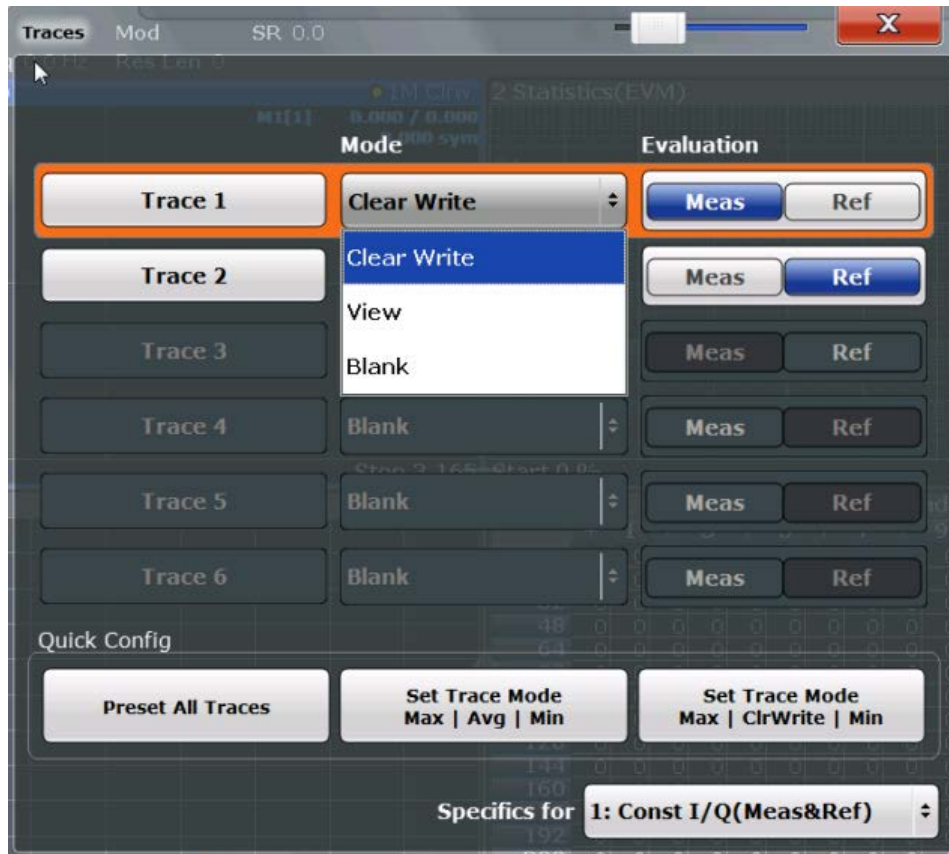

6.1 Trace Settings

The trace settings determine how the measured data is analyzed and displayed in the window. Depending on the result display, between 1 and 6 traces may be displayed.

Trace settings can be configured via the TRACE key, in the "Traces" dialog box, or in the vertical "Traces" tab of the "Analysis" dialog box.

Trace data can also be exported to an ASCII file for further analysis. For details see chapter 6.2, "Trace Export Settings", on page 188.

Trace 1/Trace 2/Trace 3/Trace 4/Trace 5/Trace 6
Selects the corresponding trace for configuration. The currently selected trace is high-lighted orange.

SCPI command:
DISPlay[:WINDow<n>]:TRACe<t>[:STATe] on page 333
Selected via numeric suffix of TRACe<t> commands

Trace Mode
Defines the update mode for subsequent traces.

The available trace modes depend on the selected result display. Not all evaluations support all trace modes.

"Clear Write"   Overwrite mode: the trace is overwritten by each sweep. This is the default setting.
The "Detector" is automatically set to "Auto Peak".

"Max Hold"	The maximum value is determined over several sweeps and displayed. The R&S FSW saves the sweep result in the trace memory only if the new value is greater than the previous one. The "Detector" is automatically set to "Positive Peak".
"Min Hold"	The minimum value is determined from several measurements and displayed. The R&S FSW saves the sweep result in the trace memory only if the new value is lower than the previous one. The "Detector" is automatically set to "Negative Peak".
"Average"	The average is formed over several sweeps. The Statistic Count determines the number of averaging procedures. The "Detector" is automatically set to "Sample".
"View"	The current contents of the trace memory are frozen and displayed.
"Blank"	Removes the selected trace from the display.

