R&S®SMW-K540, R&S®SMW-K541, R&S®SMW-K546
Envelope Tracking, AM/AM, AM/PM Predistortion, Digital Doherty
User Manual

1176950602
Version 24

ROHDE&SCHWARZ
Make ideas real

This document describes the following software options:

- R&S®SMW-K540 Envelope Tracking (1413.7215.xx)
- R&S®SMW-K541 AM/AM, AM/PM Predistortion (1413.7267.xx)
- R&S®SMW-K546 Digital Doherty (1414.6487-xx)

This manual describes firmware version FW 5.30.047.xx and later of the R&S®SMW200A.

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1176.9506.02 | Version 24 | R&S®SMW-K540, R&S®SMW-K541, R&S®SMW-K546

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

Contents

1 Welcome to the R&S SMW-K54x options

The R&S SMW-K540 is a software option that allows you to generate an envelope tracking signal, that follows the envelope variation of the RF signal.

R&S SMW-K540 key features

- Baseband signal, RF signal, and envelope signal generation out of one instrument
- Envelope signal derived directly and in real time from the baseband signal
- Fully synchronous envelope and RF signal with optional delay compensation for time alignment of the envelope signal
- Simultaneous output of envelope and inverted envelope signal
- Flexible envelope shaping based on different algorithms incl. a build-in table shaping editor
- Import/export interface for files describing shaping functions
- Real-time display of the characteristics of the envelope signal

The R&S SMW-K541 is a software option that adds functionality to define and apply AM/AM and AM/PM predistortions.

R&S SMW-K541 key features

- Applying user-defined AM/AM and AM/PM digital predistortions directly on the digital baseband signal
- Digital predistortions are applied directly and in real time to the baseband signal, i.e. to any Digital Standard signal or with ARB waveforms
- Separate or superimposed AM/AM or AM/PM predistortion also with variable order in the processing flow
- Flexible shaping of the predistortion functions based on a polynomial function and a build-in table editor
- Import/export interface for files describing the predistortion functions, i.e. load of AM/AM and AM/PM tables directly from characterization software
- Real-time display of the correction functions
- In instruments equipped with the option R&S SMW-K540, digitally predistorted baseband signal, RF signal, and envelope signal generation out of one instrument

The R&S SMW-K546 is a software option that assists development and testing of Doherty amplifiers by digitally splitting one input signal into two components for carrier and peaking amplifiers.

R&S SMW-K546 key features

- RF signals for two power amplifiers (PA) generated out of one instrument
- Ensured constant phase delta between the two RF signals
- Applying user-defined, input power dependent power and phase functions directly and in real time on the digital baseband signal

- Flexible shaping of the power and phase based on a polynomial function and a built-in table editor
- Import/export interface for files describing the power and phase functions, i.e. load of shaping tables directly from characterization software
- Real-time display of the power and phase correction values
- In instruments equipped with the option R&S SMW-K541, superimposing digital predistortion and digital Dohtery

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

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

www.rohde-schwarz.com/manual/SMW200A

Installation

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

1.1 Accessing the required settings

To open the dialog with Envelope Tracking settings

1. In the block diagram of the R&S SMW, select the "I/Q OUT" connector to unfold the "I/Q Analog" block.

   A dialog box opens that displays the provided general settings.

2. Select "I/Q Analog > I/Q Analog Outputs > General".
3. Select "RF Envelope > On".

To open the dialog with DPD settings

► In the block diagram of the R&S SMW, select "I/Q Mod > Digital Predistortion > AM/AM AM/PM".

A dialog box opens that displays the provided settings.

The signal generation is not started immediately. To start signal generation with the default settings, select "State > On".

To open the dialog with Digital Doherty settings

► In the block diagram of the R&S SMW, select "I/Q Mod > Digital Predistortion > Digital Doherty".

A dialog box opens that displays the provided settings.

1.2 What's new

This manual describes firmware version FW 5.30.047.xx and later of the R&S®SMW200A.

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

- Applying DPD to improve EVM performance at high output powers, see "To apply DPD for improved EVM performance" on page 91 and 1GP139.
- Signal routing properties for an envelop tracking signal added, see "Envelope tracking signal routing" on page 14.

1.3 Documentation overview

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

www.rohde-schwarz.com/manual/smw200a

1.3.1 Getting started manual

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

1.3.2 User manuals and help

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

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

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

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

1.3.3 Tutorials

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

1.3.4 Service manual

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

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

https://gloris.rohde-schwarz.com

1.3.5 Instrument security procedures

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

1.3.6 Printed safety instructions

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

1.3.7 Data sheets and brochures

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

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

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

1.3.8 Release notes and open source acknowledgment (OSA)

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

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

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

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

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

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

1.3.10 Videos

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

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

Figure 1-1: Product search on YouTube

1.4 Scope

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

In particular, it includes:

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

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

1.5 Notes on screenshots

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

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

2 Generation of envelope tracking signals

Envelope tracking (ET) is a method used by modern power amplifiers (PA) to improve their efficiency, especially when amplifying RF signals with a high peak to average power (PAPR). An envelope tracking detector "tracks" the power variations in the input signal of the PA. The PA then varies synchronously to this variation the supply voltage v_{cc} at its end-amplifying stage.

This section introduces the concept of the envelope tracking functionality and the way that it is implemented in the R&S SMW.

Refer to Chapter 5, "How to generate a control signal for power amplifier envelope tracking tests", on page 83 for step-by-step instruction on how to use the provided function.

2.1 Required options

The equipment layout for generation and output of envelope tracking signal includes:

- Option Standard or wideband Baseband Generator (R&S SMW-B10/-B9)
  Option Baseband Main Module, one/two I/Q paths to RF (R&S SMW-B13/B13T) or Wideband baseband main module (R&S SMW-B13XT)
  Incl. output the baseband signal at the single ended outputs
- Option Differential Analog I/Q Outputs (R&S SMW-K16) per signal path
- Option Envelope Tracking (R&S SMW-K540) per signal path
  If R&S SMW-B13XT is installed, the option can be installed once, in path A
- Optional option AM/AM AM/PM Predistortion (R&S SMW-K541) per signal path

For more information, see data sheet.

2.2 About the envelope tracking

The R&S SMW allows you to generate an envelope tracking signal, that follows the envelope variation of the RF signal.

Principle of the envelope tracking

The Figure 2-1 shows a simplified test setup for testing of a PA with an envelope tracking. This illustration is intended to explain the principle in general, not all connections and required equipment are considered.

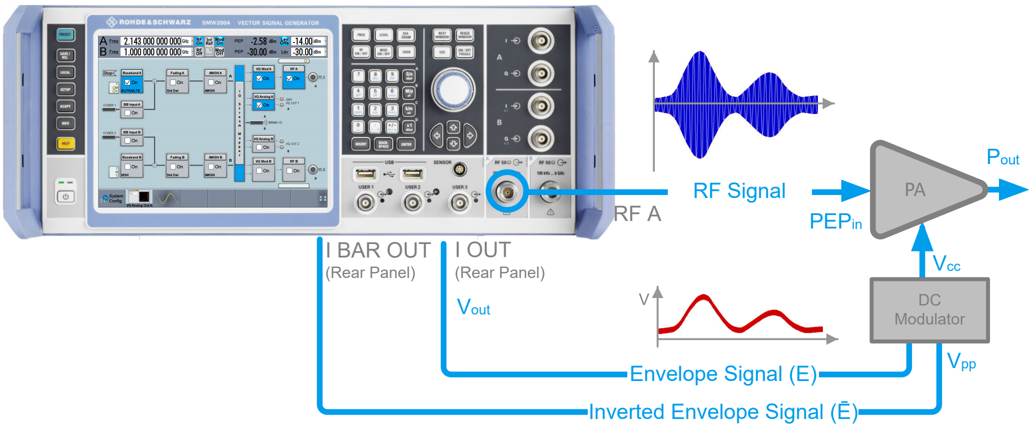


Figure 2-1: Simplified test setup for power amplifier envelope tracking tests

The R&S SMW in this setup is configured to generate both, an RF signal with complex modulation scheme and an envelope signal, that follows the envelope variation of this RF signal. A suitable test signal is, for example, an EUTRA/LTE DL signal.

The R&S SMW generates the envelope signal directly from the baseband signal. The envelope signal is a voltage signal, with voltage level V_{out} proportional to the power of the RF signal ($\sqrt{[I(t)^2+Q(t)^2]}$) of the corresponding path. If you do not apply a shaping function, the envelope signal linear dependent follows the variation of the RF signal's envelope.

The envelope signal is output at the I out and I Bar out rear panel connectors. This envelope signal is then further fed to an external DC modulator.

The PA receives the RF input signal and the dynamically adapted supply voltage v_{cc}. Ideally, the PA gain stays constant.

Envelope tracking signal routing

Gernerating envelope tracking signals typically requires one signal stream, that is "Stream A" at the R&S SMW. Routing to the signal outputs is fixed as follows:

Stream	RF output	I/Q analog output (connector)
"Stream A"	"RF A"	"I/Q Analog A" ("I/Q Out 1" = I)

Suitable baseband signal to observe the effect of the envelope tracking settings

To simplify the explanation in the following sections, we use a simple ramp function as a baseband signal modulated on the RF carrier.

Other suitable baseband signals are signals with relative constant envelope. You find a choice of predefined signals in the "Baseband > Custom Digital Mod > Set according to standard" dialog. With the default settings in this dialog, you can observe the generated envelope signal and the effects of enabled shaping.

2.2.1 Envelope voltage adaptation modes

In the R&S SMW, you define the voltage of the generated envelope signal using one of the following modes:

- **Auto Power/Normilized Envelope Voltage Adaptation:**
  In this mode, you define the desired input characteristics of the power amplifier.
  Based on these values and depending on the crest factor of the generated signal, the R&S SMW calculates:
  – The voltage on the I out/I Bar out connectors (V_{out}Min/Max) and a bias (Bias),
  – The RMS level of the RF signal
  The auto voltage adaptation mode is a suitable choice, if you have knowledge on the power amplifier components and characteristics. Common PA characteristics are the supply voltage V_{cc}, the input power PEP_{in} required for working in the linear range and the gain characteristics of the external DC modulator.
  You find the required values in the documentation of your power amplifier, for example in its data sheet.
- **Manual Envelope Voltage Adaptation:**
  In this mode, you can also define the operating range of the power amplifier based on a pre-gain and a post-gain range. Based on these values, the instrument calculates the supply voltage V_{cc}.

All modes support envelope shaping.

2.2.2 Signal parameters for testing according to the eTrak® specification

In the R&S SMW, you can select one of the predefined eTrak® interface types so that the generated signal is conformed with the MIPI®Alliance specification "Analog Reference Interface for Envelope Tracking Specification".

Table 2-1: Default parameters per eTrak® Interface Type

Parameter	1.2 Vpp	1.5 Vpp	2 Vpp
I/Q output Type	Differential	Differential	Differential
Bias	500 mV	600 mV	900 mV
Vpp Max	1.2 V	1.5 V	2 V
Vpp Max	1.2 V	1.5 V	2 V
Bipolar Input	On	On	On

2.2.3 Envelope shaping and shaping methods

Envelope shaping is a method that uses functions to describe the relationship between supply voltage and RF input power. An envelope-shaping function is a trade-off between effectivity and improved linearity of the PA.

In the R&S SMW, you can select the way you define the shaping function. You can choose between:

- 2 predefined simple linear functions
  (see Chapter 2.2.3.1, "About the linear functions", on page 16)
- 3 detroughing functions with a configurable factor
  (see Chapter 2.2.3.2, "About the detroughing function", on page 17)
- A polynomial function with up to 10 polynomial coefficients
  (see Chapter 2.2.3.3, "About the polynomial function", on page 17)
- A shaping function defined as a shaping table
  (see Chapter 2.2.3.4, "About the shaping table", on page 18)
- To set the correction values in raw format with a single remote control command
  (see Chapter 2.2.3.5, "Shaping function in raw data format", on page 19)

The linear, the detroughing and the polynomial shaping functions are mathematical expressions that are described as function of the variable x, see Table 2-2.

Table 2-2: Definition of the variable x depending on the envelope voltage adaptation mode

"Envelope Voltage Adaptation"	**x**
Auto Power	$x = V_{in} - V_{in, min}$ $x \geq 0$
Auto Normalized	$x = V_{in}/V_{in,max}$
Manual	$x = V_{Env}/V_{Env,max}$

The mathematical expressions and further information on the shaping functions are provided in the corresponding sections.

See also Chapter 2.2.3.6, "Converting shaping functions and understanding the displayed values", on page 20.

2.2.3.1 About the linear functions

The linear shaping can be used for less demanding applications, simple analysis, and the first interactions by designing the optimum envelope shape. Because the shaping gain of the linear function is 0 dB, in "Envelope Voltage Adaptation > Manual" mode this function is suitable for determining the "Pre-/Post-Gain" values (see Example"Calculating the current V_{CC} in "Manual" mode" on page 23).

Provided are two linear functions, where each of them depends on the "Envelope Voltage Adaptation" mode:

- Linear (Voltage)
  – f(x) = x in "Auto Normalized/Manual"

   - $f(x) = b*x + V_{cc,min}$ in "Auto Power"
- Linear (Power)
   - $f(x) = x^2$ in "Auto Normalized/Manual"
   - $f(x) = b*x^2 + V_{cc,min}$ in "Auto Power"

Where:

- The variable *x* depends on the "Envelope Voltage Adaptation" mode, see Table 2-2.
- The constant *b* is calculated as:
  $b = (V_{cc,max} - V_{cc,min})/(V_{in,max} - V_{in,min})$

See also Chapter 2.2.3.6, "Converting shaping functions and understanding the displayed values", on page 20.

2.2.3.2 About the detroughing function

Detroughing functions are well defined mathematical functions that prevent that the supply voltage V_{cc} drops down to zero or falls under specified limits. That is, they prevent that the signal is clipped.

Provided are the following functions:

- $f(x) = x + d*e^{-x/d}$
- $f(x) = 1 - (1 - d)*cos(x*pi/2)$
- $f(x) = d + (1 - d)*x^a$

Where:

- x is a variable, that depends on the "Envelope Voltage Adaptation" mode, see Table 2-2
- a is the Exponent (a).
- d is the Detroughing Factor (d), that limits the supply voltage V_{cc} in the low-power region and controls the shaping.
  The detroughing factor (d) can be set manually or derived from the selected V_{cc} value. In the latter case, it is calculated as follows:
  $d = V_{cc,min}/V_{cc,max}$
  See Couple Detroughing Factor with Vcc.
  A "Detroughing Factor = 0" defines a linear function.

See also Chapter 2.2.3.6, "Converting shaping functions and understanding the displayed values", on page 20.

2.2.3.3 About the polynomial function

The polynomial function is an analytical method to describe a shaping function. The polynomial function is defined as follows:

$f(x) = a_0 + \sum(a_n*x^n)$, where $n \leq 10$ and:

- Depending on the "Envelope Voltage Adaptation" mode, *f(x)* is:

  - $f(x) = V_{cc}(x)$ in "Auto Power"
  - $f(x) = V_{cc}/V_{cc,max}(x)$ in "Auto Normalized/Manual"
- The polynomial order *n*, the polynomial constant a_0, and polynomial coefficients a_0 to a_n are user-definable, see Chapter 2.7, "Polynomial coefficients settings", on page 45
- x depends on the "Envelope Voltage Adaptation" mode, see Table 2-2

The default polynomial function with n = 1, a_0 = 0 and a_0 = 1 describes a linear function.

See also:
- Figure 2-13
- Chapter 2.2.3.6, "Converting shaping functions and understanding the displayed values", on page 20.

File format of the polynomial function file

You can store a polynomial function in a file or even define the polynomial coefficients, store them as a file and load this file into the instrument. The polynomial files are files with extension `*.iq_poly`.

The file contains an optional header `# Rohde & Schwarz - IQ Output Envelope Polynomial Coefficients # a0,a1,a2,...` and a list of comma-separated coefficient values.

Example: Polynomial function file content

```
# Rohde & Schwarz - IQ Output Envelope Shaping Table
# a0,a1,a2,...
0.135,0.91,0.34,-0.59,-0.11
```

2.2.3.4 About the shaping table

The envelope-shaping table is a widely used method to define the shaping function. This kind of definition is suitable if you have knowledge on or aim to achieve an exact relation between supply voltage and RF input power. For example, with suitable settings, the shaping table can precisely describe the transition region of the PA.

You can receive information on suitable envelope-shaping values form the power amplifier manufacturer.

In the R&S SMW, there are two ways to define a shaping table function:

- **Externally**
  Create a shaping table file as a CSV file with Microsoft Excel, with a Notepad or a similar tool. Save it with the predefined extension, transfer it to and load it into the instrument.
  See also "File format of the shaping table file" on page 19.
- **Internally**
  Use the built-in editor table editor, see Chapter 2.6, "Edit I/Q envelope shape settings", on page 43.

File format of the shaping table file

The shaping table files are files with predefined extension and simple file format, see Table 2-3.

Table 2-3: Shaping table files: format and extensions

"Envelope Voltage Adaptation"	File extension	Header (optional)
Auto Power	`*.iq_lutpv`	`# Rohde & Schwarz - IQ Output Envelope Shaping Table` `# Power[dBm],Vcc[V]`
Auto Normalized/Manual	`*.iq_lut`	`# Rohde & Schwarz - IQ Output Envelope Shaping Table` `# Vin/Vmax,Vcc/Vmax`

The header is optional. The file content is list of up to 4000 comma-separated value pairs; a new line indicator separates the pairs.

Example: Shaping table file content (*.iq_lut file)

```
# Rohde & Schwarz - IQ Output Envelope Shaping Table
# Vin/Vmax,Vcc/Vmax
0.3,0.4
0.35,0.45
0.56,0.55
0.4,0.5
0.6,0.65
0,0.135
```

2.2.3.5 Shaping function in raw data format

The shaping values are defined directly, with a single remote control command. You define up to 4000 comma-separated value pairs, describing the `Vin/Vmax,Vcc/Vmax` or `Power[dBm],Vcc[V]`.

Example:

```
SOURce1:OUTPut:ANALog:ENVelope:SHAPing:PV:FILE:DATA 0,0, 0.1,0.2, 1,1
```

See:

- `[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:FILE:DATA` on page 107
- `[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:PV:FILE:DATA` on page 107
- `[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:FILE:NEW` on page 107
- `[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:PV:FILE:NEW` on page 107

2.2.3.6 Converting shaping functions and understanding the displayed values

If an envelope function is defined, the "Shaping" dialog displays the diagram of the resulting envelope shape.

See for example Figure 2-7.

Several parameters influence the displayed information:

- The selected "Envelope Voltage Adaptation" determines whether the x-axis uses normalized or linear values
- The selected "Graphic Configuration > Scale" sets the x-axis units
- The selected V_{cc}Min/Max and PEP_{in}Min/Max values set the borders of the clipping areas
- The selected "Shaping" function and the parameters influence the envelope shape.

The illustration on Figure 2-2 shows how these parameters influence a linear shaping function.

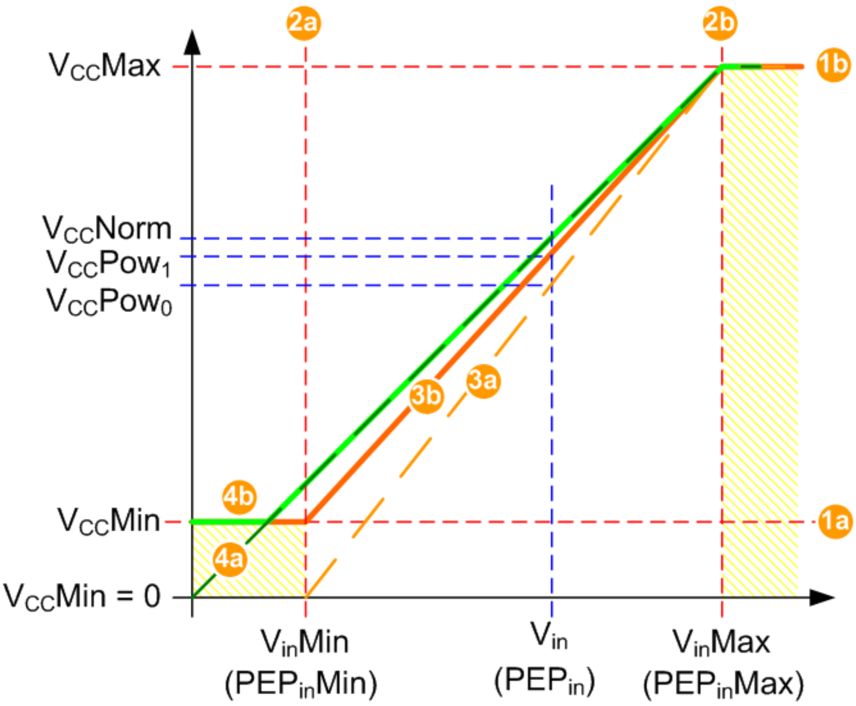


Figure 2-2: Understanding the displayed values ("Shaping > Linear (Voltage)")

Shaded area = Area where the signal is clipped and the envelope signal is held constant.
1a, 1b, 2a, 2b = $V_{cc,min}$/$V_{cc,max}$ and PEP_{in}Min/Max values that set the borders of the clipping areas
Shaping = Linear (Voltage)
3a = Linear function (dashed line) in "Auto Power" mode, if $V_{cc,min}$ = 0 V
3b = Linear function in "Auto Power" mode, if $V_{cc,min}$ > 0 V
4a = Linear function (dashed line) in "Auto Normalized" mode, if $V_{cc,min}$ = 0 V
4b = Linear function in "Auto Normalized" mode, if $V_{cc,min}$ > 0 V
V_{in} = Operating point
V_{cc}Norm = V_{cc} in "Auto Normalized" mode
$V_{cc}Pow_0$ = V_{cc} in "Auto Power" mode and $V_{cc,min}$ = 0 V
$V_{cc}Pow_1$ = V_{cc} in "Auto Power" mode and $V_{cc,min}$ > 0 V

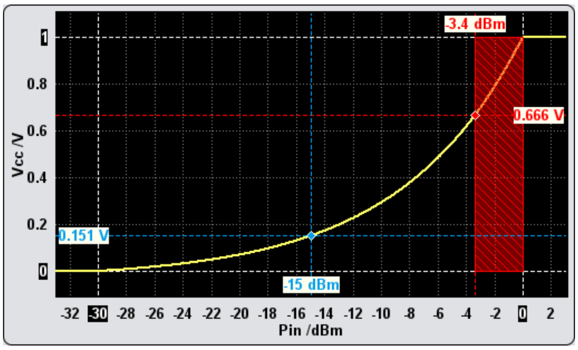
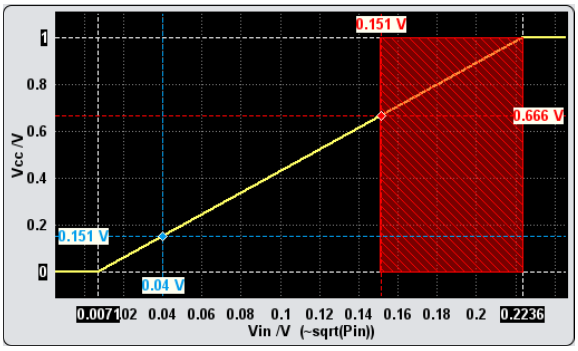
For information on the provided shaping functions and their formulas, see:

- Chapter 2.2.3.1, "About the linear functions", on page 16
- Chapter 2.2.3.2, "About the detroughing function", on page 17
- Chapter 2.2.3.3, "About the polynomial function", on page 17

The group of examples in this section uses the same linear shaping function to explain the representation in the different voltage adaptation modes. The example explains the displayed values and how they are calculated and converted. The same principle applies for the other shaping methods.

Common settings

- "Envelope Voltage Adaptation > Auto Power"
- V_{cc} Max = 1 V
- PEP_{in}Min = -30 dBm corresponds to $V_{in,min}$ = 0.0071 V
- PEP_{in}Max = 0 dBm corresponds to $V_{in,max}$ = 0.2236 V
- P_{in} = -15 dBm corresponds V_{in} = 0.04 V
- PEP = -3.4 dB
- "Shaping > Linear (Voltage)"

"Graphic Scale > Power"	"Graphic Scale > Voltage"
	

Example: Calculating the current $V_{cc}Pow_0$ ("Auto Power" mode, V_{cc} Min = 0 V)

Configuration as described in Common settings and:

- **$V_{cc,min}$ = 0 V**
- $f(x) = b*x + V_{cc,min}$
  (see Chapter 2.2.3.1, "About the linear functions", on page 16)

$V_{cc}Pow_0 = [(V_{cc,max} - V_{cc,min})/(V_{in,max} - V_{in,min})] * (V_{in} - V_{in,min}) + V_{cc,min}$

$V_{cc}Pow_0 = [(1 - 0)/(0.2236 - 0.0071)]*(0.04 - 0.0071) + 0$

$V_{cc}Pow_0$ = 0.151 V

Example: Calculating the current $V_{cc}Pow_1$ ("Auto Power" mode, V_{cc} Min > 0 V)

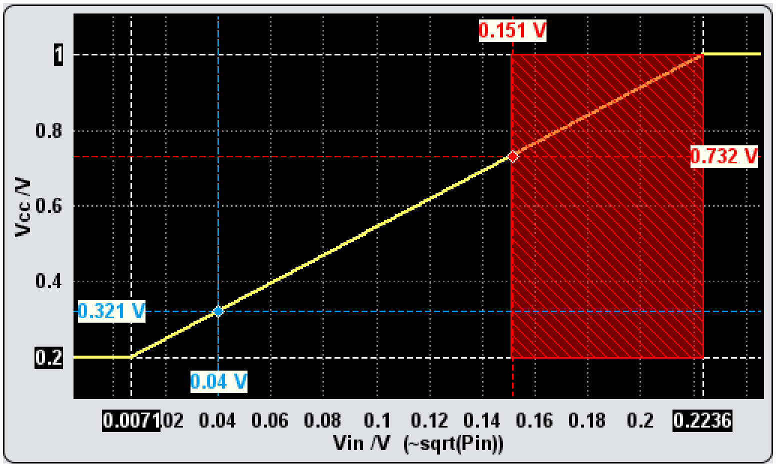
Configuration as described in Common settings and:

- **$V_{cc,min}$ = 200 mV**

$V_{cc}Pow_1 = [(V_{cc,max} - V_{cc,min})/(V_{in,max} - V_{in,min})] * (V_{in} - V_{in,min}) + V_{cc,min}$

$V_{cc}Pow_1 = [(1 - 0.2)/(0.2236 - 0.0071)]*(0.04 - 0.0071) + 0.2$

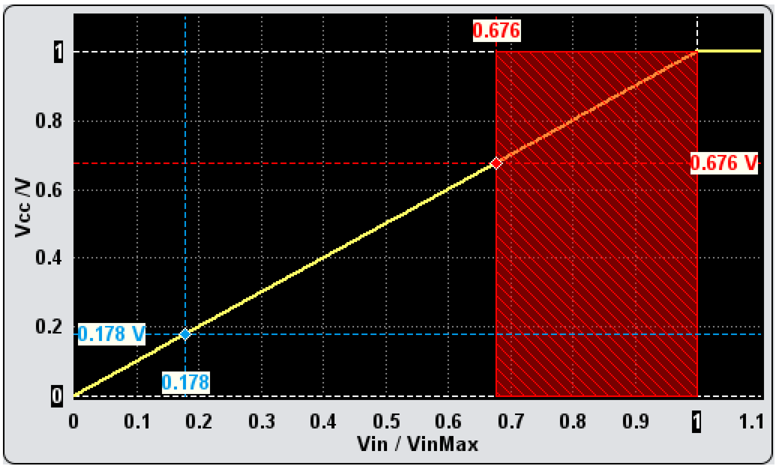
$V_{cc}Pow_1$ = 0.321 V



Example: Calculating the current $V_{cc}Norm$ ("Auto Normalized" mode)

Configuration as described in Common settings and:

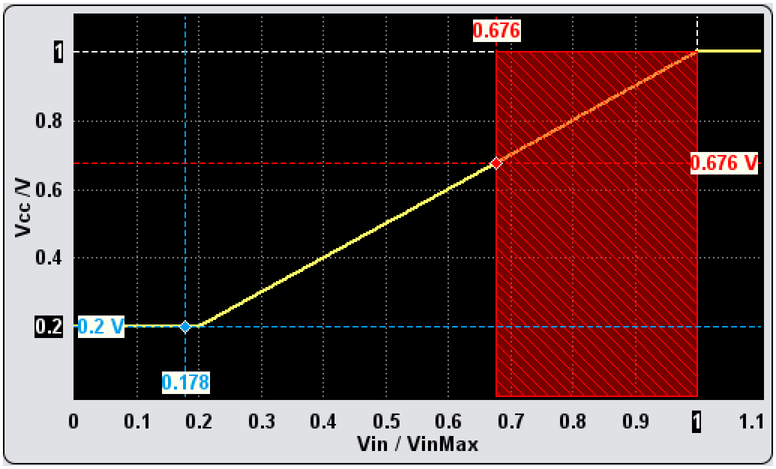
- "Envelope Voltage Adaptation > Auto Normalized"
- The x-axis shows the normalized values $V_{in}/V_{in,max}$;
  The operating point with V_{in} = 0.04 V corresponds to
  $V_{in}/V_{in.max}$ = 0.04 / 0.2236 = 0.178
- f(x) = x, i.e.
  $V_{cc}Norm = V_{in}/V_{in,max}$
  $V_{cc}Norm$ = 0.178 V



If the $V_{cc,min}$ value is changed ($V_{cc,min}$ > 0 V), then the following applies:

- If 0 < $V_{in}/V_{in,max}$ ≤ $V_{cc,min}$, the signal is clipped and V_{cc}Norm = $V_{cc,min}$
- If $V_{in}/V_{in,max}$ > $V_{cc,min}$, then V_{cc}Norm = $V_{in}/V_{in,max}$

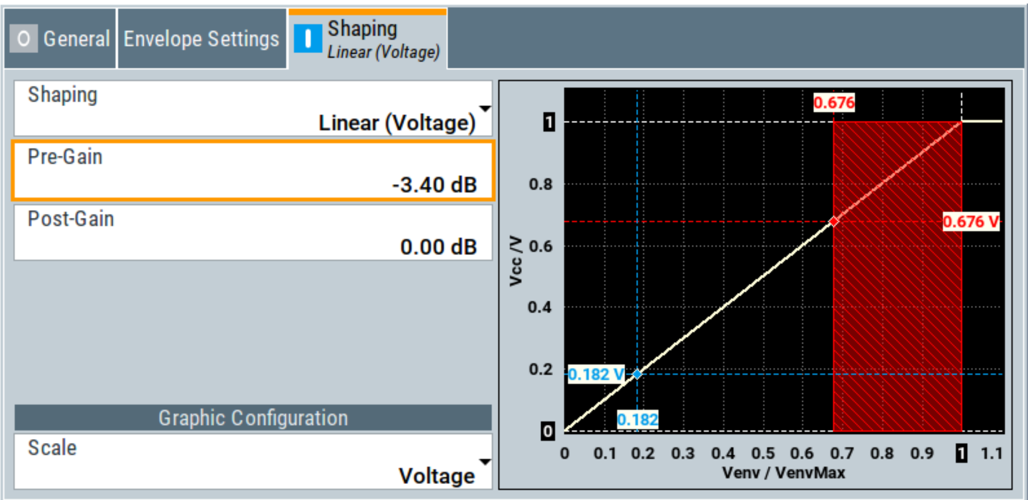
For the previous example, if $V_{cc,min}$ = 200 mV, that V_{cc}Norm = $V_{cc,min}$ = 0.2 V.



