R&S®NRPC, R&S®Recal+ Power Sensor Calibration Kit and Calibration Software Manual

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Version 19

ROHDE&SCHWARZ
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This document describes the following models and options of the power sensor calibration kits:

- R&S®NRPC18 (1418.0931.03)
- R&S®NRPC33 (1418.0677.03)
- R&S®NRPC40 (1159.6802.03)
- R&S®NRPC50 (1159.6883.03)
- R&S®NRPC67 (1418.1567.02)
- R&S®NRPC-LS (1421.7004.02)
- R&S®NRPC18-B1 (1418.0954.03)
- R&S®NRPC33-B1 (1418.0683.03)
- R&S®NRPC40-B1 (1159.6819.03)
- R&S®NRPC50-B1 (1159.6890.03)
- R&S®NRPC67-B1 (1418.1550.02)

This document describes the R&S®Recal+ power sensor calibration software with version 5.04 and higher.

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1109.0930.02 | Version 19 | R&S®NRPC, R&S®Recal+

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

Contents

1 Safety and regulatory information

The product documentation helps you use the product safely and efficiently. Follow the instructions provided here and in the following sections.

Intended use

The R&S NRPC power sensor calibration kits enable you to calibrate power sensors.

Connected between the RF output of a signal source and the sensor (DUT), you can use the calibration kits to perform both absolute accuracy and linearity calibration. A power meter indicates the power standard output. The R&S Recal+ software controls the calibration.

Observe the operating conditions and performance limits stated in the specifications document.

Target audience

The target audience is developers and technicians. The required skills and experience in power measurements depend on the used operating concept.

Where do I find safety information?

Safety information is part of the product documentation. It warns you of potential dangers and gives instructions on how to prevent personal injury or damage caused by dangerous situations. Safety information is provided as follows:

- In Section 1.1, "Safety instructions", on page 9. The same information is provided in many languages in printed format. The printed "Safety Instructions" for "Power Sensors" (document number 1171.1865.99) are delivered with the product.
- Throughout the documentation, safety instructions are provided when you need to take care during setup or operation.

1.1 Safety instructions

Products from the Rohde & Schwarz group of companies are manufactured according to the highest technical standards. To use the products safely, follow the instructions provided here and in the product documentation. Keep the product documentation nearby and offer it to other users.

Use the product only for its intended use and within its performance limits. Intended use and limits are described in the product documentation such as the specifications document, manuals and the printed "Safety Instructions" document. If you are unsure about the appropriate use, contact Rohde & Schwarz customer support.

Using the product requires skilled persons or specially trained personnel. These users also need sound knowledge of at least one of the languages in which the user interfaces and the product documentation are available.

Reconfigure or adjust the product only as described in the product documentation or the specifications document. Any other modifications can affect safety and are not permitted.

Never open the casing of the product. Only service personnel authorized by Rohde & Schwarz are allowed to repair the product. If any part of the product is damaged or broken, stop using the product. Contact Rohde & Schwarz customer support at https://www.rohde-schwarz.com/support.

Operating the product

Only use the product indoors. The product casing is not waterproof.

Observe the ambient conditions stated in the specifications document. Examples of ambient conditions are altitude, operating temperature and climatic loads.

Meaning of safety labels

Safety labels on the product and its accessories warn against potential hazards.

	Potential hazard Read the product documentation to avoid personal injury or product damage.

	Hot surface Do not touch. Risk of skin burns. Risk of fire.

1.2 Labels on the product

Labels on the product inform about:

- Personal safety
  See "Meaning of safety labels" on page 10.
- Environment safety
  See Table 1-1.
- Identification of the product
  A sticker on the product shows the product ID, a combination of the order number and the serial number of the product. The serial number identifies the product uniquely.
  See also Section 3, "Checking out the calibration kits and options", on page 15.

Table 1-1: Labels regarding environment safety

	Labeling in line with EN 50419 for disposal of electrical and electronic equipment after the product has come to the end of its life. For more information, see "Disposing of electrical and electronic equipment" on page 193.

1.3 Warning messages in the documentation

A warning message points out a risk or danger that you need to be aware of. The signal word indicates the severity of the safety hazard and how likely it will occur if you do not follow the safety precautions.

NOTICE

Potential risks of damage. Could result in damage to the supported product or to other property.

1.4 Where to find key documents on Rohde & Schwarz

Certificates issued to Rohde & Schwarz that are relevant for your country are provided at www.rohde-schwarz.com/key-documents, e.g. concerning:

- Quality management
- Environmental management
- Information security management
- Accreditations

2 Welcome

This section provides an introduction to the calibration kits.

In this manual, the term *R&S power sensor* is used for the power sensors of the NRP, R&S NRP-Z and R&S FSH-Z families. These power sensors are the main focus of this manual. Only section 9 describes the calibration of the older generations, the R&S NRV and R&S URV power sensors.

The term *R&S NRPC* is used for the R&S NRPC18, R&S NRPC33, R&S NRPC40, R&S NRPC50 and R&S NRPC67 calibration kits.

2.1 Documentation overview

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

www.rohde-schwarz.com/manual/nrpc

Further documents are available at:

www.rohde-schwarz.com/product/nrpc

2.1.1 Manual

Introduces the R&S NRPC and describes how to set up and start working with the product. Describes how to calibrate R&S power sensors using the R&S NRPC calibration kit together with the R&S Recal+ calibration software.

The user manual is also available for download or for immediate display on the internet.

2.1.2 Printed safety instructions

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

2.1.3 Instrument security procedures

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

2.1.4 Product brochures

The brochures provide an overview of the products and their applications. They contain the technical specifications of the products and list the ordering information.

www.rohde-schwarz.com/brochure-datasheet/nrpc

2.1.5 Calibration certificate

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

2.1.6 Release notes and open source acknowledgment (OSA)

The R&S NRPC firmware is installed on the R&S NRPC power standard. The corresponding release notes list new features, improvements and known issues of the current version.

The R&S NRPC firmware uses several valuable open source software packages. An open source acknowledgment document provides verbatim license texts of the used open source software. The open source acknowledgment document is available on the internet and also on the CD-ROM, included in the delivery.

www.rohde-schwarz.com/firmware/nrpc

2.1.7 R&S Recal+ calibration software

The R&S Recal+ calibration software is required on the controller. The corresponding release notes list new features, improvements and known issues of the current version, and describe the software installation and update. The integrated online help describes the user interface of the R&S Recal+ calibration software. The calibration process is described in this manual.

The R&S Recal+ calibration software is available on the internet.

www.rohde-schwarz.com/software/nrpc

2.2 Key features

Various calibration kits are available for calibration of sensors depending on the frequency range. Calibration of the sensors is supported by the R&S Recal+ software. All the calibration kits are calibrated in a traceable manner by the accredited calibration laboratory D-K-15195-01-01 of Rohde & Schwarz. This laboratory is accredited by the Deutsche Akkreditierungsstelle GmbH (DAkkS) for the relevant measured quantities. The appendix to the accreditation certificate can be found on the internet at www.dakks.de.

The calibration kits support the following functions:

- Calibration of absolute accuracy for power sensors with N-50 Ω, 3.5 mm, 2.92 mm, 2.4 mm, 1.85 mm connectors from DC to max. 67 GHz
- Linearity calibration with a level range of −60 dBm to +35 dBm at 1 GHz

- Recording the reflection with the R&S ZVX_RECAL program module
- Calculating new correction factors for the data memories based on the calibration data. For certain sensors, calibration is performed without rewriting the data memory. See Table 5-1 to Table 5-6.
- Rewriting the data memories
- Report generation

3 Checking out the calibration kits and options

To unpack and check

1. Unpack the R&S NRPC carefully.
2. Retain the original packing material. Use it when transporting or shipping the R&S NRPC later.
3. Using the delivery notes, check the equipment for completeness.
4. Check the equipment for damage.

   If the delivery is incomplete or equipment is damaged, contact Rohde & Schwarz.

3.1 R&S NRPC calibration kits

Figure 3-1: R&S NRPC calibration kit (example)

Table 3-1: Contents of the calibration kit box

Figure 3-1	Designation	R&S NRPC18	R&S NRPC33	R&S NRPC40	R&S NRPC50	R&S NRPC67
1	Microwave connecting cable	N (male) to N (male)	PC2.92 (male) to PC2.92 (male)	PC2.92 (male) to PC2.92 (male)	PC2.4 (male) to PC2.4 (male)	PC1.85 (male) to PC1.85 (male)
2	Adapter	N (male) to BNC (male)	N (male) to SMA (female)	N (male) to SMA (female)	N (male) to PC2.4 (female)	N (male) to PC2.4 (female)
3	Reference attenuator	20 dB	20 dB	20 dB	-	-

Figure 3-1	Designation	R&S NRPC18	R&S NRPC33	R&S NRPC40	R&S NRPC50	R&S NRPC67
4	Replacement adapter for the test port	-	PC2.4 (male) to PC3.5 (female)	PC2.4 (male) to PC2.92 (female)	PC2.4 (male) to PC2.4 (female)	PC1.85 (male) to PC1.85 (female)
6	Torque wrench					
7	Power standard, see Figure 3-2.					
8	R&S NRPC-B1 verification sensor	Optional, see Section 3.3, "Options for the R&S NRPC calibration kits", on page 20.				
Not shown	Precision termination	50 Ω	-	-	-	-
Not shown	Adapter cable	Connects R&S FSH-Z sensors to the R&S NRP	-	-	-	-

The R&S NRPC calibration kits support the calibration of absolute accuracy. See also Section 4.3, "Calibration of absolute accuracy", on page 23.

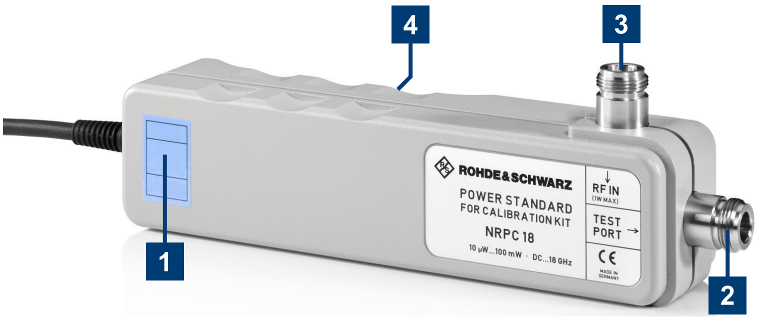


Figure 3-2: Power standard (example)

1 = "Accreditation information sticker" on page 16
2 = test port; for connecting to DUT
3 = RF input; for connecting to generator RF output
4 = "Product ID sticker" on page 16

Accreditation information sticker

Shows the following information from top to bottom: calibration certificate number without prefix, number of accredited calibration laboratory, date of the last accreditation.

Product ID sticker

Shows the product ID, a combination of the order number and the serial number of the product. The serial number is unique for each product.

For specifications such as max. input power, frequency range or test post power range, refer to the specifications documents. See also Section 2.1.4, "Product brochures", on page 12.

For maximum measurement accuracy, tighten the RF connector using a torque wrench with a nominal torque as specified in Table 3-2.

Table 3-2: R&S NRPC RF connector type

Calibration kit	RF connector type	Tightening torque
R&S NRPC18	N-50 Ω	1.3 Nm (11.5 lbf in) to 1.7 Nm (15 lbf in)
R&S NRPC33	3.5 mm	0.90 Nm (8 lbf in)
R&S NRPC40	2.92 mm	0.90 Nm (8 lbf in)
R&S NRPC50	2.4 mm	0.90 Nm (8 lbf in)
R&S NRPC67	1.85 mm	0.90 Nm (8 lbf in)

The R&S NRPC calibration kits use the technology in the NRP thermal sensors. The display of the RF power measurand takes place here entirely in the sensor all the way through the numerical measurement result. The R&S NRX base unit is used only to set the sensor parameters and to display the measured value computed in the sensor. In this manner, any influence of the power meter base unit on the measured value is eliminated for the R&S NRPC calibration kits. All the necessary correction factors including the S-parameters for the reference attenuator are saved in the data memory of the power standard.

Upon delivery, the power standards contain all the necessary data, correction and characteristic data.

3.2 R&S NRPC-LS linearity standard

The R&S NRPC-LS calibration kit supports the linearity check at 1 GHz. See also Section 4.4, "Linearity calibration", on page 24.

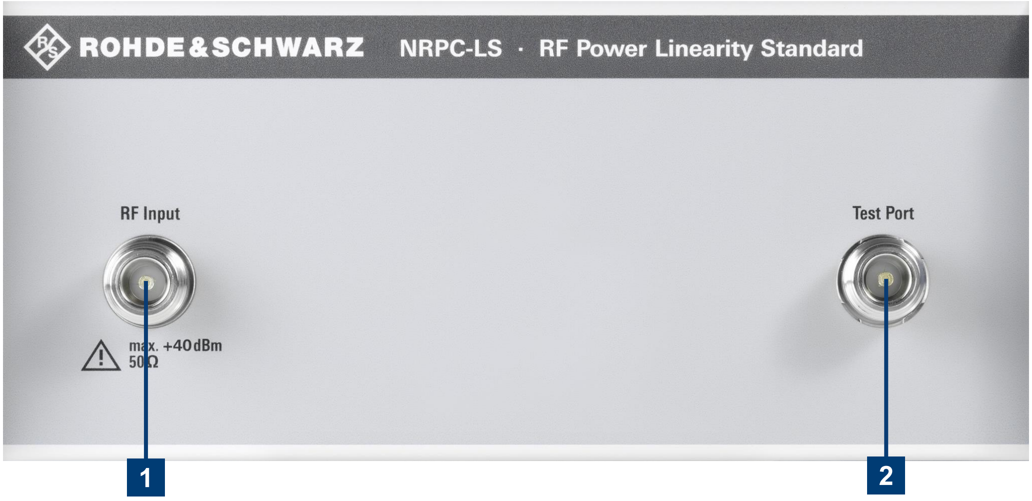


Figure 3-3: R&S NRPC-LS front view

1 = RF input, to connect to generator RF output
2 = test port to connect to DUT

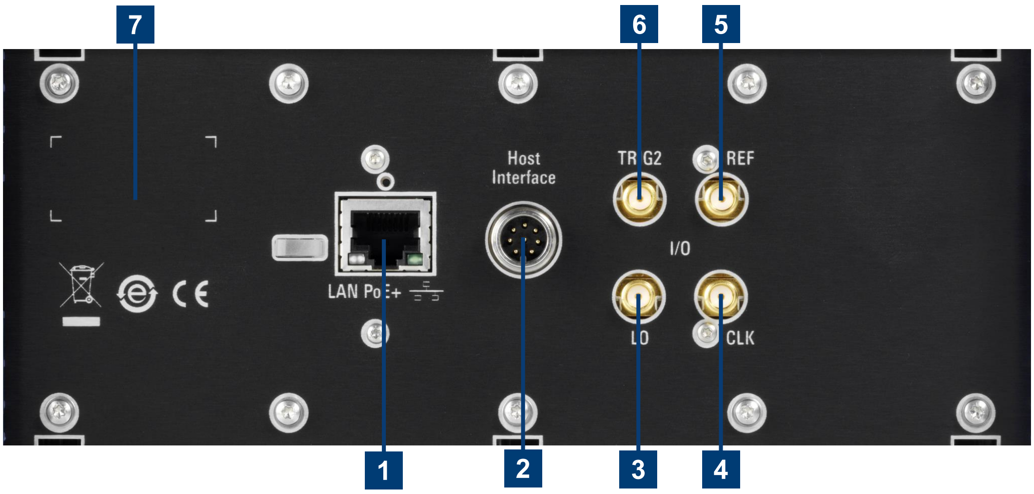


Figure 3-4: R&S NRPC-LS rear view

1 = "LAN PoE+ interface" on page 19
2 = "Host interface" on page 19
3 = "Local oscillator I/O (LO)" on page 19
4 = "Clock I/O (CLK)" on page 19
5 = "Reference I/O (REF)" on page 19
6 = "Trigger 2 I/O (TRIG2)" on page 19
7 = "Product ID sticker" on page 16

For specifications such as max. input power, frequency range or test post power range, refer to the specifications documents. See also Section 2.1.4, "Product brochures", on page 12.

The maximum input power is also printed on the housing below the RF input. Exceeding the maximum input power can damage the product.

RF connector

N-50 Ω RF connector.

For maximum measurement accuracy, tighten the RF connector using a torque wrench with a nominal torque of 1.3 Nm (11.5 lbf in) to 1.7 Nm (15 lbf in).

LAN PoE+ interface

1 gigabit LAN interface (1000BASE-T). The assignment of the RJ.45 CAT5 connector supports twisted-pair UTP/STP cables in a star configuration (UTP stands for "unshielded twisted pair", and STP for "shielded twisted pair").

Electromagnetic interference (EMI) can affect the measurement results. To avoid any impact, use category 5 cables or better.

The power for the sensor is supplied over the LAN PoE+ interface.

Network status LED:

Shows whether the LAN connection to the network is established properly or not.

Indication		State
●	Green	The sensor is correctly connected to the network. It has been assigned a valid IP address, either manually or via DHCP.
●	Red	The sensor is not connected to the network correctly. Either the connection is erroneous or the sensor has not been assigned a valid IP address yet.

Host interface

The 8-pole male sensor connector (M12) is used to connect the sensor to a base unit.

Local oscillator I/O (LO)

The female SMA connector is used as an input or output for the local oscillator (LO) signal.

Clock I/O (CLK)

The female SMA connector is used as an input or output for the sampling clock.

Reference I/O (REF)

The female SMA connector is used as an input or output for the reference clock.