SCPI command:

DISPlay[:WINDow<n>]:TRACe<t>:MODE on page 333

Evaluation

Defines whether the trace displays the evaluation of the measured signal or the reference signal (if "Meas & Ref Signal" is used as the evaluation data source, see "Signal Source" on page 197).

SCPI command:

CALCulate<n>:TRACe<t>[:VALue] on page 332

Predefined Trace Settings - Quick Config

Commonly required trace settings have been predefined and can be applied very quickly by selecting the appropriate button.

Function	Trace Settings	
Preset All Traces	Trace 1:	Clear Write
	Traces 2-6:	Blank
Set Trace Mode Max | Avg | Min	Trace 1:	Max Hold
	Trace 2:	Average
	Trace 3:	Min Hold
	Traces 4-6:	Blank
Set Trace Mode Max | ClrWrite | Min	Trace 1:	Max Hold
	Trace 2:	Clear Write
	Trace 3:	Min Hold
	Traces 4-6:	Blank

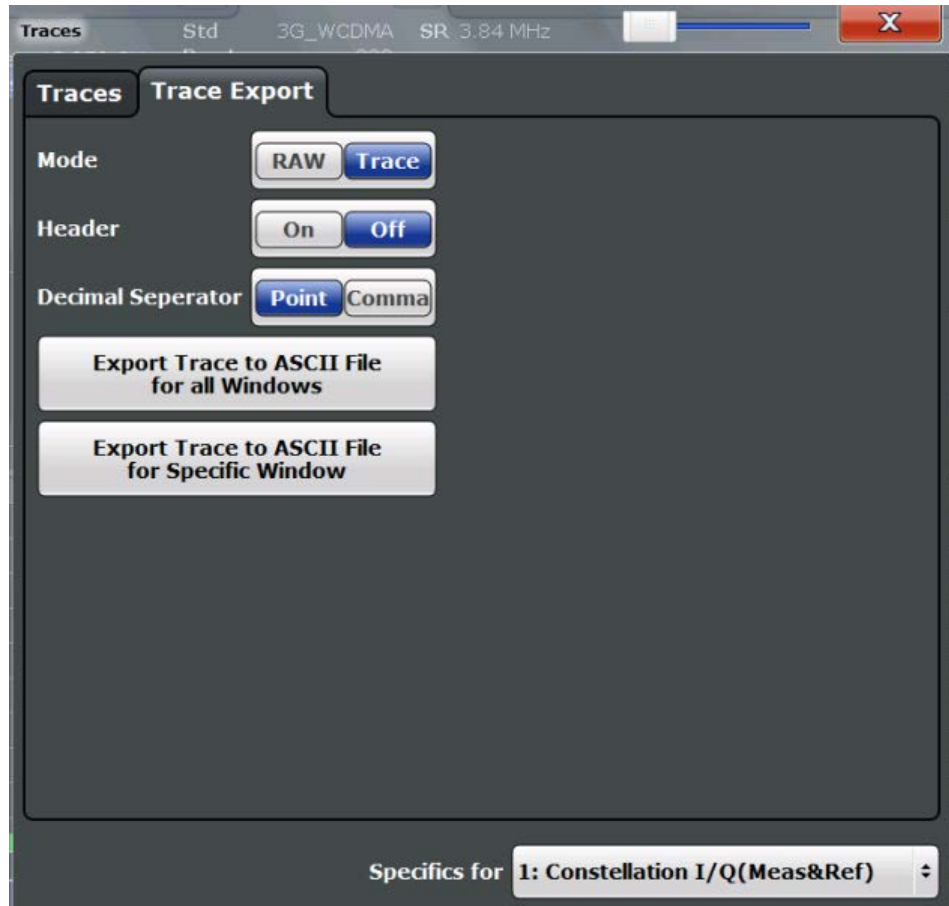**Trace 1/Trace 2/Trace 3/Trace 4 (Softkeys)**

Displays the "Traces" settings and focuses the "Mode" list for the selected trace.

SCPI command:

DISPlay[:WINDow<n>]:TRACe<t>[:STATe] on page 333

6.2 Trace Export Settings

The captured (trace) data can also be exported to an ASCII file. The format of these files can be configured.