Example: Calculating the current V_{CC} in "Manual" mode

In "Envelope Voltage Adaptation > Manual" mode, set the parameter "Pre-Gain = PEP = - 3.4 dB".

The displayed shaping function resembles the shaping function in "Auto Normalized" mode; the same formulas apply, too.



You can also query the V_{CC} values for any specified x in the supported voltage adaptation mode and units.

See `[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VCC:VALue?` on page 104.

Additional information

The described principle applies for any shaping function.

Only if linear shaping is used, the V_{CC}Norm can also be directly converted to V_{CC}Pow according to the following formula:

$f_{Pow}(x) = [f_{Norm}(x) - V_{in,min}/V_{in,max}]*[(V_{cc,max} - V_{cc,min})/(1 - V_{in,min}/V_{in,max})]$

For example, if $f_{Norm}(x) = V_{CC}Norm = 0.178$ V, $f_{Pow}(x) = V_{cc}Pow_0$ is:

$V_{cc}Pow_0 = [0.178 - 0.0071/0.2236]*[(1 - 0)/(1 - 0.0071/0.2236)]$

$V_{cc}Pow_0 = 0.151$ V

2.3 General RF envelope settings

Access:

1. In the block diagram, select the "I/Q OUT" connector to unfold the "I/Q Analog" block.
2. Select "I/Q Analog > I/Q Analog Settings > General".
3. Select "RF Envelope > On".

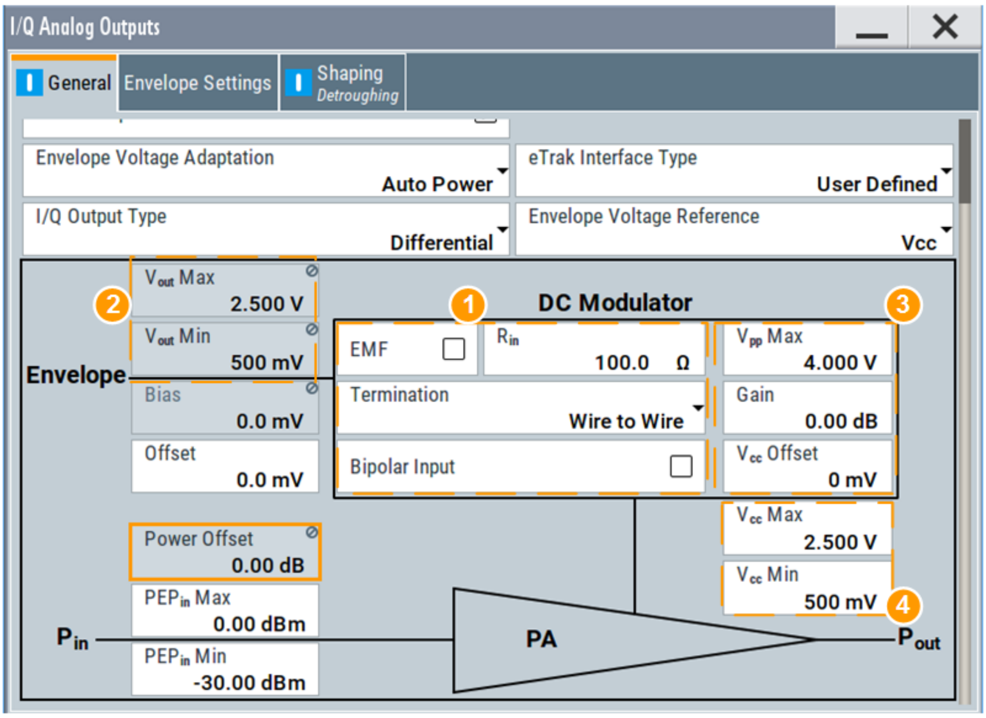


Figure 2-3: RF Envelope Settings (Example)

1 = Termination and input impedance of the circuit board
2 = Voltage level measured at the circuit board
3 = Signal characteristics of the DC Modulator
4 = Signal characteristics at the inputs of the PA (see the documentation of the PA, for example its data sheet)

The remote commands required to define these settings are described in Chapter 7.2, "SOURce:IQ:OUTPut:ENVelope commands", on page 95.

Settings:

State

Enables/disables the analog I/Q output.

Note: By default, these output connectors are deactivated.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut:ANALog:STATe` on page 93

Set to Default

Calls the default settings. The values of the main parameters are listed in the following table.

Parameter	Value
"State"	Not affected by the "Set to Default"
"RF Envelope"	Off

Parameter	Value
"I/Q Output Type"	Depends on "System Configuration > External RF and I/Q > Preset behavior: Keep connections to external instruments": • **"Off":** Single Ended • **"On":** Not affected by the "Set to Default"
"I/Q Level Vp (EMF)"	1 V
"Bias (EMF)"	0 mV

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:PRESet` on page 93

Save/Recall
Accesses the "Save/Recall" dialog, that is the standard instrument function for saving and recalling the complete dialog-related settings in a file. The provided navigation possibilities in the dialog are self-explanatory.

The settings are saved in a file with predefined extension. You can define the filename and the directory, in that you want to save the file.

See also, chapter "File and Data Management" in the R&S SMW user manual.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:SETTing:CATalog?` on page 94
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:SETTing:STORe` on page 94
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:SETTing:LOAD` on page 94
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:SETTing:DELete` on page 94

RF Envelope
Option: R&S SMW-B9 - enabled in "System Config > Mode = Standard".

Option: R&S SMW-B10 - enabled in "System Config > Mode = Standard/Advanced".

Enables the output of a control signal that follows the RF envelope. This control signal is provided for power amplifiers envelope tracking testing. The signal is output at the I out and I Bar out connectors.

See Chapter 5, "How to generate a control signal for power amplifier envelope tracking tests", on page 83

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:STATe` on page 98

Envelope Voltage Adaptation
Defines the way you configure the voltage of the envelope tracking generator (see Chapter 2.2.1, "Envelope voltage adaptation modes", on page 15).

"Auto Normalized"
Generation based on the physical characteristics of the power amplifier; the power values are normalized based on the selected PEPin Max value.
This mode enables you to use the complete range of a selected detroughing function.
See also Shaping settings and compare the values on the X axis on the graphical display.

"Auto Power" Generation based on the physical characteristics of the power amplifier, where the input power of the PA "PEP_{in}" is defined with its min and max values.

"Manual" Generation, in that the operating range of the amplifier is defined based on a pre-gain and a post-gain range.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:ADAPtion` on page 98

eTrak® Interface Type

Selects one of the predefined interface types or allows user-defined settings.

See Chapter 2.2.2, "Signal parameters for testing according to the eTrak® specification", on page 15.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:ETRak` on page 99

I/Q Output Type

Selects the type of output signal.

The provided parameters in the "I/Q Analog Outputs" dialog depend on the selected output mode.

"Single-Ended"
- If "RF Envelope > Off"
  Single-ended output at the I/Q connectors.
  Option: R&S SMW-B9: the signal from "I/Q Analog B" is output at the I Bar connectors.
- If "RF Envelope > On"
  The envelope signal E is output at the I connectors.

You can define a bias between the output signal and ground.

"Differential" Option: R&S SMW-B10 and R&S SMW-K16
Or R&S SMW-B9 and R&S SMW-K17.

- If "RF Envelope > Off"
  The analog I/Q signal components are output at the I/Q and I/Q Bar connectors.
  Option: R&S SMW-B9: the differential signal output can be activated in "I/Q Analog A" block only. Single-ended and differential signals cannot be output simultaneously.
- If "RF Envelope > On"
  The inverted envelope signal Ē is output at the I Bar connectors.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:TYPE` on page 95

Envelope Voltage Reference

Defines whether the envelope voltage V_{out} is set directly or it is estimated from the selected supply voltage V_{cc}.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VREF` on page 99

V_{out}Min/Max

Displays the minimum and maximum values of the peak-to-peak voltage V_{out} voltage on the interface between the circuit board and the DC modulator.

For "Envelope Voltage Reference" , sets the value of this parameter.

To measure the V_{out} voltage:

- Use a suitable probe, i.e. use a differential probe if a "Wire to Wire" termination is used and a single ended probe otherwise
- Measure at the circuit board after the termination impedance R_{in}.

Estimated "V_{out}Min/Max" values are calculated based on the selected supply voltage V_{cc}Min/Max, enabled Gain and V_{cc}Offset in the DC modulator.

Remote command:
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VOUT:MIN on page 100
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VOUT:MAX on page 100

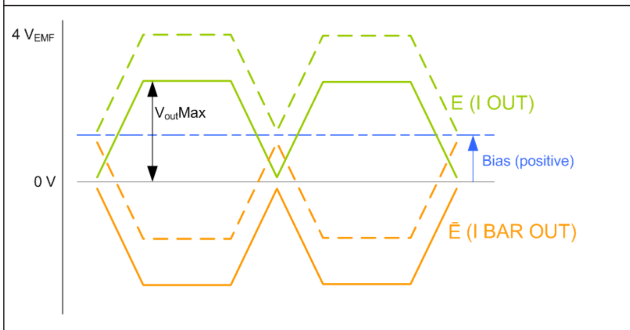
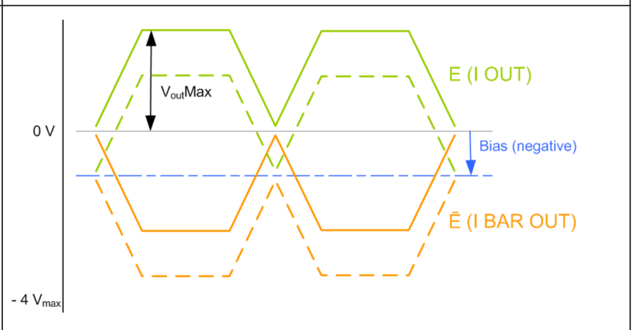
Bias

Sets a DC voltage, superimposed upon the envelope signal E and the inverted envelope signal E Bar.

Use this parameter to define the operating point of a DUT.

"I/Q Output Type"	Termination	"Bias" defines
"Single Ended"	-	The bias between the envelope signal E and ground
"Differential"	"To Ground"	Superimposed DC voltage, where "Bias" is related to the selected R_{in}. See also Table 2-4
	"Wire To Wire"	Superimposed DC voltage, where "Bias" is related to high impedance (1 MΩ).

Table 2-4: Effect of enabled bias

Effect of a positive bias	Effect of a negative bias
	

Remote command:
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:BIAS on page 100

DC Modulator characteristics

Refer to the product documentation of the external DC modulator for information on its characteristics.

The following settings are required:

EMF ← DC Modulator characteristics
Activates EMF, which defines whether the EMF or the voltage value is displayed.

An EMF-based calculation assumes an open-end circuit. Disable this parameter for testing in more realistic conditions, where you define the input impedance of the used external DC modulator R_{in}. The R&S SMW then calculates the envelope output voltage V_{out}Min/Max based on it.

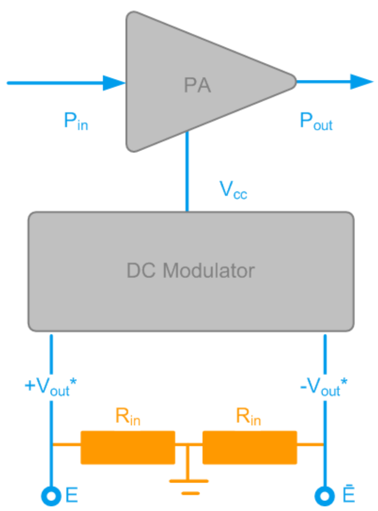
Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:EMF[:STATe]` on page 101

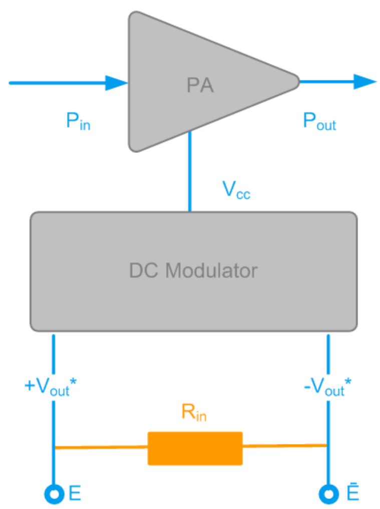
R_{in} ← DC Modulator characteristics
If "EMF > Off", sets the input impedance R_{in} of the external DC modulator.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:RIN` on page 101

Termination ← DC Modulator characteristics
If "I/Q Output Type > Differential" and "EMF > Off", defines the way the inputs of the DC modulator are terminated.

The termination influences the way an enabled Bias is applied.

<table>
<tr><th>"To Ground"</th><th>"Wire to Wire"</th></tr>
<tr><td>

*) Bias = 0 and V_{cc}Offset = 0</td><td>

*) Bias = 0 and V_{cc}Offset = 0</td></tr>
<tr><td>Both inputs of the DC modulator are terminated to ground.</td><td>This termination is also referred as a common mode voltage.</td></tr>
</table>

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:TERMination` on page 102

Bipolar Input ← DC Modulator characteristics
If "I/Q Output Type> Differential", enables the instrument to generate a bipolar signal.

The envelope signal E swings above and below the inverted envelope signal E Bar; the R&S SMW calculates and applies a suitable envelope V_{cc}Offset automatically.

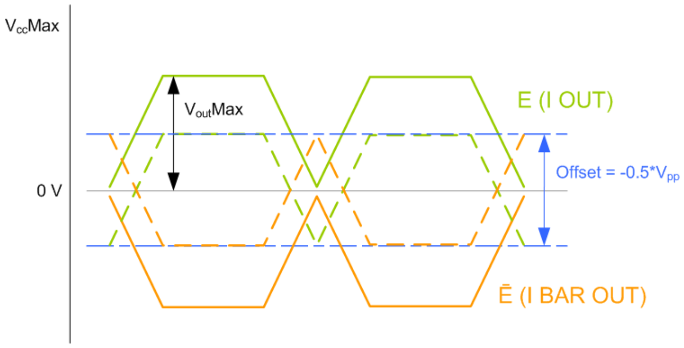


Figure 2-4: Effect of a "Bipolar Input > On"

This parameter influences the lower limit of the supply voltage V_{cc}.

The generated signal is conformed with the MIPI®Alliance specification "Specification for Analog Reference Interface for Envelope Tracking".

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:BINPut` on page 102

V_{pp}Max ← DC Modulator characteristics
Sets the maximum value of the peak-to-peak driving voltage V_{pp} of the external DC modulator.

The V_{pp} limits:
- The value range of the supply voltage V_{cc}Min/Max
  $V_{pp} \geq V_{CC}$Max
- In "I/Q Output Type > Differential", the voltage of the generated envelope signal V_{out}Min/Max as follows:
  $V_{pp} \geq V_{out}$Max[E] - V_{out}Max[E Bar], where [E] and [E Bar] refer to the envelope signal and the inverted envelope signal.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VPP[:MAX]` on page 101

Gain ← DC Modulator characteristics
Sets the gain of the external DC modulator.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:GAIN` on page 102

V_{cc}Offset ← DC Modulator characteristics
Applies a voltage offset on the supply voltage V_{cc}Min/Max, i.e. compensates a possible offset from the external DC modulator. Reduces the envelope output voltage V_{out}Min/Max by this value to maintain the supply voltage V_{cc} in the defined value range.

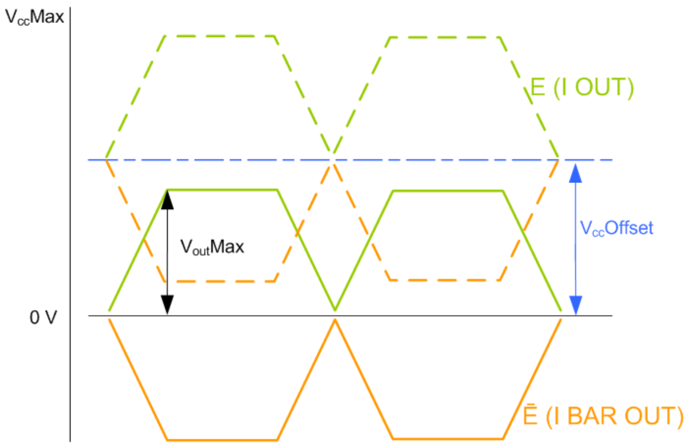


Figure 2-5: Effect of a Vcc offset

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VCC:OFFSet` on page 103

PA characteristics

Refer to the product documentation of the power amplifier (PA) for information on its characteristics.

The following settings are required:

V_{cc}Min/Max ← PA characteristics

Displays the minimum and maximum values of the supply voltage V_{cc}, as required by the power amplifier (PA).

For "Envelope Voltage Reference > Vcc", sets the minimum and maximum values of the supply voltage V_{cc}.

The value range of the supply voltage V_{cc} is determined by the allowed peak-to-peak driving voltage V_{pp} of the external DC modulator and the enabled V_{cc}Offset.

$V_{cc}Max \leq V_{pp}Max$

The V_{cc} is calculated as follows:

V_{cc} = Vout * Gain + Vcc Offset

Example:

Envelope Voltage Reference = V_{cc}

V_{cc}Offset = 0 mV

V_{cc}Max = 1 V = 0 dBV

Gain = 3 dB

V_{cc}Max [dBV] - Gain [dB] = V_{out}Max or

V_{out}Max = 0 dBV - 3 dB = -3 dBV = 0.708 V

"Bipolar Input"	Value range "V_{cc}Min"
"State > On"	V_{cc}Min = - 0.5*V_{pp}Max **Note:** Implemented as a V_{cc}Offset, see Effect of a "Bipolar Input > On".
"State > Off"	V_{cc}Min = 0 to V_{cc}Max

Remote command:
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VCC:MIN on page 103
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VCC:MAX on page 103

Power Offset ← PA characteristics
Indicates an enabled power offset, for example to compensate power attenuation because of cable lengths.

The displayed value is applied as level offset to the generated RF signal and considers the following settings:
- "RF > RF Level > Level > Offset"
- "RF > RF Level > UCOR"

Remote command:
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:POWer:OFFSet?
on page 105

PEP_{in}Min/Max ← PA characteristics
Sets the minimum and maximum values of the input power PEP_{in}, as required by the power amplifier (PA).

The "PEP_{in}Min/Max" parameters define the linear range of the PA. Refer to the product documentation of the PA for information on the characteristics of the required input signal.

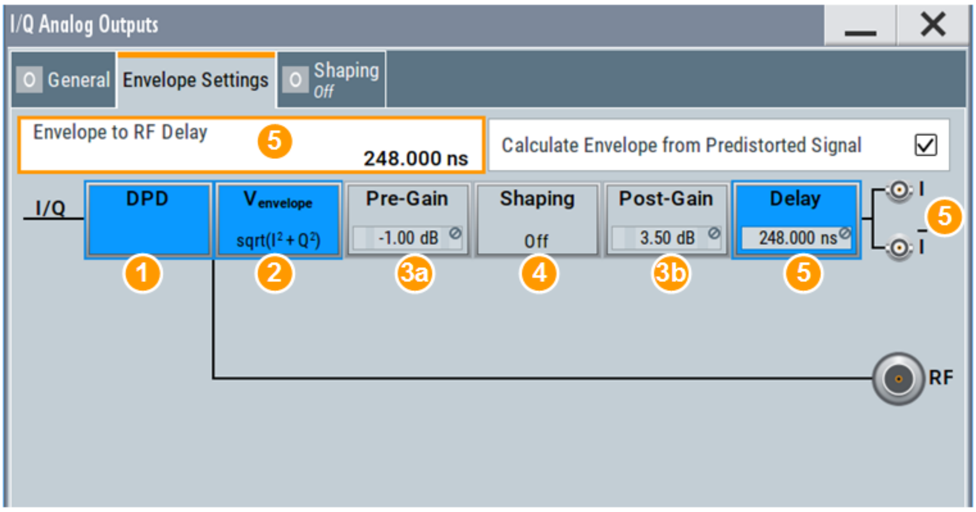
The value range corresponds to the value range of output level.

Remote command:
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:PIN:MIN on page 104
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:PIN:MAX on page 105

2.4 Envelope settings

Access:

1. Enable the generation of envelope tracking signal.
   See Chapter 2.3, "General RF envelope settings", on page 24.
2. Select "I/Q Analog Settings > Envelope Settings".



1 = Enabled Digital Predistortion
2 = Envelope detector, $\sqrt{[I(t)^2+Q(t)^2]}$; indication changes, depending on the Envelope Voltage Adaptation
3a, 3b = (for "Envelope Voltage Adaptation > Manual") Pre-Gain/Post-Gain
4 = Shaping state and shaping function; gray background color = deactivated shaping
5 = Enabled Envelope to RF Delay
6 = Indicates the output connectors, depending on the I/Q Output Type

The dialog displays an *interactive* overview diagram of the ET processing chain. The diagram displays information on shaping state, incl. current shaping method and setting, like gains or delay.

Tip: Hotspots for quick access. The displayed blocks are hotspots. Select one of them to access the related function.

The remote commands required to define these settings are described in Chapter 7.2, "SOURce:IQ:OUTPut:ENVelope commands", on page 95.

Settings:

Envelope to RF Delay

Sets the time delay of the generated envelope signal relative to the corresponding RF signal. A positive value means that the envelope signal delays relative to the RF signal and vice versa.

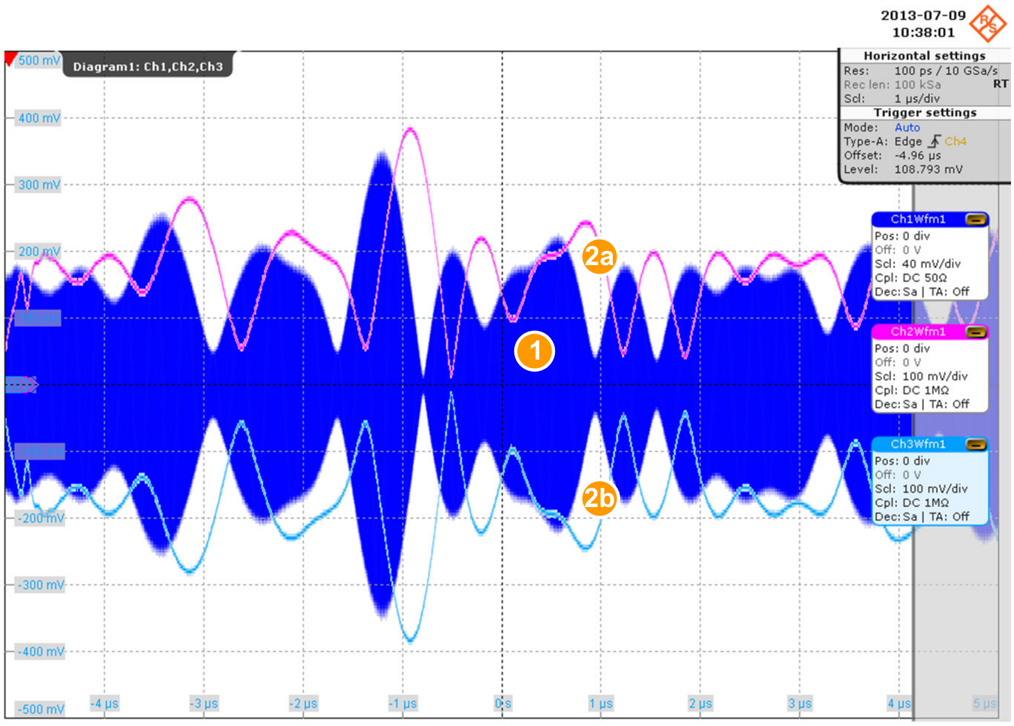


Figure 2-6: Effect of enabled positive RF delay

1 = RF signal
2a, 2b = Envelope signal E and inverted envelope signal E BAR

Use this parameter to compensate possible timing delays caused by connected cables and align the input signals at the PA to prevent unwanted effects, like memory effects or decreased linearity.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:DELay` on page 99

Calculate Envelope from Predistorted Signal
Option: R&S SMW-K541

Enables the calculation of the envelope signal from the original baseband signal or from the AM/AM and/or AM/FM predistorted signal.

See also Chapter 3, "Applying digital predistortion", on page 48.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:FDPD` on page 100

2.5 Shaping settings

Access:

1. Enable the generation of envelope tracking signal.

See Chapter 2.3, "General RF envelope settings", on page 24.

2. Enable "Envelope Voltage Adaptation > Auto Power/Normalized".
3. Select "I/Q Analog Outputs > Shaping".

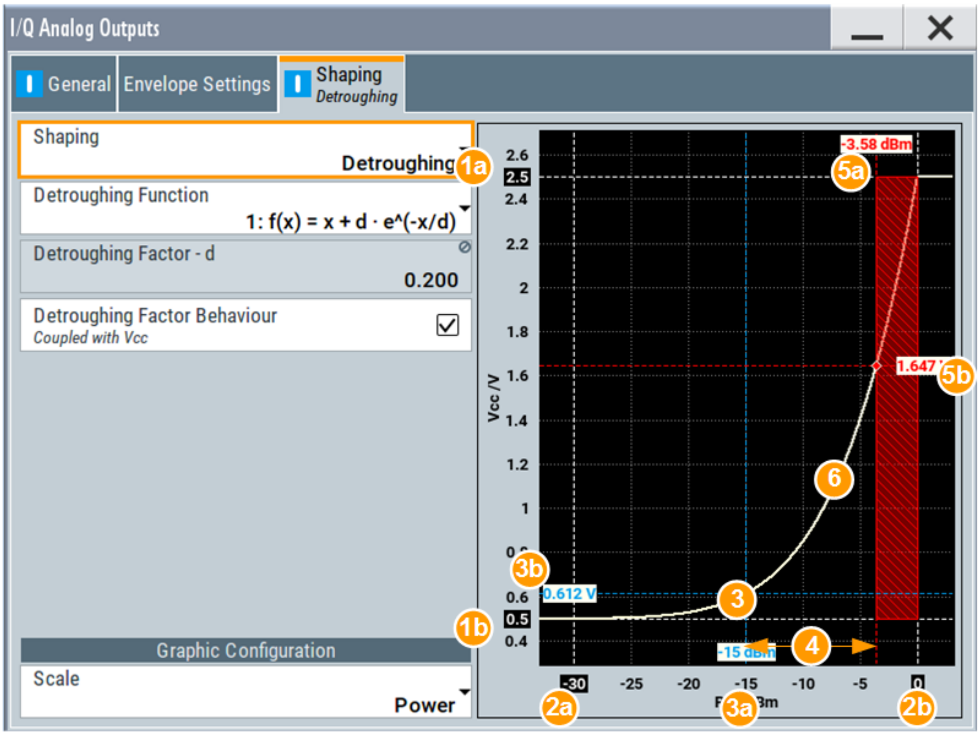


Figure 2-7: Understanding the displayed information ("Envelope Voltage Adaptation > Auto Power", "Shaping > Detroughing")

1a, 1b = Indicates the values of V_{cc}Min/Max
2a = Values smaller than PEP_{in}Min are clipped.
2b = Values greater than PEP_{in}Max are clipped.
3 = Operating point; corresponds to the RF RMS power level.
3a = Current RF RMS power level; an enabled "RF Level > Level Offset" is considered.
3b = Current V_{CC}
4 = Crest factor of the generated signal
5a, 5b = The values correspond to the PEP of the generated RF signal and the V_{CC}; shaded area indicates the calculated Pre-Gain.
6 = Current envelope shape, defined by the detroughing function and detroughing factor

The settings allow the configuration of the shape of the RF envelope signal. The instrument applies the settings and calculates the shaping function. A diagram visualizes the resulting envelope shape, as function of the selected supply voltage V_{cc} and PEP_{in} value limits, the calculated pre-gain and the estimated operating point of the PA.

See also:
- Chapter 5, "How to generate a control signal for power amplifier envelope tracking tests", on page 83.
- Chapter 2.2.3.6, "Converting shaping functions and understanding the displayed values", on page 20.

The remote commands required to define these settings are described in Chapter 7.2, "SOURce:IQ:OUTPut:ENVelope commands", on page 95.

Settings:

Shaping

Enables envelope shaping and selects the method to define the shaping function.

For detailed information on the shaping functions, see:

- Chapter 2.2.3, "Envelope shaping and shaping methods", on page 15
- Chapter 2.2.3.6, "Converting shaping functions and understanding the displayed values", on page 20.

See also Chapter 5, "How to generate a control signal for power amplifier envelope tracking tests", on page 83.

"Off" Envelope shaping is not adopted.
Previously configured values of the parameters Pre-Gain and Post-Gain are ignored.