Trigger 2 I/O (TRIG2)

The female SMA connector is used as an input or output for a trigger signal.

3.3 Options for the R&S NRPC calibration kits

The R&S NRPC-B1 option is an optional part of the R&S NRPC calibration kit. It is a verification sensor, a thermal sensor, for the associated power standard, see also Table 3-3.

For specifications such as max. input power, frequency range or test post power range, refer to the specifications documents. See also Section 2.1.4, "Product brochures", on page 12.

For maximum measurement accuracy, tighten the RF connector using a torque wrench with a nominal torque as specified in Table 3-3.

Table 3-3: R&S NRPC-B1 RF connector type

Calibration kit	RF connector type	Tightening torque	Associated power standard
R&S NRPC18-B1	N-50 Ω	1.3 Nm (11.5 lbf in) to 1.7 Nm (15 lbf in)	R&S NRPC18
R&S NRPC33-B1	3.5 mm	0.90 Nm (8 lbf in)	R&S NRPC33
R&S NRPC40-B1	2.92 mm	0.90 Nm (8 lbf in)	R&S NRPC40
R&S NRPC50-B1	2.4 mm	0.90 Nm (8 lbf in)	R&S NRPC50
R&S NRPC67-B1	1.85 mm	0.90 Nm (8 lbf in)	R&S NRPC67

3.4 Recognizing power standard models

There are two generations of the R&S NRPC power standards. The first generation is based on a thermal R&S NRP-Z sensor. The second generation is based on a thermal NRP sensor. All products of the first generation are discontinued. You can recognize the generation at the last two digits of the part number, as shown in Table 3-4.

Table 3-4: Power standard models

R&S NRPC	Part number	First generation	Second generation	Discontinued product
R&S NRPC18	1418.0948.02	x		x
	1418.0948.03		x	
R&S NRPC33	1418.0660.02	x		x
	1418.0660.03		x	
R&S NRPC40	1159.6625.02	x		x
	1159.6625.03		x	
R&S NRPC50	1159.6725.02	x		x
	1159.6725.03		x	
R&S NRPC67	1418.1573.02		x	

The same applies to the R&S NRPC-B1 options, see Table 3-5.

Table 3-5: Verification sensor models

R&S NRPC-B1	Part number	First generation	Second generation	Discontinued product
R&S NRPC18-B1	1418.1044.03	x		x
	1418.1044.04		x	
R&S NRPC33-B1	1418.0819.02	x		x
	1418.0819.03		x	
R&S NRPC40-B1	1418.0602.03	x		x
	1418.0602.04		x	
R&S NRPC50-B1	1418.0525.02	x		x
	1418.0525.03		x	
R&S NRPC67-B1	1418.1638.02		x	

4 Information and instructions on calibration

4.1 Warm-up time for devices under test (DUTs)

The R&S power sensors require a warm-up time of at least one hour after startup to attain their operating temperature. If it is frequently necessary to calibrate a series of sensors, let the uncalibrated sensors warm up while calibration is being performed on another one. In this application, you can connect them either to a multichannel R&S NRX (R&S NRX-B2 and R&S NRX-B5 option) or to a PC, preferably using the four-channel R&S NRP-Z5 USB sensor hub.

Simply connecting the sensor to the PC is not sufficient for warm-up. Instead, the sensor processor, which is the main source of heat for the sensor, must be placed in a typical operating state.

1. Connect the sensor.
2. In the Windows device manager, USB controller device group, check the status of the sensor. Wait until Window recognizes the sensor.

   If the sensor is recognized, the sensor is properly numbered.
3. Open the Windows device manager.
4. In the USB controller device group, enter the number.

   Note: For the prerequisites for numbering, see "Software requirements" on page 28.

For the R&S NRV and R&S URV5 sensors, it is adequate to wait for two minutes after connection to the R&S NRVD.

4.2 Reflection measurement

Always measure the reflection of a sensor from two perspectives. One reason is that the reflection is an important device property. The other reason is that the reflection data in complex notation can be used to reduce the measurement errors resulting from mismatching during calibration of absolute accuracy, see Section 6.2.4, "Checking the absolute accuracy", on page 50. Reflection measurement is supported by the R&S ZVX_RECAL program module together with selected network analyzers from Rohde & Schwarz. Methods for integrating reflection data from other network analyzers into the R&S Recal+ software are described in Section 8.1, "Reflection", on page 65.

4.3 Calibration of absolute accuracy

4.3.1 Refreshing the data set of the device under test

When absolute accuracy is checked, the power reading of the DUT is compared with the power reading of a power standard over the entire frequency range of the DUT. The R&S Recal+ software automatically performs a tolerance test. The test provides an indication of whether the sensor can be considered to comply with the specifications at the time point of delivery at the individual frequency points.

To ensure compliance with specifications for the following calibration interval, it is necessary for most sensors to readjust also the saved correction factors (calibration data). After the readjustment, the errors that are measured compared to the power standard disappear. You can achieve that in a subsequent measurement. Devices under test that are calibrated or adjusted in this manner reliably conform to the uncertainties specified in the specifications document.

For a few sensors, the compliance with specifications is ensured if the tolerance limits used in calibration of absolute accuracy are met. In this case, you cannot rewrite the correction factor memory. These sensor types are indicated accordingly in the "Absolute accuracy" or "Adjustment" column, see Table 5-1 to Table 5-6.

4.3.2 Gamma correction

Correction of the mismatch between the device under test and the power standard, gamma correction for short, generally reduces the influence of the mismatch by an order of magnitude. This correction is recommended in all cases, and it is even mandatory for some sensor types. These sensors are designated accordingly in Table 5-1 to Table 5-6. You can enable the gamma correction easily in the R&S Recal+ software, but it does require the availability of reflection values for the device under test in complex notation. Reflection measurement is supported by the R&S ZVX_RECAL program module in conjunction with selected network analyzers from Rohde & Schwarz.

4.3.3 R&S power sensors with attenuator

Calibration is different with the R&S NRP18S-xx and R&S NRP-Z22/23/24/92 sensors that consist of a power sensor with an attenuator connected to the input. The attenuator is treated as a connectable S-parameter device for which separate correction factors are present in the data memory for the sensor. If the uncertainties specified for the power sensor and attenuator must match after the calibration, refresh the correction factors of both when calibrating these sensors.

Like all the other R&S power sensors, calibration of the power sensors is supported by the R&S Recal+ software. However, calibration of the attenuators is not supported. Since the risk of significant measurement errors is higher compared to power calibration, we recommend that the calibration of the attenuators is handled only by experienced personnel. See also section Section 8.2, "S-parameter file for sensors with attenuators", on page 80.

To check the correctness of the existing calibration values for the attenuator roughly, run a check measurement on the power sensor with the attenuator screwed on, using the R&S Recal+ software.

4.3.4 R&S NRV-Z and R&S URV5-Z diode sensors

Some of these sensors require a power level of less than 10 µW for calibration of absolute accuracy. If so, connect the reference attenuator to the output of the power standard to reduce the power level.

4.4 Linearity calibration

For most DUTs, calibration of the linearity is used only to check that the sensor is functioning properly. Thus, the check for compliance with tolerance limits that is performed by the R&S Recal+ software is fully adequate. In such cases, you cannot refresh the set of correction factors.

5 Measurement equipment and setups

5.1 Supported R&S power sensors

5.1.1 Calibration of absolute accuracy with R&S NRPC calibration kit

Table 5-1: Power sensors supported by the R&S NRPC18 calibration kit

Power sensor	Absolute accuracy		Gamma correction is mandatory	Frequency range, DUT (generator)
	Adjustment	Check		
R&S NRP6A(N)	✓	✓	-	8 kHz to 6 GHz
R&S NRP18A(N)	✓	✓	-	8 kHz to 18 GHz
R&S NRP8E	✓	✓	-	10 MHz to 8 GHz
R&S NRP18E	✓	✓	-	10 MHz to 18 GHz
R&S NRP18P	✓	✓	-	50 MHz to 18 GHz
R&S NRP8S(N)	✓	✓	-	10 MHz to 8 GHz
R&S NRP18S(N)	✓	✓	-	10 MHz to 18 GHz
R&S NRP18S-10/20/25	✓	✓	-	10 MHz to 18 GHz
R&S NRP18T(N)	✓	✓	✓	10 MHz to 18 GHz
R&S FSH-Z1	✓	✓	-	10 MHz to 8 GHz
R&S FSH-Z18	✓	✓	-	10 MHz to 18 GHz
R&S NRP-Z11	✓	✓	-	10 MHz to 8 GHz
R&S NRP-Z21/22/23/24	✓	✓	-	10 MHz to 18 GHz
R&S NRP-Z27	✓	✓	-	DC to 18 GHz
R&S NRP-Z211	✓	✓	-	10 MHz to 8 GHz
R&S NRP-Z221	✓	✓	-	10 MHz to 18 GHz
R&S NRP-Z51 (02, 62)	✓	✓	-	10 MHz to 18 GHz
R&S NRP-Z51 (03)	✓	✓	✓	10 MHz to 18 GHz
R&S NRP-Z81	✓	✓	-	50 MHz to 18 GHz
R&S NRP-Z91 (02, 04)	✓	✓	-	9 kHz to 6 GHz
R&S NRP-Z91 (08)	-	✓	-	10 MHz to 8 GHz
R&S NRP-Z92	✓	✓	-	9 kHz to 6 GHz
R&S NRV-Z1/2	✓	✓	-	10 MHz to 18 GHz

Power sensor	Absolute accuracy		Gamma correction is mandatory	Frequency range, DUT (generator)
	Adjustment	Check		
R&S NRV-Z4/5	✓	✓	-	100 kHz to 6 GHz
R&S NRV-Z7/8	✓	✓	-	10 MHz to 13 GHz
R&S NRV-Z31/32/33	-	✓	-	30 MHz to 6 GHz
NRV-Z51 (02, 04)	✓	✓	-	10 MHz to 18 GHz
R&S NRV-Z51 (06)	✓	✓	-	1 kHz to 6 GHz
R&S NRV-Z53/54	✓	✓	-	10 MHz to 18 GHz
R&S NRV-Z53/54	✓	✓	-	10 MHz to 18 GHz
R&S NRV-Z1/2	✓	✓	-	10 MHz to 18 GHz

Table 5-2: R&S URV voltage sensors supported by the R&S NRPC18 calibration kit

Power sensor	Absolute accuracy		Gamma correction is mandatory	Frequency range, DUT (generator)
	Adjustment	Check		
R&S URV5-Z2 (02, 05)	-	✓	-	9 kHz to 3 GHz
R&S URV5-Z2 (04)	-	✓	-	9 kHz to 1 GHz
R&S URV5-Z2 (55, 56)	-	✓	-	9 kHz to 2 GHz
R&S URV5-Z4 (02, 05)	-	✓	-	100 kHz to 3 GHz
R&S URV5-Z4 (04)	-	✓	-	100 kHz to 2 GHz
R&S URV5-Z4 (55, 56)	-	✓	-	100 kHz to 2 GHz
R&S URV5-Z5 (55)	✓	✓	-	10 MHz to 18 GHz
R&S URV5-Z7	-	✓	-	20 kHz to 1 GHz
R&S URY-Z2	-	✓	-	9 kHz to 2 GHz
R&S URY-Z4	-	✓	-	100 kHz to 2 GHz
R&S URY-Z7	-	✓	-	20 kHz to 1 GHz

Table 5-3: Power sensors supported by the R&S NRPC33 calibration kit

Power sensor	Absolute accuracy		Gamma correction is mandatory	Frequency range, DUT (generator)
	Adjustment	Check		
R&S NRP33S(N)(-V)	✓	✓	✓	10 MHz to 33 GHz
R&S NRP33T(N)	✓	✓	✓	10 MHz to 33 GHz
R&S NRP-Z31	✓	✓	✓	10 MHz to 33 GHz
R&S NRP-Z37	✓	✓	✓	DC to 26.5 GHz
R&S NRP-Z52 (02, 62)	✓	✓	✓	10 MHz to 33 GHz
R&S NRP-Z52 (18)	✓	✓	✓	10 MHz to 18 GHz

Power sensor	Absolute accuracy		Gamma correction is mandatory	Frequency range, DUT (generator)
	Adjustment	Check		
R&S NRV-Z6	✓	✓	✓	50 MHz to 26.5 GHz
R&S NRV-Z52	✓	✓	✓	10 MHz to 26.5 GHz

Table 5-4: Power sensors supported by the R&S NRPC40 calibration kit

Power sensor	Absolute accuracy		Gamma correction is mandatory	Frequency range, DUT (generator)
	Adjustment	Check		
R&S NRP40P	✓	✓	✓	50 MHz to 40 GHz
R&S NRP40S(N)	✓	✓	✓	50 MHz to 40 GHz
R&S NRP40T(N)	✓	✓	✓	10 MHz to 40 GHz
R&S NRP-Z41	✓	✓	✓	50 MHz to 40 GHz
R&S NRP-Z55	✓	✓	✓	10 MHz to 40 GHz
R&S NRP-Z85	✓	✓	✓	50 MHz to 40 GHz
R&S NRV-Z15	✓	✓	✓	50 MHz to 40 GHz
R&S NRV-Z55	✓	✓	✓	10 MHz to 40 GHz

Table 5-5: Power sensors supported by the R&S NRPC50 calibration kit

Power sensor	Absolute accuracy		Gamma correction is mandatory	Frequency range, DUT (generator)
	Adjustment	Check		
R&S NRP50P	✓	✓	✓	50 MHz to 50 GHz
R&S NRP50S(N)	✓	✓	✓	50 MHz to 50 GHz
R&S NRP50T(N)	✓	✓	✓	10 MHz to 50 GHz
R&S NRP-Z61	✓	✓	✓	50 MHz to 50 GHz
R&S NRP-Z56	✓	✓	✓	10 MHz to 50 GHz
R&S NRP-Z86 (40)	✓	✓	✓	50 MHz to 40 GHz
R&S NRP-Z86 (44)	✓	✓	✓	50 MHz to 44 GHz

Table 5-6: Power sensors supported by the R&S NRPC67 calibration kit

Power sensor	Absolute accuracy		Gamma correction is mandatory	Frequency range, DUT (generator)
	Adjustment	Check		
R&S NRP67S(N)(-V)	✓	✓	✓	50 MHz to 67 GHz
R&S NRP67T(N)	✓	✓	✓	10 MHz to 67 GHz
R&S NRP-Z57	✓	✓	✓	10 MHz to 67 GHz

5.1.2 Calibration of linearity with R&S NRPC-LS standard

The R&S NRPC-LS calibration kit allows the check of almost all R&S power sensors at a calibration frequency of 1 GHz, see Table 5-1 to Table 5-6.

Most power sensors are only checked, but cannot be adjusted. For the wideband sensors R&S NRP18/40/50P and R&S NRP-Z81/85/86, you can also perform an adjustment.

Calibration of linearity with the R&S NRPC-LS calibration kit is not supported for R&S URV5-Z2 (55, 56), R&S URV5-Z4 (55, 56) and R&S URV5-Z7.

5.2 Controller

The entire calibration procedure is remote-controlled from a PC.

Hardware requirements

- The hardware requirements such as clock frequency, RAM, hard disk space are not critical.
- National Instruments IEC/IEEE bus interface, which can run under the installed operating system and act as the interface to the instruments.
  Before using the calibration kit for the first time, test the installation of the IEC/IEEE bus card with the tools supplied by the manufacturer (ibconf, ibdiag, etc.).

Software requirements

- Operating system must be Microsoft Windows® 10 or later.
- R&S Recal+ software, see Section 2.1.7, "R&S Recal+ calibration software", on page 13.
- R&S NRP-Toolkit software, see Section 5.2.1, "R&S NRP-Toolkit", on page 28.

5.2.1 R&S NRP-Toolkit

Before you start using an R&S sensor or sensor module, we recommend installing the latest R&S NRP-Toolkit.

The R&S NRP-Toolkit is the basic software package that supplies low-level drivers and tools for all R&S sensors, sensor modules and power standards.

Windows needs the drivers for numbering purposes. Install the R&S NRP-Toolkit software before you connect a sensor for the first time.

5.2.1.1 Versions and downloads

The R&S NRP-Toolkit is available for:

- Microsoft Windows® operating system, as listed in Section 5.2.1.2, "System requirements", on page 29
- macOS

The latest versions for Windows and macOS are available at:

www.rohde-schwarz.com/software/nrpc

To obtain an R&S NRP-Toolkit for other operating systems, contact the Rohde & Schwarz customer support, see Section 15.5, "Contacting customer support", on page 186.

5.2.1.2 System requirements

Hardware requirements:

- Desktop computer or laptop

For supported Microsoft Windows versions, see the release notes.