Data Export Mode
Defines whether raw I/Q data (as captured) or trace data (evaluated) is stored.

SCPI command:
`FORMat:DEXPort:MODE` on page 362

Header
If enabled, a header with scaling information etc. is included in the file.

SCPI command:
`FORMat:DEXPort:HEADer` on page 362

Decimal Separator

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

SCPI command:

FORMat:DEXPort:DSEParator on page 362

Trace ASCII Export

Opens a file selection dialog box and saves the traces of the captured data in ASCII format to the specified file and directory.

Either the traces for the selected window only (see "Specifics for" on page 125) are exported, or the traces of all windows are exported, one after the other.

For details on the file format see chapter A.3, "ASCII File Export Format for VSA Data", on page 406.

SCPI command:

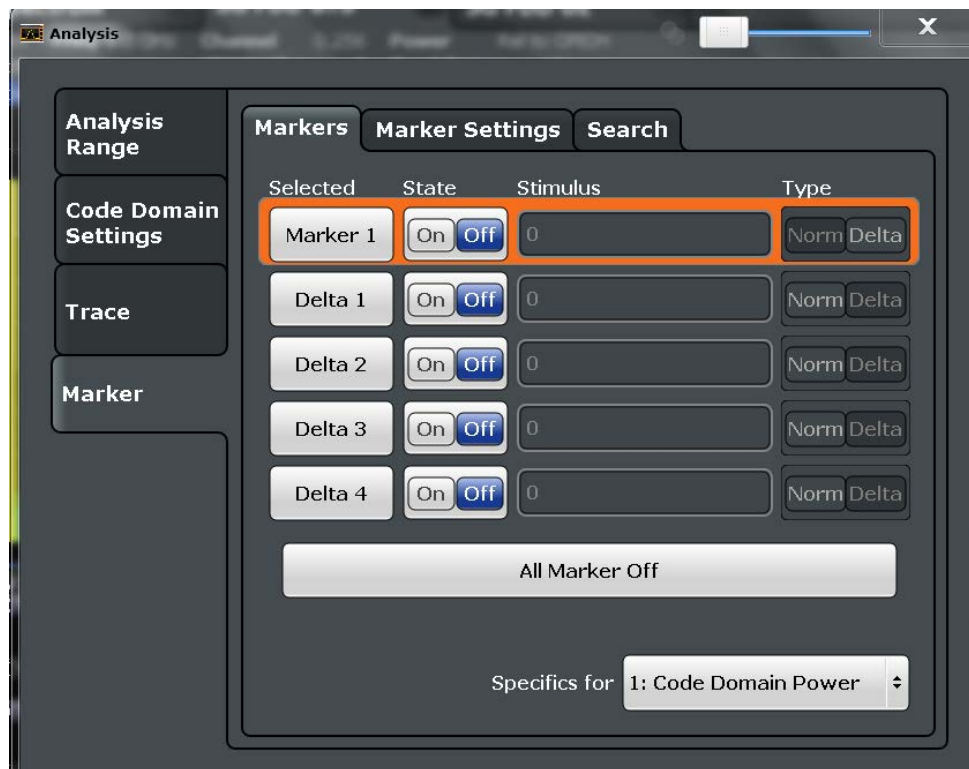MMEMory:STORe<n>:TRACe on page 363

6.3 Markers

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

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

● In the "Overview", select "Analysis", and switch to the vertical "Marker" tab.
● Press the MKR key, then select the "Marker Config" softkey.

6.3.1 Individual Marker Settings

In VSA evaluations, up to 5 markers can be activated in each diagram at any time.

Selected Marker

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

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

Marker State

Activates or deactivates the marker in the diagram.

SCPI command:
CALCulate<n>:MARKer<m>[:STATe] on page 335
CALCulate<n>:DELTamarker<m>[:STATe] on page 336

Stimulus

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

SCPI command:
CALCulate<n>:DELTamarker<m>:X on page 336
CALCulate<n>:MARKer<m>:X on page 335

Marker Type

Toggles the marker type.