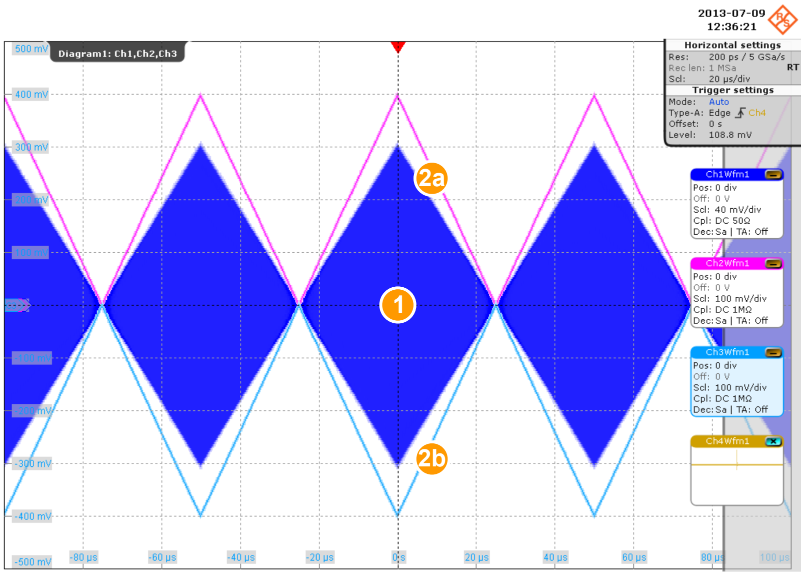


Figure 2-8: Generated RF, envelope and inverted envelope signal

1 = RF signal (simple ramp function)
2a, 2b = Envelope signal E and inverted envelope signal E Bar

"Linear (Voltage)/Linear (Power)"
The shaping function is a simple linear function.
The linear shaping is not used in practice but can be used for less demanding applications, simple analysis, and the first interactions by designing the optimum envelope shape. For "Envelope Voltage Adaption > Manual", this function is suitable to determine the "Pre-/Post-Gain" values, because the shaping gain of the linear function is 0 dB.

"Polynomial" The shaping function is defined by a polynomial with configurable order and coefficients.
Select Polynomial coefficients settings to access the settings.

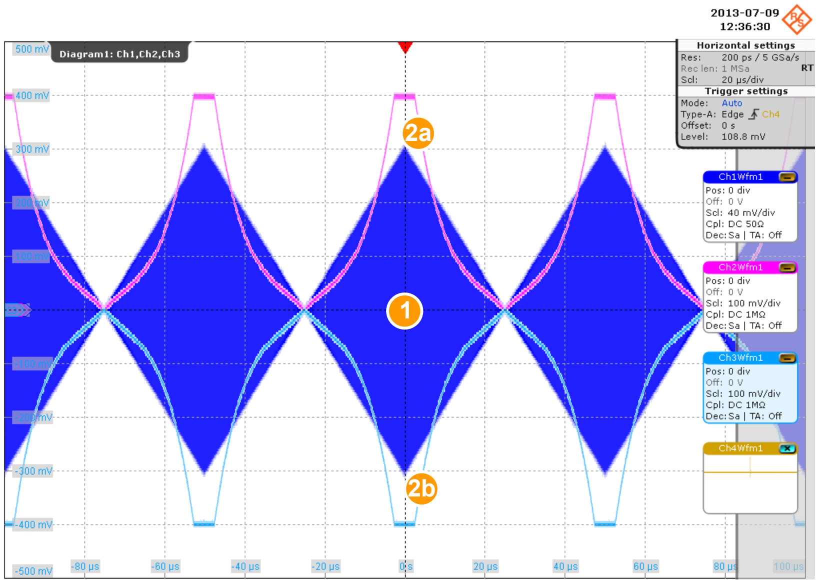


Figure 2-9: Effect of a polynomial shaping on the envelope and inverted envelope signal

1 = RF signal (simple ramp function)
2a, 2b = Envelope signal E and inverted envelope signal E Bar

"From Table" The shaping function is defined by user-defined value pairs in form of a shaping table.
This shaping function is suitable if you have knowledge on or aim to achieve an exact relation between the supply voltage and RF output power. For example, by describing the transition region of a PA.
Select "Shaping Table" to access the settings.

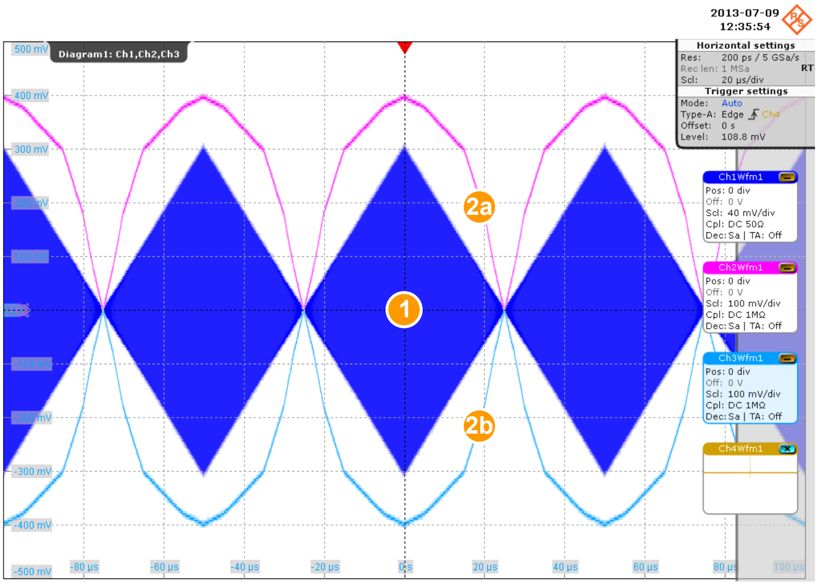


Figure 2-10: Effect of a table shaping on the envelope and inverted envelope signal

1 = RF signal (simple ramp function)
2a, 2b = Envelope signal E and inverted envelope signal E Bar

"Detroughing" The shaping function applies a detroughing to prevent that the supply voltage V_{cc} drops down to zero.
Use the "Detroughing Factor" to limit the supply voltage V_{cc} in the low-power region.

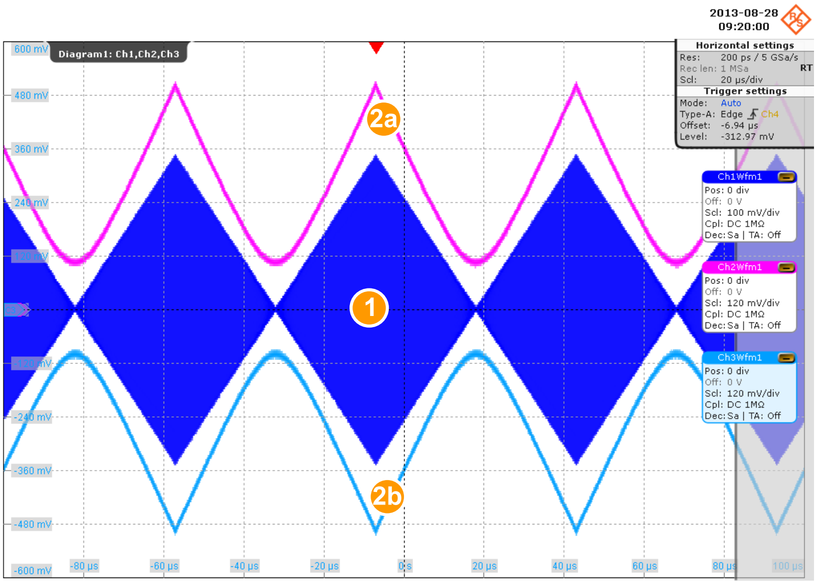


Figure 2-11: Effect of a detroughing function on the envelope and inverted envelope signal

1 = RF signal (simple ramp function)
2a, 2b = Envelope signal E and inverted envelope signal E Bar

Remote command:
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:MODE on page 105

Detroughing Function

Selects the mathematical function describing the detroughing.

The following functions are available:

- $f(x) = x + d*e^{-x/d}$
- $f(x) = 1 - (1 - d)*cos(x*pi/2)$
- $f(x) = d + (1 - d)*x^a$

Where:

- x depends on the "Envelope Voltage Adaptation" mode, see Table 2-2
- d = Detroughing Factor (d)
- a = Exponent (a)

For more information, see Chapter 2.2.3.6, "Converting shaping functions and understanding the displayed values", on page 20.

Remote command:
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:DETRoughing:FUNCtion on page 109

Detroughing Factor (d)
For inactive coupling of the detroughing factor with V_{cc}, sets a start offset to limit the supply voltage V_{cc} in the low-power region.

The detroughing factor also controls the shaping. "Detroughing Factor = 0" defines a linear function.

See also "Couple Detroughing Factor with Vcc" on page 41.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:DETRoughing:FACTor` on page 109

Couple Detroughing Factor with Vcc
Enable this parameter to derive the detroughing factor (d) from the selected V_{cc} value. This ensures that the minimum supply voltage V_{cc} does not drop under the specified limits and the signal is not clipped.

The detroughing factor is calculated as follows:

$d = V_{cc}Min/V_{cc}Max$

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:DETRoughing:COUPling` on page 109

Exponent (a)
For the third detroughing function, sets the exponent (a), see Detroughing Function.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:DETRoughing:PEXPonent` on page 109

Pre-Gain
For "Envelope Voltage Adaptation > Manual", sets a pre-gain (i.e. an attenuation) to define the operating range of the power amplifier. The pre-gain can be used to define and test only a specific (required) part of the operating range.

For "Envelope Voltage Adaptation > Auto", calculates the value automatically as following:

"Pre-Gain" = "Pin max" - "RF Level" + "Crest Factor"

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:GAIN:PRE`
on page 106

Post-Gain
For "Envelope Voltage Adaption > Manual", sets a post-gain to compensate the attenuation introduced by the pre-gain and the gain of the shaping function.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:GAIN:POST`
on page 106

Polynomial Coefficients

For "Shaping > Polynomial", accesses a dialog to describe the envelope shape as a polynomials function, see Chapter 2.7, "Polynomial coefficients settings", on page 45.

Shaping Table

For "Shaping > From Table", accesses the standard "Envelope Select" dialog with functions to define a new shaping table file, select or edit an existing one.

The shaping table files are files with predefined extension and file format, see "File format of the shaping table file" on page 19.

You can create a shaping table externally or internally.

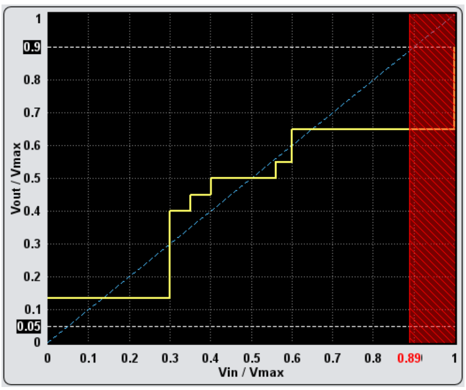
"Select"	Selects and loads an existing file.
"New"	Creates a file
"Edit"	Access a standard built-in table editor, see Chapter 2.6, "Edit I/Q envelope shape settings", on page 43.

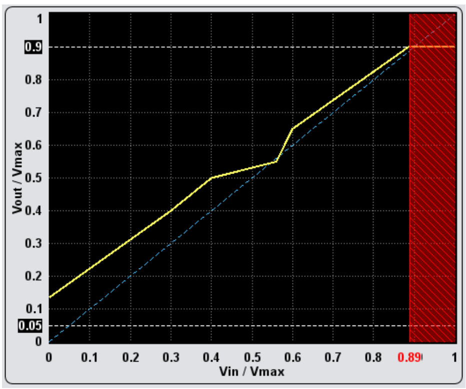
Remote command:
For "Envelope Voltage Adaption > Manual":
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:FILE:CATalog?` on page 106
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:FILE[:SELect]` on page 106
For "Envelope Voltage Adaption > Auto":
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:PV:FILE:CATalog?` on page 106
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:PV:FILE[:SELect]` on page 106

Interpolation

For "Shaping > From Table", enables a linear interpolation between limited number of defined value pairs in the table, to prevent abrupt changes.

Table 2-5: Effect of parameter "Interpolation"

<table>
<tr><th>"Interpolation > Off"</th><th>"Interpolation > Linear Voltage"</th></tr>
<tr><td>


</td><td>


</td></tr>
</table>

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:INTerp` on page 107

Graphic Configuration
Comprises settings to configure the graphical display.

Scale ← Graphic Configuration
Determines the units, "Voltage" or "Power", used on the x and y axis.

Table 2-6: Units on the x axis

"Envelope Voltage Adaption"	"Scale > Power"	"Scale > Voltage"
Auto Power	P_{in} [dBm]	V_{in} [V] = $\sqrt{P_{in}}$
Auto Normalized	P_{in}/P_{max}	V_{in}/V_{max}

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:SCALe`
on page 106

Diagram ← Graphic Configuration
Visualizes the resulting envelope shape, as function of the selected supply voltage V_{cc} and PEP_{in} value limits, the calculated pre-gain and the estimated operating point of the PA.

See Figure 2-7.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VCC:VALue:LEVel?`
on page 103
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VCC:VALue:PEP?`
on page 103
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VCC:VALue?` on page 104

2.6 Edit I/Q envelope shape settings

The envelope shaping table is a method to define the shaping function.

Access:

1. Enable the generation of envelope tracking signal.
   See Chapter 2.3, "General RF envelope settings", on page 24.
2. Select "Envelope Voltage Adaptation > Manual".
3. Select "Shaping Settings > Shaping > From Table".
4. Select "Shaping Table > New"
5. Enter the "File Name", e.g. *MyLUT*

   The "Envelope Shaping File" dialog closes.
   The "Shaping > Shaping Table" confirms that the newly created file is assigned.
6. Select "Shaping Table > MyLUT > Edit"

7. Define the value pairs "Vin/Vmax" and "Vcc/Vmax". The order is uncritical.

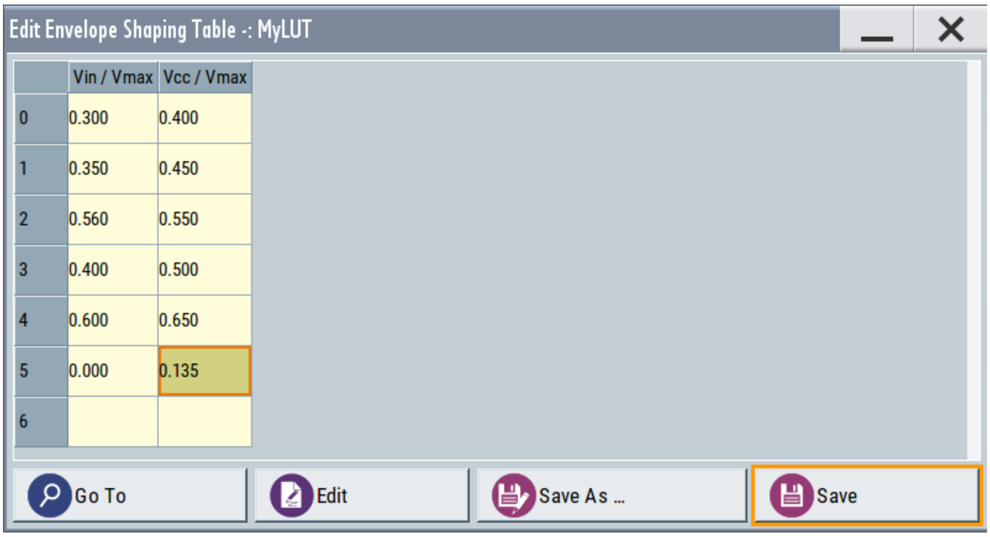


Figure 2-12: Shaping table in "Envelope Voltage Adaptation > Manual" mode

8. Select "Save".

   The instrument loads the configured values automatically and displays the shaping function.

9. Select "Shaping Settings > Interpolation > Linear (Voltage)".

   The display confirms the used interpolation.

The remote commands required to define these settings are described in Chapter 7.2, "SOURce:IQ:OUTPut:ENVelope commands", on page 95.

Settings:

Vin/Vmax, Vcc/Vmax/Power (dBm), Vcc (V)

Sets the normalized values of the value pairs.

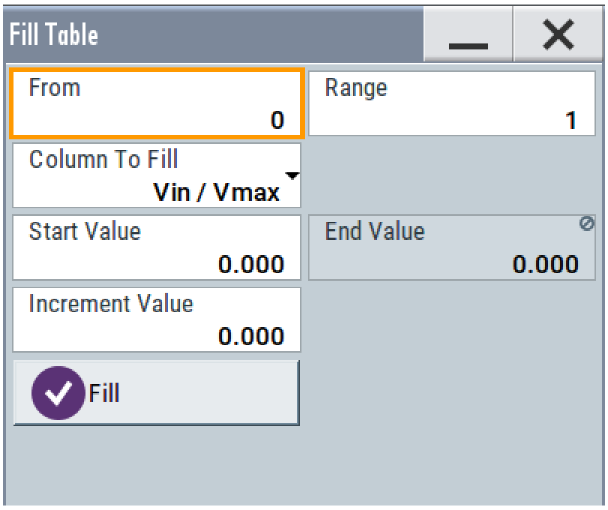
"Vin/Vmax, Vcc/Vmax"
Value pairs in "Envelope Voltage Adaptation > Manual/Auto Normalized" mode.

"Power(dBm), Vcc(V)"
Value pairs in "Envelope Voltage Adaptation > Auto Power" mode.

Remote command:
n.a.

Fill Table Automatically

Standard function for filling a table automatically with user-defined values.



"From / Range"
Defines the start line and number of the rows to be filled.

"Select Column to Fill"
Selects the respective value, including the unit.

"Start / End Value"
Default values corresponding to the selected column.

"Increment" Determines the step size.

"Fill" Fills the table.
Fill both columns and then save the list. Otherwise the entries are lost.

Goto, Edit, Save As, Save
Standard functions for editing of data lists.

Changed and unsaved values are displayed on a yellow background.

Remote command:
n.a.

2.7 Polynomial coefficients settings

Access:

1. Enable the generation of envelope tracking signal.
   See Chapter 2.3, "General RF envelope settings", on page 24.
2. Select "Envelope Voltage Adaptation > Auto Normalized".
3. Select "Shaping Settings > Shaping > Polynomial".
4. Select "Polynomial Coefficients".

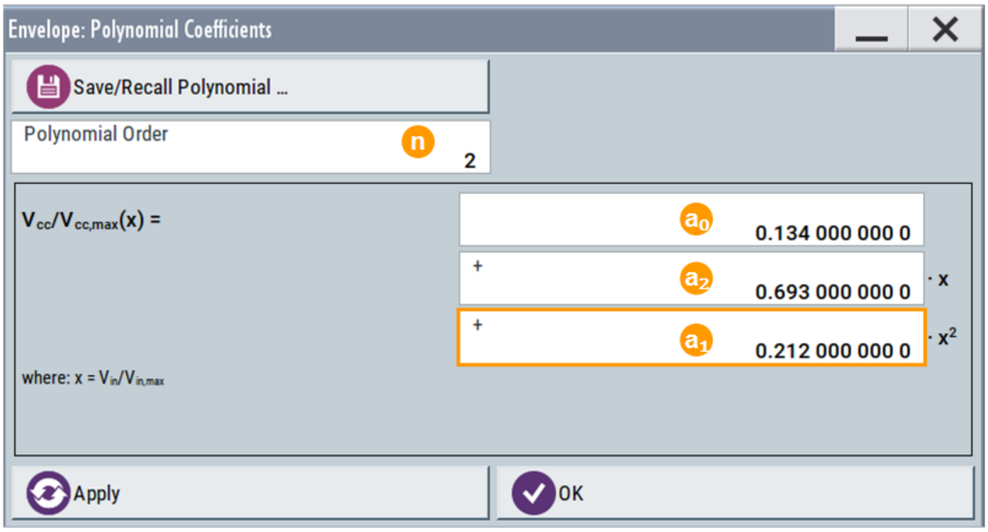


Figure 2-13: Polynomial Coefficients: Understanding the displayed information

The polynomial function is an analytical method to describe a shaping function. With the provided settings, you can define a polynomial function with up to 10th order to describe the envelope shape.

5. Select "Polynomial Order = 2" (n = 2).
6. Set the constant a_0 and the polynomial coefficients a_1 and a_2.
7. Select "Apply".

   The instrument loads the configured values and displays the shaping function.
8. To store the defined shaping function:
   a) Select "Save/Recall Polynomial"
   b) Navigate throughout the file system.
   c) Enter a "File Name", e.g. *MyPolynomial_2thOrder*
   d) Select "OK".
9. Select "Polynomial Coefficients > OK" to close the dialog.

The remote commands required to define these settings are described in Chapter 7.2, "SOURce:IQ:OUTPut:ENVelope commands", on page 95.

Settings:

Save/Recall Polynomial

Accesses the "Save/Recall" dialog, that is the standard instrument function for saving and recalling the complete dialog-related settings in a file. The provided navigation possibilities in the dialog are self-explanatory.

The settings are saved in a file with predefined extension. You can define the filename and the directory, in that you want to save the file.

See also, chapter "File and Data Management" in the R&S SMW user manual.

The polynomial files are files with extension `*.iq_poly`, see "File format of the polynomial function file" on page 18.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:COEFficients:CATalog?` on page 108
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:COEFficients:STORe` on page 108
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:COEFficients:LOAD` on page 108

Polynomial Order
Defines the polynomial order `n`, that is the number of polynomial coefficients (see Chapter 2.2.3.3, "About the polynomial function", on page 17).

To confirm the settings, select "Apply".

Remote command:
See `[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:COEFficients` on page 107.

Polynomial constant and coefficients
Sets the polynomial constant a_0 and the polynomial coefficients a_1 to a_n.

The polynomial constant and coefficients influence the envelope shape.

Remote command:
`[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:COEFficients` on page 107

Apply, OK
Triggers the instrument to adopt the selected function.

Use "OK" to apply the setting and exits the dialog.

Remote command:
See `[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:COEFficients` on page 107

3 Applying digital predistortion

Digital predistortion (DPD) is a method to improve the efficiency of RF power amplifiers. In the R&S SMW, the generated digital signal can be deliberately AM/AM and AM/PM predistorted.

3.1 Required options

The equipment layout for digital predistortion includes:

- Option standard or wideband baseband generator (R&S SMW-B10/-B9)
  Option baseband main module, one/two I/Q paths to RF (R&S SMW-B13/B13T) or wideband baseband main module (R&S SMW-B13XT)
- Option frequency (e.g. R&S SMW-B1003/-B2003)
- Option AM/AM AM/PM predistortion (R&S SMW-K541) per signal path;
  Where each signal path must be equipped with baseband generator, main module and frequency option
- Optional option envelope tracking (R&S SMW-K540) per signal path

3.2 About digital predistortion

Power amplifiers are an essential part of any telecommunication systems. While amplifying the transmitted signal, power amplifiers sometimes also distort this signal and change its amplitude and/or phase characteristics. Such distortions result in undesired effects like spectrum regrowth, harmonic generation, intermodulation (IM) products, or increased bit error rate.

The principle of the digital predistortion

To compensate for the distortions caused by the transmission system, the signal is deliberately digitally predistorted. Digital predistortion (DPD) is a method to apply wanted and well-defined predistortion on the transmitted signal. When this signal is amplified, the resulting signal features the identical characteristics, as the initial signal before the predistortion.

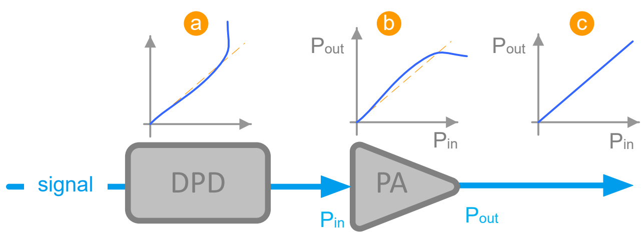


Figure 3-1: Illustration of predistortion principle

DPD = Digital predistortion
PA = Power amplifier
a = Predistortion function
b = Characteristic of the power amplifier, for example the non-linear input power vs. output power (AM/AM) function
c = Ideal linearized characteristic of the amplified signal

Digital predistortion models

When testing power amplifiers, it is important to measure and analyze signal distortions.

Of several known models, this implementation focuses on the following two types of distortion:

- The AM/AM (amplitude-to-amplitude) distortion and
- The AM/PM (amplitude-to-phase) distortion.

An AM/AM representation is a standard method that shows the signal power level at the input of the DUT against the power level at the output of the DUT. The default unit for both axes is dBm but the AM/AM representation can also be normalized.

An AM/PM curve shows the phase difference in degrees (y-axis) for every input power level (x-axis).

With option R&S SMW-K541, you can define both, an AM/AM and an AM/PM predistortion and apply them separately or superimposed on each other on the generated digital baseband signal.

If your instrument is equipped with the option R&S SMW-K540, you can also apply predistortions on the generated envelope signal.

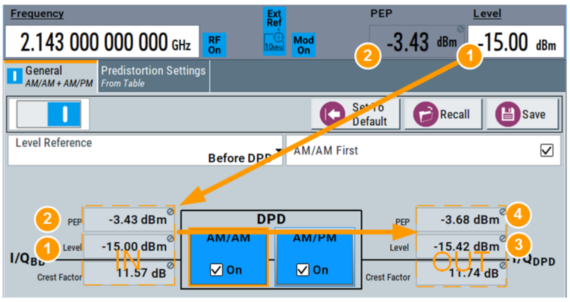
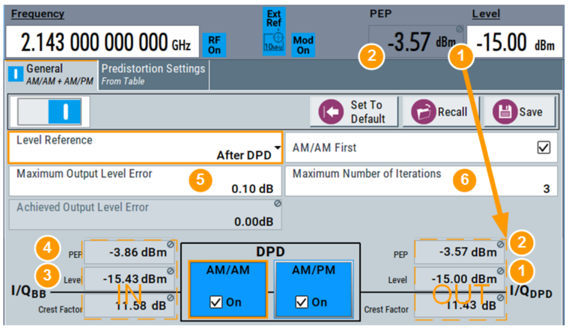
Refer to Chapter 2, "Generation of envelope tracking signals", on page 13 for more information.

3.2.1 Defining the power level of the generated signal

You can define the level of the generated signal in one of the following ways:

- **"Level Reference > Before DPD"**
  In this mode, the "Level" parameter in the status bar of the instrument defines the signal level before the DPD is applied.
  Signal with selected level is pre-distorted and depending on the selected AM/AM and AM/PM functions, attenuated or boosted.
  See Table 3-1.
- **"Level Reference > After DPD"**
  In this mode, you define the resulting signal level. Based on this value and depending on current predistortion function, the R&S SMW calculates the level of the signal to be pre-distorted.
  The level calculation requires several interaction cycles; the number of iterations is a trade-off between level accuracy and speed.
  See "To perform manual iterations to achieve a desired resulting signal level after the DPD" on page 89 for explanation of how the interactions are performed.

Table 3-1: Difference between the level reference modes

"Level Reference > Before DPD"	"Level Reference > After DPD"
	
1: "Level$_{IN}$ = Level = -15 dBm", i.e. signal level before DPD 2: "PEP$_{IN}$ = PEP -3.43 dBm", i.e. PEP of the signal before DPD 3: "Level$_{OUT}$ = -15.42 dBm", resulting signal level after DPD 4: "PEP$_{OUT}$ = -3.68 dBm", resulting PEP of the signal after DPD	1: "Level$_{OUT}$ = Level = -15 dBm", i.e. signal level after DPD 2: "PEP$_{OUT}$ = PEP = -3.57 dBm", i.e. PEP of the signal after DPD 3: "Level$_{IN}$ = -15.43 dBm", calculated signal level before DPD 4: "PEP$_{IN}$ = -3.86 dBm", calculated of the signal before DPD 5: allowed maximum level error 6: maximum number of iterations used to achieve the required level error

3.2.2 Defining the correction values

In the R&S SMW, you can select the way you define the predistortion function and choose between:

- A polynomial function with up to 10 polynomial coefficients
  (see Chapter 3.2.2.1, "Polynomial function", on page 50)
- A predistortion function defined as a look-up table
  (see Chapter 3.2.2.2, "Shaping table", on page 51)
- A normalized data
  (see Chapter 3.2.2.3, "Normalized data", on page 52)
- To set the correction values in raw format with a single remote control command
  (see Chapter 3.2.2.4, "Predistortion function in raw data format", on page 53).

3.2.2.1 Polynomial function

The polynomial function is an analytical method to describe a predistortion function. When using the polynomial function, you do not define the correction values (ΔPower and ΔPhase) directly as it is in the look-up table. You describe the predistortion function and the R&S SMW derives the correction values out of it.

See Chapter 3.3.4, "Polynomial coefficients settings", on page 65.

This implementation uses a polynomial with complex coefficients defined as follows:

$P_{DPD}(x) = \sum[(a_n+j*b_n)*x^n]$,

Where:

- n = "Polynomial Order" ≤ 10
- $x = P_{in}/P_{in}Max$
- a_n and b_n are user-defined coefficients, defined as Cartesian (polar) or cylindrical coordinates.
  In Cartesian coordinates system, the coefficients b_n are expressed in degrees.

The R&S SMW calculates the AM/AM and AM/PM predistortion functions as follows:

- $AM/AM(x) = abs[P_{DPD}(x)]$
- $AM/PM(x) = tan^{-1}\{Im[P_{DPD}(x)]/Re[P_{DPD}(x)]\}$

A dedicated graphical display visualizes the resulting functions, see Figure 3-4.

The R&S SMW calculates the correction values (ΔAM/AM and ΔAM/PM functions) as follows:

- $\Delta AM/AM(x) = AM/AM(x) - x = abs[P_{DPD}(x)] -x$
- $\Delta AM/PM(x) = AM/PM(x) = tan^{-1}\{Im[P_{DPD}(x)]/Re[P_{DPD}(x)]\}$

A dedicated graphical display visualizes the calculated correction functions, see Figure 3-5 and compare with Figure 3-4.