5.2.1.3 R&S NRP-Toolkit for Windows

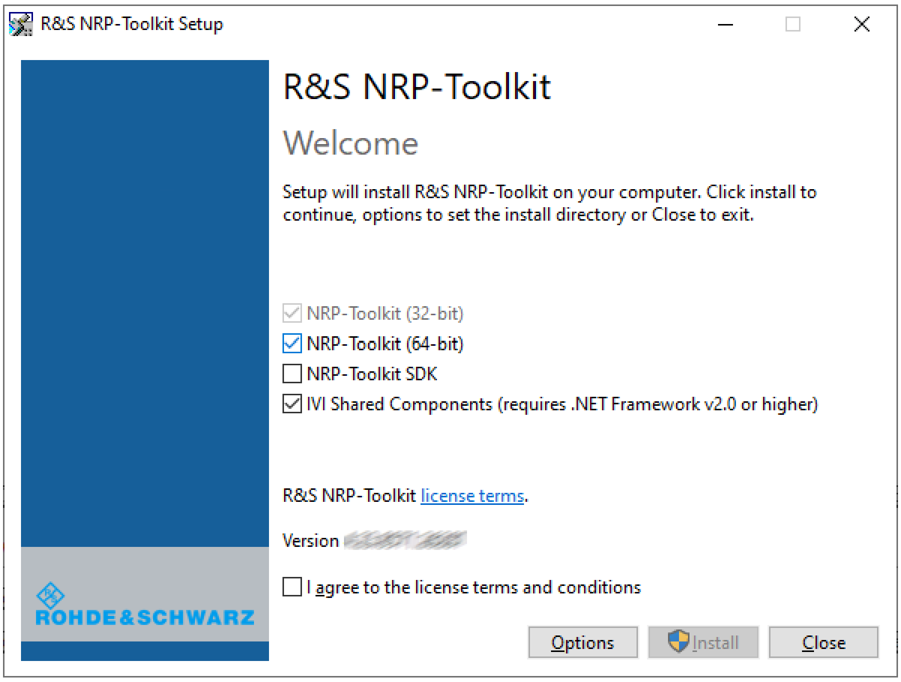
The R&S NRP-Toolkit installer for Windows-based systems contains the components described in the release notes.

To install the R&S NRP-Toolkit

1. Start the R&S NRP-Toolkit installer on the Windows-based computer.

   In the "NRP-Toolkit Setup" dialog, the correct R&S NRP-Toolkit version for your operating system, 32-bit or 64-bit, is already selected.

2. Enable the packages that you want to install.
   - "IVI Shared Components"
     Installs the USBTMC driver. Enabled by default because the installation is recommended.



3. Accept the license terms to continue with the installation.
4. Click "Next" and complete the installation process.

To uninstall the R&S NRP-Toolkit

Use the Windows functionality for removing apps and features. The R&S NRP-Toolkit itself has no uninstall functionality.

Components of the R&S NRP-Toolkit for Windows

The components of the R&S NRP-Toolkit depend on the operating system. The following tools are part of the R&S NRP-Toolkit for Windows.

Firmware Update

Installs new firmware on the sensor.

See Section 10, "Firmware update", on page 93.

5.2.2 Optional software

The R&S ZVX_RECAL is separate program module of the R&S Recal+ calibration software that supports program-controlled reflection measurements together with selected network analyzers from Rohde & Schwarz. The R&S ZVX_RECAL program module is available on the internet at:

www.rohde-schwarz.com/software/nrpc

5.3 Additional measurement equipment

In addition to the Controller, further measurement equipment is required that is not included in the calibration kit delivery.

5.3.1 R&S NRP-ZK6, R&S NRP-ZK8 interface cable

For the NRP power sensors, an R&S NRP-ZK6 or R&S NRP-ZK8 interface cable is mandatory. The interface cables are available in different lengths.

For the R&S NRPC-LS, an R&S NRP-ZK8 interface cable is mandatory.

5.3.2 R&S NRX power meter

Hardware requirements

The R&S NRX must have the R&S NRX-B1 option, a 50 MHz/1 GHz sensor check source, so that a quick check of the sensors can be performed before calibration is started.

Firmware requirements

In order for the R&S Recal+ calibration software to function properly, the firmware version must be equal or higher than 02.31.

Table 5-7: Required options for the R&S NRX power meter

Short name	Long name
R&S NRX-B1	Sensor check source
R&S NRX-K2	Second measurement channel
R&S NRX-B4	Third and fourth sensor connector
R&S NRX-K4	Third and fourth measurement channel
R&S NRX-B8	GPIB/IEEE-488 interface

5.3.3 Generators for calibration of absolute accuracy

The required characteristics depend on the frequency measurement range and the power measurement range of the DUT, see Table 5-1 to Table 5-6. The generator must cover the entire frequency range. Table 5-8 shows a selection of generators from the current Rohde & Schwarz product line that are recommended for operation of the

R&S NRPC calibration kit. This selection makes it possible to cover a wide frequency range with only a few types.

Supported generators in the current R&S product range:

- R&S SMA100B
  The required options are listed in Table 5-8.
- R&S SMB100A
  The required options are listed in Table 5-9.

We recommend the R&S SMA100B generator with the R&S SMA100B-B120 option since it can be used for calibration of absolute accuracy and linearity.

Older generators supported by the R&S Recal+ software are listed in Table 5-10.

Table 5-8: Required R&S SMA100B options

Required options	f range, DUT					
	≥ 8 kHz to ≤ 6 GHz	≥ 8 kHz to ≤ 18 GHz	≥ 10 MHz to ≤ 18 GHz	≥ 10 MHz to ≤ 40 GHz	≥ 10 MHz to ≤ 50 GHz	≥ 10 MHz to ≤ 67 GHz
R&S SMAB-B106 R&S SMAB-K31 * R&S SMAB-B32 *	✓					
R&S SMAB-B120 R&S SMAB-K33 R&S SMAB-B34 *	✓	✓	✓			
R&S SMAB-B140	✓	✓	✓	✓		
R&S SMAB-B150 R&S SMAB-B37	✓	✓	✓	✓	✓	
R&S SMAB-B167 R&S SMAB-B39 R&S SMAB-K40	✓	✓	✓	✓	✓	✓
* The "high output power" (R&S SMAB-K31, R&S SMAB-K33) and "ultra high output power" (R&S SMAB-B32, R&S SMAB-B34) options are only necessary for calibration of the linearity. We recommended selecting this option.						

Table 5-9: Required R&S SMB100A options

Required options	f range, DUT					
	≥ 8 kHz to ≤ 6 GHz	≥ 8 kHz to ≤ 18 GHz	≥ 10 MHz to ≤ 18 GHz	≥ 10 MHz to ≤ 40 GHz	≥ 10 MHz to ≤ 50 GHz	≥ 10 MHz to ≤ 67 GHz
R&S SMB-B120 R&S SMB-B31 **			✓			
R&S SMB-B140 R&S SMBB-B32			✓	✓		
** The R&S SMB-B31 option is necessary only for calibration of the R&S NRV-Z53/54 power sensors.						

Table 5-10: Supported generators that are discontinued

Generator	Required options	f range, DUT					
		≥ 9 kHz to ≤ 3 GHz	≥ 9 kHz to ≤ 6 GHz	≥ 10 MHz to ≤ 18 GHz	≥ 10 MHz to ≤ 26.5 GHz	≥ 10 MHz to ≤ 33 GHz	≥ 10 MHz to ≤ 40 GHz
R&S SML03 R&S SMV03		✓					
R&S SME06 R&S SMT06		✓	✓				
R&S SMB100A	R&S SMB100A-B106	✓	✓				
R&S SMR20				✓			
R&S SMR27/30				✓	(✓)		
R&S SMR40				✓	(✓)		(✓) *
R&S SMP02/22				✓			
R&S SMP03				✓	✓		
R&S SMP04				✓	✓	✓	(✓) *
R&S SMF100A	R&S SMF-B144, R&S SMF-B2, R&S SMF-B27			✓	✓	✓	
R&S SMF100A	R&S SMF-B34			✓	✓	✓	
* Only suitable for calibration of R&S NRV-Z6/15.							

5.3.4 Generators for calibration of linearity

The R&S SMA100B generator is mandatory for linearity measurements with R&S Recal+ and the R&S NRPC-LS calibration kit. All power sensors from Rohde & Schwarz are measured at a calibration frequency of 1 GHz. See Table 5-1 to Table 5-6.

The R&S SMA100B with frequency option up to 20 GHz and with the "High output power" and "Ultra high output power" options is excellent suitable for calibration of linearity. See Table 5-8.

5.3.5 Vector network analyzers for calibration of matching

The required characteristics are focused primarily on the frequency range and connector used by the DUT, see Table 5-1 to Table 5-6. Its lower frequency limit is less important since the power sensors from Rohde & Schwarz do not exhibit any significant changes in the matching at lower frequencies. Accordingly, a standard lower frequency limit of 10 MHz can be assumed when selecting an appropriate analyzer.

Table 5-11 lists a group of network analyzers that are selected because you only need very few types to cover a very large frequency range. Only these analyzers along with the analyzers listed in Table 5-12 are currently supported by the R&S Recal+ calibration software and the R&S ZVX_RECAL program module.

Of course, it is also possible to use other network analyzers. However, you have to ensure that the appropriate frequency points are measured and the calibration results are made available in the necessary file format.

See also Section 8.1.5, "Formatting and saving the reflection measured values", on page 75.

For calibration of the supported network analyzers, the calibration kits listed in Table 5-13 are recommended. For sensors with a 3.5 mm connector, the R&S ZN-Z235 standard kit with a frequency range of 26.5 GHz is not adequate. Instead, use the R&S ZV-Z235E extended kit that is specified for use up to 33 GHz.

For the sake of traceability and higher accuracy, the accredited calibration is recommended at the laboratory D-K-15195-01-01 operated by Rohde & Schwarz.

The accredited calibration is included only for the R&S ZV-Z235E and R&S NRPC calibration kits. For all other products, you have to order it separately.

Table 5-11: Supported R&S network analyzers

Network analyzer	f range, DUT					
	≥ 8 kHz to ≤ 6 GHz	≥ 8 kHz to ≤ 18 GHz	≥ 10 MHz to ≤ 18 GHz	≥ 10 MHz to ≤ 40 GHz	≥ 10 MHz to ≤ 50 GHz	≥ 10 MHz to ≤ 67 GHz
R&S ZNB8	✓ *	✓ **				
R&S ZNB20		✓ **	✓			
R&S ZNB43		✓ **	✓	✓		
R&S ZNA26		✓ **	✓			
R&S ZNA43		✓ **	✓	✓		
R&S ZNA50		✓ **	✓	✓	✓	
R&S ZNA67		✓ **	✓	✓	✓	✓
* A vector network analyzer with a lower frequency limit of 9 kHz is sufficient. The calibration software extrapolates the 8 kHz matching value.						
** Frequency range is only supported by a combination of two vector network analyzers. One for the lower frequency range (e.g. R&S ZNB8) and one for the upper frequency range (e.g. R&S ZNB20).						

Table 5-12: Supported R&S network analyzers that are discontinued

Network analyzer	R&S NRPC calibration kit used for power calibration				
	R&S NRPC18	R&S NRPC33	R&S NRPC40	R&S NRPC50	R&S NRPC67
R&S ZVM	✓				
R&S ZVB20	✓				
R&S ZVK	✓	✓	✓		
R&S ZVA24	✓				

Network analyzer	R&S NRPC calibration kit used for power calibration				
	R&S NRPC18	R&S NRPC33	R&S NRPC40	R&S NRPC50	R&S NRPC67
R&S ZVA40	✓	✓	✓		
R&S ZVA50	✓	✓	✓	✓	
R&S ZVA67	✓	✓	✓	✓	✓

Table 5-13: Recommended calibration kits for network analyzers

Connector	N-50 Ω	3.5 mm	2.92 mm	2.4 mm	1.85 mm
Frequency range	DC to 18 GHz	DC to 33 GHz	DC to 40 GHz	DC to 50 GHz	DC to 67 GHz
Type	R&S ZV-Z270	R&S ZV-Z235E	R&S ZN-Z229	R&S ZN-Z224	R&S ZN-Z218

5.4 Power calibration setup for R&S power sensors

This section describes the measurement equipment and setup for power calibration of NRP, R&S NRP-Z and R&S FSH-Z1/18 power sensors.

For information on power calibration of discontinued power sensor families, see Section 9.1, "Power calibration of R&S NRV-Z and R&S URV5-Z sensors", on page 88.

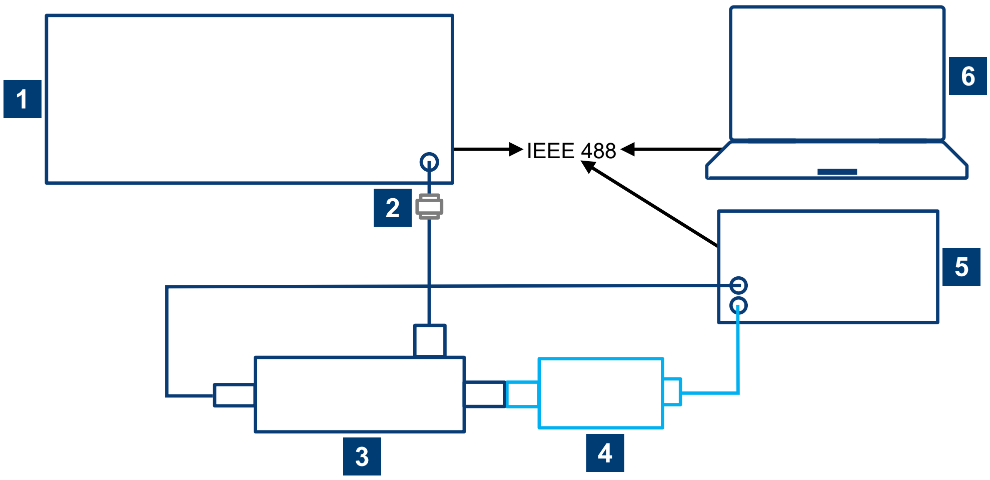


Figure 5-1: Setup for power calibration of R&S power sensors

1 = Generator
2 = Depending on the generator used, an adapter for connecting the RF cable can be required.
3 = R&S NRPC
4 = DUT
5 = R&S NRX power meter; for connecting NRP power sensors and R&S NRPC power standard, use an R&S NRP-ZK6 or R&S NRP-ZK8 interface cable.
6 = Controller, a computer with R&S Recal+ installed

Generator, power meter and computer are connected via their IEEE-488 interfaces.

Additional requirements for specific sensor types

- R&S FSH-Z1/18 power sensors:
  An adapter cable is required for connecting the power sensor to the R&S NRX.
- R&S NRPxA(N) average power sensors:
  An R&S SMA100B generator is required (covers the entire frequency range of 8 kHz up to 18 GHz).
- R&S NRP18S-xx power sensors: Remove the attenuator before performing the calibration.

For details on the measurement equipment, see:

- Section 5.1, "Supported R&S power sensors", on page 25
- Section 5.2, "Controller", on page 28
- Section 5.3.2, "R&S NRX power meter", on page 31
- Section 5.3.3, "Generators for calibration of absolute accuracy", on page 31
- Section 5.3.4, "Generators for calibration of linearity", on page 33
- Section 5.3.5, "Vector network analyzers for calibration of matching", on page 33

5.5 Linearity calibration setup for R&S power sensors

This section describes the measurement equipment and setup for linearity calibration of NRP, R&S NRP-Z and R&S FSH-Z1/18 power sensors.

For information on power calibration of discontinued power sensor families, see Section 9.2, "Linearity calibration of R&S NRV-Z and R&S URV5-Z sensors", on page 90.

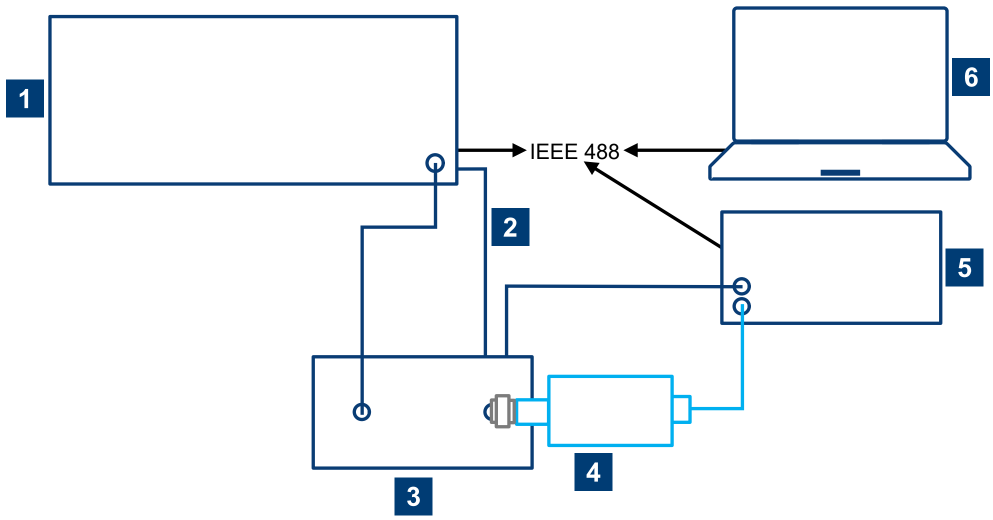


Figure 5-2: Setup for linearity calibration of R&S power sensors

1 = R&S SMA100B generator
2 = 10 MHz reference; connect the internal reference oscillator of the generator to the reference clock of the R&S NRPC-LS.
3 = R&S NRPC-LS

4 = DUT; depending on the DUT used, an adapter for connecting to the test port of the R&S NRPC-LS can be required. See Table 5-14.
5 = R&S NRX power meter; for connecting the NRP power sensors, use an R&S NRP-ZK6 or R&S NRP-ZK8 interface cable; for connecting the R&S NRPC-LS power standard, use an R&S NRP-ZK8 interface cable.
6 = Controller, a computer with R&S Recal+ installed

Table 5-14: Adapter for connecting the DUT to the R&S NRPC-LS

Connector of DUT	Calibration kit	Adapter included in calibration kit
3.5 mm	R&S NRPC33	N (male) to SMA (female)
2.92 mm	R&S NRPC40	N (male) to SMA (female)
2.4 mm	R&S NRPC50	N (male) to PC2.4 (female)
1.85 mm	R&S NRPC67	N (male) to PC2.4 (female)

For details on the measurement equipment, see:
- Section 5.1, "Supported R&S power sensors", on page 25
- Section 5.2, "Controller", on page 28
- Section 5.3.2, "R&S NRX power meter", on page 31
- Section 5.3.3, "Generators for calibration of absolute accuracy", on page 31
- Section 5.3.4, "Generators for calibration of linearity", on page 33
- Section 5.3.5, "Vector network analyzers for calibration of matching", on page 33

6 Sensor calibration

6.1 Preparing

The installation of the R&S Recal+ calibration software and the R&S ZVX_RECAL program module is described in the release notes, see also Section 2.1.7, "R&S Recal+ calibration software", on page 13.