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

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

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

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

SCPI command:

CALCulate<n>:MARKer<m>[:STATe] on page 335

CALCulate<n>:DELTamarker<m>[:STATe] on page 336

Assigning the Marker to a Trace

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

The marker can also be assigned to the currently active trace using the "Marker to Trace" softkey.

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

SCPI command:

CALCulate<n>:MARKer<m>:TRACe on page 335

All Markers Off

Deactivates all markers in one step.

SCPI command:

CALCulate<n>:MARKer<m>:AOFF on page 334

Couple Windows

If enabled, markers in all diagrams with the same x-axis (time or symbols) have coupled x-values (except for capture buffer display), i.e. if you move the marker in one diagram, it is moved in all coupled diagrams.

SCPI command:

CALCulate<n>:MARKer<m>:LINK on page 334

6.3.2 Marker Search Settings

Several functions are available to set the marker to a specific position very quickly and easily. In order to determine the required marker position, searches may be performed. The search results can be influenced by special settings.

These settings are available as softkeys in the "Marker To" menu, or in the "Search" tab of the "Marker" dialog box. To display this tab, do one of the following:

- Press the MKR key, then select the "Marker Config" softkey. Then select the horizontal "Search" tab.
- In the "Overview", select "Analysis", and switch to the vertical "Marker Config" tab. Then select the horizontal "Search" tab.
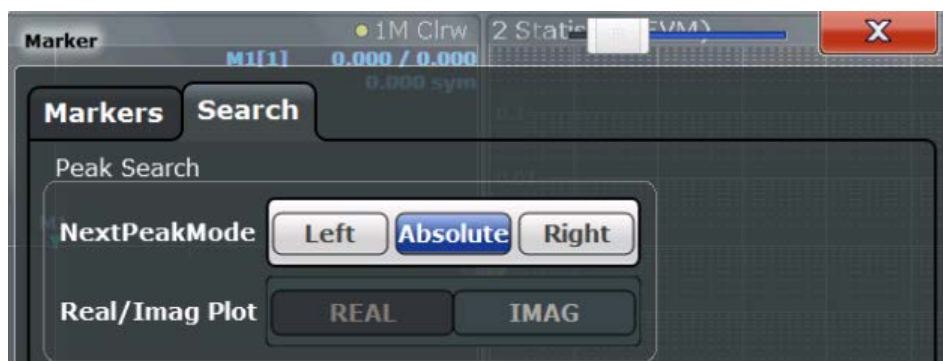
Search Mode for Next Peak
Selects the search mode for the next peak search.

"Left"   Determines the next maximum/minimum to the left of the current peak.

"Absolute"   Determines the next maximum/minimum to either side of the current peak.

"Right"   Determines the next maximum/minimum to the right of the current peak.

SCPI command:
CALCulate<n>:DELTamarker<m>:MAXimum:LEFT on page 337
CALCulate<n>:MARKer<m>:MAXimum:LEFT on page 339
CALCulate<n>:DELTamarker<m>:MAXimum:NEXT on page 338
CALCulate<n>:MARKer<m>:MAXimum:NEXT on page 339
CALCulate<n>:DELTamarker<m>:MAXimum:RIGHt on page 338
CALCulate<n>:MARKer<m>:MAXimum:RIGHt on page 339
CALCulate<n>:DELTamarker<m>:MINimum:LEFT on page 338
CALCulate<n>:MARKer<m>:MINimum:LEFT on page 340
CALCulate<n>:DELTamarker<m>:MINimum:NEXT on page 338
CALCulate<n>:MARKer<m>:MINimum:NEXT on page 340
CALCulate<n>:DELTamarker<m>:MINimum:RIGHt on page 339
CALCulate<n>:MARKer<m>:MINimum:RIGHt on page 340

Real / Imag Plot
Defines whether marker search functions are performed on the real or imaginary trace of the "Real/Imag" measurement.

SCPI command:
CALCulate<n>:MARKer:SEARch on page 341

Search Limits (Left / Right)

If activated, limit lines are defined and displayed for the search. Only results within the limited search range are considered.

SCPI command:

CALCulate:MARKer:X:SLIMits[:STATe] on page 342

CALCulate:MARKer:X:SLIMits:LEFT on page 341

CALCulate:MARKer:X:SLIMits:RIGHT on page 341

6.3.3 Marker Positioning Functions

The following functions set the currently selected marker to the result of a peak search. These functions are available as softkeys in the "Marker To" menu, which is displayed when you press the MKR -> key.