File format of the polynomial file

You can store a polynomial function in a file or even define the polynomial coefficients, store them as a file and load this file into the instrument. The polynomial files are files with the extension `*.dpd_poly`.

The file contains an optional header `# Rohde & Schwarz - Digital Predistortion Polynomial Coefficients # a0,b0, a1,b1, a2,b2, ...` and a list of comma-separated coefficient value pairs, stored in Cartesian coordinates.

For values above the selected Input Range (PEP_{in}) From/To, the predistortion function assumes a linear ratio of the input to output power.

Example: Polynomial function file content

```
# Rohde & Schwarz - Digital Predistortion Polynomial Coefficients
# a0,b0, a1,b1, a2,b2, ...
0,0,-0.25,0.2,0.6,-0.3,0.3,0.3,0.5,-0.4
```

3.2.2.2 Shaping table

In the R&S SMW, there are two ways to define the predistortion function in form of a shaping table:

- **Externally**
  Create a correction table file as a CSV file with Microsoft Excel, with a Notepad or a similar tool. Save the file with the predefined extension, transfer and load it into the instrument.
  See also "File format of the correction table file" on page 52.
- **Internally**

Use the built-in editor table editor, see Chapter 3.3.3, "Edit predistortion table settings", on page 62.

File format of the correction table file

The correction table files are files with predefined extension and simple file format, see Table 3-2.

Table 3-2: Shaping table files: format and extensions

Predistortion model	File extension	Header (optional)
AM/AM	`*.dpd_magn`	`# Rohde & Schwarz - Digital AM/AM Predistortion Table Pin[dBm],deltaPower[dB]`
AM/PM	`*.dpd_phase`	`# Rohde & Schwarz - Digital AM/PM Predistortion Table Pin[dBm],deltaPhase[deg]x`

The header is optional. The file content is a list of up to 4000 comma-separated value pairs, describing the delta values for amplitude or phase related to the absolute input power P_{in}. A new line indicator separates the pairs.

For values above the selected Input Range (PEP_{in}) From/To, the predistortion function assumes a linear ratio of the input to output power.

Example: Shaping table file content (*.dpd_magn file)

```
# Rohde & Schwarz - Digital AM/AM Predistortion Table
Pin[dBm],deltaPower[dBm]
-30,0.5
3,-0.01
```

3.2.2.3 Normalized data

In the R&S SMW, there are two ways to define the predistortion function as normalized data:

- **Externally**
  We recommend that you calculate the normalized correction data by a connected R&S®FSW equipped with R&S®FSW-K18 power amplifier and envelope tracking measurements option.
  You can also create the correction table file as a CSV file with Microsoft Excel, with a Notepad or a similar tool. Save the file with the predefined extension, transfer and load it into the instrument.
  See also "File format of the correction table file" on page 52.
- **Internally**
  Use the built-in editor table editor, see Chapter 3.3.3, "Edit predistortion table settings", on page 62.

File format of the normalized data

The normalized data files are files with predefined extension `*.dpd_norm` and simple file format, see "File format of the normalized data" on page 52.

The file contains an optional header `# Rohde & Schwarz - Digital Predistortion Normalized Table Data # PinMax [dBm] # number of points # Vin/Vmax, deltaV/V, deltaPhase [deg]`, the values of the Pin_{Max}, the number of the subsequent points and a list of comma-separated groups of three values.

Example: Normalized data file content

```
# Rohde & Schwarz - Digital Predistortion Normalized Table Data
# PinMax [dBm]
# number of points
# Vin/Vmax, deltaV/V, deltaPhase [deg]
10
4096
0,0,0
0.0002442,-0.00018246,0.28052
0.0004884,-0.00036487,0.28041
0.0007326,-0.00054723,0.2803
0.0009768,-0.00072954,0.28019
0.001221,-0.00091181,0.28008
0.0014652,-0.001094,0.27996
...
```

3.2.2.4 Predistortion function in raw data format

The predistortion values are defined directly, with a single remote control command:

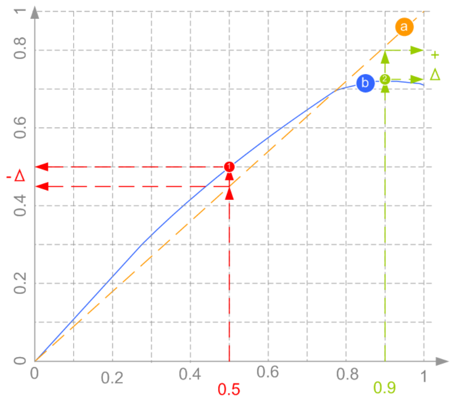
- Define up to 4000 comma-separated value pairs, describing the absolute input power P_{in} and the delta values for amplitude or phase (ΔPower and ΔPhase).
  Example:
  `SOURce1:IQ:DPD:SHAPing:TABLe:AMAM:FILE:DATA -30.4,-5.2, -25.1,-4.5, -18.5,-2.5, -10.5,-1`
  See:
  – `[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMAM:FILE:DATA` on page 120
  – `[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMPM:FILE:DATA` on page 120
  – `[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMAM:FILE:NEW` on page 120
  – `[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMPM:FILE:NEW` on page 120
- Define the absolute maximum input power Pin_{max}, the number of subsequent points, and the normalized values Vin/Vmax, ΔV/V, ΔPhase [deg] as binary data. See `[:SOURce<hw>]:IQ:DPD:SHAPing:NORMalized:DATA` on page 123.

3.2.3 Finding out the correction values

If you know the properties of the used power amplifier, you can calculate suitable correction values.

We assume that the characteristics of a power amplifier have been measured and that the left graphic in the following table shows the AM/AM curve of this amplifier.

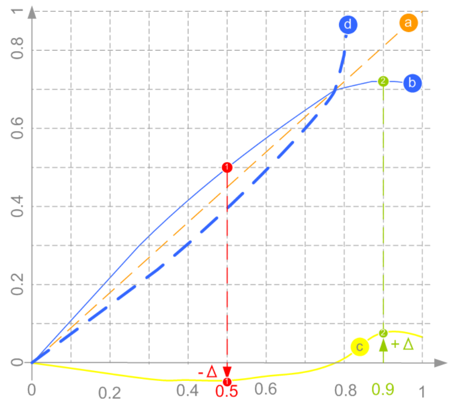
Defining correction coefficients for an AM/AM predistortion (example)



a = ideal characteristic; if the amplifier did not distort the signal, the normalized magnitude would be a line

b = measured AM/AM curve; the normalized magnitude varies as a function of input power

Resulting AM/AM predistortion function (example)



a = ideal characteristic

b = measured AM/AM curve

c = resulting AM/AM predistortion function, i.e. correction values curve

d = ideal predistorted signal

The required correction coefficient ΔPower is the difference between the ideal and the real normalized amplitude for one particular input power. To compensate for the nonlinearity and the deviation from the ideal line: select a negative correction value (-Δ) for any input power where the real normalized amplitude is greater than the ideal one (1). Logically, a positive correction value (+Δ) compensates for (i.e. boost) an amplitude that is smaller than the ideal one (2).

Ideally, a signal predistorted with a suitable function (c) and then amplified by the particular PA would have a linear characteristic (a).

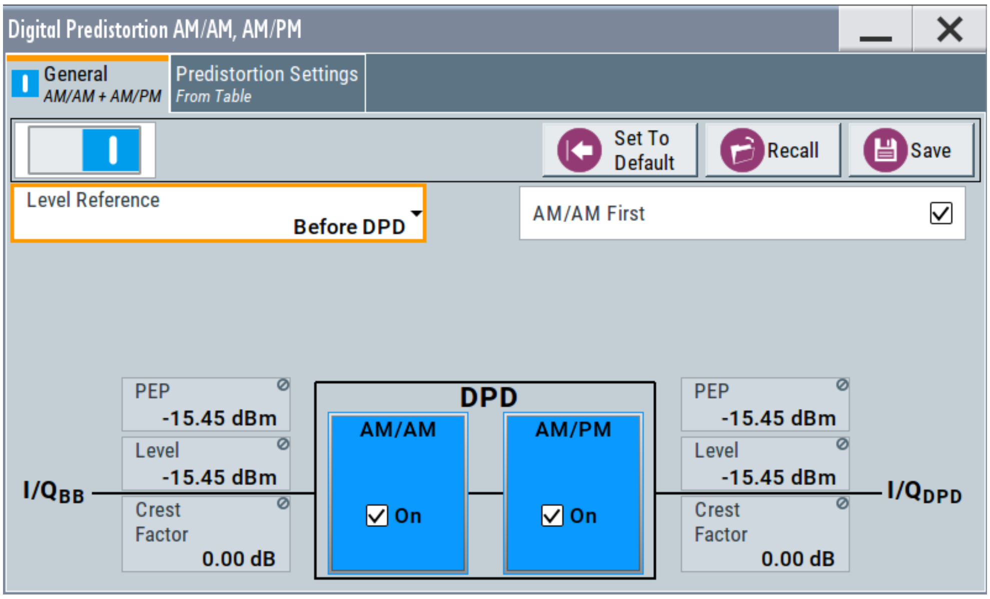
In the practice, however, you do not calculate the correction coefficients manually but they are calculated automatically. A suitable solution is the R&S®FS-K130PC software or the R&S®FSW-K18 power amplifier and envelope tracking measurements option, see Chapter 6, "How to apply a DPD to improve the efficiency of RF PAs", on page 87.

3.3 Digital predistortions AM/AM and AM/PM settings

You can add digital predistortion to the generated baseband signal and thus compensate an amplitude and a phase distortion of the DUT, for example of the tested power amplifier.

Access:

► Select "I/Q Mod > Digital Predistortion > AM/AM AM/PM".



The dialog covers the settings for digital predistortion, like select and enabling an AM/AM and/or AM/PM predistortion, select the way the predistortion function is defined and specify the correction values.

The remote commands required to define these settings are described in Chapter 7.3, "SOURce:IQ:DPD subsystem", on page 110.

Settings:

3.3.1 General settings

State

Option: R&S SMW-B9 - enabled in "System Config > Mode = Standard".

Option: R&S SMW-B10 - enabled in "System Config > Mode = Standard/Advanced".

Enables/disables the generation of digital predistorted signals.

Remote command:
[:SOURce<hw>]:IQ:DPD:STATe on page 112

Set to Default
Calls the default settings. The values of the main parameters are listed in the following table.

Parameter	Value
"State"	Not affected by the "Set to Default"
"Level Reference"	Before DPD
"AM/AM First"	Off
"AM/PM, AM/AM"	Off

Remote command:
[:SOURce<hw>]:IQ:DPD:PRESet on page 113

Save/Recall
Accesses the "Save/Recall" dialog, that is the standard instrument function for saving and recalling the complete dialog-related settings in a file. The provided navigation possibilities in the dialog are self-explanatory.

The settings are saved in a file with predefined extension. You can define the filename and the directory, in that you want to save the file.

See also, chapter "File and Data Management" in the R&S SMW user manual.

Remote command:
[:SOURce<hw>]:IQ:DPD:SETTing:CATalog? on page 113
[:SOURce<hw>]:IQ:DPD:SETTing:STORe on page 113
[:SOURce<hw>]:IQ:DPD:SETTing:LOAD on page 113
[:SOURce]:IQ:DPD:SETTing:DELete on page 113

AM/AM First
Toggles the order the AM/AM and AM/PM predistortions are applied.

Remote command:
[:SOURce<hw>]:IQ:DPD:AMFirst on page 114

Level Reference
Switches between dynamic and static adaptation of the range the selected DPD is applied on.

"Before DPD/After DPD"
Selects dynamic range calculation and defines whether the selected "Level" value corresponds to the signal level before or after the predistortion, see Chapter 3.2.1, "Defining the power level of the generated signal", on page 49.
Option: R&S SMW-K546
If in the same path "I/Q Mod > Digital Predistortion > Digital Doherty > General > State > On", the value is set to "Level Reference = Before DPD" and cannot be changed.

"Static DPD" Selects static (constant) range limits. To adjust the range, use the parameter Pre-Gain.

Remote command:
`[:SOURce<hw>]:IQ:DPD:LREFerence` on page 114

Maximum Output Level Error
For "Level Reference > After DPD", sets the allowed maximum error, see Chapter 3.2.1, "Defining the power level of the generated signal", on page 49.

Remote command:
`[:SOURce<hw>]:IQ:DPD:OUTPut:ERRor:MAX` on page 115

Maximum Number of Iterations
For "Level Reference > After DPD", sets the maximum number of performed iterations to achieving the required Maximum Output Level Error.

See also Chapter 3.2.1, "Defining the power level of the generated signal", on page 49.

Remote command:
`[:SOURce<hw>]:IQ:DPD:OUTPut:ERRor:MAX` on page 115

Achieved Output Level Error
Displays the resulting level error, see Chapter 3.2.1, "Defining the power level of the generated signal", on page 49.

Remote command:
`[:SOURce<hw>]:IQ:DPD:OUTPut:ERRor?` on page 114

Input/Output PEP, Level and Crest Factor
Displays the calculated values the before and after the DPD.

See "To perform manual iterations to achieve a desired resulting signal level after the DPD" on page 89.

A value of -1000 indicates that the calculation is impossible or there are no measurements results available.

Remote command:
`[:SOURce<hw>]:IQ:DPD:INPut:PEP?` on page 116
`[:SOURce<hw>]:IQ:DPD:INPut:LEVel?` on page 116
`[:SOURce<hw>]:IQ:DPD:INPut:CFACtor?` on page 116
`[:SOURce<hw>]:IQ:DPD:OUTPut:PEP?` on page 116
`[:SOURce<hw>]:IQ:DPD:OUTPut:LEVel?` on page 116
`[:SOURce<hw>]:IQ:DPD:OUTPut:CFACtor?` on page 116

AM/AM and AM/PM State
Enables/disables the AM/AM and AM/PM digital predistortion.

If both predistortions are enabled simultaneously, the instrument applies the AM/AM predistortion first and compensates the phase error of the PA afterwards.

Compare the displayed signal processing chain.

Remote command:
`[:SOURce<hw>]:IQ:DPD:AMAM:STATe` on page 114
`[:SOURce<hw>]:IQ:DPD:AMPM:STATe` on page 114

3.3.2 Predistortion settings

Access:

1. Select "I/Q Mod > Digital Predistortion > AM/AM AM/PM > Predistortion Settings".
2. Select a shaping function, for example the shaping file form Example"Shaping table file content (*.dpd_magn file)" on page 52.

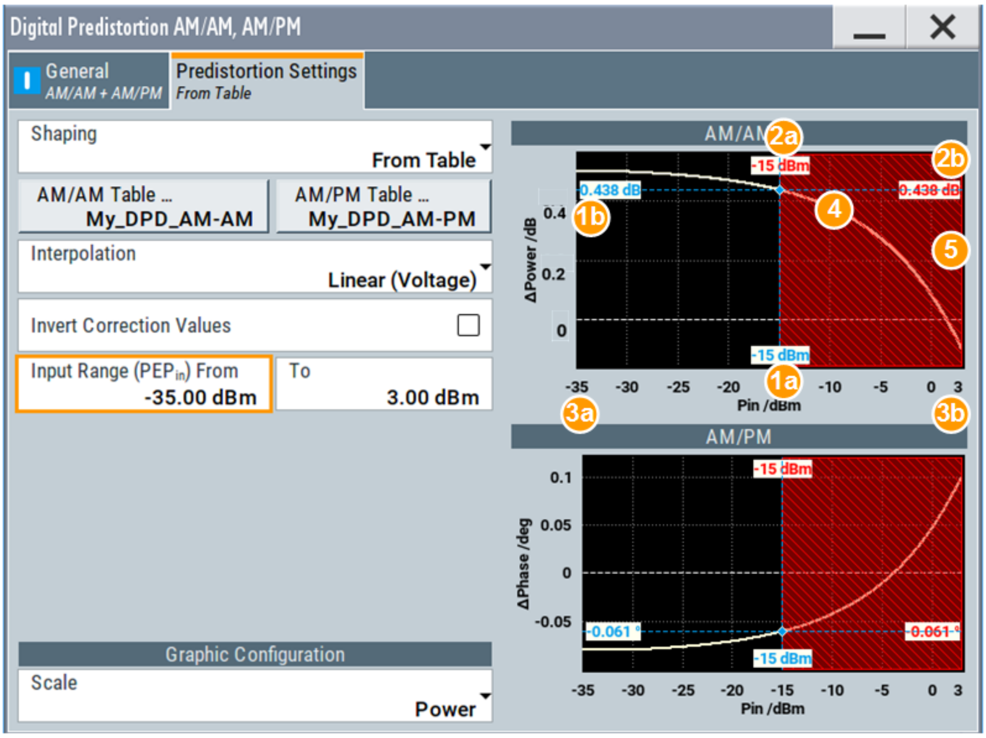


Figure 3-2: Predistortion Settings > From Table: Understanding the displayed information

1a	=	Normalized value of the current RF RMS power level
2a	=	Normalized value of the current PEP of the generated RF signal
1b, 2b	=	Correction values
White dashed line	=	Ideal zero correction function; no correction is necessary.
Yellow curve	=	Predistortion function
3a, 3b	=	Input Range (PEP_{in}) From/To
4	=	Positive correction coefficients to compensate values below the ideal ones
5	=	Values greater than the PEPin Max are ignored.

The dialog covers the settings for digital predistortion, like select and enabling an AM/AM and/or AM/PM predistortion, select the way the predistortion function is defined and specify the correction values.

Settings:

Shaping

Selects the method to define the correction coefficients.

"From Table" As value pairs in form of a shaping table.
Select "AM/AM or AM/PM Shaping Table" to access the settings, see Chapter 3.3.3, "Edit predistortion table settings", on page 62.
Select "Power Table" or "Phase Table" to to access the settings.

"Polynomial" By a polynomial with configurable order and coefficients.
Select "Polynomial Coefficients" to access the settings, see Chapter 3.3.4, "Polynomial coefficients settings", on page 65.

"Normalized" As a normalized data.
Select "Normalized Data" to access the settings, see Chapter 3.3.5, "Normalized data settings", on page 68.

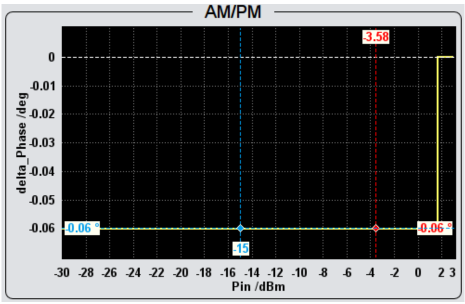
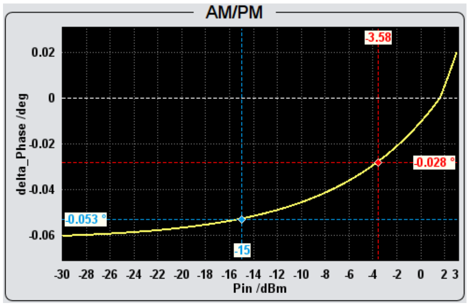
"Classic Doherty" Option: R&S SMW-K546
Selects a shaping function defined by the "Power" coefficient.

Remote command:
`[:SOURce<hw>]:IQ:DPD:SHAPing:MODE` on page 116
`[:SOURce<hw>]:IQ:DOHerty:SHAPing:MODE` on page 132

Interpolation

For "Shaping > From Table/Normalized", enables a linear interpolation between limited number of defined value pairs in the table, to prevent abrupt changes.

Table 3-3: Effect of parameter Interpolation

<table>
<tr><th>"Interpolation > Off"</th><th>"Interpolation > Linear (Power)"</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Remote command:
`[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:INTerp` on page 121
`[:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:INTerp` on page 121

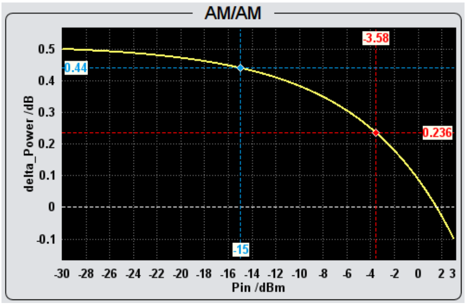
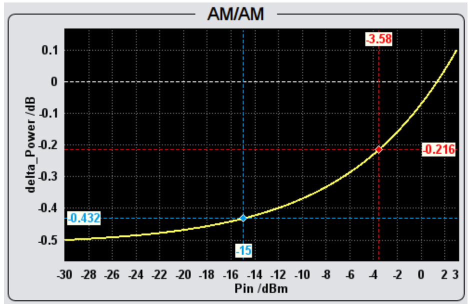
Invert Correction Values

Inverts the defined correction values.

Applies the exact invert predistortion coefficients without changing the defined predistortion table.

This function is also useful to toggle between predistortions with corrections related to the input power and to the output power.

Table 3-4: Effect of parameter Invert correction values

"Invert correction values > Off"	"Invert correction values > On"
	

Remote command:
[:SOURce<hw>]:IQ:DPD:SHAPing[:TABLe]:INVert on page 121
[:SOURce<hw>]:IQ:DOHerty:SHAPing[:TABLe]:INVert on page 121

Input Range (PEP_{in}) From/To

Defines the minimum and maximum input power PEP_{in}.

If you apply digital predistortion on signals used for power amplifier tests with envelope tracking, set the PEP_{in}Max value to the maximum value of the input power PEPin Max, as required by the power amplifier (PA).

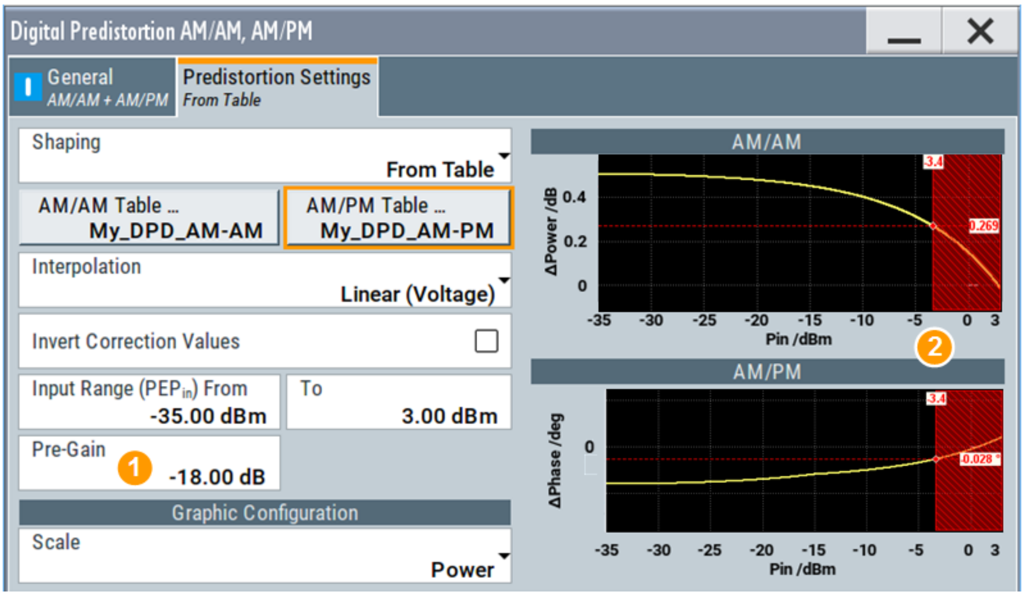
Remote command:
[:SOURce<hw>]:IQ:DPD:PIN:MIN on page 119
[:SOURce<hw>]:IQ:DPD:PIN:MAX on page 119
[:SOURce<hw>]:IQ:DOHerty:PIN:MIN on page 119
[:SOURce<hw>]:IQ:DOHerty:PIN:MAX on page 119

Pre-Gain

For "General > Level Reference > Static DPD", sets a pre-gain (i.e. an attenuation) to define the range the DPD is applied in. The pre-gain can be used to define and test only a specific (required) part of the operating range.

For "General > Level Reference > Before/After DPD", the range is limited by the current PEP of the signal.

See Figure 3-2.



1 = Pre-gain limits the effective range of the shaping function
2 = Values above this limit are ignored

Remote command:
[:SOURce<hw>]:IQ:DPD:GAIN:PRE on page 116

Shaping Table

Accesses the standard "Predistortion Select" dialog with functions to define a new shaping table file, select, or edit an existing one.

The shaping table files are files with predefined extension and file format, see "File format of the correction table file" on page 52.

You can create a shaping table externally or internally.

"Select"	Selects and loads an existing file.
"New"	Creates a file.
"Edit"	Access a standard built-in table editor, see Chapter 3.3.3, "Edit predistortion table settings", on page 62.

Remote command:
For AM/AM distortions:
[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMAM:FILE:CATalog? on page 119
[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMAM:FILE[:SELect] on page 120
For AM/PM distortions:
[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMPM:FILE:CATalog? on page 119
[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMPM:FILE[:SELect] on page 120
For power:
[:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:AMAM:FILE:CATalog?
on page 119
[:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:AMAM:FILE[:SELect]
on page 120
For phase:

[:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:AMPM:FILE:CATalog? on page 119
[:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:AMPM:FILE[:SELect] on page 120

Polynomial Coefficients
For "Shaping > Polynomial", accesses a dialog to describe the predistortion function as a polynomial function, see Chapter 3.3.4, "Polynomial coefficients settings", on page 65.

Normalized Data
For "Shaping > Normalized", accesses a dialog to describe the predistortion function as a normalized data, see Chapter 3.3.5, "Normalized data settings", on page 68.

Graphic Configuration
Comprises setting to configure the graphical display.

Scale ← Graphic Configuration
Determines the unit of the x-axis, "Voltage" or "Power".

Remote command:
[:SOURce<hw>]:IQ:DPD:SCALe on page 119
[:SOURce<hw>]:IQ:DOHerty:SCALe on page 119

AM/AM and AM/PM Diagrams ← Graphic Configuration
Visualize the resulting correction functions, as function of the selected PEP_{in} value limits.

See Figure 3-2.

Remote command:
[:SOURce<hw>]:IQ:DPD:AMAM:VALue:LEVel? on page 124
[:SOURce<hw>]:IQ:DPD:AMAM:VALue:PEP? on page 125
[:SOURce<hw>]:IQ:DPD:AMAM:VALue? on page 125
[:SOURce<hw>]:IQ:DPD:AMPM:VALue:LEVel? on page 124
[:SOURce<hw>]:IQ:DPD:AMPM:VALue:PEP? on page 125
[:SOURce<hw>]:IQ:DPD:AMPM:VALue? on page 125
[:SOURce<hw>]:IQ:DOHerty:AMAM:VALue:LEVel? on page 124
[:SOURce<hw>]:IQ:DOHerty:AMAM:VALue:PEP? on page 125
[:SOURce<hw>]:IQ:DOHerty:AMAM:VALue? on page 125
[:SOURce<hw>]:IQ:DOHerty:AMPM:VALue:LEVel? on page 124
[:SOURce<hw>]:IQ:DOHerty:AMPM:VALue:PEP? on page 125
[:SOURce<hw>]:IQ:DOHerty:AMPM:VALue? on page 125

3.3.3 Edit predistortion table settings

The predistortion table is an internal editor where you define the correction values, ΔPower and ΔPhase, in form of a look-up table.

Access:

1. Select "I/Q Mod > Digital Predistortion > AM/AM AM/PM > Predistortion Settings".
2. Select "Shaping > From Table".
3. Select "AM/AM > Shaping Table > Predistortion AM/AM Shaping File > New"
4. Enter the "File Name", e.g. *My_DPD_AM-AM*

   The "Predistortion AM/AM Shaping File" dialog closes.
   The "Shaping Table > My_DPD_AM-AM" confirms that the newly created file is assigned.
5. Select "Shaping Table > Predistortion AM/AM Shaping File > Edit"
6. Define the value pairs "Pin/dBm" and "ΔPower/dB". The order is uncritical.

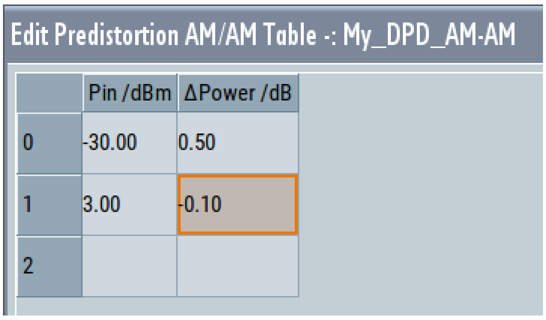


Figure 3-3: Example of an AM-AM predistortion table values

7. Select "Save".

   The instrument loads the configured values automatically and displays the function of the delta correction values.
8. Select "Predistortion Settings > Interpolation > Linear".

   The display confirms the used interpolation.

Settings:

Pin (dBm), Delta Power (dB)/Pin (dBm), Delta Phase (deg)

Sets the correction value pairs.

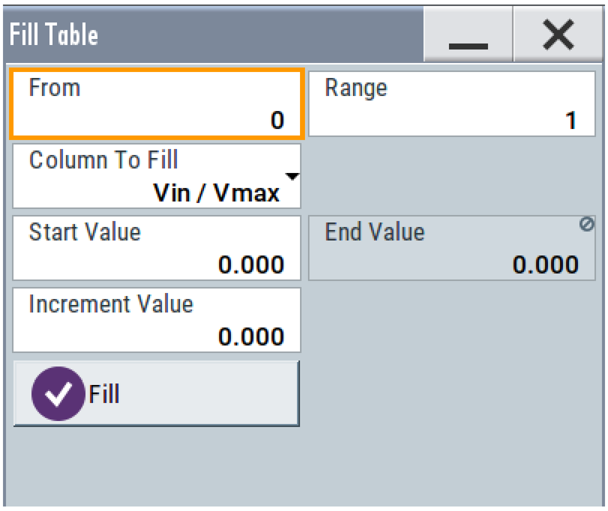
"Pin, ΔPower"
Value pairs for the AM/AM predistortion

"Pin, ΔPhase"
Value pairs for the AM/PM predistortion

Remote command:
See [:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMAM:FILE[:SELect]
on page 120
and [:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMPM:FILE[:SELect]
on page 120
See [:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:AMAM:FILE[:SELect]
on page 120
and [:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:AMPM:FILE[:SELect]
on page 120

Fill Table Automatically

Standard function for filling a table automatically with user-defined values.