6.1.1 Starting the calibration software

► To start the calibration software:

- Double-clicking the following icon on the desktop:

- Use the Windows® search.

If R&S Recal+ is called for the first time, some variables are not yet defined. Accordingly, R&S Recal+ prompts you to enter the name and address of the calibration laboratory, initialize the measuring equipment, etc. The required steps are described in detail in the sections below. All entries are saved in the `recal32.ini` initialization file and are applied automatically when R&S Recal+ is called again.

6.1.2 Entering the name and address of the calibration laboratory

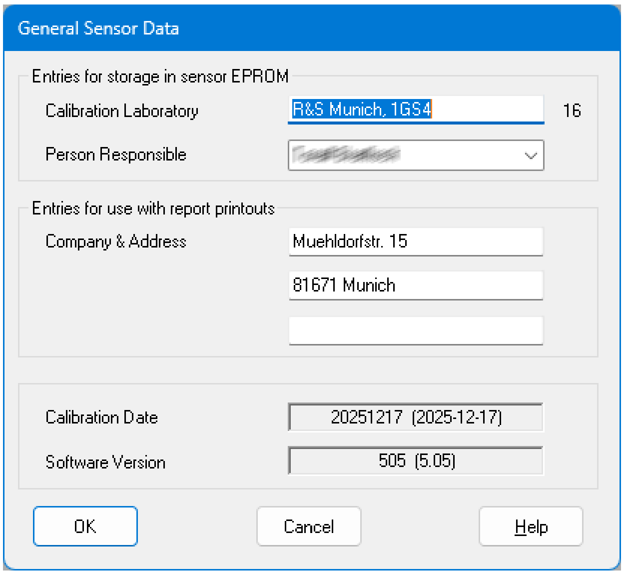


Figure 6-1: General Sensor Data dialog

Access: "Options" menu > "General Sensor Data"

To enter the data in the "General Sensor Data" dialog

1. "Calibration Laboratory": Name of the calibration laboratory, max. 20 characters.
2. "Person Responsible": Name of the person carrying out the calibration: Up to 5 persons, max. 20 characters per entry.
3. To add a new person:
   a) Mark the name currently displayed.
   b) Overwrite the name.
   c) Confirm with the [Enter] key.
4. To delete individual names:
   a) Mark the name currently displayed.
   b) Click "Delete".
5. "Company & Address": Name of the company to which the calibration laboratory belongs, max. 40 characters; company address, max. 40 characters.

   For subsequent modifications, under "Options", use the "General Sensor Data..." dialog.

6.1.3 Defining directories

After correct installation, the following subdirectories are created automatically.

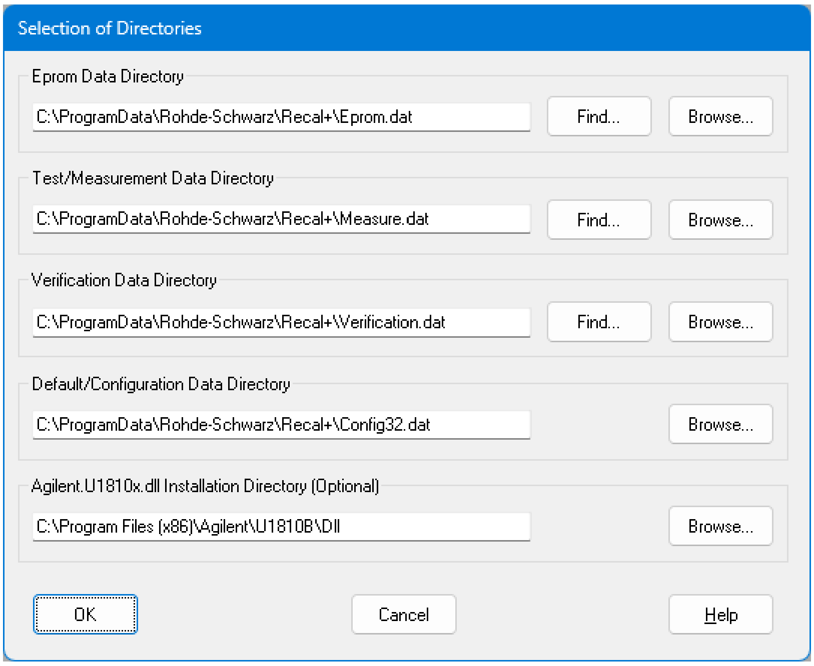


Figure 6-2: Selection of Directories dialog

Access: "Options" menu > "Directories"

1. If the directories are suitable for you, click "OK".
2. If you want to select another subdirectory, click "Browse".

6.1.4 Initializing the measuring equipment

Initialize all remote-controlled instruments before any measurements are made. These instruments are:

- R&S NRX
- Generator for calibration of absolute accuracy
- Generator for linearization
- Vector network analyzer

To prepare to initialize the measuring equipment

1. Connect the instruments to the controller using the IEC/IEEE bus.
2. Switch on the instruments.

6.1.4.1 Configuring power meters with the R&S NRPC calibration kit

Operating an R&S NRPC calibration kit requires at least one R&S NRX base unit to which the power standards and R&S power sensors can be connected. For calibrating sensors of the R&S NRV-Z and R&S URV5-Z families, an R&S NRVD base unit is also necessary. Overall, two base units can be controlled. Connect the DUT to channel A or channel B of the basic power meter. You can connect the power standards to any of the available channels. Table 6-1 shows the possible combinations:

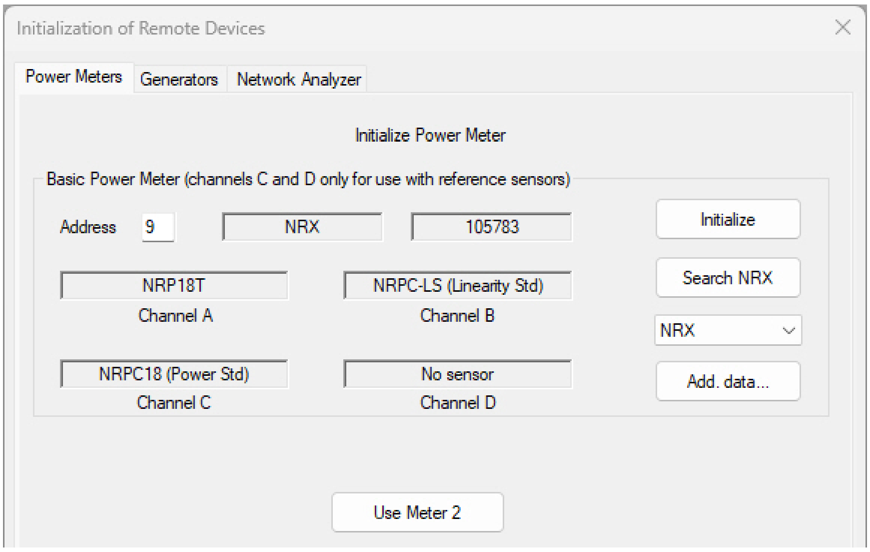
Table 6-1: Basic power meters configuration

Basic power meter			Meter 2 **
R&S NRX			R&S NRX
Channel A (B)	Channel B (A)	Channel C / D *	Channel A / B / C / D *
DUT (R&S power sensor)	R&S NRPC	R&S NRPC	R&S NRPC
* Availability depends on the R&S NRX configuration. ** Necessary if more power standards from the R&S NRPC calibration kits are to be connected.			

Regardless of the selected combination, the R&S NRPC reinitializes before calibrating a sensor. After clicking "Add data...", information is provided for each R&S NRPC that was used in the last calibration. After changing the power standard, this information is only updated after starting a new measurement ( ).

6.1.4.2 Initializing the R&S NRX

Access: "Options" menu > "Remote Devices" > "Initialization of Remote Devices" dialog



1. In the "Initialization of Remote Devices" dialog, select the "Meter" tab.
2. Under "Basic Power Meter", click "Search NRX".

The calibration software now searches for an R&S NRX from among the instruments that are connected to the IEC/IEEE bus. If the search is successful, the address of the device is displayed in the address field. Click "Search NRX" again if a second R&S NRX was found that you do not want to use as the basic power meter.

3. Click "Initialize".

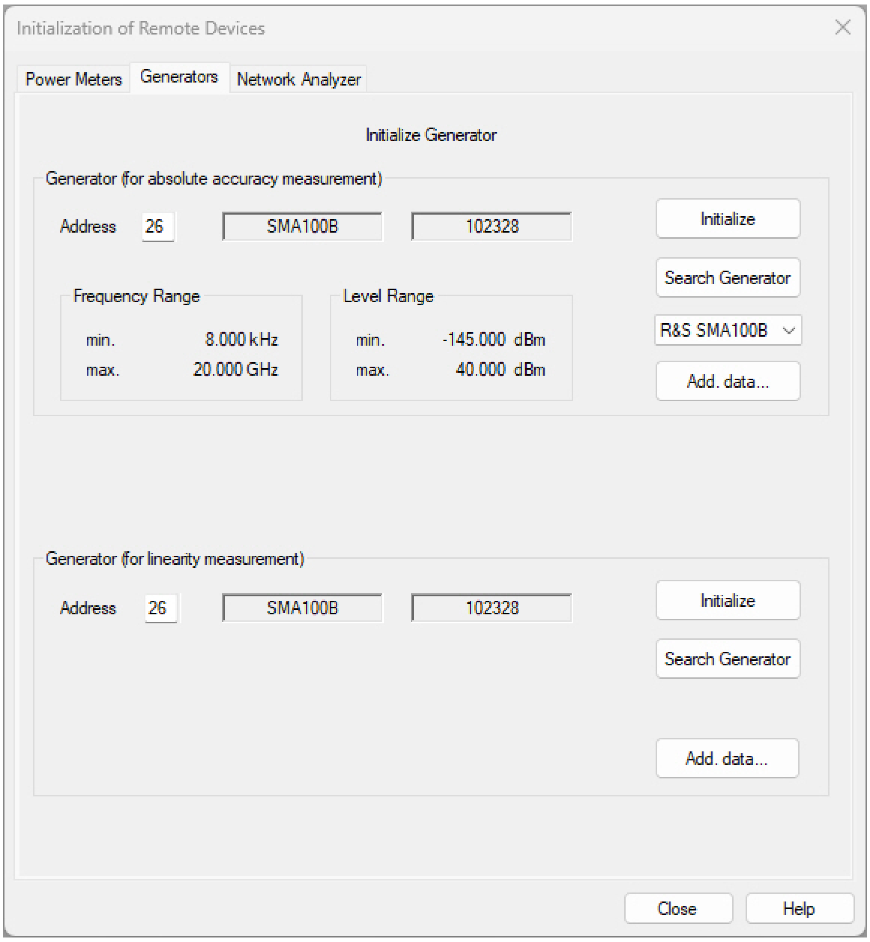
   The calibration software initializes the R&S NRX that was found at the specified address.

4. If a second R&S NRX is available, click "Use Meter 2".

5. Proceed as for the first power meter.

6.1.4.3 Initializing generators

Access: "Options" menu > "Remote Devices" > "Initialization of Remote Devices" dialog



1. In the "Initialization of Remote Devices" dialog, select the "Generator" tab.

2. Under "Generator (for absolute accuracy measurement)", initialize the generator for the absolute accuracy measurement:
   a) Click "Search Generator".
   b) Click "Initialize".
   c) Click "Add data..." to enter the calibration expiry date and the calibration certificate number.
      For some older generators, also enter the serial number.

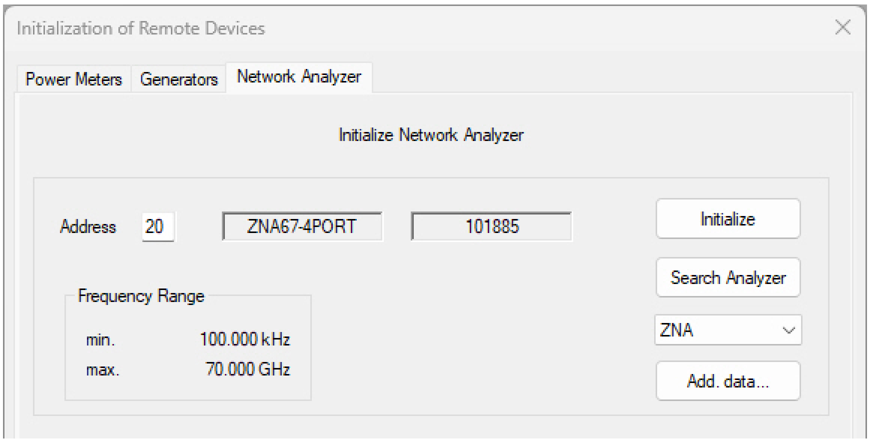
   Note: If multiple generators for calibrating absolute accuracy are connected at the same time, e.g. an R&S SMB100A-B106 and an R&S SMF100A-B144, only one of the instruments can be initialized. If the generator is replaced, reinitialization is necessary. The previously assigned IEC/IEEE bus address is automatically suggested.
3. Under "Generator (for linearity measurement)", initialize the generator for the linearity measurement:
   a) Click "Search Generator".
   b) Click "Initialize".
   c) Click "Add data..." to enter the calibration expiry date and the calibration certificate number.
4. Click "Close".

   All entries are saved in the `recal32.ini` file to be used by R&S Recal+ in the next session.

   Tip: For further modifications, use the "Remote Devices" dialog in the "Options" menu.

6.1.4.4 Initializing network analyzers

Access: "Options" menu > "Remote Devices" > "Initialization of Remote Devices" dialog



The "Network Analyzer" tab is only available if the R&S ZVX_RECAL program module is installed.

1. In the "Initialization of Remote Devices" dialog, select the "Network Analyzer" tab.
2. Select the type that you want to use.
3. Initialize the vector network analyzer:
   a) Click "Search Analyzer".
   b) Click "Initialize".
   c) Click "Add data..." to enter the calibration expiry date and the calibration certificate number.
4. Click "Close".

   All entries are saved in the `recal32.ini` file to be used by R&S Recal+ in the next session.

6.2 Performing the calibration

A power or voltage sensor is calibrated in several phases that are shown in Table 6-2 in the appropriate order. After the incoming inspection, calibration of the incoming condition is performed for the matching, absolute accuracy and linearity. The R&S Recal+ software checks the resulting data for compliance with the appropriate tolerance limits. For sensors whose correction factor set can be refreshed, this data forms the basis for a new correction factor set.

As the next step, generate an initial report with the "Calibration Report (Incoming)". As a rule, prepare this documentation for all sensors whose correction factor set (EPROM file) cannot be overwritten, e.g. for all R&S URV5-Z voltage sensors. For these sensors, the calibration process is also generally complete once the "Calibration Report (Incoming)" is generated. Send the DUTs that exceed the tolerance limits to the manufacturer for repair.

For most sensors, the correction factor set can be overwritten. Then reporting of the incoming condition is necessary only if the DUT exhibited non-compliance with the relevant specifications. If the measurement errors are so large that the device is clearly damaged or subject to unnatural premature aging, sent the DUT for repair. Otherwise, you can overwrite the correction factor set.

The new correction factor set is obtained from the measurement results gathered during the incoming test and the saved correction factors. Overwriting the data memory with this data ensures that the DUT uncertainty during subsequent usage is only slightly larger than the uncertainty of the calibration. To verify this fact, test the absolute accuracy once again after the data memory is refreshed. For some sensors, this check also includes a check of the linearity with the modified correction factors. The measurement results are documented with the "Calibration Report". Archiving of all relevant data marks the end of the calibration cycle.

The sequence of calibration steps suggested in Table 6-2 is not mandatory when using the R&S Recal+ calibration software that means you are free to create a calibration cycle that best meets your requirements. For example, you can choose to omit documentation, repeat measurements several times or omit individual calibration steps, e.g. linearization or matching. It is not possible to select meaningless combinations such as calculating a new EPROM file without measurement data. The following sections explain each of the calibration steps in detail.

Table 6-2: Overview of a complete calibration cycle

Phase		**Section**	**Comments**
I	Preparation	Section 6.2.1, "Initial checks", on page 46	
II	Calibration on delivery	Section 6.2.2, "Checking the matching", on page 47	
		Section 6.2.3, "Checking the linearity", on page 48 Section 6.2.4, "Checking the absolute accuracy", on page 50	
		Section 8.2, "S-parameter file for sensors with attenuators", on page 80	If relevant, measuring the attenuator on ext. meas. setup, only for the R&S NRP-Z22/23/24/92).
III	Documentation of calibration	Section 6.4, "Generating the calibration report", on page 55	Only sensors whose correction factor set can be overwritten.
IV	Refreshing the data memory	Section 6.4.2, "Calculating a new EPROM file", on page 57 Section 6.4.3, "Overwriting the data memory of a sensor with flash EPROM", on page 58	
V	Outgoing calibration	Section 6.2.4, "Checking the absolute accuracy", on page 50 Section 6.2.3, "Checking the linearity", on page 48	
VI	Documentation of calibration	Section 6.4, "Generating the calibration report", on page 55	
VII	Archiving	Section 6.5, "Archiving", on page 60	

- The recommended ambient temperature during calibration is 23 ºC. Deviations of ±3 ºC maximum are permissible, but avoid them, if possible. Larger temperature deviations can cause the measurement uncertainties specified for the R&S NRPC calibration kits to be exceeded.
- Allow the test setup to warm up for at least one hour before calibration.
- After the power standard and linearity standard are connected to the base unit, allow them to warm up for at least one hour.
- Allow the R&S URV5-Z and R&S NRV sensors a few minutes to obtain normal operating temperature after connecting to the R&S NRVD base unit. Due to their higher self-warming, the R&S power sensors require about 30 minutes to warm up on an R&S NRX base unit or computer.