Peak Search

Sets the selected marker/delta marker to the maximum of the trace. If no marker is active, marker 1 is activated.

SCPI command:

CALCulate<n>:MARKer<m>:MAXimum[:PEAK] on page 340

CALCulate<n>:DELTamarker<m>:MAXimum[:PEAK] on page 338

Search Next Peak

Sets the selected marker/delta marker to the next (lower) maximum of the assigned trace. If no marker is active, marker 1 is activated.

SCPI command:

CALCulate<n>:MARKer<m>:MAXimum:NEXT on page 339

CALCulate<n>:DELTamarker<m>:MAXimum:NEXT on page 338

Max |Peak|

Sets the active marker/delta marker to the largest absolute peak value (maximum or minimum) of the selected trace.

SCPI command:

CALCulate<n>:MARKer<m>:MAXimum:APEak on page 339

Search Minimum

Sets the selected marker/delta marker to the minimum of the trace. If no marker is active, marker 1 is activated.

SCPI command:

CALCulate<n>:MARKer<m>:MINimum[:PEAK] on page 340

CALCulate<n>:DELTamarker<m>:MINimum[:PEAK] on page 339

Search Next Minimum

Sets the selected marker/delta marker to the next (higher) minimum of the selected trace. If no marker is active, marker 1 is activated.

SCPI command:

CALCulate<n>:MARKer<m>:MINimum:NEXT on page 340

CALCulate<n>:DELTamarker<m>:MINimum:NEXT on page 338

6.4 Modulation Accuracy Limit Lines

The results of a modulation accuracy measurement can be checked for violation of defined limits automatically (see "Modulation Accuracy" on page 18).

Limits and the limit check are configured in the "Limits" dialog box that is displayed when you press the "ModAcc Limits Config" softkey in the "Lines" menu.
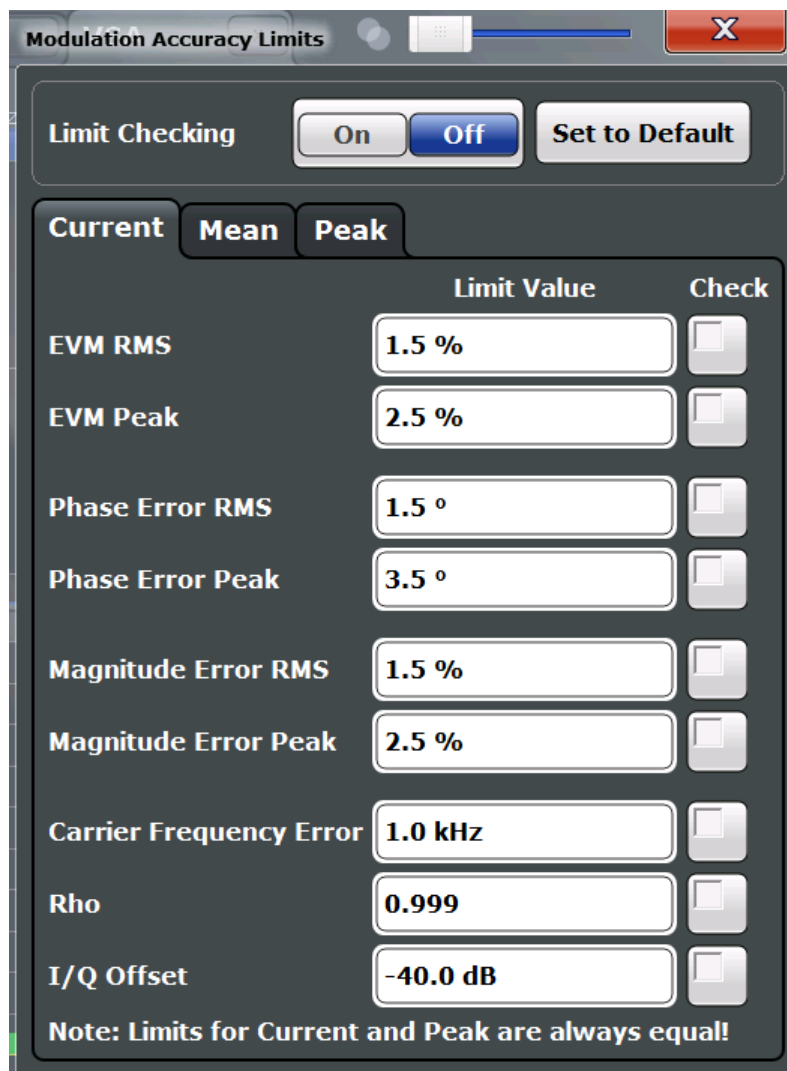
For details on working with limits see chapter 7.3.2, "How to Check Limits for Modulation Accuracy", on page 216.