"From / Range"
Defines the start line and number of the rows to be filled.

"Select Column to Fill"
Selects the respective value, including the unit.

"Start / End Value"
Default values corresponding to the selected column.

"Increment" Determines the step size.

"Fill" Fills the table.
Fill both columns and then save the list. Otherwise the entries are lost.

Goto, Edit, Save As, Save

Standard functions for editing of data lists.

Changed and unsaved values are displayed on a yellow background.

Remote command:
n.a.

3.3.4 Polynomial coefficients settings

Alternatively to the look-up table, you can define the predistortion functions as a polynomial function. The R&S SMW calculates the AM/AM and AM/PM predistortion functions and the required correction coefficients out of the defined polynomial.

To access the polynomial coefficients setting and define a higher-order polynomial

1. Select "I/Q Mod > Digital Predistortion > AM/AM AM/PM > Predistortion Settings".
2. Select "Shaping > Polynomial".
3. Select "AM/PM > Polynomial Coefficients".

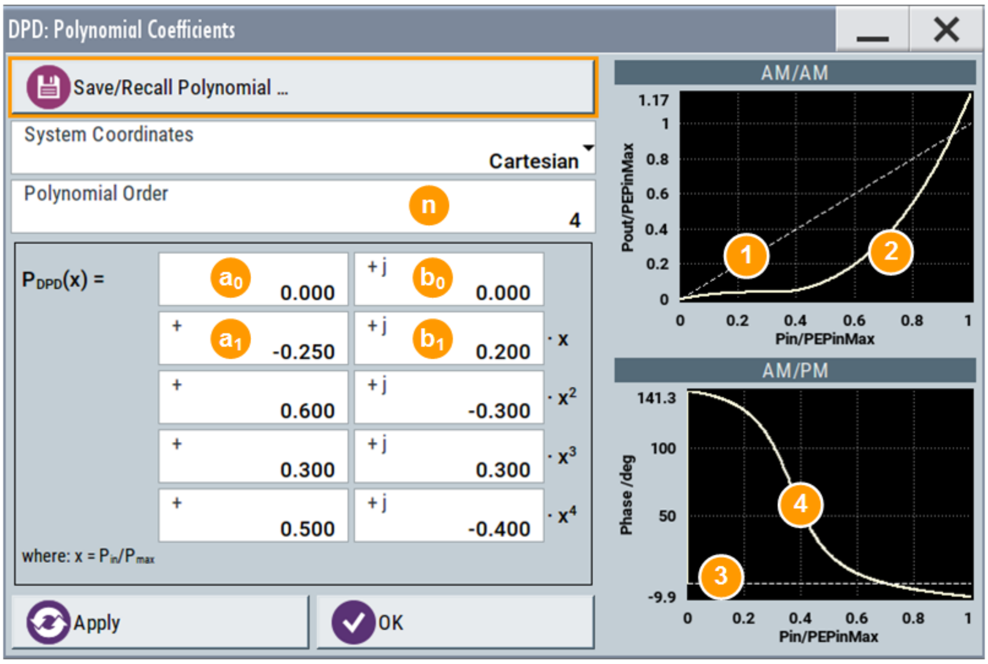


Figure 3-4: Polynomial Coefficients: Understanding the displayed information

n = Polynomial order
a0, b0, ... = Polynomial coefficients
1 = Ideal AM/AM function (the normalized amplitude is a line).
2 = Resulting AM/AM predistortion function, calculated as AM/AM(x) = abs[P_{DPD}(x)]
3 = Ideal AM/PM function (constant phase at 0 degrees)
4 = Resulting AM/PM predistortion function, calculated as AM/PM(x) = $\tan^{-1}$\{Im[P_{DPD}(x)]/Re[P_{DPD}(x)]\}

With the provided settings, you can define a polynomial function with up to 10th order to describe the predistortion function.
The graphical display updates on-the-fly and visualizes the resulting AM/AM and AM/PM functions.

4. Select "Polynomial Order = 4" (n = 4).
5. Set the polynomial coefficients a_0 to b_4.
   Use, for example, the values shown on Figure 3-4.

6. Select "Apply".

   The instrument loads the configured values, calculates the correction values, and displays the predistortion functions.

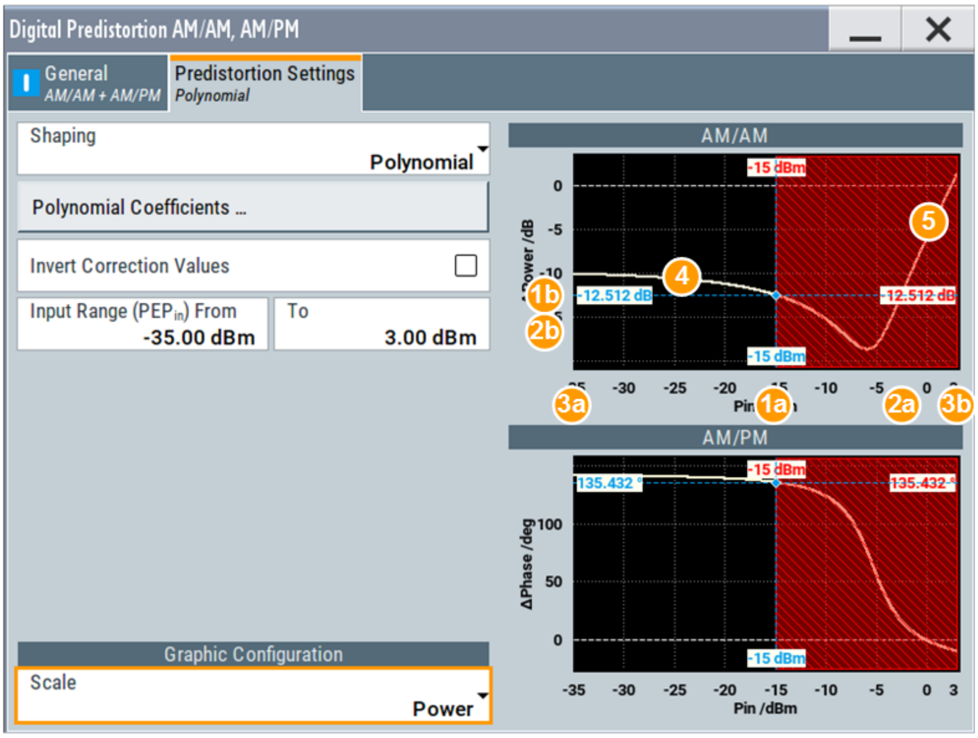


Figure 3-5: Predistortion Settings > Polynomial: Understanding the displayed information

1a	= Current RF RMS power level
2a	= Current PEP of the generated RF signal
1b, 2b	= Correction values
White dashed line	= Ideal zero function; no correction is necessary.
AM/AM yellow curve	= AM/AM correction values, calculated as ΔAM/AM(x) = AM/AM(x) - x
AM/PM yellow curve	= AM/PM correction values, calculated as ΔAM/PM(x) = AM/PM(x)
3a, 3b	= X-axis scale, calculated from the Input Range (PEP_{in}) From/To
4	= Negative correction coefficients
5	= Values greater than the PEPin Max are ignored.

7. To store the defined predistortion function:
   a) Select "Save/Recall Polynomial"
   b) Navigate throughout the file system.
   c) Enter a "File Name", e.g. *MyPolynomial_4thOrder*
   d) Select "OK".
8. Select "Polynomial Coefficients > OK" to close the dialog.

Settings:

Save/Recall Polynomial

Accesses the "Save/Recall" dialog, that is the standard instrument function for saving and recalling the complete dialog-related settings in a file. The provided navigation possibilities in the dialog are self-explanatory.

The settings are saved in a file with predefined extension. You can define the filename and the directory, in that you want to save the file.

See also, chapter "File and Data Management" in the R&S SMW user manual.

The polynomial files are files with extension `*.dpd_poly`, see "File format of the polynomial file" on page 51. The polynomial function is stored in Cartesian format.

Remote command:
`[:SOURce<hw>]:IQ:DPD:SHAPing:POLYnomial:COEFficients:CATalog?` on page 122
`[:SOURce<hw>]:IQ:DPD:SHAPing:POLYnomial:COEFficients:LOAD` on page 122
`[:SOURce<hw>]:IQ:DPD:SHAPing:POLYnomial:COEFficients:STORe` on page 122
`[:SOURce<hw>]:IQ:DOHerty:SHAPing:POLYnomial:COEFficients:CATalog?` on page 122
`[:SOURce<hw>]:IQ:DOHerty:SHAPing:POLYnomial:COEFficients:LOAD` on page 122
`[:SOURce<hw>]:IQ:DOHerty:SHAPing:POLYnomial:COEFficients:STORe` on page 122

System Coordinates

Defines whether the polynomial function is defined in Cylindrical (Polar) or in Cartesian coordinates.

Remote command:
n.a.

Polynomial Order

Defines the polynomial order `n`, that is the number of polynomial coefficients (see Chapter 3.2.2.1, "Polynomial function", on page 50).

The polynomial order defines the degree, complexity, and the number of terms in the polynomial function.

Remote command:
See `[:SOURce<hw>]:IQ:DPD:SHAPing:POLYnomial:COEFficients` on page 121.
See `[:SOURce<hw>]:IQ:DOHerty:SHAPing:POLYnomial:COEFficients` on page 121.

Apply, OK
Triggers the instrument to adopt the selected function.

Use "OK" to apply the setting and exits the dialog.

Remote command:
`[:SOURce<hw>]:IQ:DPD:SHAPing:POLYnomial:COEFficients` on page 121
`[:SOURce<hw>]:IQ:DOHerty:SHAPing:POLYnomial:COEFficients`
on page 121

Polynomial coefficients
Sets the polynomial coefficients a_0 to a_n and b_0 to b_n.

In "System Coordinates > Cylindrical", the polynomial coefficients b_0 to b_n are expressed in degrees.

The polynomial coefficients influence the shape of the predistortion function, see Figure 3-4 for an illustration of a polynomial function.

Select "Apply" to confirm the settings.

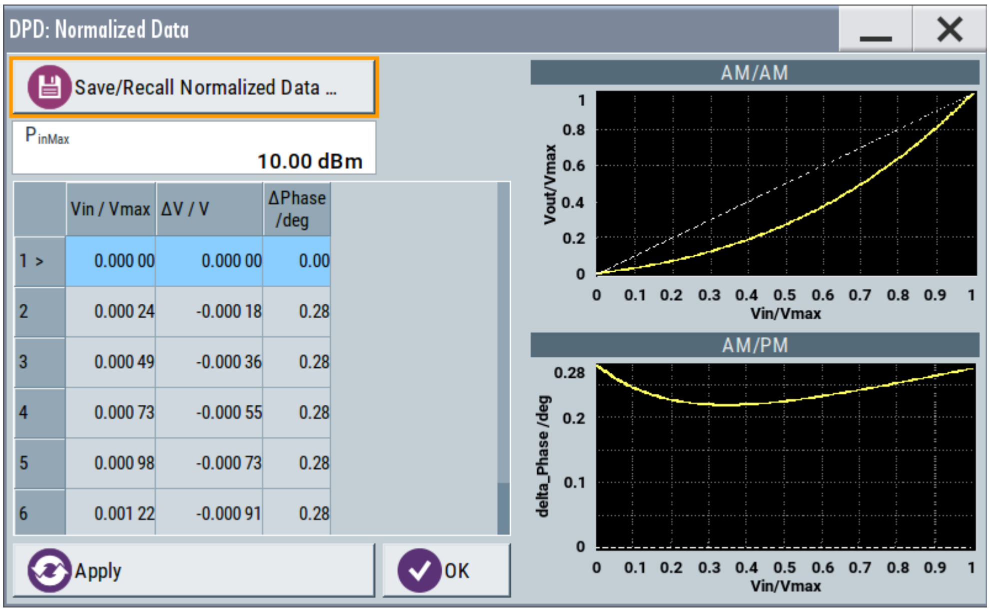
Remote command:
See "Apply, OK" on page 68.

3.3.5 Normalized data settings

The normalized data table is an internal editor where you define the correction values, Vin/Vmax, ΔV/V and ΔPhase, in form of a table.

To access the internal editor

1. Select "I/Q Mod > Digital Predistortion > AM/AM AM/PM > Predistortion Settings".
2. Select "Shaping > Normalized Data".
3. Select "Normalized Data".



4. Enter the Pin_{max}.
   Note: Enter the correction values in the required order. The value range of the subsequent correction values adjusts automatically.

5. To store the setting in a file, select "Save/Recall Normalized Data > Save".
   Enter a "File Name", e.g. *My_DPD_Normalized*.

Settings:

Save/Recall Normalized Data

Accesses the "Save/Recall" dialog, that is the standard instrument function for saving and recalling the complete dialog-related settings in a file. The provided navigation possibilities in the dialog are self-explanatory.

The settings are saved in a file with predefined extension. You can define the filename and the directory, in that you want to save the file.

See also, chapter "File and Data Management" in the R&S SMW user manual.

The normalized data files are files with extension `*.dpd_norm`, see "File format of the normalized data" on page 52.

Remote command:
`[:SOURce<hw>]:IQ:DPD:SHAPing:NORMalized:DATA:CATalog?` on page 124
`[:SOURce<hw>]:IQ:DPD:SHAPing:NORMalized:DATA:LOAD` on page 124
`[:SOURce<hw>]:IQ:DPD:SHAPing:NORMalized:DATA:STORe` on page 124
`[:SOURce<hw>]:IQ:DOHerty:SHAPing:NORMalized:DATA:CATalog?`
on page 124

[:SOURce<hw>]:IQ:DOHerty:SHAPing:NORMalized:DATA:LOAD on page 124
[:SOURce<hw>]:IQ:DOHerty:SHAPing:NORMalized:DATA:STORe on page 124

Pin_{Max}
Sets the value of the maximum input power level.

Pin_{max} corresponds to a normalized input power of 1, that is the max. allowed value on the x-axis.

Select "Apply" to confirm the settings.

Remote command:
n.a.

Vin/Vmax, Delta V/V, Delta Phase (deg)
Sets the correction as a group of three values.

Select "Apply" to confirm the settings.

Remote command:
See "Apply, OK" on page 70.

Apply, OK
Triggers the instrument to adopt the normalized data.

Use "OK" to apply the setting and exits the dialog.

Remote command:
[:SOURce<hw>]:IQ:DPD:SHAPing:NORMalized:DATA on page 123
[:SOURce<hw>]:IQ:DOHerty:SHAPing:NORMalized:DATA on page 123

3.4 Compensating non-linear RF effects

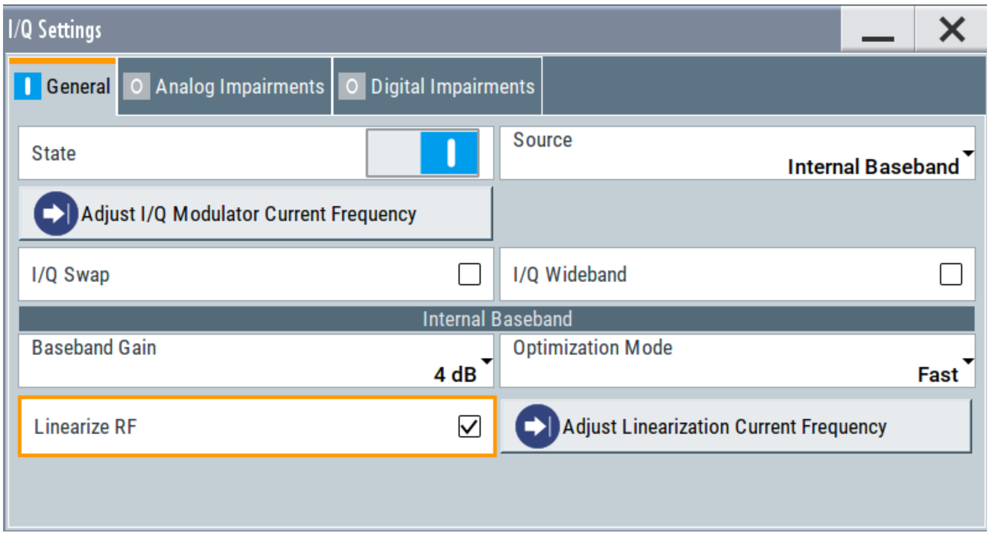
The R&S SMW provides a built-in function for compensating of its own non-linear RF effects caused by the amplifiers. If the function is enabled, the instrument uses the digital predistortion function and applies automatically calculated AM/AM predistortion values to the generated baseband signal.

The RF linearization and the "Digital Predistortions, AM/AM and AM/PM" cannot be used simultaneously; activating the "Linearize RF" parameter disables the "Digital Predistortions, AM/AM and AM/PM" settings.

To access the required settings:

1. Select "I/Q Mod > I/Q Modulator > General > Linearize RF".

2. Select "Adjust Linearization Current Frequency".



The R&S SMW calculates the required correction values for the selected RF and the current generated signal.

Settings:

Linearize RF

Option: R&S SMW-K541

Enables an automatic AM/AM predistortion of the non-linear RF chain.

During RF linearization, disables "Digital Predistortions AM/AM and AM/PM" settings.

Remote command:
`[:SOURce<hw>]:IQ:DPD:LRF:STATe` on page 116

Adjust Linearization Current Frequency

Calculates the correction data for the currently selected frequency.

During RF linearization, disables "Digital Predistortions AM/AM and AM/PM" settings.

Remote command:
`[:SOURce<hw>]:IQ:DPD:LRF:ADJust?` on page 117

4 Testing Doherty power amplifiers

Power amplifiers are an essential part of any telecommunication systems and the Doherty power amplifiers (PA) in particular are widely used in wireless base stations. A typical digitally assisted Doherty amplifier uses two parallel working PAs, one for the carrier amplification and the second one for the peaking amplification. Hence, testing of these dual-input digital Doherty amplifiers requires two synchronous control signals, one for each of the build-in PAs.

In the R&S SMW, you can generate the required two baseband signals and two RF signal that act as control signals out of the same instrument.

4.1 Required options

The equipment layout for generating signals for testing Doherty amplifiers includes:

- Option standard or wideband baseband generator (R&S SMW-B10/-B9)
  Option baseband main module, two I/Q paths to RF (R&S SMW-B13T) or wideband baseband main module (R&S SMW-B13XT)
- Option frequency (e.g. R&S SMW-B1003 and R&S SMW-B2003)
- Option Phase coherence (R&S SMW-B90)
- 2x Option AM/AM AM/PM predistortion (R&S SMW-K541)
- Option Digital Doherty (R&S SMW-K546)

4.2 About the digital Doherty power amplifiers

The Digital Doherty option assists you by the development of Doherty amplifiers by digitally splitting one input signal into components for carrier and peaking amplifiers.

The Figure 4-1 shows a simplified test setup for testing of Doherty amplifiers. This illustration is intended to explain the principle in general, not all connections and required equipment are considered.

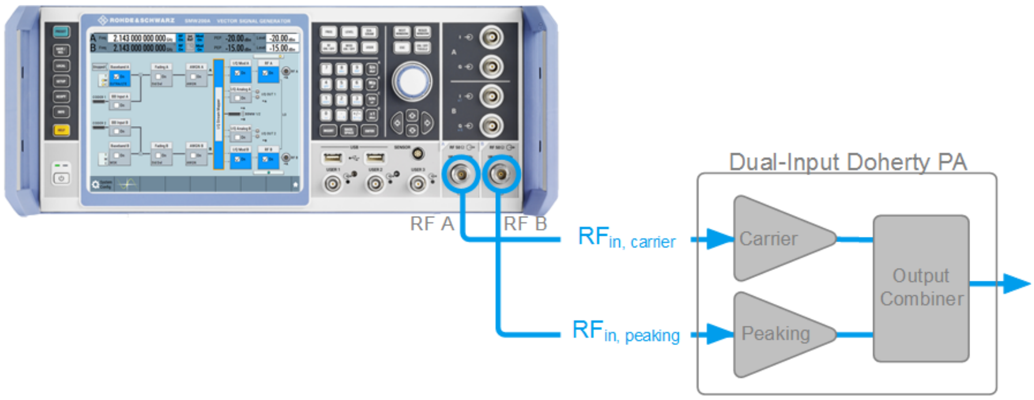


Figure 4-1: Simplified test setup for testing dual-input digital Doherty power amplifiers

$RF_{in, carrier}$ = corresponds to the unmodified input signal
$RF_{in, peaking}$ = derived from the control signal for the carrier amplifier by modifying it with power and phase values

The input (baseband) signal is output unmodified at the RF A output and is intended for the carrier amplifier. The signal for the peaking amplifier is output at the RF B output. You modify this signal by applying a power and phase relative to the signal at the RF A. To split optimally the signal components for the amplifier, the power and phase values are adjusted as a function of the input power.

If the Digital Doherty is activated, the R&S SMW works in constant phase mode, so that the phases of the signal at the RF outputs are kept aligned.

A suitable input test signal is, for example, a continuous wave (CW) signal or your test signal loaded as a waveform in the ARB generator. The control signals are output at the RF A/RF B connectors and fed to the inputs of the Doherty power amplifiers.

Additionally to defining the power and phase values, you can also apply digital predistortion (DPD). If activated ("I/Q Mod > Digital Predistortion > AM/AM AM/PM > State > On"), digital predistortion is applied before the Digital Doherty. With other words, the input signal is predistorted before the signal components are derived.

4.2.1 RF phase alignment

To ensure efficient operation of the amplifier, the R&S SMW uses internal algorithm to keep the phase alignment between the RF signals whenever the Digital Doherty is activated ("Digital Doherty > State > On").

The phases of the RF signals are influenced by several parameters, that can be divided into two groups:

- Phase parameters *within* the "Digital Doherty" dialog

  You can, for example:

  – Use the phase offset parameter ("Digital Doherty" > Phase Offset) to calibrate the overall phase of the signal.
  – Apply phase delta correction values ("Digital Doherty" > "Phase Delta > State") for phase compensation based on the input level.

- Phase-related parameters *outside* the "Digital Doherty" dialog

Tips for best results

Modifying one of the parameters within the "Digital Doherty" dialog ensures RF signals with aligned phases.

This behavior cannot be guaranteed for parameters outside the "Digital Doherty" dialog.

For details, see "Tips for best results" on page 74.

Table 4-1: Do and Do not

Which parameter of the output RF signals do you want to change?	Do not use	Use instead
RF frequency	"Status bar > A/B > Frequency"	"I/Q Stream Mapper > Frequency Offset" (adds frequency offset and thus shifts the signal digitally in the frequency domain)
RF level	"Status bar > A/B > Level"	"Digital Doherty" > Dig Att (attenuates the signal digitally and thus changes the level of the output signal)
Used baseband signal	Different waveforms in the two paths	Load the same waveform the ARB generator "Baseband > ARB > Load Waveform"
	Do not modify the baseband signal while "Digital Doherty" is activated	Always configure the baseband signal first Configure and activate the "Digital Doherty"

4.2.2 Defining the correction values

In the R&S SMW, you can select the way you define the correction function and choose between:

- A polynomial function with up to 10 polynomial coefficients
  (see Chapter 3.2.2.1, "Polynomial function", on page 50)
- A shaping function defined as a look-up table
  (seeChapter 3.2.2.2, "Shaping table", on page 51)
- A normalized data
  (see Chapter 3.2.2.3, "Normalized data", on page 52)
- The parameters of classical Doherty amplifier
  See "Power Breakpoint" on page 80.

Because the first three methods follow the same concept as the methods used by the DPD functionality, these methods and the corresponding settings are described together.

4.3 Digital Doherty settings

In the following, we assume that you are familiar with the DPD functionality because the DPD option is a prerequisite for the digital Doherty functionalities.

For background information on the DPD principles and description of the provided settings, see Chapter 3, "Applying digital predistortion", on page 48.

Access:

► Select "I/Q Mod > Digital Predistortion > Digital Doherty".

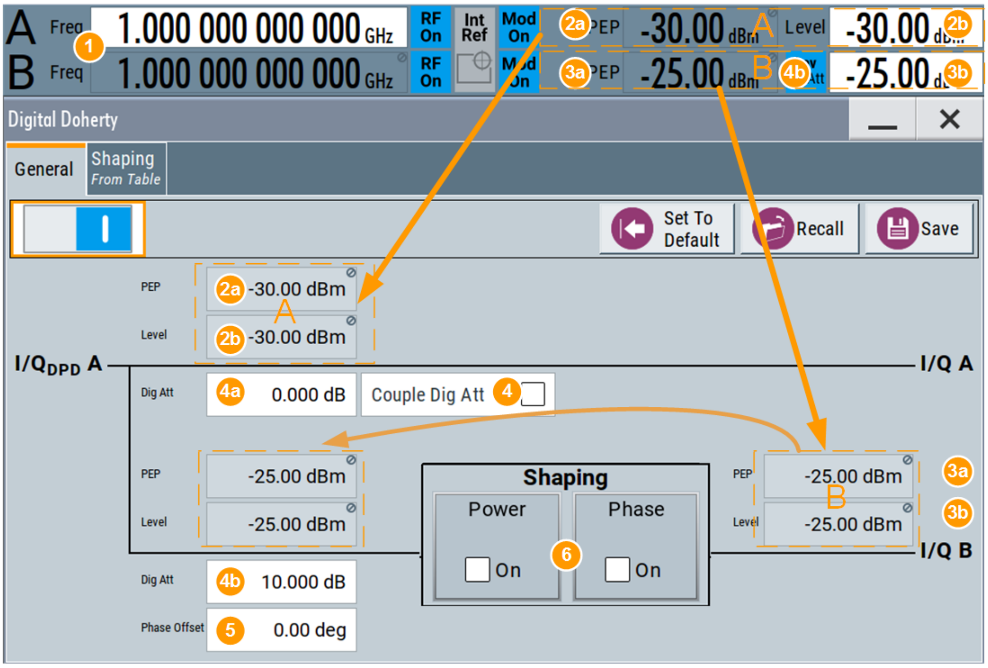


Figure 4-2: Digital Doherty: Understanding the displayed information

1 = "Frequency A = Frequency B" so that both RF outputs use the same frequency
2a, 2b = "PEP" and "Level" values in path A, calculated based on the current baseband signal
3a, 3b = "PEP" and "Level" values in path B at the I/Q outputs; shaping ("Power Spilt" and "Phase Delta") and DPD are considered
4, 4a, 4b = If "Couple Dig Att = Off", you can set different attenuation values "Dig Att" in path A and B; in this example, a "Dig Att = 10 dB" is applied on the second path. The indication "Lev Att" on the "Status bar" confirms the coupling.
5 = Adds a phase offset for compensating for phase differences between the signals or for introducing a phase between them deliberately; resembles the value of the parameter "I/Q Mod B > Digital Impairments > Phase Offset"
6 = You can enable "Power Spilt" and "Phase Delta" shaping according to the selected shaping function

The dialog covers the settings for digital Doherty, like defining the level settings, enabling power and phase corrections, select the way these correction functions are defined and specifying the correction values.

Interdepended settings

If digital Doherty is enabled ("State > On"), the following configurations and settings are set automatically:

- The signal at the RF outputs is at the same frequency, i.e. "Status bar > Frequency A = Frequency B".
- To ensure phase alignment between the two control signals:
  - The local oscillators of both paths are locked, i.e. "RF > LO Coupling > Mode > A internal & A -> B Coupled".
    You recognize this state by the LO indication on the Block diagram.
  - The phase difference between the two RF signals is looked; i.e. "RF > Level > RF Level > Settings Characteristics = Continuous-Phase".
- The level of the RF signals can be changed ("Status bar > Level") but the allowed level range is selected so that the continuous phase condition is ensured.
- The displayed "PEP" and "Level" values ("Status bar > PEP/Level") are calculated based on the current baseband signal.
- The signals at the RF outputs are generated from the same stream and if DPD is not enabled, from the same baseband signal. The signal at the second RF output (RF B) is, if enabled, predistorted by user-defined power and/or phase corrections. Thus, the signal from the "Baseband A" and the corresponding stream A is automatically routed to both RF outputs, i.e. "Block diagram > I/Q Stream Mapper > Stream A > RF A/RF B".
  You recognize this state by Steam A indication at each of the RF A and RF B outputs.

Because the provided configurations and settings are similar to the DPD settings, they are described together. The same apples also for the remote control commands.

This section describes only the **settings that are dedicated to the digital Doherty** option. For description of all other settings, see Chapter 3.3, "Digital predistortions AM/AM and AM/PM settings", on page 54.

The remote commands required to define the settings are described in:

- Chapter 7.5, "SOURce:IQ:DOHerty subsystem", on page 126
- Chapter 7.4, "SOURce:IQ:DPD and SOURce:IQ:DOHerty subsystem", on page 117.

4.3.1 General settings

Access:

► Select "I/Q Mod > Digital Predistortion > Digital Doherty".

See Figure 4-2.

State

Option: R&S SMW-B9 - enabled in "System Config > Mode = Standard".

Option: R&S SMW-B10 - enabled in "System Config > Mode = Standard/Advanced".

Enables/disables the generation of control signals for testing Doherty amplifiers.

If digital Doherty is enabled ("State > On"), some configurations and settings are set automatically, see "Interdepended settings" on page 76.

Remote command:
`[:SOURce]:IQ:DOHerty:STATe` on page 128

Set to Default

Calls the default settings. The values of the main parameters are listed in the following table.

Parameter	Value
"State"	Not affected by the "Set to Default"
"Couple Dig. Att."	Off
"Power"	Off
"Phase"	Off
"Dig. Att.", "Phase Offset", "PEP", "Level"	As set in other dialogs Not affected by the "Set to Default"

Remote command:
`[:SOURce]:IQ:DOHerty:SETTing:PRESet` on page 129

Save/Recall

Accesses the "Save/Recall" dialog, that is the standard instrument function for saving and recalling the complete dialog-related settings in a file. The provided navigation possibilities in the dialog are self-explanatory.

The settings are saved in a file with predefined extension. You can define the filename and the directory, in that you want to save the file.