6.2.1 Initial checks

To prevent measurement errors during calibration, inspect the DUT closely and perform a few simple tests. This approach also prevents any potential damage to the calibration kit.

To inspect the DUT

1. Inspect the sensor cable for external damage.
2. Verify that the cable is properly connected to the sensor and data memory.
3. Clean the RF connectors.
4. Check the position of the inner conductor to the reference plane of the RF connector.
5. Connect the DUT to a suitable base unit.
6. Connect the RF interface of the DUT to the test generator.
7. Make sure that there is a good connection between the connector and the sensor casing.
8. Power on the test generator. The power reading must be stable even if the sensor cable is moved or the sensor casing is bent or twisted slightly.

To perform a self-test

Applies only for the R&S power sensors.

1. Start the R&S Recal+ software.
2. Initialize the base unit as a "basic power meter".
3. In the toolbar, click  to open the "Measurement with Recal+" dialog.
4. Select the "NRP Sensor Test" tab.
5. Click "Execute Test" to perform the built-in self-test for the selected DUT.

   The test results consist of a global "SUCCESSFUL" or "FAILED" assessment along with individual test results.

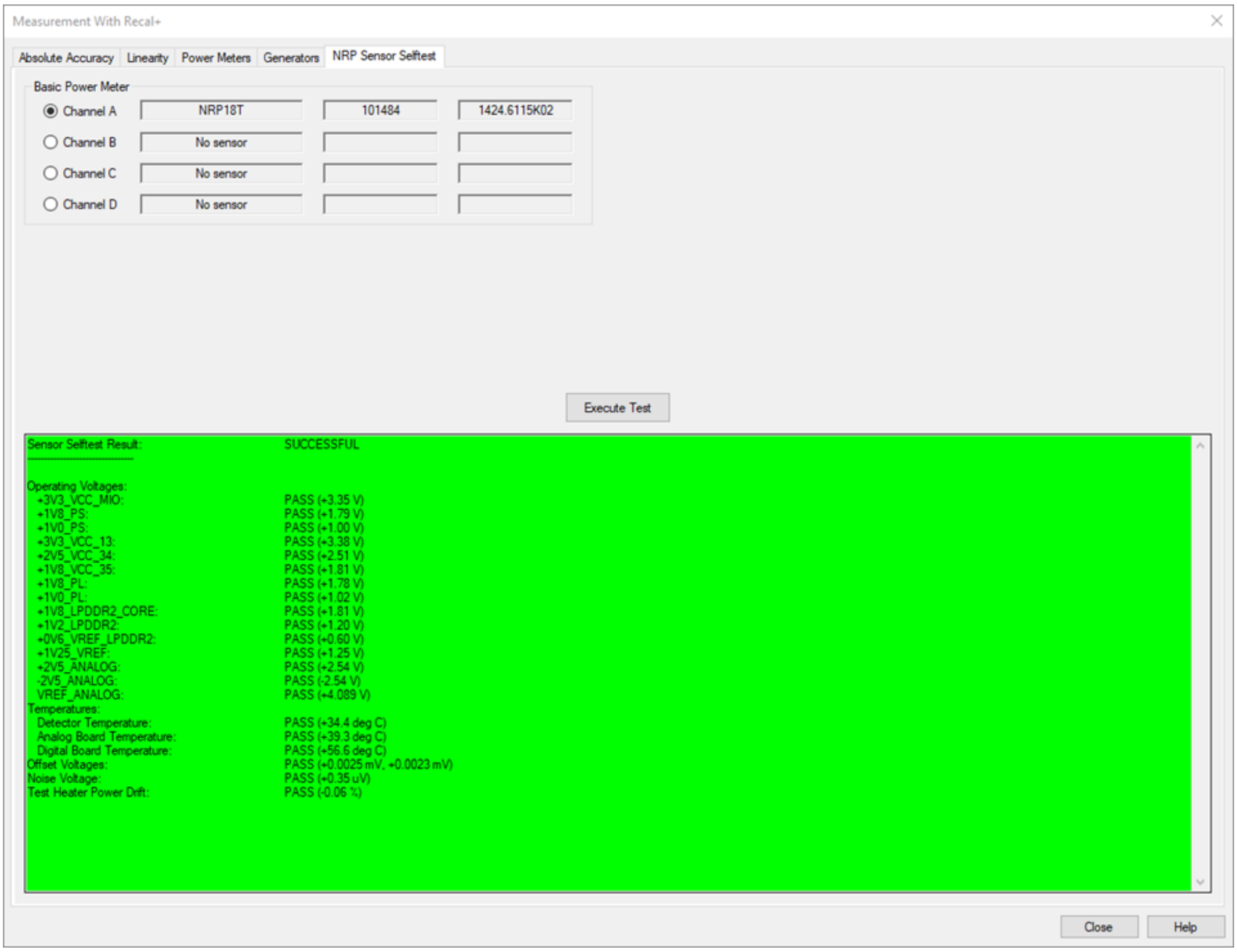


Figure 6-3: NRP Sensor Test tab with measurement results

6.2.2 Checking the matching

The matching of the DUT is measured with the aid of a vector network analyzer. The required steps are described in Section 8.1.4, "Configuring the network analyzer", on page 73.

If it is necessary to measure the absolute accuracy with gamma correction, the reflection data of the DUT must be determined beforehand and saved in the `...\recal\measure.dat` file. Otherwise, you cannot enable the gamma correction function.

6.2.3 Checking the linearity

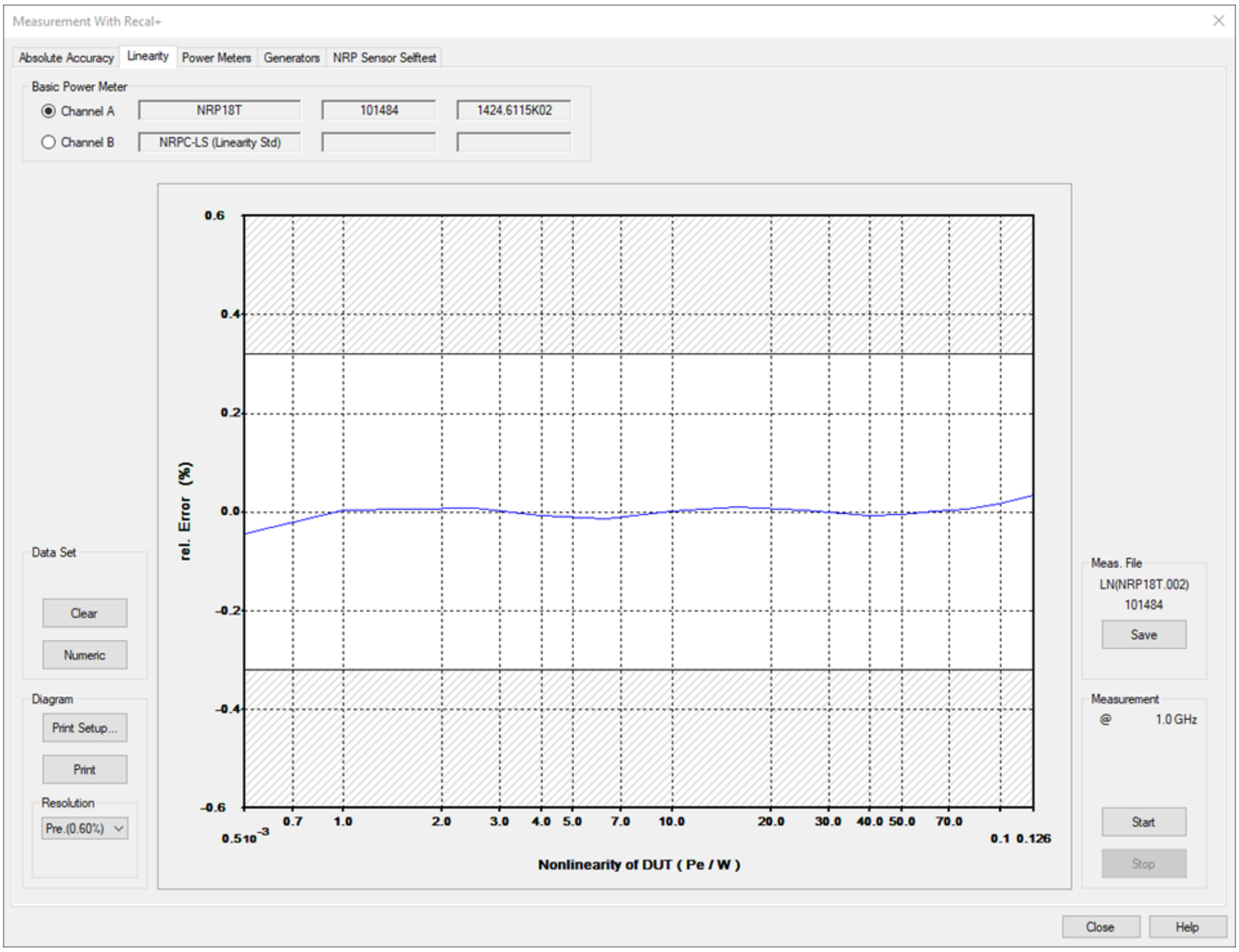


Figure 6-4: Linearity tab at the end of a measurement procedure

Access: in the toolbar > "Measurement with Recal+" dialog

To check the linearity

1. Prepare the appropriate test setup for the sensor as described in Section 5.5, "Linearity calibration setup for R&S power sensors", on page 36.
2. Initialize any instruments that have not yet been initialized ("Meter" or "Generator" tab).
3. In the toolbar, click .
4. Select the "Linearity" tab.
5. Select the graphics or numerical display mode for measured values. See also "Displaying the measurement results on screen" on page 52.
6. Click "Start".

The linearity measurement starts. Starting from the specific reference power of the sensor, the power applied to the DUT is increased until the nominal power is reached. The relative changes in power measured by the DUT (voltage changes for the R&S URV5-Z sensors) are compared to the changes measured by the linearity standard. They are output as linearity errors in %.

Note: During the linearity measurement on R&S power sensors, the R&S NRX base unit can generate an overload message at the last level step. It is safe to ignore this message.

7. Check whether the measured errors are within the tolerance band in the graphical display.
8. Click "Save" to save the measurement results in a file with the specified filename.

   Note: Only saved measurement results can be output in the calibration report and used when the data memory contents are recalculated.

Repeating incorrect measurements

Occasionally, you have to repeat a measurement because, for example, the RF connector of the sensor is loose.

► Click "Start" to restart the measurement.

Displaying the measurement results on screen

The linearity errors of the DUT can be displayed in graphical or list format.

► Click "Numeric (Diagram)" to toggle between the two modes.

► Click "Print" to print the graphical displays.

Graphical display (nonlinearity of DUT)

The linearity errors of the DUT are plotted as the "Rel. error (%)" together with the tolerance band versus the input power "P_{in}" or the input voltage "V_{in}". Generally, it is safe to assume that a sensor that exceeds the tolerance limits is defective and must be sent back to Rohde & Schwarz central service for repair. Send all sensors for repair for which a correction of the linearity is not possible, see Table 5-1 to Table 5-6. The measurement points at which the tolerance limits are exceeded are indicated by an asterisk (*) in the calibration report.

You can set the vertical resolution of the diagram to a customized scaling, see "To customize the scaling" on page 49, or select one of the following four settings in the "Resolution" list: "Pre. (x %)", "Fine (1 %)", "Coarse (50 %)", "y %". "Pre (x %)"yields the optimum resolution for the sensor (Preset). "y %" is the customized scaling last selected.

To customize the scaling

1. Place the mouse cursor on the label for the highest value on the scale.

   The symbol appears.

2. Double-click and enter the number needed for this maximum value.
3. To enlarge the graphical display:
   a) Place the mouse cursor over the diagram. The ZOOM symbol appears.
   b) Double-click.

   Tip: When in zoom mode, you can display the context menu without having to return to the normal display ([Esc] key).

Outputting numeric measured values

The list has four columns, namely the index number of the level step ("Index"), the nominal level step ("Nom. Level" in "W" or "V"), the value measured for the DUT ("Meas. Level" in "W" or "V") and the linearity error of the DUT ("Error" in "%").

6.2.4 Checking the absolute accuracy

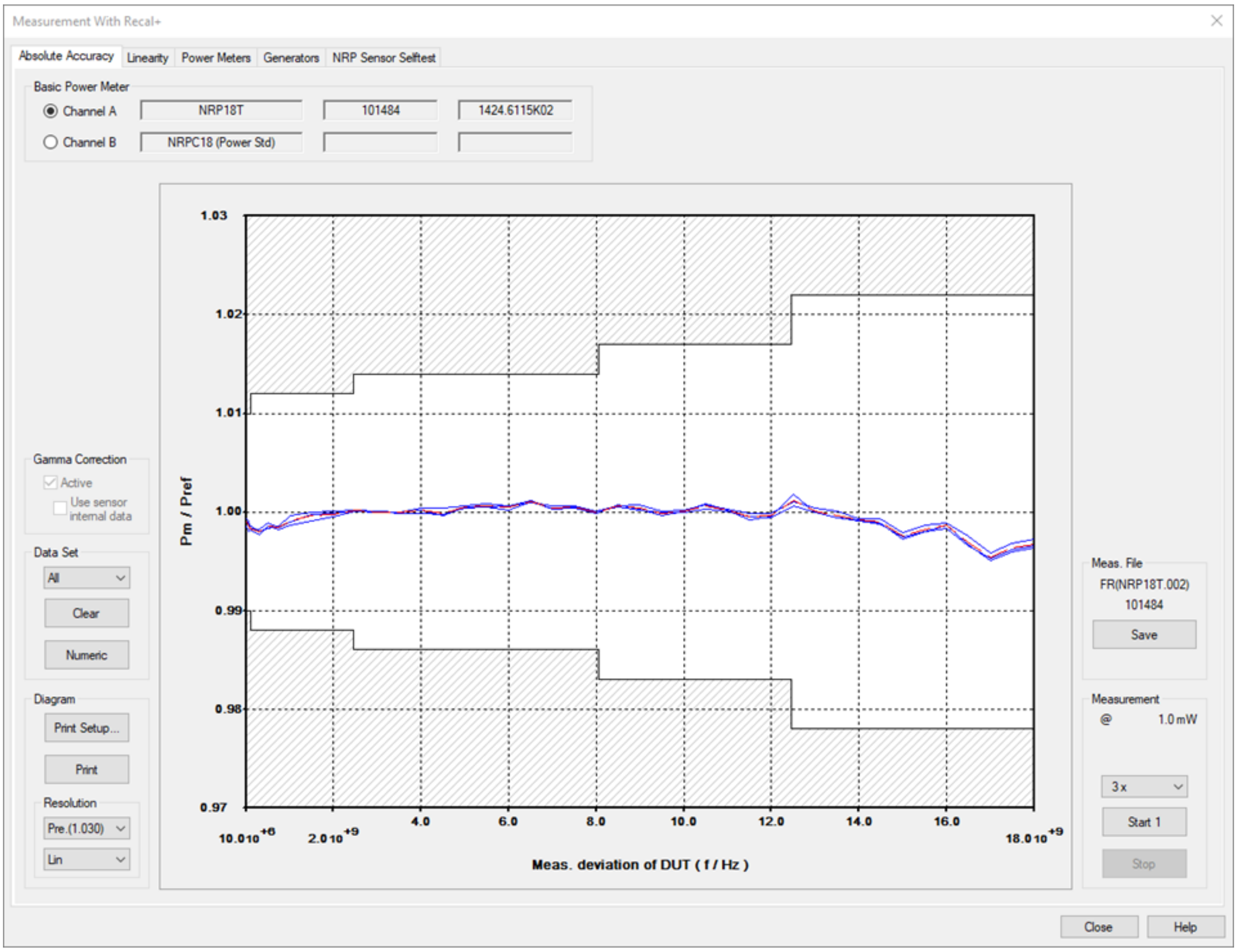


Figure 6-5: Absolute Accuracy tab at the end of a measurement sequence

Access: in the toolbar > "Measurement with Recal+" dialog

To check the absolute accuracy

For all thermal R&S power sensors and all sensors with a frequency range of more than 18 GHz, measure with gamma correction. If you measure without gamma correction, the R&S Recal+ software outputs a warning after you start the measurement. You cannot use the measurement data generated in this manner to create a correction factor set.

For the R&S URV5-Z sensors, gamma correction is not possible.

1. If you measure without gamma correction:
   a) Determine the reflection data of the DUT beforehand.
   b) Save the reflection data in the `...\recal\measure.dat` file.
   c) Enable the option for gamma correction.