Checking Modulation Accuracy Limits
Activates or deactivates evaluation of modulation accuracy limits in the result summary.

SCPI command:
CALCulate:LIMit:MACCuracy:STATe on page 342

Set to Default
Restores the default limits and deactivates all checks.

SCPI command:
CALCulate:LIMit:MACCuracy:DEFault on page 342

Current/Mean/Peak
Defines and activates the limits for the currently measured value, the mean and the peak value on separate tabs. Note that the limits for the current and peak values are always the same.

Limit Value ← Current/Mean/Peak
Define the limit with which the currently measured, mean or peak value is to be compared. A different limit value can be defined for each result type. Depending on the modulation type, different result types are available.

Result type	Remote command
PSK, MSK, QAM:	
EVM RMS	CALCulate<n>:LIMit:MACCuracy:EVM:RCURrent:VALue on page 345
EVM Peak	CALCulate<n>:LIMit:MACCuracy:EVM:PCURrent:VALue on page 345
Phase Err Rms	CALCulate<n>:LIMit:MACCuracy:PERRor:RCURrent:VALue on page 346
Phase Err Peak	CALCulate<n>:LIMit:MACCuracy:PERRor:PCURrent:VALue on page 346
Magnitude Err Rms	CALCulate<n>:LIMit:MACCuracy:MERRor:RCURrent:VALue on page 346
Magnitude Err Peak	CALCulate<n>:LIMit:MACCuracy:MERRor:PCURrent:VALue on page 346
Carr Freq Err	CALCulate<n>:LIMit:MACCuracy:CFERror:CURRent:VALue on page 344
Rho	CALCulate<n>:LIMit:MACCuracy:RHO:CURRent:VALue on page 347

Result type	Remote command
IQ Offset	`CALCulate<n>:LIMit:MACCuracy:OOFFset:CURRent:VALue` on page 346
FSK modulation only:	
Freq Err Rms	`CALCulate<n>:LIMit:MACCuracy:FERRor:RCURrent:VALue` on page 345
Freq Err Peak	`CALCulate<n>:LIMit:MACCuracy:FERRor:PCURrent:VALue` on page 345
Magnitude Err Rms	`CALCulate<n>:LIMit:MACCuracy:MERRor:RCURrent:VALue` on page 346
Magnitude Err Peak	`CALCulate<n>:LIMit:MACCuracy:MERRor:PCURrent:VALue` on page 346
FSK Dev Err	`CALCulate<n>:LIMit:MACCuracy:FERRor:PCURrent:VALue` on page 345
Carr Freq Err	`CALCulate<n>:LIMit:MACCuracy:CFERror:CURRent:VALue` on page 344

Check ← Current/Mean/Peak

Considers the defined limit value in the limit check, if checking is activated.

SCPI command:

`CALCulate<n>:LIMit:MACCuracy:<ResultType>:<LimitType>:STATe` on page 343

6.5 Display and Window Configuration

The captured I/Q data can be evaluated using various different methods without having to start a new measurement.

As opposed to the R&S FSW Spectrum application or other applications, in VSA configuring the result display requires two steps:

1. **Display Configuration:** In the first step, you select the data source for the evaluation and the window placement in the SmartGrid.
   The SmartGrid mode is activated automatically when you select the "Display Config" softkey from the main VSA menu or the "Display Config" button in the Overview. Note, however, that this button is only displayed in the general Overview, not for window-specific configuration ("Specifics for" must be disabled).
   The default evaluation for the selected data source is displayed in the window.
   Up to 16 result displays can be displayed simultaneously in separate windows. The VSA evaluation methods are described in chapter 3, "Measurements and Result Displays", on page 15.
   For details on working with the SmartGrid see the R&S FSW Getting Started manual.