See also, chapter "File and Data Management" in the R&S SMW user manual.

Remote command:
`[:SOURce]:IQ:DOHerty:SETTing:CATalog?` on page 129
`[:SOURce]:IQ:DOHerty:SETTing:STORe` on page 129
`[:SOURce]:IQ:DOHerty:SETTing:LOAD` on page 129
`[:SOURce]:IQ:DOHerty:SETTing:DELete` on page 130

PEP, Level

Indicated are the PEP and level values per signal path, where:

- The values for I/Q A are derived from the baseband signal and correspond to the values at the I/Q output and RF A output and are displayed in the "Status bar".
- The values for I/Q B *after the shaping functions* are the values at the I/Q output and are also displayed and set in the Status bar.
  The values for I/Q B *before the shaping* are calculated automatically depending on the baseband signal and the DPD and considering the "Power" and "Phase" shaping functions so that the resulting PEP and Level at the I/Q B are as set in the Status bar.

See also Figure 4-2.

"---.--" Indicates that the values are in calculation.

Remote command:
I/Q A and I/Q B:
`[:SOURce<hw>]:IQ:DOHerty:OUTPut:PEP?` on page 132
`[:SOURce<hw>]:IQ:DOHerty:OUTPut:LEVel?` on page 132
I/Q B:
`[:SOURce<hw>]:IQ:DOHerty:INPut:PEP?` on page 131
`[:SOURce<hw>]:IQ:DOHerty:INPut:LEVel?` on page 131
Calculation status:
see `[:SOURce]:IQ:DOHerty:MEASurement[:STATe]?` on page 133

Dig Att

Applies additional digital attenuation to the signal.

The value resembles the value set with the parameter "Block diagram > RF > Level > RF Level > Digital Attenuation".

If Couple Dig Att > "Off", you can set th values for both outputs separately.

Remote command:
`[:SOURce<hw>]:IQ:DOHerty:POWer:ATTenuation` on page 131

Couple Dig Att

Enable this parameter to couple the "Dig Att" values for both signals; the difference between the values is, however, maintained.

Example:

For "$I/Q_{DPD}A$ > Dig Att = 30 dB", "$I/Q_{DPD}B$ > Dig Att = 20 dB" and "Couple Dig Att = On", if "$I/Q_{DPD}A$ > Dig Att = 40 dB" than "$I/Q_{DPD}B$ > Dig Att" is set to 30 dB.

Remote command:
`[:SOURce]:IQ:DOHerty:POWer:ATTenuation:COUPling[:STATe]`
on page 130

Phase Offset

Adds a phase offset for compensating for phase differences between the signals or for introducing a phase dealy between them deliberately.

The value resembles the value set with the parameter "I/Q Mod B > Digital Impairments > Phase Offset".

Remote command:
`[:SOURce<hw>]:IQ:DOHerty:PHASe:OFFSet` on page 130

Power and Phase State

Enables/disables the power and phase corrections.

If both shaping functions are enabled simultaneously, the instrument applies the power correction values first and compensates the phase error of the PA afterwards.

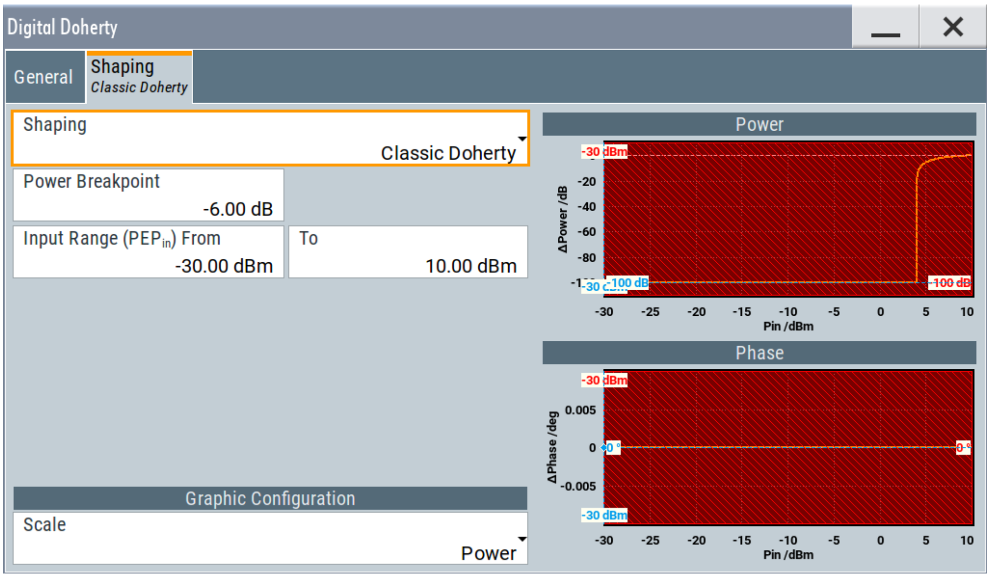
Compare the displayed signal processing chain.

Remote command:
`[:SOURce<hw>]:IQ:DOHerty:SHAPing:POWer:STATe` on page 131
`[:SOURce<hw>]:IQ:DOHerty:SHAPing:PHASe:STATe` on page 131

4.3.2 Shaping settings and settings for classic Doherty shaping

Access:

1. Select "I/Q Mod > Digital Predistortion > Digital Doherty > Shaping".
2. Select a shaping function, for example select "Shaping > Classic Doherty".



The dialog covers the shaping settings, like select the way the shaping function is defined and specify the correction values.
This section lists only the settings dedicated to digital Doherty. For description of all other settings, see Chapter 3.3.2, "Predistortion settings", on page 58.

Settings:

Power Breakpoint

Sets the power breakpoint value required for the calculation of the correction function if classic Doherty shaping is used.

Remote command:

`[:SOURce<hw>]:IQ:DOHerty:SHAPing:POWer:BREakpoint` on page 132

4.3.3 Edit shaping table settings

The shaping table is an internal editor where you define the correction values, ΔPower and ΔPhase, in form of a look-up table.

Access:

1. Select "I/Q Mod > Digital Predistortion > Digital Doherty > Shaping".
2. Select "Shaping > From Table".
3. Select "Power Table > New"
4. Enter the "File Name", e.g. *My_Power*

   The "Doherty Power Table" dialog closes.
   The "Shaping > Power Table > My_Power" confirms that the newly created file is assigned.
5. Select "Power Table > File > Edit"
6. Define the value pairs "Pin/dBm" and "ΔPower/dB". The order is uncritical.

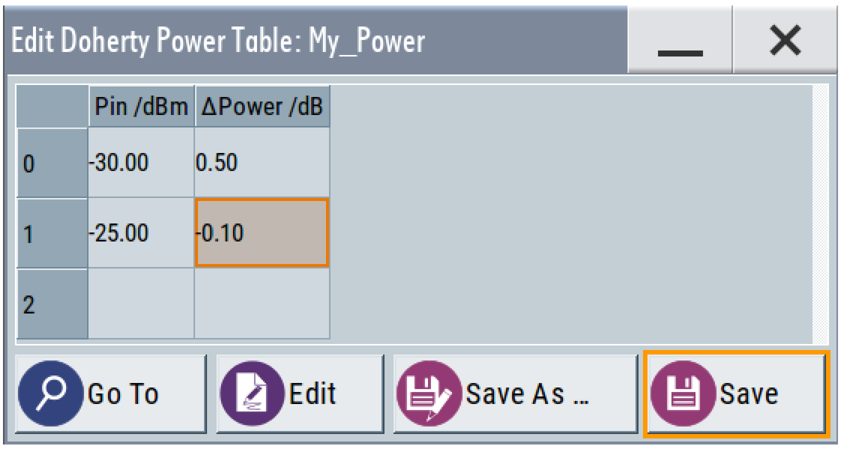


Figure 4-3: Example of a Power Table values

7. Select "Save".

   The instrument loads the configured values automatically and displays the function of the delta correction values.
8. Select "Shaping > Interpolation > Linear (Power)".

   The display confirms the used interpolation.

For settings description, see Chapter 3.3.3, "Edit predistortion table settings", on page 62.

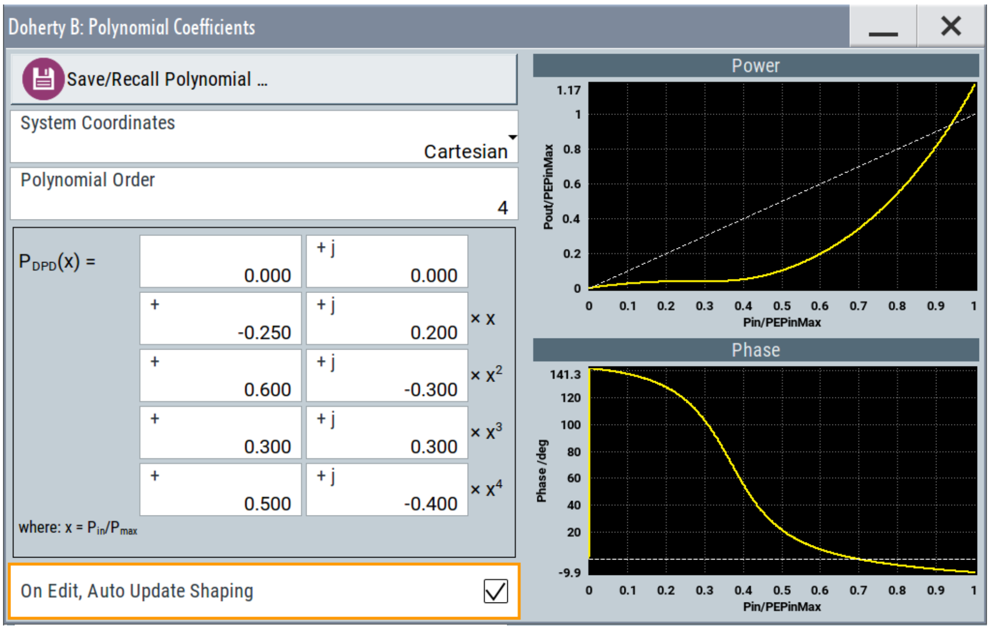
4.3.4 Polynomial coefficients settings

Alternatively to the look-up table, you can define the correction functions as a polynomial function. The R&S SMW calculates the power and phase correction functions and the required correction coefficients out of the defined polynomial.

To access the polynomial coefficients setting and define a higher-order polynomial

1. Select "I/Q Mod > Digital Predistortion > Digital Doherty > Shaping".
2. Select "Shaping > Polynomial".
3. Select "Polynomial Coefficients"

   See Figure 3-4.
   With the provided settings, you can define a polynomial function with up to 10th order to describe the shaping function.
   The graphical display updates on-the-fly and visualizes the resulting functions.
4. Select "Polynomial Order = 4" (n = 4).
5. Set the polynomial coefficients a_0 to b_4.



6. Select "On Edit, Auto Update Shaping > On"

   The instrument loads the configured values, calculates the correction values, and displays the shaping functions.
   See Figure 3-5.

7. To store the defined shaping function:
   a) Select "Polynomial Coefficients > Save/Recall Polynomial"
   b) Navigate throughout the file system and enter a "File Name", e.g. *MyPolynomial_4thOrder*
   c) Select "OK".
8. Select "Polynomial Coefficients > OK" to close the dialog.

   For settings description, see Chapter 3.3.4, "Polynomial coefficients settings", on page 65.

Dedicated settings:

On Edit, Auto Update Shaping
If enabled, the any setting change is applied on-the-fly.

The "Apply" and "OK" functions are disabled.

4.3.5 Normalized data settings

The normalized data table is an internal editor where you define the correction values, Vin/Vmax, ΔV/V and ΔPhase, in form of a table.

To access the internal editor

1. Select "I/Q Mod > Digital Predistortion > Digital Doherty > Shaping".
2. Select "Shaping > Normalized Data".
3. Select "Normalized Data".

   See "To access the internal editor" on page 68.
4. Enter the Pin_{max}.
   Note: Enter the correction values in the required order. The value range of the subsequent correction values adjusts automatically.
5. To store the setting in a file, select "Save/Recall Normalized Data > Save".
   Enter a "File Name", e.g. *My_Normalized*.

   For settings description, see Chapter 3.3.5, "Normalized data settings", on page 68.

5 How to generate a control signal for power amplifier envelope tracking tests

Refer to Figure 2-1 for an example of a simplified test setup for power amplifier testing with envelope tracking. The illustration is intended to explain the principle in general, not all connections and required equipment are considered.

The R&S SMW in this setup is configured to generate an LTE RF signal with complex modulation scheme and high peak to average power (PAPR), and the required envelope signal. A polynomial shaping function is defined. The PA receives the RF input signal and the dynamically adapted supply voltage. Ideally, the gain of the PA should stay constant.

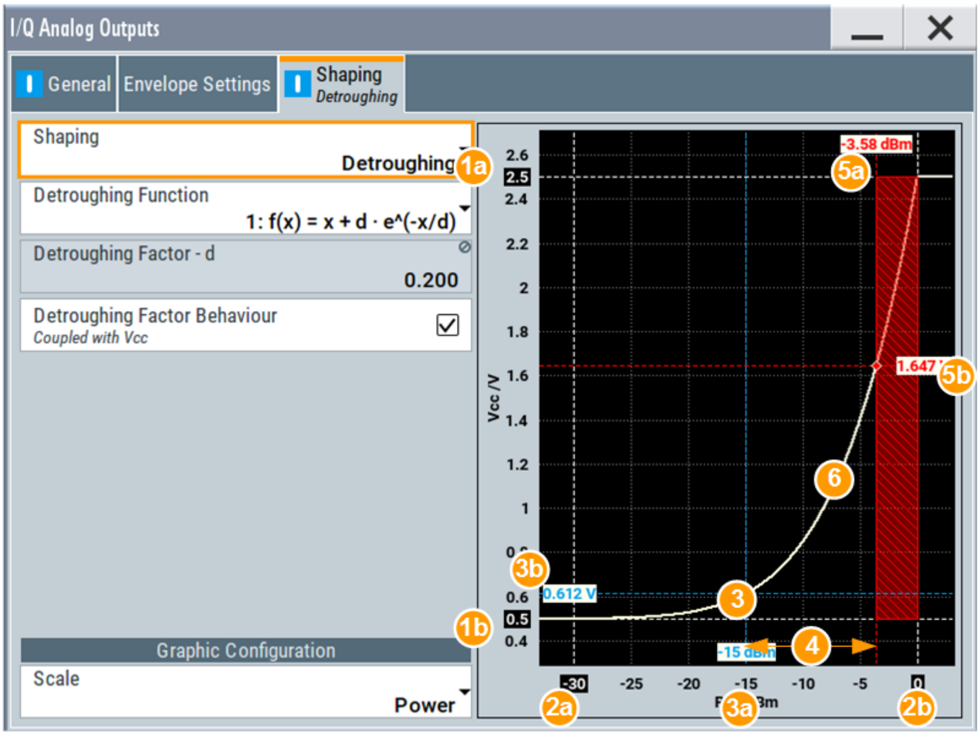
Required are the following values:

- Characteristics of the power amplifier: supply voltage V_{CC}, the input power PEP_{in}
- Characteristics of the external DC modulator: gain, peak-to-peak voltage V_{PP}, input impedance R_{in}

The following step-by-step instructions assume one signal stream ("Stream A") with one RF output "RF A" and I/Q analog output ("I/Q Analog A"), see "Envelope tracking signal routing" on page 14.

To configure the R&S SMW to generate the RF and RF envelope signal

1. Enable the R&S SMW to generate an EUTRA/LTE FDD DL signal.
   Select "Baseband > EUTRA/LTE" and enable for example:
   a) Select "Link Direction > Downlink"
   b) Select "Test Model > E-TM1_1--5MHZ"
   c) Enable "State > On"
2. Set "Frequency = 2.143 GHz" and "Level = -15 dB"
3. In the block diagram, select "I/Q Out > I/Q Analog > I/Q Analog Outputs > General":
   a) Select "RF Envelope > On".
   b) Select "Envelope Voltage Adaptation > Auto Power"
   c) Select "I/Q Output Type > Differential"
   d) Configure the settings as shown on Figure 2-3.
   e) Select "I/Q Analog Outputs > Envelope Settings" and set for example "Envelope to RF Delay = 10 ps"
   f) Select "I/Q Analog Outputs > Shaping > Shape > Detroughing".
   g) Set "Detroughing Function = 1: $f(x) = x + d*e^{(-x/d)}$".
   h) Set "Detroughing Factor (d) > Coupled with Vcc = On".
   i) Select "Graphic Configuration > Scale > Power".



1a, 1b = V_{CC}min = 0.5 V, V_{CC}max = 2.5 V
2a, 2b = P_{in}min = -30 dBm, P_{in}max = 0 dBm
3 = RF Level = -15 dBm (operating point)
3a, 3b = Current V_{CC} = 0.612 V (operating point)
4 = Crest factor = 11.6 dB
5a = PEP = -3.4 dBm; current P_{in}max limit
5b = Current V_{CC} limit

4. Select "I/Q Analog Output > State > On"
5. Enable "RF > State > On".
6. Trigger the signal generation
7. Select "I/Q Out > I/Q Analog > I/Q Analog Outputs > General", enable "Power Offset = 1 dB" and compare the operating point.

   The level display value in the status bar of the instrument shows "Level = -14 dBm" and confirms that a "Level Offset = Power Offset = 1 dB" is enabled.

   The instrument generates and outputs:
   - An RF signal with the specified level and level offset
   - An RF envelope signal that follows the power changes of the RF signal.

   The envelope signal E is output at the I Out connector; the inverted envelope signal E BAR at the I Bar Out. The voltage of this envelope signal is automatically adjusted so that the supply voltage stays within the specified limits.

   To observe the impact of baseband signal and its crest factor on the generated envelope signal, try out the following:
   - Select "Baseband > Off" and compare the displayed envelope shape, in particular the shaded area.

- Select "Baseband > On", enable "Baseband > EUTRA/LTE > Filter/Clipping/ ARB... > Clipping > State > On" and select "Clipping Level = 75%"

Possible extensions

Consider to extend the test setup as follows:

- To apply digital predistortion (DPD) on the baseband signal and compare the behavior of the power amplifier (DUT)
  See Chapter 6, "How to apply a DPD to improve the efficiency of RF PAs", on page 87.
- To perform RF analysis, use the R&S®FSW
- To measure and evaluate the AM/AM and AM/PM distortions, use the R&S®FSW-K18 Power Amplifier and Envelope Tracking Measurements.
- To observe the characteristics of the generated signal, use an oscilloscope, for example R&S®RTO

How to optimize the signal to improve the linearity and efficiency of the power amplifier

Refer to Figure 5-1 for an example of a simplified test setup for power amplifier testing with envelope tracking and digital predistortion. The illustration is intended to explain the principle in general, not all connections and required equipment are considered.

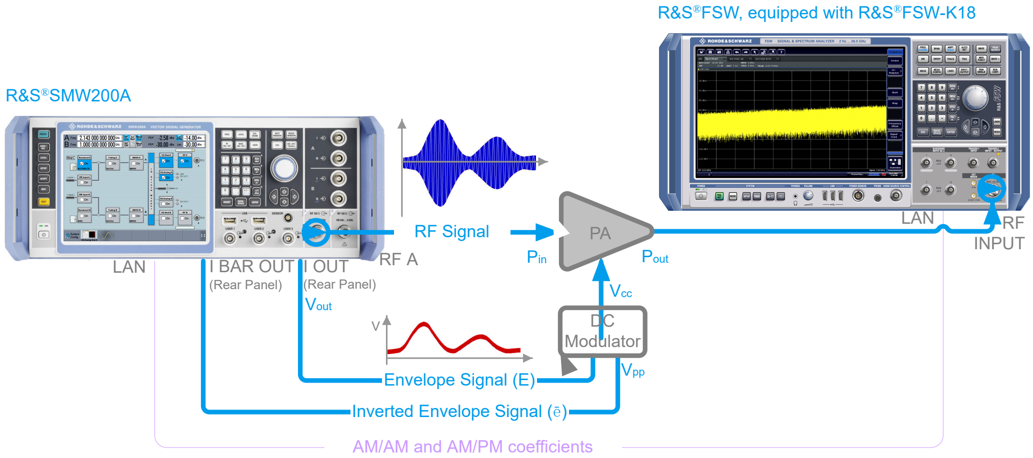


Figure 5-1: Simplified test setup for power amplifier envelope tracking tests with DPD

Use the following general guidelines:

1. Provide the output signal of the DUT to the R&S®FSW and measure the signal. Suitable RF measurements are the ACLR and EVM characteristics of the signal.
2. In the R&S SMW, select "I/Q Analog Outputs > Envelope Settings" and vary the "Envelope to RF Delay" to minimize the ACLR and EVM measured with the R&S®FSW.
3. Change the shaping method and shaping function and measure the power amplifier characteristics.

Did its linearity and efficiency improved?

4. Use the R&S®FSW-K18 to evaluate the signal, calculate suitable predistortion values, and store the AM/AM and AM/PM tables.
5. Transfer the predistortion functions to R&S SMW and load them (select "I/Q Mod > AM/AM AM/PM > Predistortion Settings").
   See Chapter 6, "How to apply a DPD to improve the efficiency of RF PAs", on page 87.
6. In the R&S®FSW, measure the power amplifier characteristics.

   Did its linearity improved?

6 How to apply a DPD to improve the efficiency of RF PAs

Refer to Figure 6-1 for an example of a simplified test setup for power amplifier testing with envelope tracking and digital predistortion. The illustration is intended to explain the principle in general, not all the connections and required equipment are considered.

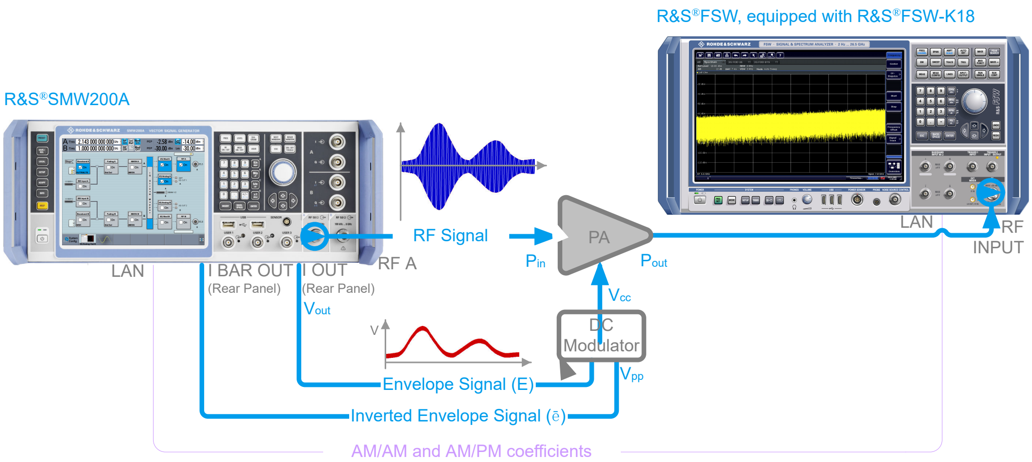


Figure 6-1: Simplified test setup for power amplifier envelope tracking tests with DPD

A real test setup comprises of the following equipment:

- R&S SMW to generate the RF signal, and to calculate and apply the DPD.
  In test setups for envelope tracking tests, the R&S SMW also generates the envelope tracking signal.
- R&S®FSW equipped with R&S®FSW-K18 Power Amplifier and Envelope Tracking Measurements to:
  – Measure and analyze the AM/AM and AM/PM predistortion
  – Calculate the AM/AM and AM/PM correction tables
  – Store and export the correction tables
- DUT, that is the power amplifier.
- Optional, R&S®RTO to monitor the generated envelope signal.

General steps for tests to improve the efficiency of RF power amplifiers

Consider the following general steps:

1. Enable the R&S SMW to generate a baseband signal. A suitable baseband signal is a simple ramp function or, to minimize memory effects, a signal with small bandwidth.
2. Compare the input waveform to the output of the power amplifier and determine how the amplifier is distorting the signal.

The normalized AM/AM and AM/PM curves show the variation of the magnitude and phase over the variation of the input power and thus provide a suitable representation and good basis for analysis.

3. A simple straightforward method to retrieve the DPD correction values is to "invert" the curves, see Chapter 3.2.3, "Finding out the correction values", on page 53.
   Use the R&S®FSW-K18 to retrieve the AM/AM and AM/PM correction values automatically.
4. Use the retrieved correction values and define the predistortion functions.
5. Enable the AM/AM and AM/PM predistortion and predistort the original baseband signal.
   See "To configure the R&S SMW to predistort the baseband signal" on page 88
6. Measure the behavior of the power amplifier, for example perform EVM and ACP measurements or evaluate the AM/AM and AM/PM curves.

   Does the output signal of the DUT have a better performance with regards to ACP and/or EVM?

To configure the R&S SMW to predistort the baseband signal

1. Enable the R&S SMW to generate an EUTRA/LTE FDD DL signal.
2. Set "Frequency = 2.143 GHz" and "Level = -15 dB".
3. In the block diagram, select "I/Q Mod > Digital Predistortion > AM/AM, AM/PM", and perform the following:
   a) Select "Digital Predistortion AM/AM, AM/PM > Predistortion Settings" and enable "Shaping > From Table".
   b) Select "AM/AM Table > New", enter a file name, and select "AM/AM Table > Edit".
   c) Enter the correction values and select "Save".
      See the example on Figure 3-3.
   d) Adjust the AM/PM correction values in the same way.
   e) Select "Interpolation > Liner (Power)".
   f) Select "Digital Predistortion AM/AM, AM/PM > General".
   g) Select "Maximum Input Power PEP_{IN} Max > 3 dBm".
   h) Select "AM/AM State > On", "AM/PM State > On" and "Predistortion State > On".
   i) Select "Level Reference > After DPD", "Maximum Output Level Error = 0.1 dB" and "Maximum Number of Iterations = 3".
4. Enable "RF > State > On".
5. Trigger the signal generation

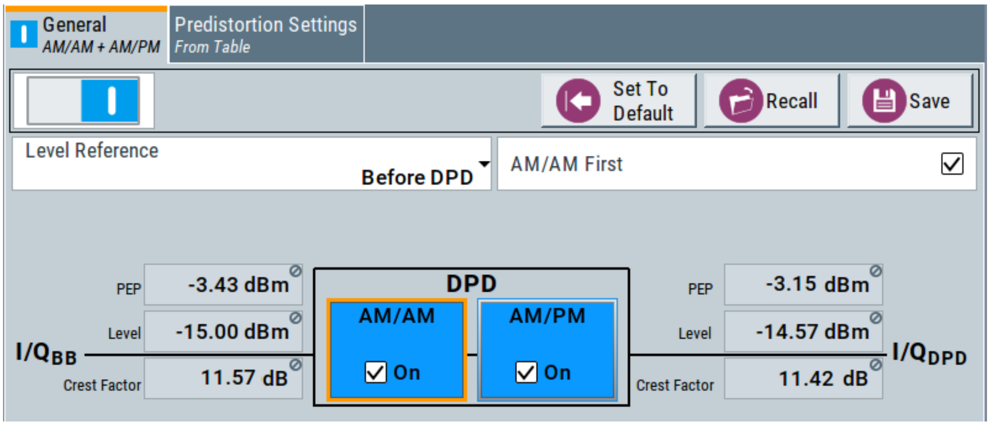
To perform manual iterations to achieve a desired resulting signal level after the DPD

To explain the iteration principle, we assume that the R&S SMW has been configured as described in "To configure the R&S SMW to predistort the baseband signal" on page 88 and the DPD uses an AM/AM predistortion function as shown on Figure 6-2.

To achieve a signal level of -15 dB after the DPD, perform the following steps and obey the rule:

Vary the "Level" with small steps.
Always start with small value and increase the "Level" at the subsequent iterations.

1. Select "Digital Predistortion AM/AM, AM/PM > General > Level reference > Before DPD".



2. Calculate the Δ_{P_1}.

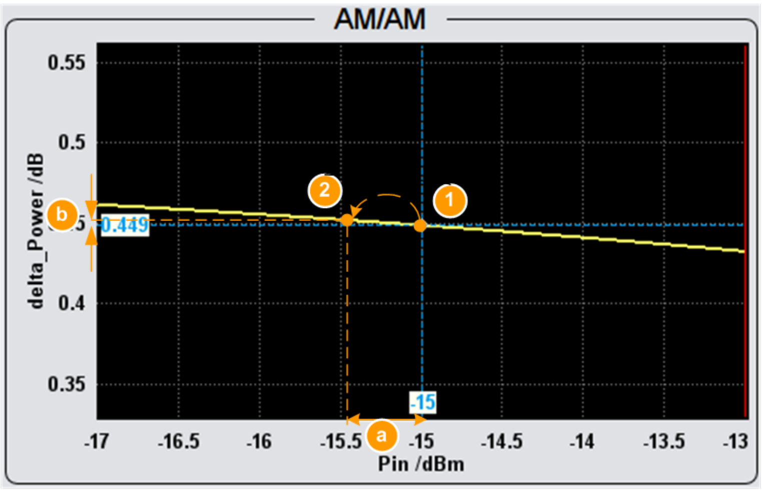


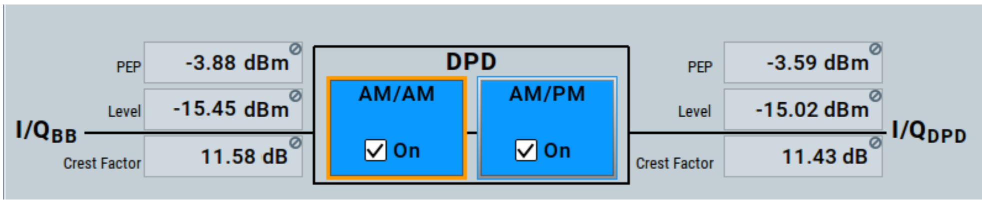
Figure 6-2: Manual iterations on an example AM/AM predistortion function ("Input Range PEPin = -17 dBm to -12 dBm"): Step#1

1 = current operating point: P_{IN} = $Level_{IN\_1}$ = -15 dBm
2 = first iteration with $Level_{IN\_2}$
a = Δ_{P_1}
b = difference between the correction values at the current and the new operating points

- $Level_{IN\_1}$ = Level = -15 dBm
- $Level_{OUT\_1}$ = -15.42 dBm
- Δ_{P_1} = Level - $Level_{OUT\_1}$ = -15 + 15.42 = 0.42 dBm

3. Set the "Level" = Level + Δ_{P_1} = -15.45 dBm.

   The diagram displays the achieved output values; $Level_{OUT\_2}$ = - 15.02 dBm.