   Note: You can start the measurement only if reflection data is available for the DUT in complex notation. Otherwise, an error message is displayed.
2. If you do not need gamma correction for the DUT, disable the option.
3. Prepare the test setup as shown in Section 5.4, "Power calibration setup for R&S power sensors", on page 35.
4. Initialize the instruments that have not already been initialized ("Meter" and "Generator" tabs).
5. In the toolbar, click .
6. Select the "Absolute Accuracy" tab.
7. Select the measurement channel to which the DUT is connected.
8. If you need to measure with gamma correction for the sake of accuracy, enable the corresponding option.
9. Under "Measurement", specify the number of measurement cycles ("1x", "2x", "3x", "4x"). For the initial calibration, perform at least three cycles as a basis for recalculating the correction factors. For the second calibration after the data memory has been overwritten, one measurement is usually sufficient because the measurement errors are very small.
10. Select a graphical or numeric result display. See "Displaying the measurement results on screen" on page 52.
11. Click "Start 1".

    The first cycle is started. When measurements are performed with the reference attenuator, the "Attenuator" dialog appears shortly after the start. Click "OK" only if you are sure that the displayed file is the correct one for the attenuator in the measurement setup. The filename to the right of the "at" header has to be identical to the serial number of the attenuator.
    Otherwise, select the appropriate file from the "file selection" list.
    You can suppress the routine display of the "Attenuator" dialog by disabling "Confirm before each measurement".

If several measurement cycles are carried out, after each cycle, the R&S Recal+ software prompts you to reconnect the sensor in a modified position and continue the measurement.

12. Disconnect the RF connector.
13. Turn the sensor or attenuator by 90°, 120° or 180° depending on the number of cycles.
14. Treat the power attenuator of the R&S NRV-Z32/33/53/54 sensors as the reference attenuator.
15. Click "Ja" ("Yes").

    Once the measurement sequence is completed, the averaged power or voltage ratio is displayed as a red line in the diagram.
16. Click "Save" to save the measurement results in a file with the specified filename.

    Note: Only saved measurement results can be output in the calibration report and used when the data memory contents are recalculated.

Repeating faulty measurements

Occasionally, you have to repeat a measurement because, for example, the RF connector of the sensor is loose.

1. Under "Data set", select the faulty cycle.
2. Click "Clear".

   The associated measurement result display is removed from the diagram.
3. Click "Start" to repeat the measurement.

Displaying the measurement results on screen

The measurement errors of the DUT can be displayed in graphical or list format.

► Select the data that you want to display:
- Under "Data Set/Path", for R&S power sensors
- Under "Data Set" in all other cases

► Click "Numeric (Diagram)" to toggle between the two modes.

► Click "Print" to print the graphical displays.

Graphical display (measured deviation of DUT)

The measurement errors of the DUT are displayed together with the tolerance band as a power ratio "P_m/P_{ref}" or a voltage ratio "V_m/V_{ref}" (index m: DUT) versus frequency. Consider the R&S URV5-Z2/4/7 and R&S NRV-Z31/32/33 defective if the tolerance limits are exceeded, in which case you have to send them back to Rohde & Schwarz central service for repair. Otherwise, you have to decide on a case-by-case basis. Out of tolerance conditions below 1 GHz often indicate that the sensor is defective. The measurement points at which the tolerance limits are exceeded are indicated by an asterisk (*) in the calibration report.

You can set the graphical scale using "Lin/Log" (scale for frequency axis) and "Resolution" (vertical resolution). You can set the vertical resolution of the diagram to a customized scaling, see "To customize the scaling" on page 53, or select one of the following four settings in the "Resolution" list: "Pre. (x)", "Fine (1.05)", "Coarse (1.5)", "y". "Pre. (x)" yields the optimum resolution (Preset) for the sensor. "y" is the customized scaling last selected.

To customize the scaling

1. Place the mouse cursor on the label for the highest value on the scale.

   The symbol appears.
2. Double-click and enter the number needed for this maximum value.
3. To enlarge the graphical display:
   a) Place the mouse cursor over the diagram. The symbol appears.
   b) Double-click.

   Tip: When in zoom mode, you can display the context menu without having to return to the normal display ([Esc] key).

Outputting numeric measured values

The list has four columns, namely the index number ("Index") of the frequency point, the frequency ("Frequency"), the power ratio "P_m/P_{ref}" or the voltage ratio "V_m/V_{ref}" ("Factor") and the measured value for the power standard ("Level"). The values that are output are for the current measurement.

Usage of torque wrenches

All R&S NRPC calibration kits include an appropriate torque wrench for the given connector type. The torque is set to ensure a dependable connection and also to prevent wear and tear.

6.3 Troubleshooting measurement problems

Start... is disabled

Possible cause: The power standard and/or the DUT are not connected to the R&S NRX or R&S NRVD.

► Check the test setup as shown in Section 5.4, "Power calibration setup for R&S power sensors", on page 35.

Possible cause: The R&S NRX, R&S NRVD, and/or generator have not been initialized.

1. Select the "Power Meters" and/or "Generators" tab.
2. Repeat the initialization. See Section 6.1.4, "Initializing the measuring equipment", on page 40.

Error message at the start of or during the measurements

"Error detected: Measurement out of tolerance (± 50%). Please check your test equipment."

Possible cause: The level on the power standard or linearity standard and/or DUT is too high or too low. You forgot to insert or remove the reference attenuator, or the power standard is not connected to the generator.

1. Check the test setup as shown in Section 5.4, "Power calibration setup for R&S power sensors", on page 35.
2. Verify the calibration kit.

The measurement result spread for the cycles is too large

Only occurs in absolute accuracy measurements.

Possible cause: The DUT, power standard or attenuator is defective.

► Verify the calibration kit.

6.4 Generating the calibration report

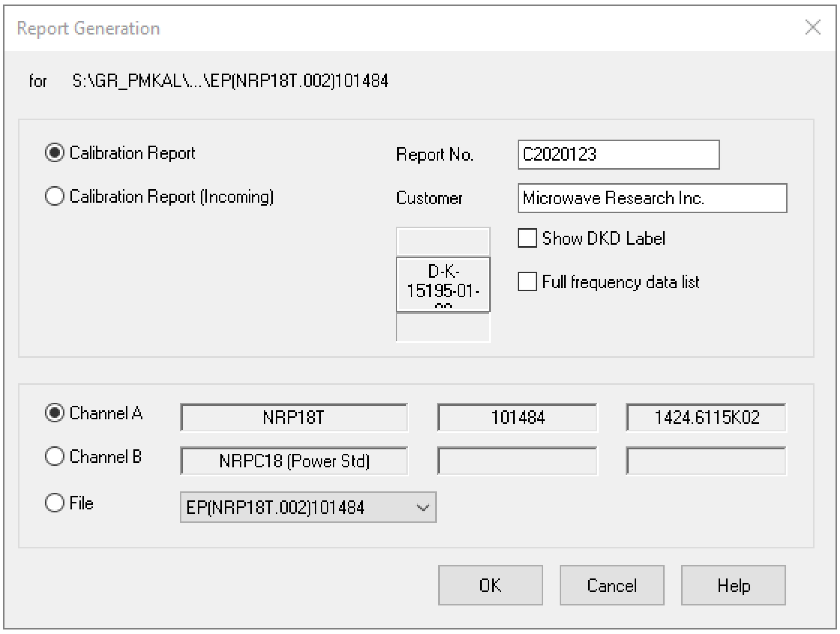


Figure 6-6: Report Generation dialog

Access: "Calibration" / "File" menu > "Calibration reports"

A calibration report documenting the calibration procedure can be generated at any time. It contains a cover sheet with general information, a list of the measuring equipment used, and a list of the measurement results. There are two versions of the calibration report.

The "Calibration Report (Incoming)" documents the incoming condition, and the "Calibration Report" describes the status after the data memory has been overwritten and the final control measurements have been performed. While the "Calibration Report (Incoming)" is merely a straightforward measurement report listing all measurement points, the "Calibration Report" also contains information about the saved calibration factors. We recommended generating the "Calibration Report" only if the sensor data set has been adjusted and the data memory of the sensor has been overwritten. If an adjustment is possible depends on the sensor type, see Table 5-1 to Table 5-6.

To generate the calibration reports

1. In the "Report Generation" dialog, mark the measurement channel to which the calibrated sensor is connected or select the EPROM file for the sensor from the file list that is displayed, filename: `ep(<sensor>)<serial no.>`.
2. Select "Calibration Report (Incoming)" or "Calibration Report".
3. For complete documentation, fill out the "Report No." and "Customer" fields.
4. Click "OK".

The calibration report, excluding the cover sheet and the list of measuring equipment, is displayed on screen.

5. To view the complete calibration report on the screen, select the "Print Preview" dialog in the "File" menu.
6. Print the calibration report or save the calibration report in a PDF file, using a printer driver for creating PDF files.

Note regarding the calibration report (incoming) for R&S power sensors and R&S NRV-Z sensors

When the new EPROM file for the sensor has been calculated, the R&S Recal+ software saves a backup copy of the incoming calibration and the data memory contents in the `...\recal\measure.dat\income` and `...\recal\eprom.dat\income` directories. Using this data, you can output the "Calibration Report (Incoming)" at the very end of calibration. R&S Recal+ accesses the saved files and uses the data from the `...\recal\measure.dat` or `...\recal\eprom.dat` directory for the "Calibration Report (Incoming)" only if it does not find data for the sensor in the "income" subdirectories.

To avoid incorrect calibration reports when the entire procedure is repeated, delete all files with the serial number of the sensor from the "income" subdirectories before the first measurement. See also Section 6.5, "Archiving", on page 60.

6.4.1 Suppressing the Rohde & Schwarz logo

By default, the logo of Rohde & Schwarz is placed in the upper right-hand corner of the calibration report.

To suppress the Rohde & Schwarz logo

1. Using a text editor, in the Windows directory, open the `recal.ini` file.
2. Go to the `[LAB ID]` section.
3. Make the following entry: `NoLogo = TRUE`.

6.4.2 Calculating a new EPROM file

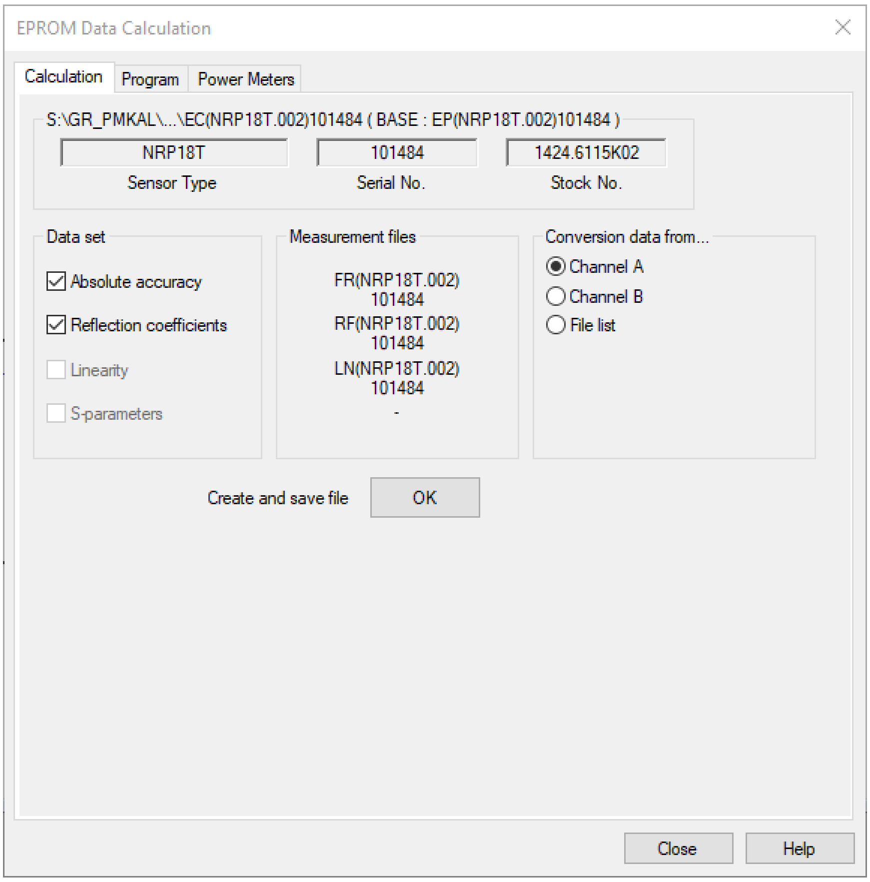


Figure 6-7: Calculation tab with measurement files

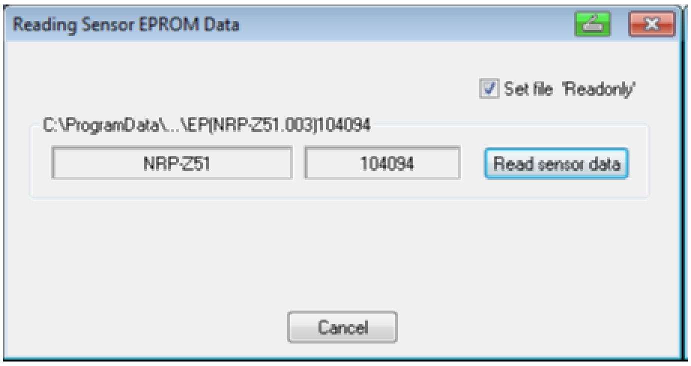
Access: in the toolbar > "EPROM Data Calculation" dialog

The following section only applies to sensors whose data memories are to be overwritten. This process involves generating a new EPROM file from the measurement results and the (old) EPROM data of the sensor. You can load these EPROM data into the sensor via the R&S NRX or R&S NRVD or, for sensors with UV-erasable EPROM, with a suitable programming device.

To configure the calculation

1. In the "EPROM Data Calculation" dialog, select the "Calculation" tab.
2. Under "Conversion data from", specify the source of the (old) EPROM file in one of the following ways:
   - Select the measurement channel to which the sensor in question is connected.
   - Select "File List" and select the appropriate EPROM file `ep(<sensor>)<serial no.>` from the list.

   If the EPROM file is selected via the measurement channel, a prompt to read in sensor data is displayed.



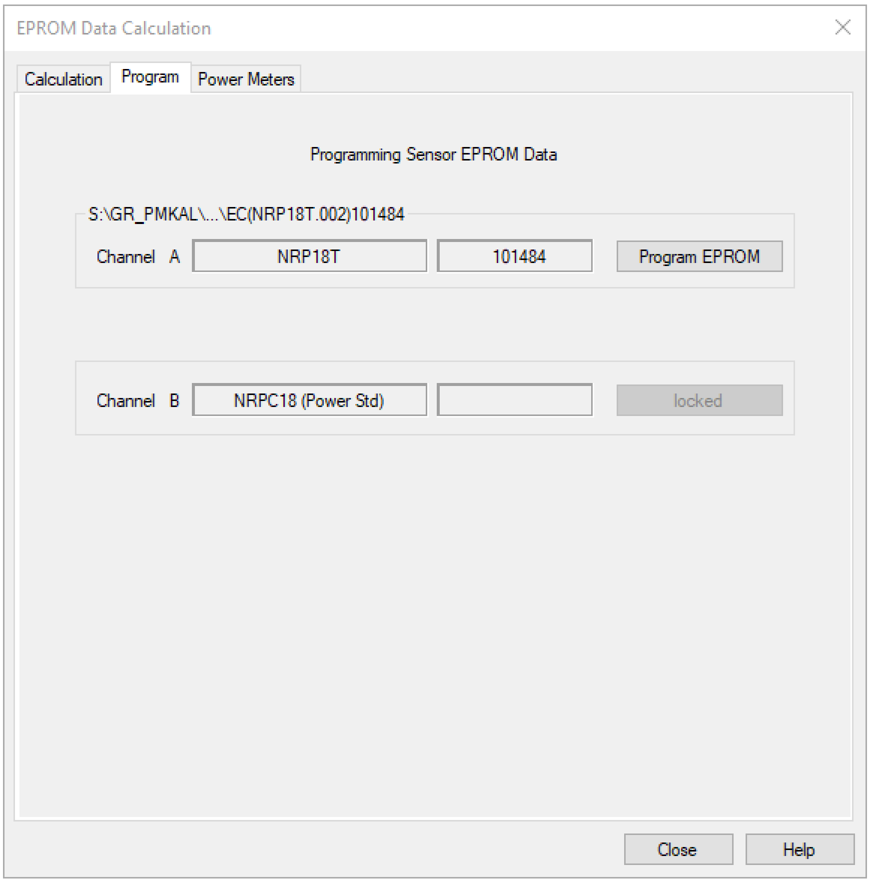
3. Click "Read sensor data".
4. Wait for the end of the reading operation.
5. Close the dialog.

   If measurement data is available for the selected EPROM file, this fact is indicated on the "EPROM Data Calculation" tab in the "Data set" field. The filenames are listed in the "Measurement files" field.
6. Click "Create and save file".

   The R&S Recal+ software calculates a new EPROM file and saves it under the name `ec(<sensor>)<serial no.>`. When finished, an according message is displayed.

6.4.3 Overwriting the data memory of a sensor with flash EPROM

Any compatible file can be written to a sensor data memory. This file is a new file named `ec(<sensor>)<serial no.>` that is generated from measurement data. However, after the data memory has been overwritten, it is also possible to restore the original contents from the `eo(<sensor>)<serial no.>` file.



1. In the "EPROM Data Calculation" dialog, select the "Program" tab.
2. Connect the sensor to channel A or channel B on the R&S NRX or R&S NRVD, if not already done.
3. Click , if not already done.
4. Select the "Program" tab.

   Depending on the button label, various options are available for the measurement channel in question.
5. If the button label is "Program EPROM", a recalculated `EPROM file ec...` whose name contains the serial number of the sensor is available. To overwrite the data memory with this file:
   a) Click "Program EPROM".
   b) Confirm the operation again.
   c) If you want to use a different file to overwrite the data memory, in the file manager or Explorer, delete the `ec...` file whose name contains the serial number of the sensor from the `...\recal\eprom.dat` directory.
   d) Continue with step 7.