2. **Window Configuration:** In a second step, you can select a different evaluation method (result type) for the window, based on the data source selected in the "Display Configuration".

6.5.1 Window Configuration

For each window you can select a different evaluation method (result type), based on the data source selected in the "Display Configuration". Further window settings are available for some result types.

The "Window Configuration" is displayed when you select the "Window Config" softkey from the main VSA menu.

Some settings are only displayed after you select the "More" button in the dialog box. To hide these settings, select the "Less" button.

Signal Source
Data source as selected in the "Display Configuration" (see chapter 3, "Measurements and Result Displays", on page 15). If you change the signal source setting here, the default result type for the new data source is activated for the current window.

SCPI command:
LAYout:ADD[:WINDow]? on page 351

Result Type
The result type defines the evaluation method used in the current window.

The available result types in VSA are described in chapter 3.2, "Result Types in VSA", on page 19.

SCPI command:
CALCulate<n>:FORMat on page 357

Result Type Transformation
For certain result types it is not only possible to see the common "over time" representation of the measurement, but also the spectrum or the statistics (in form of a histogram). These are the transformations of the results.

These settings are not available for symbol evaluation, i.e. the following signal sources:

● Symbols
● Modulation Accuracy

"Normal"　　　　　Evaluation in time domain
　　　　　　　　　　X-axis displays time values.

"Spectrum"   Evaluation in frequency domain
               X-axis displays frequency values. The usable I/Q bandwidth is indicated
               in the display.

"Statistics"   Statistical evaluation (histogram)
               X-axis displays former y-values. Y-axis displays statistical information:

- Trace 1: the probability of occurrence of a certain value is plotted
  against the value
- Trace 2: the cumulated probability of occurance is plotted against
  the value.

SCPI command:
CALCulate<n>:DDEM:SPECtrum[:STATe] on page 357
CALCulate<n>:STATistics:CCDF[:STATe] on page 358

Highlight Symbols
If enabled, the symbol instants are highlighted as squares in the window for measured
and reference signals in time (normal) display, as well as error displays.

Only evaluations that are based on symbols (e.g. constellations or traces) support this
function.

SCPI command:
DISPlay[:WINDow<n>]:TRACe:SYMBol on page 360

Display Points/Sym
Defines the number of display points that are displayed per symbol. If more points per
symbol are selected than the defined Sample Rate, the additional points are interpolated
for the display. The more points are displayed per symbol, the more detailed the trace
becomes.

For more information see chapter 4.7, "Display Points vs Estimation Points per Symbol", on page 115

Note: If the capture buffer is used as the signal source, the Sample Rate defines the
number of displayed points per symbol; the "Display Points/Sym" parameter is not available.

If "Auto" is enabled, the Sample Rate value is used.

Alternatively, select the number of points to be displayed per symbol manually. The
available values depend on the source type.

"1"   only the symbol time instants are displayed

"2, 4, 8, 16, 32"   more points are displayed than symbols

"Capture Over-   the number of samples per symbol defined in the signal capture settings
sampling"   are displayed (see "Sample Rate" on page 153)

SCPI command:
DISPlay[:WINDow<n>]:PRATe[:VALue] on page 359
DISPlay[:WINDow<n>]:PRATe:AUTO on page 359