4. Calculate the Δ_{P_2}.

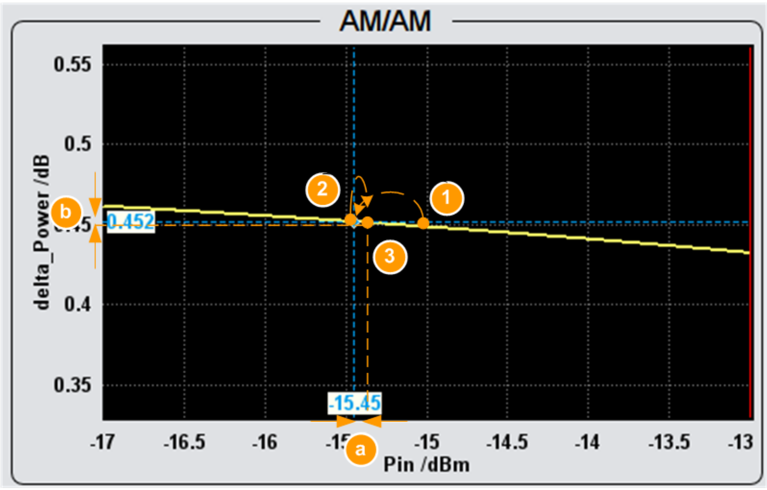


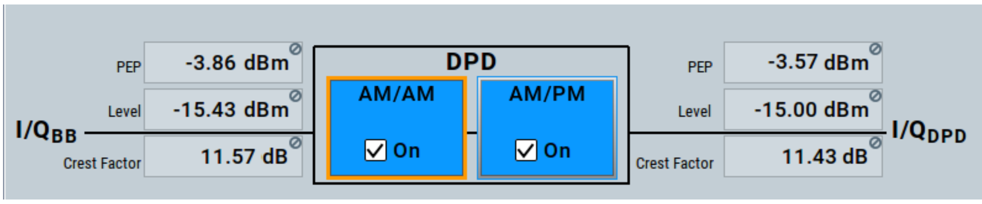
Figure 6-3: Manual iterations on an example AM/AM predistortion function ("Input Range PEPin = -17 dBm to -12 dBm"): Step#2

1 = initial operating point: P_{IN} = $Level_{IN\_1}$ = -15 dBm
2 = current operating point: P_{IN} = $Level_{IN\_2}$ = -15.45 dBm
3 = second iteration with $Level_{IN\_3}$
a = Δ_{P_2}
b = difference between the correction values at the current and the new operating points

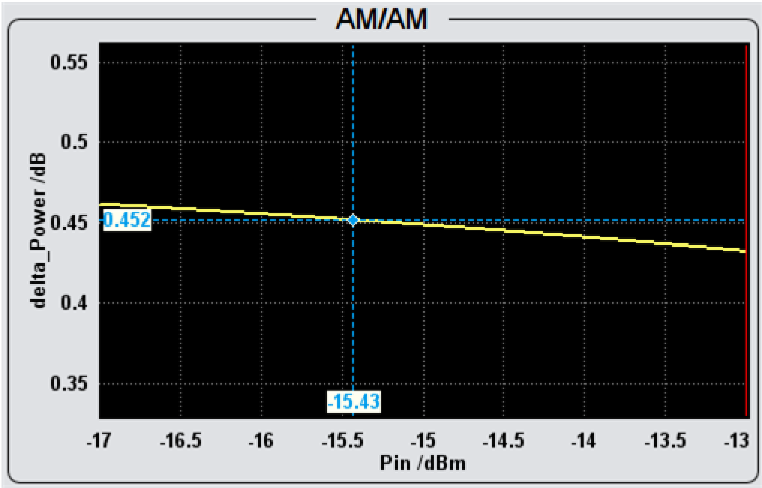
- $Level_{IN\_2}$ = - 15.55
- $Level_{OUT\_2}$ = -15.02 dBm
- Δ_{P_2} = Level - $Level_{OUT\_2}$ = -15 + 15.02 = - 0.02 dBm

5. Set "Level" = Level + Δ_{P_2} = -15.43 dBm

   The diagram confirms the achieved output value; $Level_{OUT\_3}$ = - 15 dBm.



6. Compare the operating point on the AM/AM functions.



To apply DPD for improved EVM performance

You can use the R&S FSW signal and spectrum analyzer with the option R&S FSW-K18 to create a Hammerstein model for the output stage of the R&S SMW. Apply this model to counteract inherent non-linearities and memory effects and improve the Error Vector Magnitude (EVM) at high output powers of the R&S SMW.

► See application note 1GP139

7 Remote-control commands

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

Conventions used in SCPI command descriptions

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

Common suffixes

The following common suffixes are used in remote commands:

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

Value ranges and *RST values

The values ranges and the `*RST` values correspond to the values of standard baseband instrument (R&S SMW-B10).

Programming examples

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

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

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

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

The following commands specific to the R&S SMW-K540/-K541 options are described here:

7.1 SOURce:IQ:OUTPut subsystem

This section describes the commands of the output of an analog I/Q signal.

[:SOURce<hw>]:IQ:OUTPut:ANALog:STATe <State>

Activates the specified analog I/Q output.

Note: By default, the output connectors [I/Q Out x] are deactivated.

Suffix:

:SOURce<hw>	1|2 Selects the [I/Q Out] connectors

Parameters:

<State>	1 | ON | 0 | OFF *RST: 0

Example: `SOURce:IQ:OUTPut:ANALog:STATe ON`
Activates the output of the analog I/Q signal on the [I/Q Out 1] connectors.

Manual operation: See "State" on page 25

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:PRESet

Sets the default settings (`*RST` values specified for the commands).

Not affected are:

- The state set with the command `[:SOURce<hw>]:IQ:OUTPut:ANALog:STATe`.
- If `SCONfiguration:EXTernal:PBEHaviour 1`, the I/Q ouptput type set with the command `[:SOURce<hw>]:IQ:OUTPut[:ANALog]:TYPE`.

Example: `SOURce1:IQ:OUTPut:ANALog:PRESet`

Usage: Event

Manual operation: See "Set to Default" on page 25

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:SETTing:CATalog?

Queries the files with I/Q output settings in the default directory. Listed are files with the file extension `*.iqout`.

Return values:

<Catalog> string

Usage: Query only

Manual operation: See "Save/Recall" on page 26

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:SETTing:STORe <Filename>

Stores the current settings into the selected file; the file extension (`*.iqout`) is assigned automatically.

Setting parameters:

<Filename> "<filename>"

Filename or complete file path

Usage: Setting only

Manual operation: See "Save/Recall" on page 26

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:SETTing:LOAD <Filename>

Loads the selected file from the default or the specified directory. Loaded are files with extension `*.iqout`.

Setting parameters:

<Filename> "<filename>"

Filename or complete file path

Usage: Setting only

Manual operation: See "Save/Recall" on page 26

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:SETTing:DELete <Filename>

Deletes the selected file from the default or specified directory. Deleted are files with the file extension `*.iqout`.

Setting parameters:

<Filename> "<filename>"

Filename or complete file path

Usage: Setting only

Manual operation: See "Save/Recall" on page 26

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:TYPE <Type>

Sets the type of the analog signal.

Example: `SOURce1:IQ:OUTPup:ANALog:TYPE DIFFerential`

Options: DIFFerential requires R&S SMW-K16

Manual operation: See "I/Q Output Type" on page 27

7.2 SOURce:IQ:OUTPut:ENVelope commands

The following remote control commands require software option R&S SMW-K540.

Example: Generating an RF envelope signal and defining the shaping function

```
*RST
// enable LTE signal
SOURce1:BB:EUTRa:SETTing:TMOD:DL "E-TM1_1__5MHz"
SOURce1:BB:EUTRa:STATe 1

// define the RF level and frequency
SOURce1:FREQuency:CW 2143000000
SOURce1:POWer:LEVel:IMMediate:AMPLitude -15
SOURce1:POWer:LEVel:IMMediate:OFFSet 0.5
SOURce1:CORRection:VALue?
// Response: 1

// enable RF envelope generation and define the settings
SOURce1:IQ:OUTPut:ANALog:ENVelope:STATe 1
SOURce1:IQ:OUTPut:ANALog:ENVelope:ADAPtion AUTO
SOURce1:IQ:OUTPut:ANALog:TYPE DIFF
SOURce1:IQ:OUTPut:ANALog:ENVelope:ETRak USER
SOURce1:IQ:OUTPut:ANALog:ENVelope:VREF VCC
SOURce1:IQ:OUTPut:ANALog:ENVelope:POWer:OFFSet?
// Response: 1.5

SOURce1:IQ:OUTPut:ANALog:ENVelope:VPP:MAX 4
SOURce1:IQ:OUTPut:ANALog:ENVelope:GAIN 0
SOURce1:IQ:OUTPut:ANALog:ENVelope:EMF:STATe 1
SOURce1:IQ:OUTPut:ANALog:ENVelope:RIN 50
SOURce1:IQ:OUTPut:ANALog:ENVelope:TERMination GROund
SOURce1:IQ:OUTPut:ANALog:ENVelope:BINPut 1
SOURce1:IQ:OUTPut:ANALog:ENVelope:VCC:OFFSet 2

SOURce1:IQ:OUTPut:ANALog:ENVelope:VCC:MIN 0.5
SOURce1:IQ:OUTPut:ANALog:ENVelope:VCC:MAX 2.5

SOURce1:IQ:OUTPut:ANALog:ENVelope:BIAS 0
SOURce1:IQ:OUTPut:ANALog:ENVelope:OFFSet -2
SOURce1:IQ:OUTPut:ANALog:ENVelope:VOUT:MAX?
```

```
// Response: 0.5
SOURce1:IQ:OUTPut:ANALog:ENVelope:VOUT:MIN?
// Response: -1.5

SOURce1:IQ:OUTPut:ANALog:ENVelope:PIN:MIN -30
SOURce1:IQ:OUTPut:ANALog:ENVelope:PIN:MAX 0

SOURce1:IQ:OUTPut:ANALog:ENVelope:DELay 0.00000000001
SOURce1:IQ:OUTPut:ANALog:ENVelope:FDPD OFF

// enable envelope shaping
// SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:MODE DETR
// SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:DETRoughing:FUNCtion F3
// SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:DETRoughing:COUPling OFF
// SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:DETRoughing:FACtor 0.225
// SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:DETRoughing:PEXPonent 1

// quering the oprating point level, current PEP and levels
// SOURce1:IQ:OUTPut:ANALog:ENVelope:ADAPtion?
// Response: Auto
// SOURce1:IQ:OUTPut:ANALog:ENVelope:VCC:VALue:LEVel?
// Response: 0.927
// SOURce1:IQ:OUTPut:ANALog:ENVelope:VCC:VALue:PEP?
// Response: 1.922
// SOURce1:IQ:OUTPut:ANALog:ENVelope:VCC:VALue? 1,NORM,VOLT
// Response: 2.5
// SOURce1:IQ:OUTPut:ANALog:ENVelope:VCC:VALue? 0,NORM,VOLT
// Response: 0.563
// SOURce1:IQ:OUTPut:ANALog:ENVelope:PIN:MAX?
// Response: 0
// SOURce1:IQ:OUTPut:ANALog:ENVelope:PIN:MIN?
// response: -30
// SOURce1:IQ:OUTPut:ANALog:ENVelope:VCC:VALue? 0,DBM,POW
// Response: 2.5
// SOURce1:IQ:OUTPut:ANALog:ENVelope:VCC:VALue? -30,DBM,POW
// Response: 0.563

SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:MODE TABL
SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:PV:FILE:CATalog?
// Response: myLUT_pv
SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:PV:FILE:SELect "/var/user/myLUT_pv.iq_lutpv"
SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:INTerp LIN
SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:SCALe POWer

// change the envelope shaping mode
SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:MODE POLY
// query files with polynomial functions in the default user directory
SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:COEFficients:CATalog?
// Response: env_poly_evm,myPoly
SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:COEFficients:LOAD "myPoly"
SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:COEFficients?
```

```
// Response: 0.135,0.82
SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:COEFficients 0.135,0.83
SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:COEFficients:STORe "/var/user/myPoly.iq_poly"

// enable the outputs
SOURce1:IQ:OUTPut:ANALog:STATe 1
OUTPut1:STATe 1

// store the settings
MMEMory:CDIRectory "/var/user/setups"
SOURce1:IQ:OUTPut:ANALog:SETTings:CATalog?
// Response: etrak_v1-2
SOURce1:IQ:OUTPut:ANALog:SETTings:STORe "my_ET"

SOURce1:IQ:OUTPut:ANALog:PREset
// change the envelope voltage adaptation mode
SOURce1:IQ:OUTPut:ANALog:ENVelope:ADAPtion MAN

SOURce1:IQ:OUTPut:LEVel 4

SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:GAIN:PRE -3
SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:GAIN:POST 2.5

// change the envelope shaping mode
SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:MODE TABL
SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:FILE:CATalog?
// Response: myLUT_vv
SOURce1:IQ:OUTPut:ANALog:ENVelope:SHAPing:FILE:SELect "/var/user/myLUT_vv.iq_lut"

// set the shaping values in raw format
// SOURce1:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:FILE:DATA  0,0, 0.1,0.2, 1,1
// SOURce1:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:FILE:CATalog?
// Response: myLUT_vv
// set the shaping values and store them into a file
// SOURce1:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:FILE:NEW "LUT_vv_raw", 0,0, 0.1,0.2, 1,1.5
// SOURce1:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:FILE:CATalog?
// Response: myLUT_vv, LUT_vv_raw
```

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:STATe <State>

Enables the output of a control signal that follows the RF envelope.

Parameters:

<State> 1 | ON | 0 | OFF
*RST: 0

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "RF Envelope" on page 26

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:ADAPtion <AdaptionMode>

Defines the envelope voltage adaption mode.

Parameters:
<AdaptionMode> AUTO | MANual | POWer

AUTO = Auto Normalized, POWer = Auto Power, MANual = Manual

*RST: AUTO

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Envelope Voltage Adaptation" on page 26

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:ETRak <ETrakIfcType>

Selects one of the predefined interface types or allows user-defined settings.

See Table 2-1.

Parameters:
<ETrakIfcType> USER | ET1V2 | ET1V5 | ET2V0

*RST: USER

Example: `SOURce1:IQ:OUTPut:ANALog:ENVelope:ETRak ET2V0`

Manual operation: See "eTrak® Interface Type" on page 27

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VREF <VoltageReferenc>

Defines whether the envelope voltage V_{out} is set directly or it is estimated from the selected supply voltage V_{cc}.

Parameters:
<VoltageReferenc> VCC | VOUT

*RST: VCC

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Envelope Voltage Reference" on page 27

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:DELay <Delay>

Enables a time delay of the generated envelope signal relative to the corresponding RF signal.

Parameters:
<Delay> float

Range: -500E-9 to 500E-9
Increment: 1E-12
*RST: 0

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Envelope to RF Delay" on page 33

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:FDPD <CalcFromDpdStat>

Enables calculation of the envelope from predistorted signal.

Parameters:

<CalcFromDpdStat> 1 | ON | 0 | OFF

*RST: 0

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Options: R&S SMW-K540/K541

Manual operation: See "Calculate Envelope from Predistorted Signal" on page 34

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VOUT:MIN <VoutMin>
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VOUT:MAX <VoutMax>

Queries the minimum and maximum values of the estimated envelope output voltage V_{out}.

Parameters:

<VoutMax> float

Range: 0.04 to 8
Increment: 1E-3
*RST: 1

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "V_{out}Min/Max" on page 28

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:BIAS <Bias>

Sets a bias.

Parameters:

<Bias> float

Range: -3.390V to 3.990V (R&S SMW-B10) / -0.2V to 2.5V (R&S SMW-B9)
Increment: 1E-4
*RST: 0
Default unit: V

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95.

Manual operation: See "Bias" on page 28

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:OFFSet <Offset>

Sets an offset between the envelope and the inverted envelope signal.

Parameters:

<Offset> float

Range: $(-4+V_p/2+V_{bias}/2)$,V to $(4-V_p/2-V_{bias}/2)$,V (R&S SMW-B10) / -2V to 2V (R&S SMW-B9)
Increment: 1E-4
*RST: 0
Default unit: V

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95.

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VPP[:MAX] <VppMax>

Set the maximum value of the driving voltage V_{pp} of the used external DC modulator.

Parameters:

<VppMax> float

Range: 0.02V to 8V (R&S SMW-B10) / 0.04V to 4V (R&S SMW-B9)
Increment: 1E-3
*RST: 1
Default unit: V

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95.

Manual operation: See "V_{pp}Max" on page 30

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:EMF[:STATe] <EmfState>

Defines whether the EMF or the voltage value is used.

Parameters:

<EmfState> 1 | ON | 0 | OFF

*RST: 1

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "EMF" on page 29

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:RIN <InputResistance>

Sets the input impedance R_{in} of the used external DC modulator.

Parameters:

<InputResistance> float

Range: 50|100 to 1E6
Increment: 0.1
*RST: 50

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "R_{in}" on page 29

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:TERMination <Termination>

Sets how the inputs of the DC modulator are terminated.

Parameters:

<Termination> GROund | WIRE

*RST: GROund

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Termination" on page 29

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:BINPut <BipolarInput>

Enables the generation of a bipolar signal.

Parameters:

<BipolarInput> 1 | ON | 0 | OFF

*RST: 0

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Bipolar Input" on page 29

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:GAIN <Gain>

Sets the gain of the used external DC modulator.

Parameters:

<Gain> float

Range: -50 to 50
Increment: 0.01
*RST: 0

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Gain" on page 30

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VCC:OFFSet <VccOffset>

Applies a voltage offset on the supply voltage V_{cc}.

Parameters:

<VccOffset> float

Range: 0 to 30
Increment: 1E-3
*RST: 0
Default unit: mV

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "V_{cc}Offset" on page 30

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VCC:MIN <VccMin>
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VCC:MAX <VccMax>

Sets the maximum value of the supply voltage V_{cc}.

Parameters:

<VccMax> float

Range: 0.04 to 8
Increment: 0.001
*RST: 1

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "V_{cc}Min/Max" on page 31

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VCC:VALue:PEP?

Queries the Vcc value of the current PEP of the generated RF signal.

Return values:

<VccForCrtPep> float

Range: 0 to 38
Increment: 1E-3
*RST: 0

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Usage: Query only

Manual operation: See "Diagram" on page 43

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VCC:VALue:LEVel?

Queries the Vcc value of the current RMS power level (operating point).

Return values:

<VccForRfLevel> float

Range: 0 to 38
Increment: 1E-3
*RST: 0

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Usage: Query only

Manual operation: See "Diagram" on page 43

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:VCC:VALue? <xValue>, <xUnit>, <xScale>

Queries the V_{CC} value for the selected `<xValue>`.

Query parameters:

<xValue> float

Value on the x-axis
Value range depends on the selected "Envelope Voltage Adaptation" and PEP_{in}Min and PEP_{in}Max values.

<xUnit> NORMalized | DBM | V

*RST: NORMalized

<xScale> VOLTage | POWer

*RST: VOLTage

Return values:

<VccValue> float

Range: 0 to 38
Increment: 1E-3
*RST: 0

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Usage: Query only

Manual operation: See "Diagram" on page 43

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:PIN:MIN <PinMin>

Sets the minimum value of the input power P_{in}.

Parameters:

<PinMin> float

Range: -145 to 20
Increment: 0.01
*RST: -30

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "PEP_{in}Min/Max" on page 32

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:PIN:MAX <PinMax>

Sets the maximum value of the input power P_{in}.

Parameters:

<PinMax> float

Range: -145 to 20
Increment: 0.01
*RST: -20

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "PEP_{in}Min/Max" on page 32

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:POWer:OFFSet?

Queries the current power offset, that is the sum of enabled "RF Level > Offset" and "User Correction".

Return values:

<PowerOffset> float

Range: -200 to 200
Increment: 0.01
*RST: 0

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Usage: Query only

Manual operation: See "Power Offset" on page 32

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:MODE <ShapingMode>

Enables envelope shaping and selects the method to define the shaping function.

Parameters:

<ShapingMode> OFF | LINear | TABLe | POLYnomial | DETRoughing | POWer

`LINear` = Linear (Voltage)
`POWer` = Linear (Power)

*RST: OFF

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95.

Manual operation: See "Shaping" on page 36

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:SCALe <Scale>

Determines the units used on the x and y axis.

Parameters:

<Scale> POWer | VOLTage

*RST: VOLTage

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Scale" on page 43

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:GAIN:PRE <PreGain>
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:GAIN:POST <PostGain>

Sets a post-gain.

Parameters:

<PostGain> float

Range: -3 to 20
Increment: 1E-2
*RST: 0

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Post-Gain" on page 41

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:FILE:CATalog?
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:PV:FILE:CATalog?

Queries the available table shaping files in the default directory. Only files with the file extension `*.iq_lut` or `*.iq_lutpv` are listed.

Return values:

<Catalog> string

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Usage: Query only

Manual operation: See "Shaping Table" on page 42

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:FILE[:SELect] <Filename>
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:PV:FILE[:SELect] <Filename>

Selects an envelope shaping file (extension `*.iq_lut` or `*.iq_lutpv`).

Parameters:

<Filename> string

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Shaping Table" on page 42

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:FILE:DATA
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:PV:FILE:DATA

Defines the shaping function in a raw data format.

See also `[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:PV:FILE:NEW` on page 107.

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:FILE:NEW
[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:PV:FILE:NEW

Stores the shaping values into a file with the selected file name and loads it.

The file is stored in the default directory or in the directory specified with the absolute file path. If the file does not yet exist, a new file is created. The file extension is assigned automatically.

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Usage: Setting only

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:INTerp <Interpolation>

For envelope shaping with shaping tables, enables linear interpolation.

Parameters:

<Interpolation> OFF | LINear | POWer

`LINear` = Linear (Voltage)
`POWer` = Linear (Power)

*RST: OFF

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Interpolation" on page 42

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:COEFficients

Sets the polynomial coefficients.

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Polynomial Order" on page 47
See "Polynomial constant and coefficients" on page 47
See "Apply, OK" on page 47

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:COEFficients: CATalog?

Queries the available polynomial files in the default directory. Only files with the file extension `*.iq_poly` are listed.

Return values:

<Catalog> string

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Usage: Query only

Manual operation: See "Save/Recall Polynomial" on page 46

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:COEFficients:STORe <Filename>

Saves the polynomial function as polynomial file.

Setting parameters:

<Filename> string

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Usage: Setting only

Manual operation: See "Save/Recall Polynomial" on page 46

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:COEFficients:LOAD <Filename>

Loads the selected polynomial file.

Setting parameters:

<Filename> string

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Usage: Setting only

Manual operation: See "Save/Recall Polynomial" on page 46

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:DETRoughing:FUNCtion <DetrFunction>

Sets the detroughing function.

Parameters:

<DetrFunction> F1 | F2 | F3

*RST: F1

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Detroughing Function" on page 40

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:DETRoughing:COUPling <CouplingState>

Enables/disables deriving the detroughing factor (d) from the selected V_{cc} value.

Parameters:

<CouplingState> 1 | ON | 0 | OFF

*RST: 0

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Couple Detroughing Factor with Vcc" on page 41

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:DETRoughing:FACTor <DetrFactor>

Sets the detroughing factor.

Parameters:

<DetrFactor> float

Range: 0 to 2
Increment: 1E-3
*RST: 0.2

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Detroughing Factor (d)" on page 41

[:SOURce<hw>]:IQ:OUTPut[:ANALog]:ENVelope:SHAPing:DETRoughing:PEXPonent <PowerExponent>

Sets the exponent (a) for the detroughing function `F3`.

Parameters:

<PowerExponent> float

Range: 1 to 10
Increment: 1E-3
*RST: 2

Example: See Example"Generating an RF envelope signal and defining the shaping function" on page 95

Manual operation: See "Exponent (a)" on page 41

7.3 SOURce:IQ:DPD subsystem

The `SOURce:IQ:DPD` subsystem contains the commands for enabling and configuring of digital predistortion.

Option: see Chapter 3.1, "Required options", on page 48.

Example: Defining correction coefficients and enabling digital predistortion

```
*RST


// enable LTE signal
SOURce1:BB:EUTRa:SETTing:TMOD:DL "E-TM1_1__5MHz"
SOURce1:BB:EUTRa:STATe 1

// define the RF level and frequency
SOURce1:FREQuency:CW 2143000000
SOURce1:POWer:LEVel:IMMediate:AMPLitude -15

SOURce1:IQ:DPD:PIN:MIN -35
SOURce1:IQ:DPD:PIN:MAX -2.5

// select look-up table files with correction values
SOURce1:IQ:DPD:SHAPing:MODE TABLe
SOURce1:IQ:DPD:SHAPing:TABLe:AMAM:FILE:CATalog?
// Response: My_DPD_AM-AM,MyDPD_AM-AM
SOURce1:IQ:DPD:SHAPing:TABLe:AMAM:FILE:SELect "My_DPD_AM-AM"
SOURce1:IQ:DPD:SHAPing:TABLe:AMPM:FILE:CATalog?
// Response: My_DPD_AM-PM,MyDPD_AM-PM
SOURce1:IQ:DPD:SHAPing:TABLe:AMPM:FILE:SELect "My_DPD_AM-PM"
SOURce1:IQ:DPD:SHAPing:TABLe:INTerp LINear
SOURce1:IQ:DPD:SHAPing:TABLe:INVert?
// Response: 0

// enable digital predistortion
SOURce1:IQ:DPD:AMPM:AMFirst 1
SOURce1:IQ:DPD:AMAM:STATe 1
SOURce1:IQ:DPD:AMPM:STATe 1
```

```
SOURce1:IQ:DPD:LREFerence BDPD
SOURce1:IQ:DPD:STATe 1

// enable the output
SOURce1:IQ:STATe 1
OUTPut1:STATe 1

// query the PEP, level and crest factor values before and after the DPD
SOURce1:IQ:DPD:INPut:PEP?
// Response: -3.43
SOURce1:IQ:DPD:INPut:LEVel?
// Response: -15
SOURce1:IQ:DPD:INPut:CFACtor?
// Response: 11.57

SOURce1:IQ:DPD:OUTPut:PEP?
SOURce1:IQ:DPD:OUTPut:LEVel?
SOURce1:IQ:DPD:OUTPut:CFACtor?

// change level reference and
// query the PEP, level and crest factor values before and after the DPD
SOURce1:IQ:DPD:LREFerence ADPD
SOURce1:IQ:DPD:OUTPut:ERRor:MAX 0.1
SOURce1:IQ:DPD:OUTPut:ITERations:MAX 3
SOURce1:IQ:DPD:MEASurement:STATe?
// Response: 1
SOURce1:IQ:DPD:OUTPut:ERRor?
// Response: 0
SOURce1:IQ:DPD:OUTPut:PEP?
// Response: -3.57
SOURce1:IQ:DPD:OUTPut:LEVel?
// Response: -15
SOURce1:IQ:DPD:OUTPut:CFACtor?
// Response: 11.43

// enable static DPD and set the pre-gain
SOURce1:IQ:DPD:LREFerence SDPD
SOURce1:IQ:DPD:GAIN:PRE -18
// set the predistorion values in raw format
SOURce1:IQ:DPD:SHAPing:TABLe:AMAM:FILE:DATA -30.4,-5.2, -25.1,-4.5, -18.5,-2.5, -10.5,-1
SOURce1:IQ:DPD:SHAPing:TABLe:AMPM:FILE:DATA -30.4, -5, -25.1, 5, -10, 0
SOURce1:IQ:DPD:SHAPing:TABLe:AMPM:FILE:CATalog?
// Response: My_DPD_AM-PM,MyDPD_AM-PM
// set the predistorion values and store them into a file
SOURce1:IQ:DPD:SHAPing:TABLe:AMPM:FILE:NEW "DPD_AM-PM_raw", -30.4, -5, -25.1, 5, -10, 0
SOURce1:IQ:DPD:SHAPing:TABLe:AMPM:FILE:CATalog?
// Response: My_DPD_AM-PM,MyDPD_AM-PM,DPD_AM-PM_raw
SOURce1:IQ:DPD:AMPM:VALue:PEP?
// Response: 4.255
SOURce1:IQ:DPD:AMPM:VALue:VALue? -30,DBM
```

```
// Response:-4.439

// change the shaping mode
SOURce1:IQ:DPD:SHAPing:MODE POLYnomial
// query files with polynomial functions in the default user directory
SOURce1:IQ:DPD:SHAPing:POLYnomial:COEFficients:CATalog?
// Response: MyDTD_Poly,myDTD_Poly4th
SOURce1:IQ:DPD:SHAPing:POLYnomial:COEFficients:LOAD "MyDTD_Poly4th"
SOURce1:IQ:DPD:SHAPing:POLYnomial:COEFficients?
// Response: 0,0,-0.25,0.2,0.6,-0.3,0.3,0.3,0.5,-0.4
SOURce1:IQ:DPD:SHAPing:POLYnomial:COEFficients:STORe "/var/user/myPoly.dpd_poly"
```

Commands:

[:SOURce<hw>]:IQ:DPD:STATe <State>

Enabels/disables the generation of digitally pre-distorted signals.

Parameters:

<State> 1 | ON | 0 | OFF
*RST: 0

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

Manual operation: See "State" on page 55

[:SOURce<hw>]:IQ:DPD:PRESet

Sets the default DPD settings (`*RST` values specified for the commands).

Not affected is the state set with the command `[:SOURce<hw>]:IQ:DPD:STATe`.