6. If the button label is "Browse", no `EPROM ec...` file whose name contains the serial number of the sensor is available. Select any file from the `...\recal\eprom.dat` directory:
   a) Select the file.
   b) Click "Program EPROM".
      Confirm the operation.
      The flash EPROM is deleted and overwritten. Depending on the amount of correction data, this process can take a few minutes.
7. Click "Close".

   Note: If the button label is "Read only", it is not possible to write data to the data memory via the R&S NRVD (UV-EPROM).

6.5 Archiving

To prevent conflicts between old and new data, delete the files generated during calibration from the `...\recal\eprom.dat` and `...\recal\measure.dat` working directories and the `...\income` subdirectories before the individual sensor is calibrated again.

R&S Recal+ provides an archiving function allowing files to be copied to a new directory, deleted from the working directories and dearchived.

6.5.1 Copying files to archive

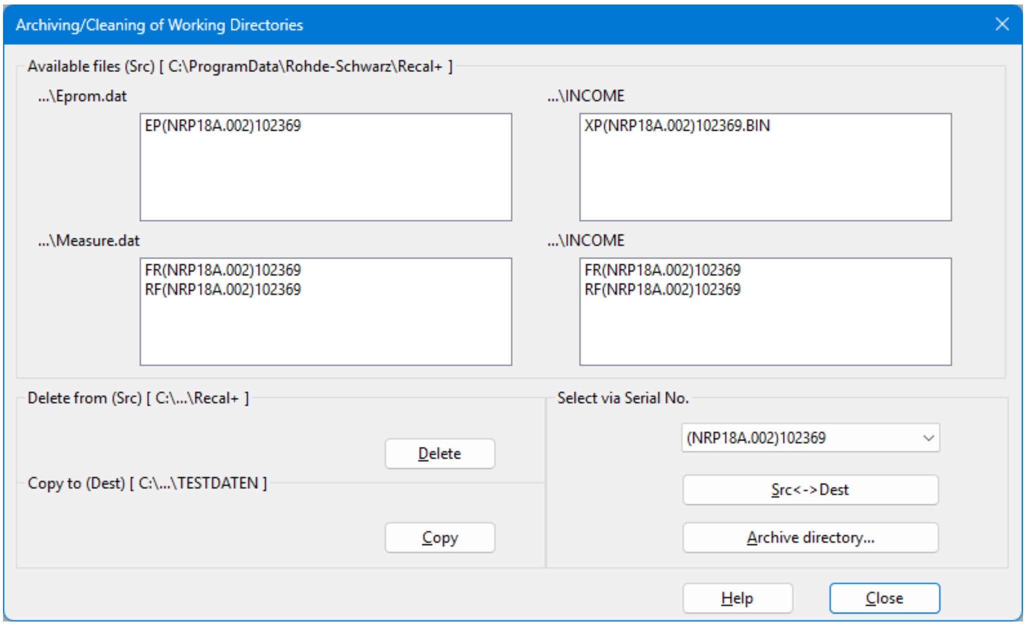


Figure 6-8: Archiving/Cleaning of NRPC Working Directories dialog

Access: "File" menu > "Archive"

1. Using Windows Explorer or the file manager, create an archive directory, e.g. `...\recal\archive`.
2. In the "Archiving/Cleaning of NRPC Working Directories" dialog under "Select via Serial No.", select the sensor that you want to archive.

   All files available in the working directories are displayed.
3. Click "Archive directory" to select the archive directory.
4. Click "Copy".

   R&S Recal+ copies all files to the archive directory.
   The `...\eprom.dat`, `...\measure.dat` and `...\income` subdirectories are created automatically.
5. Click "Delete" to delete all files from the working directories.

   Note: If you want to delete only some of the files, select these files first.

6.5.2 Fetching files from archive

This procedure is identical to the procedure for archiving except that you have to interchange the source and target by clicking "Src ↔ Dest". The archive directory is displayed under "Delete from (Src) [...]" and the working directory under "Copy to (Dest) [...]". You can switch back to archiving by clicking "Src ↔ Dest" again.

7 Verification

To prevent faulty calibration of sensors, it is necessary to check the measurement accuracy of the power standards using the verification set, R&S NRPC-B1 option. Like a normal calibration of absolute accuracy, verification with the verification set is a quick and easy process that we recommend performing regularly (before usage or daily).

7.1 Built-in self-test

The R&S NRPC power standards are equipped with an internal reference circuit for checking the long-term stability of the integrated power sensor. The reference circuit includes a highly stable DC voltage source that can be used to supply a second heater on the transducer. The reference circuit is enabled whenever a built-in self-test is performed and an in-circuit test is executed.

To perform the self-test

1. In the toolbar, click .
2. In the "Measurement with Recal+" dialog, select the "NRP Sensor Test" tab.
3. Select the power standard.
4. Click the "Execute Test" button to perform the built-in self-test.

   The test results consist of a global "SUCCESSFUL" or "FAILED" assessment along with individual test results. The result of the in-circuit test is displayed under "Test Heater Power Drift". Along with a "SUCCESSFUL" or "FAILED" assessment, the percent is indicated by which the sensitivity of the test cell has changed compared to the last calibration by German Accreditation Body (DKD) laboratory D-K-15195-01-01.

Perform a self-test of the R&S NRPC-B1 verification sensor in the same manner. Here too, the change in the measured sensitivity compared to the last calibration by the German Accreditation Body laboratory mentioned above is displayed under "Test Heater Power Drift".

You can trigger in-circuit testing of the power standard as part of the self-test. The in-circuit testing is also executed automatically by the R&S Recal+ software before each calibration of absolute accuracy.

7.2 Comparison measurements with the R&S NRPC-B1 verification sensor

For each R&S NRPC calibration kit, you can order an R&S NRPC-B1 verification sensor as an option. It consists of a thermal sensor with an input impedance of 100 Ω. These thermal sensors have been adjusted on the associated power standard and exhibit only very minor errors compared to it. Therefore, large errors indicate that there has probably been some change in the components involved. Due to the strong mismatch of the verification sensor, it is possible to detect aging or wear and tear at an early stage. They are reflected in the power measurement accuracy and the matching.

To use the R&S NRPC-B1 verification sensor

1. Verify that the calibration kit matches the verification sensor by comparing the serial numbers of the power standard with the data on the bottom of the verification sensor.
2. Prepare the measurement setup for checking the absolute accuracy as shown in Section 5.4, "Power calibration setup for R&S power sensors", on page 35.
3. Check the absolute accuracy with the associated verification sensor.
4. Perform one or more measurement cycles, depending on the requirement. Otherwise proceed as described in Section 6.2.4, "Checking the absolute accuracy", on page 50.

The averaged trace must lie within the tolerance band shown in the graphical display. The tolerance limits are significantly tighter compared to a normal thermal sensor. If the trace rises or falls uniformly over all the frequency range, this behavior indicates a change in the sensitivity of the power standard or the verification sensor. An oscillating frequency response as seen in Figure 7-1 indicates that the matching conditions on the RF connection have changed. In this case, inspect the sensor visually and clean the connectors. If the ripple does not disappear despite cleaning the connectors of the verification sensor and the power standard, exchange the RF connector with the supplied replacement adapter. See Section 17.2, "Exchanging the test port RF connector", on page 190.

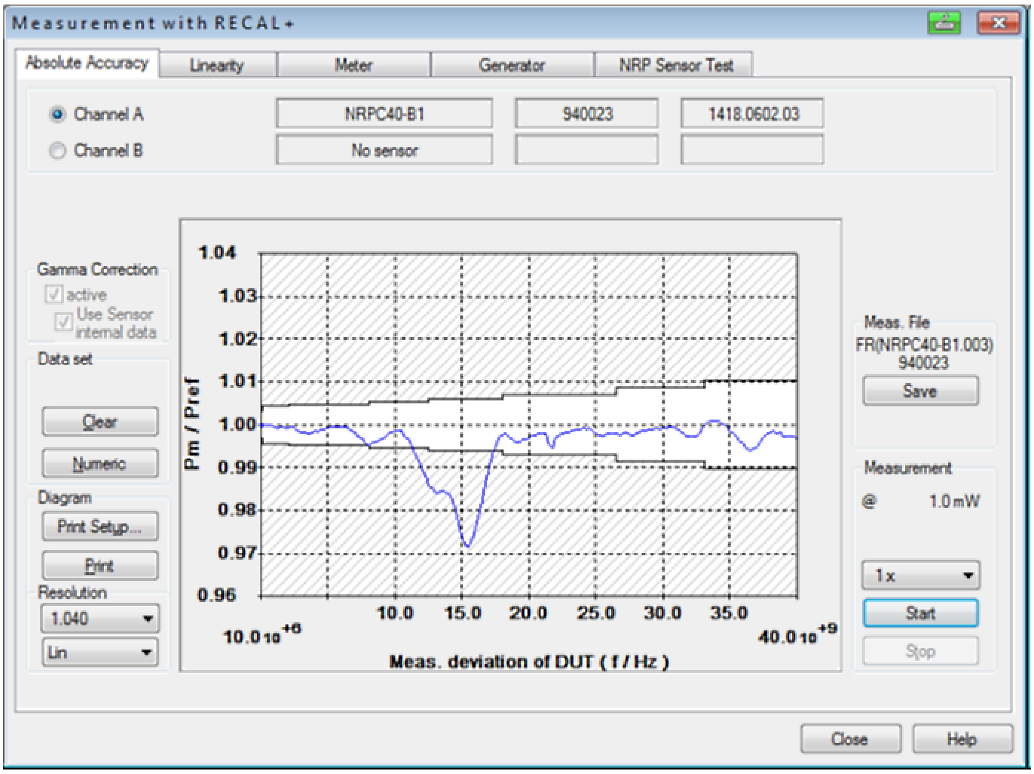


Figure 7-1: Verification result for an R&S NRPC40 power standard following damage to the RF connectors

The reference attenuators in the R&S NRPC18, R&S NRPC33 and R&S NRPC40 are not checked.

The verification measurement with the R&S NRPC-B1 is saved as an FR file with a time stamp in the `Verification.dat` folder.

8 Measurements on a separate measurement setup

You can measure reflection, absolute accuracy and linearity also on separate measurement setups. After the measurement, transfer the measurement results in the form of standard ASCII files to R&S Recal+ for further processing. The required measurement frequencies and levels for each type of sensor are stored in a configuration file.

The configuration files are stored in the `...recal\config.dat` directory. You can read them with any standard text editor. The filename consists of the type designation of the sensor and the three-digit model code (padded on left with zeros). For example, for an R&S NRV-Z1 sensor with material number 0828.3018.03, the filename is `nrv-z1.003`.

Save the measurement results in the `...recal\measure.dat` directory in an ASCII file whose name consists of a header (`rf`: reflection; `ln`: linearity; `fr`: absolute accuracy; `sp`: S-parameter for attenuators) and the serial number of the sensor. The structure of these files is shown in Table 8-2 to Table 8-8.

8.1 Reflection

There are the following possibilities for the reflection measurement:

- Program-controlled measurement and transfer of the measurement data using the R&S ZVX_RECAL program module in conjunction with selected network analyzers from Rohde & Schwarz. See also Section 5.2.2, "Optional software", on page 30.
- Manual or program-controlled measurement with any other suitable network analyzer and further processing of the measurement data:
  - Creating one file each with the reflection and measurement uncertainty data in Touchstone format and importing these files using R&S Recal+.
  - Manually creating a single file with reflection and measurement uncertainty data in a format compatible with R&S Recal+ and saving this file in the …`\Recal+\measure.dat` directory.

8.1.1 Program-controlled reflection measurement with R&S ZVX_RECAL

After the program is successfully installed, the "Measurement with Recal+" dialog ( ) contains the "Reflection/S-Parameter" tab.

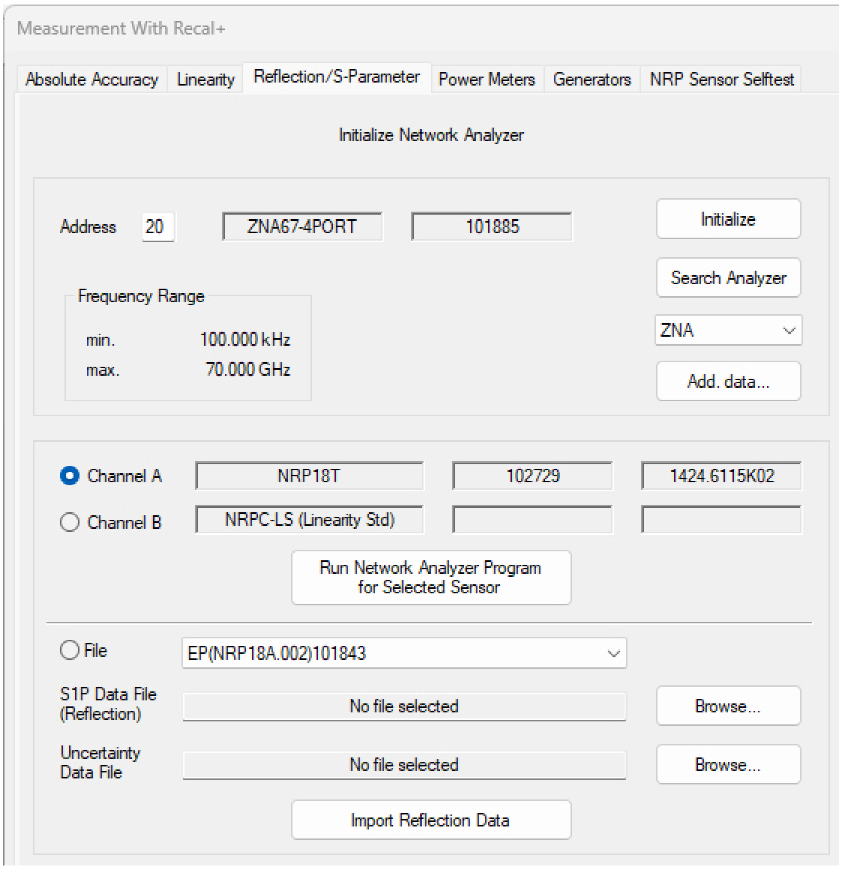


Figure 8-1: Reflection/S-Parameter tab

On this tab, you select the network analyzer and DUT and start the test program.

To prepare for the measurement

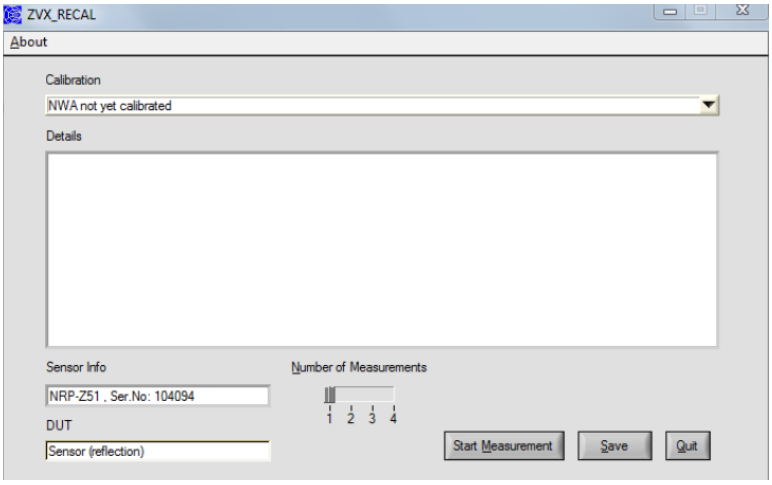
► At the network analyzer, save the data for the calibration kits you want to measure with.

To perform a reflection measurement

1. At the network analyzer, read in the calibration kit.
2. Connect the network analyzer to the test system via IEC/IEEE bus.
3. At the test system, start the R&S Recal+ software.
4. On the "Reflection/S-Parameter" tab, initialize vector network analyzer:
   a) Select the type of network analyzer that is connected.
   b) Use the "Search Analyzer" dialog to search for the GPIB address of the connected instrument. If you know the GPIB address, you can enter it into the "Address" field and skip the search.
   c) Initialize the network analyzer.

5. On the "Reflection/S-Parameter" tab, select the sensor as "Channel A" or "channel B" of the basic power meter.
6. On the "Reflection/S-Parameter" tab, click "Run Network Analyzer Program for selected sensor".

   The R&S ZVX_RECAL program module starts in a separate dialog.

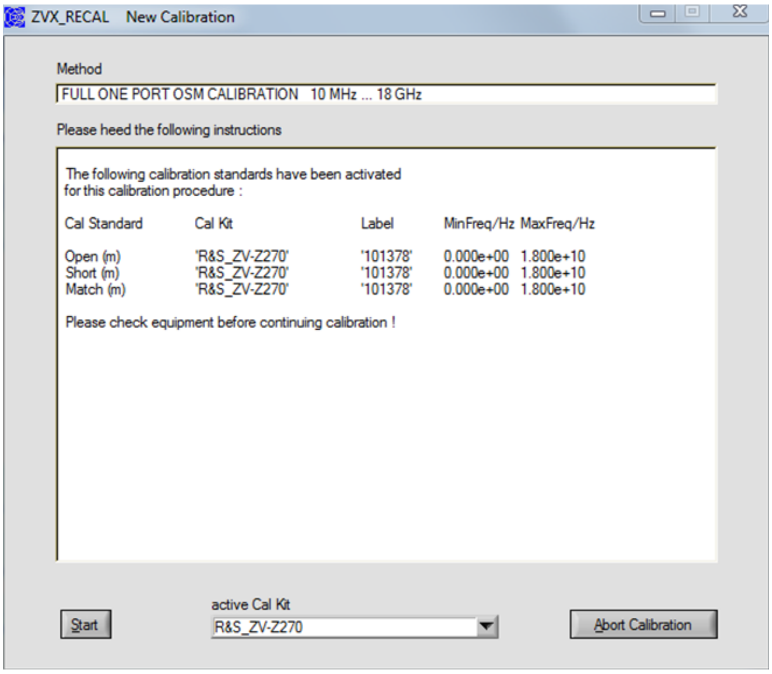


7. Calibrate the vector network analyzer. See "To calibrate vector network analyzer" on page 67.
8. Measure the reflection of the DUT. See "To measure the reflection of the DUT" on page 69.