Oversampling
Defines the sample basis for statistical evaluation. This setting is only available for the
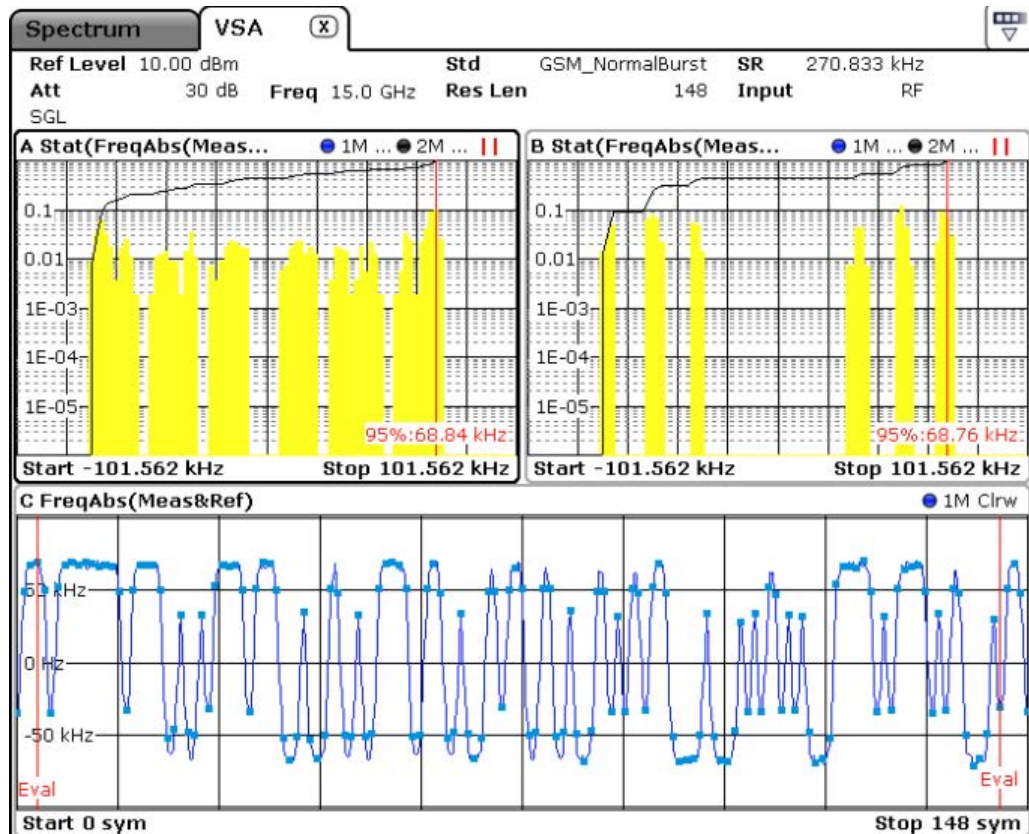result type transformation "Statistics".

Fig. 6-1: Statistics measurement: window C: measured signal (symbols highlighted); window A: statistics for all trace points; window B: statistics for symbol instants only

"Symbols only"   Statistics are calculated for symbol instants only
                   See window B in figure 6-1.

"Infinite"   Statistics are calculated for all trace points (symbol instants and inter-
                   mediate times)
                   See window A in figure 6-1.

"auto"   currently not used

SCPI command:
CALCulate<n>:STATistics:MODE on page 359

6.6 Zoom Functions

The zoom functions are only available from the toolbar.

Single Zoom

A single zoom replaces the current diagram by a new diagram which displays an enlarged extract of the trace. This function can be used repetitively until the required details are visible.

SCPI command:

DISPlay[:WINDow<n>]:ZOOM:STATe on page 348

DISPlay[:WINDow<n>]:ZOOM:AREA on page 347

Multiple Zoom

In multiple zoom mode, you can enlarge several different areas of the trace simultaneously. An overview window indicates the zoom areas in the original trace, while the zoomed trace areas are displayed in individual windows. The zoom area that corresponds to the individual zoom display is indicated in the lower right corner, between the scrollbars.

SCPI command:

DISPlay[:WINDow<n>]:ZOOM:MULTiple<zoom>:STATe on page 349

DISPlay[:WINDow<n>]:ZOOM:MULTiple<zoom>:AREA on page 348

Restore Original Display

Restores the original display and closes all zoom windows.

SCPI command:

DISPlay[:WINDow<n>]:ZOOM:STATe on page 348 (single zoom)

DISPlay[:WINDow<n>]:ZOOM:MULTiple<zoom>:STATe on page 349 (for each multiple zoom window)

Deactivating Zoom (Selection mode)

Deactivates zoom mode; tapping the screen no longer invokes a zoom, but selects an object.

SCPI command:

DISPlay[:WINDow<n>]:ZOOM:STATe on page 348 (single zoom)

DISPlay[:WINDow<n>]:ZOOM:MULTiple<zoom>:STATe on page 349 (for each multiple zoom window)