Usage: Event

Manual operation: See "Set to Default" on page 56

[:SOURce<hw>]:IQ:DPD:SETTing:CATalog?

Queries the files with digital predistortion setting in the default directory. Listed are files with the file extension `*.dpd`.

Return values:
<Catalog> string

Usage: Query only

Manual operation: See "Save/Recall" on page 56

[:SOURce]:IQ:DPD:SETTing:DELete <Filename>

Deletes the selected file from the default or specified directory. Deleted are files with the file extension `*.dpd`.

Setting parameters:
<Filename> "<filename>"
Filename or complete file path

Usage: Setting only

Manual operation: See "Save/Recall" on page 56

[:SOURce<hw>]:IQ:DPD:SETTing:LOAD <Filename>

Loads the selected file from the default or the specified directory. Loaded are files with extension `*.dpd`.

Setting parameters:
<Filename> "<filename>"
Filename or complete file path

Usage: Setting only

Manual operation: See "Save/Recall" on page 56

[:SOURce<hw>]:IQ:DPD:SETTing:STORe <Filename>

Stores the current settings into the selected file; the file extension (`*.dpd`) is assigned automatically.

Setting parameters:

<Filename> "<filename>"

Filename or complete file path

Usage: Setting only

Manual operation: See "Save/Recall" on page 56

[:SOURce<hw>]:IQ:DPD:AMAM:STATe <State>
[:SOURce<hw>]:IQ:DPD:AMPM:STATe <State>

Enabels/disables the AM/AM and AM/PM digital predistortion.

Parameters:

<State> 1 | ON | 0 | OFF

*RST: 0

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

Manual operation: See "AM/AM and AM/PM State" on page 57

[:SOURce<hw>]:IQ:DPD:AMFirst <AmAmFirstState>

Sets that the AM/AM predistortion is applied before the AM/PM.

Parameters:

<AmAmFirstState> 1 | ON | 0 | OFF

*RST: 0

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

Manual operation: See "AM/AM First" on page 56

[:SOURce<hw>]:IQ:DPD:LREFerence <LevelReference>

Sets whether a dynamic (`BDPD|ADPD`) or a static (`SDPS`) adaptation of the range the selected DPD is applied on.

Parameters:

<LevelReference> BDPD | ADPD | SDPD

*RST: BDPD

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

Manual operation: See "Level Reference" on page 56

[:SOURce<hw>]:IQ:DPD:OUTPut:ERRor?

Queries the resulting level error.

Return values:
<AchievedError> float

Example: see Example"Defining correction coefficients and enabling digital predistortion" on page 110

Usage: Query only

Manual operation: See "Achieved Output Level Error" on page 57

[:SOURce<hw>]:IQ:DPD:OUTPut:ERRor:MAX <MaximumError>

Sets the allowed maximum error.

Parameters:
<MaximumError> float

Range: 0.01 to 1
Increment: 0.01
*RST: 0.1

Example: see Example"Defining correction coefficients and enabling digital predistortion" on page 110

Manual operation: See "Maximum Output Level Error" on page 57
See "Maximum Number of Iterations" on page 57

[:SOURce<hw>]:IQ:DPD:OUTPut:ITERations:MAX <MaxIterations>

Sets the maximum number of performed iterations to achieving the required error set with `[:SOURce<hw>]:IQ:DPD:OUTPut:ERRor:MAX`.

Parameters:
<MaxIterations> integer

Range: 1 to 10
*RST: 3

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

[:SOURce<hw>]:IQ:DPD:MEASurement:STATe?

Queries whether the interactions are competed.

Return values:
<MeasureValidity> 1 | ON | 0 | OFF

*RST: 1

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

Usage: Query only

[:SOURce<hw>]:IQ:DPD:INPut:CFACtor?
[:SOURce<hw>]:IQ:DPD:OUTPut:CFACtor?
[:SOURce<hw>]:IQ:DPD:INPut:LEVel?
[:SOURce<hw>]:IQ:DPD:OUTPut:LEVel?
[:SOURce<hw>]:IQ:DPD:INPut:PEP?
[:SOURce<hw>]:IQ:DPD:OUTPut:PEP?

Queries the measured values the before and after the enabled digital predistortion.

Return values:

<PEP> float

The query returns `-1000` if the calculation is impossible or there are no measurements results available.

Example: see Example"Defining correction coefficients and enabling digital predistortion" on page 110

Usage: Query only

Manual operation: See "Input/Output PEP, Level and Crest Factor" on page 57

[:SOURce<hw>]:IQ:DPD:GAIN:PRE <PreGain>

Sets a pre-gain (i.e. an attenuation) to define the range the static DPD is applied in.

Parameters:

<PreGain> float

Range: -50 to 20
Increment: 1E-2
*RST: 0

Example: see Example"Defining correction coefficients and enabling digital predistortion" on page 110

Manual operation: See "Pre-Gain" on page 60

[:SOURce<hw>]:IQ:DPD:SHAPing:MODE <Shaping>

Selects the method to define the correction coefficients.

Parameters:

<Shaping> TABLe | POLYnomial | NORMalized

*RST: TABLe

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110.

Manual operation: See "Shaping" on page 59

[:SOURce<hw>]:IQ:DPD:LRF:STATe <LinearizeRf>

Activates linearization of the RF.

Parameters:

<LinearizeRf> 1 | ON | 0 | OFF

*RST: 0

Example:

```
SOURce1:IQ:DPD:LRF:STATe 1
SOURce1:IQ:DPD:LRF:ADJust?
// Response: 0
```

Manual operation: See "Linearize RF" on page 71

[:SOURce<hw>]:IQ:DPD:LRF:ADJust?

Calculates the predistortion values for the current frequency.

Return values:

<AdjustResult> 0 | 1 | RUNning | STOPped

*RST: STOPped

Usage: Query only

Manual operation: See "Adjust Linearization Current Frequency" on page 71

7.4 SOURce:IQ:DPD and SOURce:IQ:DOHerty subsystem

The `SOURce:IQ:DPD` and `SOURce:IQ:DOHerty` subsystems contain commands for enabling and configuring of digital predistortion and the digital Doherty.

Option:

- `SOURce:IQ:DPD` requires R&S SMW-K541
  See also Chapter 3.1, "Required options", on page 48.
- `SOURce:IQ:DOHerty` requires R&S SMW-K546
  See also Chapter 4.1, "Required options", on page 72.

Both subsystems use commands with similar syntax and identical functionality. This section lists the commands that are **common for both subsystems**.

For description of the commands, applying to only one of the options, see:

- Chapter 7.3, "SOURce:IQ:DPD subsystem", on page 110
- Chapter 7.5, "SOURce:IQ:DOHerty subsystem", on page 126

Suffixes

The following common suffixes are used in the remote commands:

Suffix	Value range	Description
SOURce<hw>:IQ:DPD	1 | 2	Defines the signal at that the DPD is applied
SOURce<hw>:IQ:DOHerty:SHAPing	2	Digital Doherty shaping can be used only for I/Q B signal

Mnemonics

The `SOURce:IQ:DOHerty` commands reuse the syntax of the `SOURce:IQ:DPD` commands. Within the `SOURce:IQ:DOHerty` subsystem, the mnemonics `AMAM` and `AMPM` apply to te power and the phase corrections respectively.

[:SOURce<hw>]:IQ:DOHerty:PIN:MIN <PepInMin>
[:SOURce<hw>]:IQ:DOHerty:PIN:MAX <PepInMax>
[:SOURce<hw>]:IQ:DPD:PIN:MIN <PepInMin>
[:SOURce<hw>]:IQ:DPD:PIN:MAX <PepInMax>

Sets the value range of the input power.

Parameters:

<PepInMax> float

Range: -145 to 20
Increment: 0.01
*RST: 10

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

Manual operation: See "Input Range (PEP_{in}) From/To" on page 60

[:SOURce<hw>]:IQ:DOHerty:SCALe <Scale>
[:SOURce<hw>]:IQ:DPD:SCALe <Scale>

Determines the units used on the x and y-axis.

Parameters:

<Scale> POWer | VOLTage

*RST: POWer

Manual operation: See "Scale" on page 62

[:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:AMAM:FILE:CATalog?
[:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:AMPM:FILE:CATalog?
[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMAM:FILE:CATalog?
[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMPM:FILE:CATalog?

Queries the available table files in the default directory. Only files with the extension `*.dpd_magn`(AM/AM) or `*.dpd_phase`(AM/PM) are listed.

Return values:

<Catalog> string

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

Usage: Query only

Manual operation: See "Shaping Table" on page 61

[:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:AMAM:FILE[:SELect] <Filename>
[:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:AMPM:FILE[:SELect] <Filename>
[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMAM:FILE[:SELect] <Filename>
[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMPM:FILE[:SELect] <Filename>

Selects a file with correction values (extension `*.dpd_magn` (AM/AM) or `*.dpd_phase`(AM/FM)).

Parameters:

<Filename> string

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

Manual operation: See "Shaping Table" on page 61
See "Pin (dBm), Delta Power (dB)/Pin (dBm), Delta Phase (deg)" on page 63

[:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:AMAM:FILE:NEW
[:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:AMPM:FILE:NEW
[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMAM:FILE:NEW
[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMPM:FILE:NEW

Stores the correction values into a file with the selected file name and loads it.

The file is stored in the default directory or in the directory specified with the absolute file path. If the file does not yet exist, a new file is created. The file extension is assigned automatically.

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

Usage: Setting only

[:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:AMAM:FILE:DATA
[:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:AMPM:FILE:DATA
[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMAM:FILE:DATA
[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMPM:FILE:DATA

Defines the predistortion function in a raw data format.

See also `[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:AMPM:FILE:NEW` on page 120.

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

[:SOURce<hw>]:IQ:DOHerty:SHAPing:TABLe:INTerp <Interpolation>
[:SOURce<hw>]:IQ:DPD:SHAPing:TABLe:INTerp <Interpolation>

Enables a linear (voltage or power) interpolation between the defined correction values.

Parameters:

<Interpolation> OFF | POWer | LINear

POWer
Linear power interpolation

LINear
Linear voltage interpolation

*RST: OFF

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

Manual operation: See "Interpolation" on page 59

[:SOURce<hw>]:IQ:DOHerty:SHAPing[:TABLe]:INVert <InvertValues>
[:SOURce<hw>]:IQ:DPD:SHAPing[:TABLe]:INVert <InvertValues>

Inverts the defined correction values.

Parameters:

<InvertValues> 1 | ON | 0 | OFF

*RST: 0

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

Manual operation: See "Invert Correction Values" on page 59

[:SOURce<hw>]:IQ:DOHerty:SHAPing:POLYnomial:COEFficients <I0>, <J0>, <J1>, <J1>
[:SOURce<hw>]:IQ:DPD:SHAPing:POLYnomial:COEFficients <I0>, <J0>, <J1>, <J1>

Sets the polynomial coefficients as a list of up to 10 comma separated value pairs.

In Cartesian coordinates system, the coefficients b_n are expressed in degrees.

Parameters:

<I0> float

Range: -1E6 to 1E6
Increment: 1E-3
*RST: 0

<J0> float

Range: -1E6 to 1E6
Increment: 1E-3
*RST: 0

<J1> float

Range: -1E6 to 1E6
Increment: 1E-3
*RST: 0

<J1> float

Range: -1E6 to 1E6
Increment: 1E-3
*RST: 0

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110.

Manual operation: See "Polynomial Order" on page 67
See "Apply, OK" on page 68

[:SOURce<hw>]:IQ:DOHerty:SHAPing:POLYnomial:COEFficients:CATalog?
[:SOURce<hw>]:IQ:DPD:SHAPing:POLYnomial:COEFficients:CATalog?

Queries the available polynomial files in the default directory. Only files with the file extension `*.dpd_poly` are listed.

Return values:
<Catalog> string

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

Usage: Query only

Manual operation: See "Save/Recall Polynomial" on page 67

[:SOURce<hw>]:IQ:DOHerty:SHAPing:POLYnomial:COEFficients:LOAD <Filename>
[:SOURce<hw>]:IQ:DPD:SHAPing:POLYnomial:COEFficients:LOAD <Filename>

Loads the selected polynomial file.

Setting parameters:
<Filename> string

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

Usage: Setting only

Manual operation: See "Save/Recall Polynomial" on page 67

[:SOURce<hw>]:IQ:DOHerty:SHAPing:POLYnomial:COEFficients:STORe <Filename>
[:SOURce<hw>]:IQ:DPD:SHAPing:POLYnomial:COEFficients:STORe <Filename>

Saves the polynomial function as polynomial file.

Setting parameters:

<Filename> string

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110

Usage: Setting only

Manual operation: See "Save/Recall Polynomial" on page 67

[:SOURce<hw>]:IQ:DOHerty:SHAPing:NORMalized:DATA <Data>
[:SOURce<hw>]:IQ:DPD:SHAPing:NORMalized:DATA <Data>

Defines the normalized predistortion function in a raw data format (binary data).

Parameters:

<Data> <#><LengthNoBytes><NoBytes><NormData>

<#>
The binary data must start with the sign #

<LengthNoBytes>
ASCII format
Sets the length of `<NoBytes>`, i.e. the number of digits used to write `<NoBytes>`

<NoBytes>
An ASCII integer value that specifies the number of bytes that follow in the `<NormData>` part
Each of the `<NormData>` parameters is coded with 8 bytes.
Then the number of bytes `<NoBytes>` is calculated as:
`<NoBytes>` = 8 + 8 + n(8+8+8), where n is the number of points `<NoPoints>`.

<NormData>
<PinMax><NoPoints>{<VinVmax><DeltaV><DeltaPhase>}
Values in **binary format**, describing the maximum absolute input power Pin_{max}, the number of subsequent points *n* and the normalized values Vin/Vmax, ΔV/V, ΔPhase [deg].

Example:

```
SOURce1:IQ:DPD:SHAPing:NORMalized:DATA #240<values>
// the binary <values> are not printable
SOURce1:IQ:DPD:SHAPing:NORMalized:DATA:CATalog?
// norm
SOURce1:IQ:DPD:SHAPing:NORMalized:DATA:STORe "My_DPD_Normalized"
SOURce1:IQ:DPD:SHAPing:NORMalized:DATA:CATalog?
// norm,My_DPD_Normalized
SOURce1:IQ:DPD:SHAPing:NORMalized:DATA:LOAD "norm"
SOURce1:IQ:DPD:SHAPing:NORMalized:DATA?
// #3112
// the binary data <NormData> is 112 bytes long (3 points are defined)
// binary data is machine readable but not printable
```

Manual operation: See "Apply, OK" on page 70

[:SOURce<hw>]:IQ:DOHerty:SHAPing:NORMalized:DATA:CATalog?
[:SOURce<hw>]:IQ:DPD:SHAPing:NORMalized:DATA:CATalog?

Queries the available files with normalized data in the default directory. Only files with the file extension `*.dpd_norm` are listed.

Return values:

<Catalog> string

Example: See `[:SOURce<hw>]:IQ:DPD:SHAPing:NORMalized:DATA` on page 123.

Usage: Query only

Manual operation: See "Save/Recall Normalized Data" on page 69

[:SOURce<hw>]:IQ:DOHerty:SHAPing:NORMalized:DATA:LOAD <Filename>
[:SOURce<hw>]:IQ:DPD:SHAPing:NORMalized:DATA:LOAD <Filename>

Loads the selected file.

Setting parameters:

<Filename> string

Example: See `[:SOURce<hw>]:IQ:DPD:SHAPing:NORMalized:DATA` on page 123.

Usage: Setting only

Manual operation: See "Save/Recall Normalized Data" on page 69

[:SOURce<hw>]:IQ:DOHerty:SHAPing:NORMalized:DATA:STORe <Filename>
[:SOURce<hw>]:IQ:DPD:SHAPing:NORMalized:DATA:STORe <Filename>

Saves the normalized data in a file.

Setting parameters:

<Filename> string

Example: See `[:SOURce<hw>]:IQ:DPD:SHAPing:NORMalized:DATA` on page 123.

Usage: Setting only

Manual operation: See "Save/Recall Normalized Data" on page 69

[:SOURce<hw>]:IQ:DOHerty:AMAM:VALue:LEVel?
[:SOURce<hw>]:IQ:DOHerty:AMPM:VALue:LEVel?
[:SOURce<hw>]:IQ:DPD:AMAM:VALue:LEVel?
[:SOURce<hw>]:IQ:DPD:AMPM:VALue:LEVel?

Queries the delta phase value for the current root mean square (RMS) power level of the generated RF signal.

Return values:

<DeltaPhase> float

Range: -180 to 180
Increment: 0.01
*RST: 0

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110.

Usage: Query only

Manual operation: See "AM/AM and AM/PM Diagrams" on page 62

[:SOURce<hw>]:IQ:DOHerty:AMAM:VALue:PEP?
[:SOURce<hw>]:IQ:DOHerty:AMPM:VALue:PEP?
[:SOURce<hw>]:IQ:DPD:AMAM:VALue:PEP?
[:SOURce<hw>]:IQ:DPD:AMPM:VALue:PEP?

Queries the delta phase value for the current peak envelope power (PEP) level of the generated RF signal.

Return values:

<DeltaPhase> float

Range: -180 to 180
Increment: 0.01
*RST: 0

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110.

Usage: Query only

Manual operation: See "AM/AM and AM/PM Diagrams" on page 62

[:SOURce<hw>]:IQ:DOHerty:AMAM:VALue? <XValue>, <XUnit>
[:SOURce<hw>]:IQ:DOHerty:AMPM:VALue? <XValue>, <XUnit>
[:SOURce<hw>]:IQ:DPD:AMAM:VALue? <XValue>, <XUnit>
[:SOURce<hw>]:IQ:DPD:AMPM:VALue? <XValue>, <XUnit>

Queries the delta phase value of the generated RF signal for a selected `<XValue>`.

Query parameters:

<XValue> float

Value on the x-axis.
Value range depends on the selected PEP_{in}Min and PEP_{in}Max values.

Range: -100 to 100
Increment: 0.01

<XUnit> DBM | V

*RST: DBM

Return values:

<DeltaPhase> float

Range: -180 to 180
Increment: 0.01
*RST: 0

Example: See Example"Defining correction coefficients and enabling digital predistortion" on page 110.

Usage: Query only

Manual operation: See "AM/AM and AM/PM Diagrams" on page 62

7.5 SOURce:IQ:DOHerty subsystem

The `SOURce:IQ:DOHerty` subsystem contains the commands for enabling and configuring of digital Doherty.

Option: R&S SMW-K546.

Example: Defining correction coefficients and enabling digital Doherty

```
*RST


// enable LTE signal
SOURce1:BB:EUTRa:SETTing:TMOD:DL "E-TM1_1__5MHz"
SOURce1:BB:EUTRa:STATe 1

// define the RF level and frequency
SOURce1:FREQuency:CW 2143000000
SOURce1:POWer:LEVel:IMMediate:AMPLitude -15

SOURce:IQ:DOHerty:POWer:ATTenuation:COUPling:STATe 0
SOURce1:IQ:DOHerty:POWer:ATTenuation 0
SOURce2:IQ:DOHerty:POWer:ATTenuation 0
SOURce2:IQ:DOHerty:PHASe:OFFSet 10

SOURce1:IQ:DOHerty:PIN:MIN -35
SOURce1:IQ:DOHerty:PIN:MAX -2.5

// select look-up table files with correction values
SOURce2:IQ:DOHerty:SHAPing:MODE TABLe
SOURce2:IQ:DOHerty:SHAPing:TABLe:AMAM:FILE:CATalog?
// Response: My_PowSplit
SOURce2:IQ:DOHerty:SHAPing:TABLe:AMAM:FILE:SELect "My_PowSplit"
SOURce2:IQ:DOHerty:SHAPing:TABLe:AMPM:FILE:CATalog?
// Response: My_Phase
SOURce2:IQ:DOHerty:SHAPing:TABLe:AMPM:FILE:SELect "My_Phase"
SOURce2:IQ:DOHerty:SHAPing:TABLe:INTerp LINear
SOURce2:IQ:DOHerty:SHAPing:TABLe:INVert?
```

```
// Response: 0

// enable digital predistortion
SOURce2:IQ:DOHerty:SHAPing:PHASe:STATe 1
SOURce2:IQ:DOHerty:SHAPing:POWer:STATe 1
SOURce1:IQ:DOHerty:STATe 1

// enable the output
SOURce1:IQ:STATe 1
SOURce2:IQ:STATe?
// Response: 1
OUTPut1:STATe 1

SCONfiguration:OUTput:MAPPing:RF1:STReam1:STATe?
// Response: 1
SCONfiguration:OUTput:MAPPing:RF2:STReam1:STATe?
// Response:  1
SOURce1:FREQuency:LOSCillator:MODE?
// Response:  COUP
SOURce1:POWer:LBEHaviour?
// Response: CPH
SOURce1:POWer:POWer -20
SOURce1:POWer:ATTenuation DIGital?
// Response: 0
SOURce2:POWer:LBEHaviour?
// Response:  CPH
SOURce2:POWer:POWer -15
SOURce2:POWer:ATTenuation DIGital?
// Response: 0
SOURce2:BB:IMPairment:RF2:POFFset?
// Response: 10

// query the PEP, level and crest factor values before and after the DPD
SOURce1:IQ:DOHerty:OUTPut:PEP?
// Response: -20
SOURce1:IQ:DOHerty:OUTPut:LEVel?
// Response: -20
SOURce2:IQ:DOHerty:INPut:PEP?
// Response: -15
SOURce2:IQ:DOHerty:INPut:LEVel?
// Response: -15
SOURce2:IQ:DOHerty:OUTPut:PEP?
// Response: -15
SOURce2:IQ:DOHerty:OUTPut:LEVel?
// Response: -15

// set the correction values and store them into a file
// SOURce2:IQ:DOHerty:SHAPing:TABLe:AMPM:FILE:CATalog?
// Response: My_PowSplit
// SOURce2:IQ:DOHerty:AMPM:VALue:PEP?
// Response: 5
```

```
// change the shaping mode
SOURce2:IQ:DOHerty:SHAPing:MODE POLYnomial
// query files with polynomial functions in the default user directory
SOURce2:IQ:DOHerty:SHAPing:POLYnomial:COEFficients:CATalog?
// Response: test,my_Poly4th
SOURce2:IQ:DOHerty:SHAPing:POLYnomial:COEFficients:LOAD "My_Poly4th"
SOURce2:IQ:DOHerty:SHAPing:POLYnomial:COEFficients?
// Response: 0,0,-0.25,0.2,0.6,-0.3,0.3,0.3,0.5,-0.4
SOURce2:IQ:DOHerty:SHAPing:POLYnomial:COEFficients:STORe "/var/user/myPoly.dpd_poly"

// query the operation point
SOURce2:IQ:DOHerty:AMAM:VALue:PEP?
// Response: -10.959
SOURce2:IQ:DOHerty:AMPM:VALue:PEP?
// Response: 139.471

SOURce2:IQ:DOHerty:AMAM:VALue? 0,DBM
// Response: -18.178
SOURce2:IQ:DOHerty:AMPM:VALue? 0,DBM
// Response: 96.729
```


[:SOURce]:IQ:DOHerty:STATe <State>

Enabels/disables the generation of digitally Doherty signals.

Parameters:

<State> 1 | ON | 0 | OFF

*RST: 0

Example: See Example"Defining correction coefficients and enabling digital Doherty" on page 126.

Manual operation: See "State" on page 77

[:SOURce]:IQ:DOHerty:SETTing:PRESet

Sets the default settings (`*RST` values specified for the commands).

Not affected is the state set with the command `[:SOURce]:IQ:DOHerty:STATe`.

Example: See Example"Defining correction coefficients and enabling digital Doherty" on page 126.

Usage: Event

Manual operation: See "Set to Default" on page 77

[:SOURce]:IQ:DOHerty:SETTing:CATalog?

Queries the files with digital Doherty setting in the default directory. Listed are files with the file extension `*.di_doher`.

Return values:

<Catalog> string

A comma-separated list of filenames; the file extenssion is omitted

Example: See Example"Defining correction coefficients and enabling digital Doherty" on page 126.

Usage: Query only

Manual operation: See "Save/Recall" on page 77

[:SOURce]:IQ:DOHerty:SETTing:LOAD <Filename>

Loads the selected file from the default or the specified directory. Loaded are files with extension `*.di_doher`.

Setting parameters:

<Filename> "<filename>"

Filename or complete file path

Example: See Example"Defining correction coefficients and enabling digital Doherty" on page 126.

Usage: Setting only

Manual operation: See "Save/Recall" on page 77

[:SOURce]:IQ:DOHerty:SETTing:STORe <Filename>

Stores the current settings into the selected file; the file extension (`*.di_doher`) is assigned automatically.

Setting parameters:

<Filename>	"<filename>" Filename or complete file path
Example:	See Example"Defining correction coefficients and enabling digital Doherty" on page 126.
Usage:	Setting only
Manual operation:	See "Save/Recall" on page 77

[:SOURce]:IQ:DOHerty:SETTing:DELete <Filename>

Deletes the selected file from the default or specified directory. Deleted are files with the file extension `*.di_doher`.

Setting parameters:

<Filename>	"<filename>" Filename or complete file path
Example:	See Example"Defining correction coefficients and enabling digital Doherty" on page 126.
Usage:	Setting only
Manual operation:	See "Save/Recall" on page 77

[:SOURce<hw>]:IQ:DOHerty:PHASe:OFFSet <Attenuation>

Adds a phase offset.

Suffix:

<hw>	2

Parameters:

<Attenuation>	float Range: -999.99 to 999.99 Increment: 0.01 *RST: 0
Example:	See Example"Defining correction coefficients and enabling digital Doherty" on page 126.
Manual operation:	See "Phase Offset" on page 78

[:SOURce]:IQ:DOHerty:POWer:ATTenuation:COUPling[:STATe] <State>

If enabled, the digital attenuation values set with the command `[:SOURce<hw>]:IQ:DOHerty:POWer:ATTenuation` for both signals are coupled. The difference between the values is, however, maintained.

Suffix:

<hw>	1

Parameters:
<State> 1 | ON | 0 | OFF

*RST: 0

Example: See Example"Defining correction coefficients and enabling digital Doherty" on page 126.

Manual operation: See "Couple Dig Att" on page 78

[:SOURce<hw>]:IQ:DOHerty:POWer:ATTenuation <Attenuation>

Adds additional digital attenuation to the signal.

Parameters:
<Attenuation> float

Range: -3.522 to 80
Increment: 1E-3
*RST: 30

Example: See Example"Defining correction coefficients and enabling digital Doherty" on page 126.

Manual operation: See "Dig Att" on page 78

[:SOURce<hw>]:IQ:DOHerty:SHAPing:PHASe:STATe <State>
[:SOURce<hw>]:IQ:DOHerty:SHAPing:POWer:STATe <State>

Enables/disables the power and phase corrections.

Suffix:
<hw> 2

Parameters:
<State> 1 | ON | 0 | OFF

*RST: 0

Example: See Example"Defining correction coefficients and enabling digital Doherty" on page 126.

Manual operation: See "Power and Phase State" on page 79

[:SOURce<hw>]:IQ:DOHerty:INPut:PEP?
[:SOURce<hw>]:IQ:DOHerty:INPut:LEVel?

Queries the PEP and level values.

Suffix:
<hw> 2

Return values:
<Level> float

Example: See Example"Defining correction coefficients and enabling digital Doherty" on page 126.

Usage: Query only

Manual operation: See "PEP, Level" on page 78

[:SOURce<hw>]:IQ:DOHerty:OUTPut:PEP?
[:SOURce<hw>]:IQ:DOHerty:OUTPut:LEVel?

Queries the PEP and level values.

Return values:

<Level> float

Example: See Example"Defining correction coefficients and enabling digital Doherty" on page 126.

Usage: Query only

Manual operation: See "PEP, Level" on page 78

[:SOURce<hw>]:IQ:DOHerty:SHAPing:MODE <Shaping>

Selects the method to define the correction coefficients.

Parameters:

<Shaping> TABLe | POLYnomial | NORMalized | DOHerty

*RST: TABLe

Example: See Example"Defining correction coefficients and enabling digital Doherty" on page 126.

Manual operation: See "Shaping" on page 59

[:SOURce<hw>]:IQ:DOHerty:SHAPing:POWer:BREakpoint <Split>

Sets the power value required for the calculation of the correction function if classic Doherty shaping is used.

Suffix:

<hw> 2

Parameters:

<Split> float

Range: -50 to 0
Increment: 0.01
*RST: -6

Example:

```
SOURce1:IQ:DOHerty:SHAPing:MODE DOHerty
SOURce1:IQ:DOHerty:SHAPing:POWer:BREakpoint -6
```

Manual operation: See "Power Breakpoint" on page 80

[:SOURce]:IQ:DOHerty:MEASurement[:STATe]?

Query the calculation status of the PEP and Level values.

Return values:

<MeasureValidity> 1 | ON | 0 | OFF

1|ON
PEP and Level output values are valid

0|OFF
PEP and Level output values are in calculation
In the user interface, you recognize this state if "---.--" is indicated.

Example: `SOURce:IQ:DOHerty:MEASurement:STATe?`

Usage: Query only

Manual operation: See "PEP, Level" on page 78

Glossary: Publications and references

Symbols

1GP104: Rohde & Schwarz application note 1GP104 "Envelope Tracking and Digital Pre-Distortion Test Solution for RF Amplifiers"

1GP139: Rohde & Schwarz application note 1GP139 "Digital Predistortion for improved EVM Performance"

1MA269: Rohde & Schwarz application note 1MA269 "Linearization of RF Frontends"

1MA279: Rohde & Schwarz application note 1MA279 "Doherty, Balanced, Push-Pull & Spatial Amplifier Performance Enhancement"

1MA299: Rohde & Schwarz application note 1MA299 "Linearity Measurements on RFFE Components"

1SL371: Rohde & Schwarz application note 1SL371 "Linearization of RF Amplifiers"

1SL383: Rohde & Schwarz application note 1SL383 "Investigate RF Power Amplifier Linearization Benefits in EDA"

G

GFM345: Rohde & Schwarz application note GFM345 "R&S®SMW-K546 Digital Doherty"

List of commands

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