   Tip: We recommend checking the immunity of the sensor from mounting the connector in a different angular position by connecting it multiple times.
9. Click "Quit" to return to R&S Recal+.

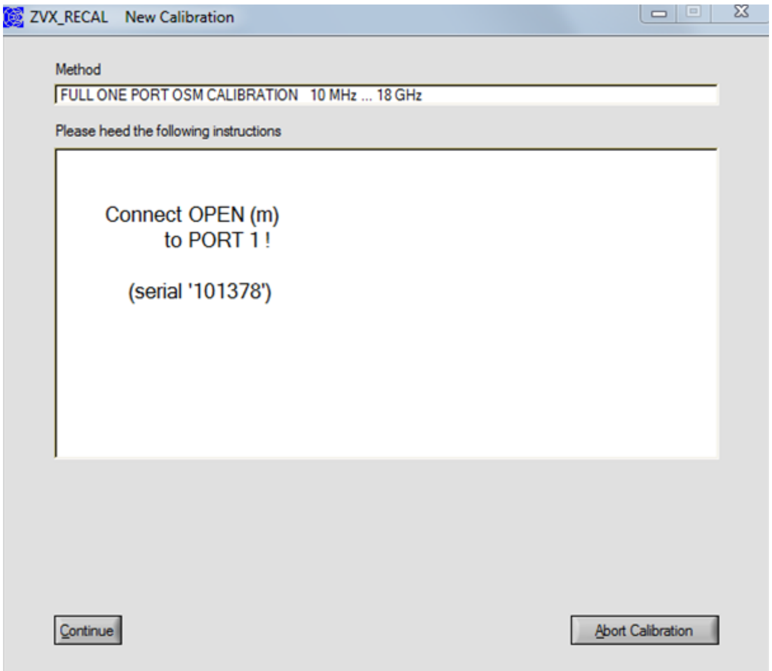
To calibrate vector network analyzer

1. In the "Calibration" list, select "New: One Port OSM".



2. In the "active Cal Kit" list, select an appropriate calibration kit. The list only shows the calibration kits that are suitable for the connector to the DUT.
3. Initiate the calibration by clicking "Start".

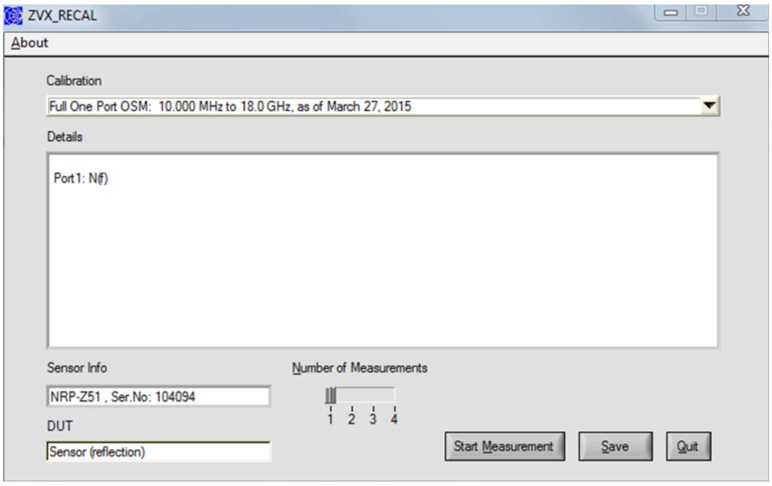
   A dialog prompts you to connect the first calibration standard.



4. Connect the requested calibration standard (check the serial number) to the network analyzer.
5. Click "Continue".

6. Proceed in the same manner for the other calibration standards.
7. Confirm the "Calibration complete" message with "OK".

   The calibration of the network analyzer is saved for subsequent reuse. The R&S ZVX_RECAL user interface is displayed in the foreground.

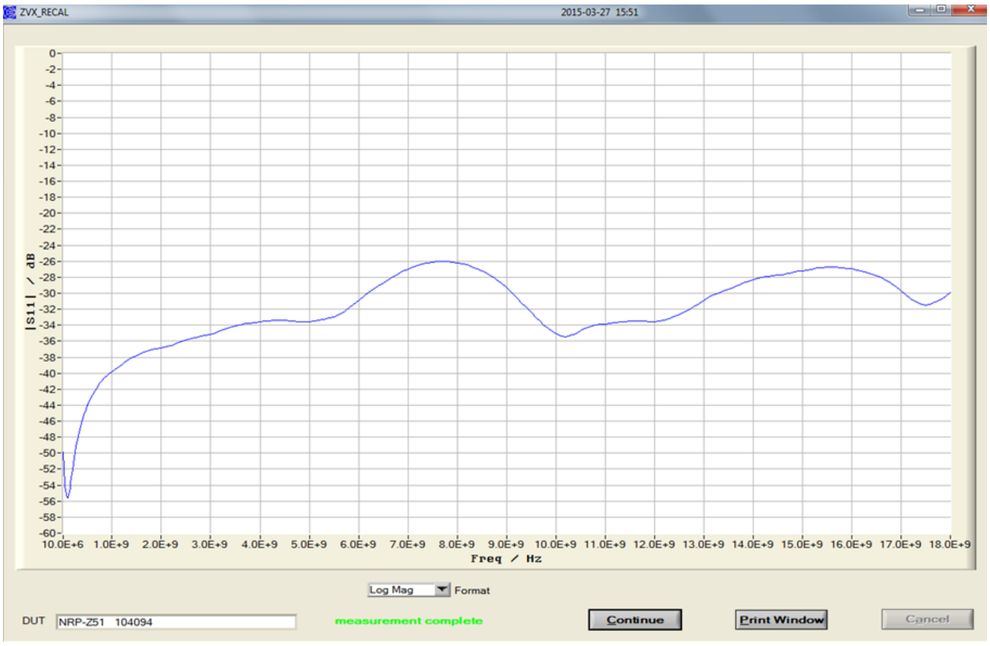


To measure the reflection of the DUT

1. In the "Number of Measurements" list, select the number of measurements.
2. Click "Start Measurement".
3. When prompted, connect the DUT to the network analyzer.

4. Click "OK".

   The measurement begins. After it is completed, the graphical display of the reflection measurement results is shown.

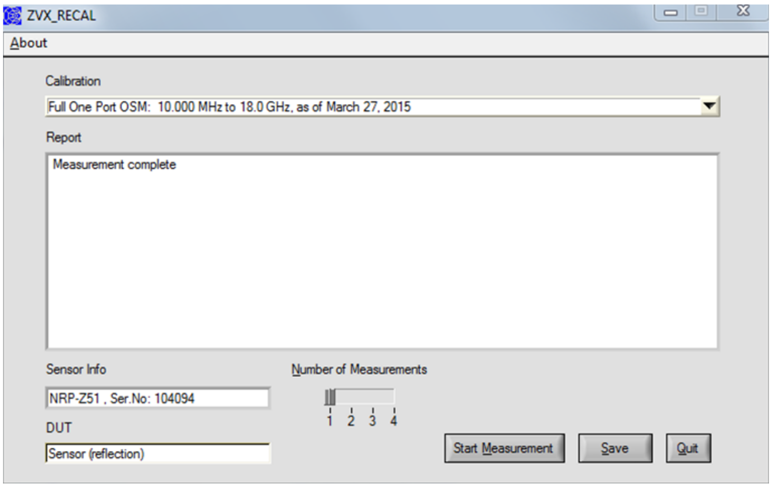


5. Click "Continue".

   The result depends on the number of set measurements.

6. If you are prompted to connect the DUT in another angular position, do so.

7. If the R&S ZVX_RECAL user interface is displayed with the message that the measurement is completed, click "Save".



An average measurement result is created from the individual measurements and saved in the ...`\recal+\measure.dat` directory as a file named as:

`rf (<type designation>) <serial no.>`

8.1.2 Information about reflection measurements with R&S ZVX_RECAL

Frequency range and number of frequencies

Both parameters are set solely as a function of the connector type. This means that sensors with identical connectors are adjusted at the same frequencies having the significant benefit that only a single calibration is required per connector type. The measurement points that are not necessary for the sensor are automatically discarded during subsequent evaluation of the measurement data. A standard value of 10 MHz is used as the lower frequency limit.

Validity of the calibration

The network analyzer calibration is saved with the date. If multiple DUTs with the same connector type are adjusted in sequence, the calibration of the network analyzer calibration can be reused. You only need to ensure that the system data like directivity, reflection tracking and source match of the network analyzer have not changed significantly. Changes generally occur due to drift of the network analyzer vs. time or changes on the test port of the network analyzer. If you are in doubt, perform a new calibration using "New: One Port OSM (User)".

Measurement uncertainty

Reflection measurements on power sensors are influenced primarily by the accuracy of the calibration kit and the stability of the network analyzer. The reflection of the actual sensor has only a secondary influence. The measurement uncertainty can be generalized as follows:

$U = a + b\,|\Gamma|$

The term *a* is independent of the measurement result and is primarily a function of the effective directivity. The term *b* considers the effective reflection tracking and the effective source match. Since power sensors generally exhibit very good matching, the influence of *b* tends to be small.

When calculating the measurement uncertainties, the R&S ZVX_RECAL program module uses the values listed in Table 8-1 for the term *a*. They are valid when using the recommended calibration kits, see Table 5-13. For *b*, *a* conservative estimate of 0.04 is used in all cases.

Table 8-1: Expanded measurement uncertainties (k = 2) for a well-matched DUT (term a)

Frequency range	N (50 Ω)	3.5 mm	2.92 mm	2.4 mm	1.85 mm
DC to 0.1 GHz	0.005	0.005	0.005	0.005	0.005
> 0.1 GHz to 2.4 GHz	0.005	0.005	0.005	0.005	0.005
> 2.4 GHz to 8.0 GHz	0.005	0.007	0.007	0.007	0.007
> 8.0 GHz to 12.4 GHz	0.005	0.009	0.009	0.009	0.009
> 12.4 GHz to 18.0 GHz	0.006	0.009	0.009	0.010	0.010
> 18.0 GHz to 26.5 GHz	-	0.011	0.011	0.014	0.014

Frequency range	N (50 Ω)	3.5 mm	2.92 mm	2.4 mm	1.85 mm
> 26.5 GHz to 33.0 GHz	-	0.011	0.011	0.015	0.015
> 33.0 GHz to 40.0 GHz	-	-	0.011	0.015	0.015
> 40.0 GHz to 50.0 GHz	-	-	-	0.017	0.017
> 50.0 GHz to 67.0 GHz	-	-	-	-	0.020

At low frequencies, vector network analyzers tend to exhibit a large, system-related statistical uncertainty. To reduce this uncertainty, R&S ZVX_RECAL sets the bandwidth of the network analyzer accordingly. In addition, the measurement result for the 10 MHz frequency point is determined based on measurement results for multiple frequency points in the immediate vicinity of 10 MHz. Both steps help to reduce stochastic error influences considerably.

Saving the measurement result

The measured reflection coefficients are saved along with the measurement uncertainties and general information in the `...\recal\measure.dat` directory. The file contains only the frequency points that are relevant for the applicable sensor. The filename is structured as follows:

```
rf (<type>) <serial no.>
```

For a sensor of type R&S NRV-Z15 with serial number 102972, it is as follows:

```
rf(NRP-Z21)102972
```

Additional information about reflection measurements of R&S NRP18A(N) with R&S ZVX_RECAL

Reflection measurements of R&S NRP18A(N) sensors with a frequency start from 8 kHz up to 18 GHz require two network analyzers. The first network analyzer covers the frequency range from 8 (9) kHz to 100 MHz, the second from 100 MHz up to 18 GHz. R&S ZVX_RECAL measures the reflection using two vector network analyzers alternating in any order.

Depending on the measurements performed, the R&S ZVX_RECAL user interface is displayed with "Measurement of a frequency subrange complete" (Figure 8-2) or a message that the measurement is completed.

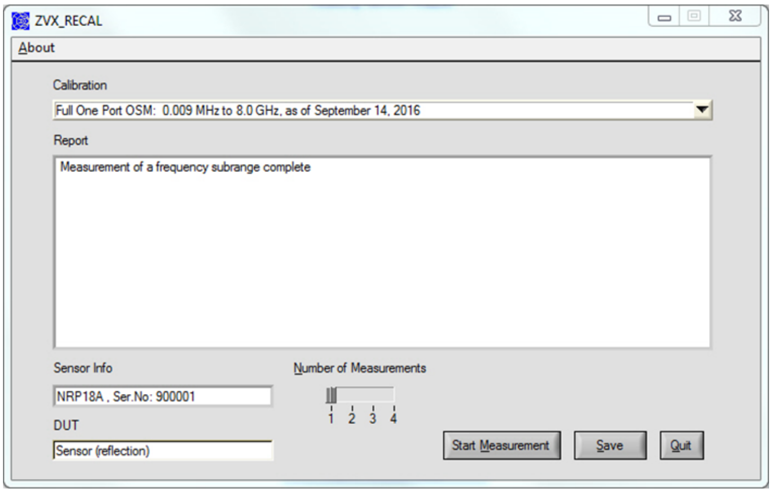


Figure 8-2: User interface after reflection measurement of a frequency subrange

8.1.3 Reflection measurement without using R&S ZVX_RECAL

Supported network analyzers are listed in Table 5-8 and Table 5-10.

If the network analyzer used for the reflection measurement is not supported by the R&S Recal+ software, you need to:

- Configure the measurement properly.
- Save the measurement data in a format that is compatible with the R&S Recal+ software.

8.1.4 Configuring the network analyzer

All necessary information is saved in the configuration file for the sensor to be calibrated. The configuration files are stored in the ...`\recal+\config32.dat` directory and the filename contains the type designation and variant identifier of the sensor. They are created in ASCII format and can be read using any standard editor. Fig. Figure 8-3 shows parts of the configuration file for the R&S NRV-Z15 CW power sensor that is representative of all the sensors with only a single measurement path in this context.

```
freqLevel= 1.0E-6
...
frequencyresponse=
      50E6  , 1.0
      100E6  , 1.0
      500E6  , 1.0
        ...
        ...
       40E9  , 1.0
DataBlockEnd
...
reflectionCoefficients=
      50E6  ,0.070
    4.05E9  ,0.157
DataBlockEnd
...
```

Figure 8-3: Excerpt from nrv-z15.002 configuration file for R&S NRV-Z15 sensor type with variant identifier 02

freqLevel = Measurement level for calibration of absolute accuracy
frequencyresponse = Measurement frequencies for calibration of absolute accuracy and matching
reflectionCoefficients = Specified reflection coefficients: 50 MHz to 4 GHz ≤ 0.07, > 4 GHz to 40 GHz ≤ 0.157

For a thermal sensor or if the measurement data is not used for gamma correction of the calibration of absolute accuracy, the exact measurement level in the reflection measurement is not critical. Otherwise, the measurement level has to be as large as the value used for calibration of absolute accuracy. This value is saved in the configuration file under the `freqLevel` entry and has the unit of W for a power sensor. For values under 10 µW (−20 dBm), the reflection measurement can be performed with no problem at a measurement level of −20 dBm. Reflection changes hardly occur if there is further level reduction. The selected measurement time is such that the measurement uncertainties resulting from the measurement noise remain small compared to the error influences that are due to the calibration of the network analyzer. The values in Table 8-1 can be used as a starting point for the total measurement uncertainty.

For multipath sensors, multiple level specifications are present under the `freqNpathLevel` entry. For two-path sensors, use the second entry for the first path. For three-path sensors, use the second entry for the third path.

The measurement frequencies are listed under the `frequencyresponse` entry. These values apply for calibration of absolute accuracy and for the reflection measurement, and measured values must be available for these frequencies. To be able to define structured sweeps, it can be necessary to make measurements at other frequencies besides the listed ones. The R&S Recal+ software is configured for this use case and accepts additional frequency points, but only for the reflection measurement.

The measurement data is best saved as a Touchstone file in the `*.s1p` format for easy further processing, see Section 8.1.5, "Formatting and saving the reflection measured values", on page 75.

The configuration files for the sensors also include the limits specified in the specifications document for the magnitude of the linear reflection coefficient. These specifications are listed in the table under the `reflectionCoefficients` entry. The left column contains in each case the frequency starting at which the limit specified in the right column is valid. The value in the last row is logically valid up to the upper frequency limit of the sensor. With the R&S URV5-Z2 and R&S URV5-Z4 voltage sensors, the reflection is measured at the male connector end. Terminate the female connector with the precision termination.

8.1.5 Formatting and saving the reflection measured values

To evaluate the network analyzer measurement data using the R&S Recal+ software, save the data in an RF file in the …`\recal+\measure.dat` directory. There are two possibilities:

- Creating one ASCII file each with the reflection and measurement uncertainty data in Touchstone format and importing these files using the R&S Recal+ software.
- Manually creating a single ASCII file with reflection and measurement uncertainty data in a format compatible with R&S Recal+ and saving this file in the …`\recal+\measure.dat` directory.

Importing reflection and measurement uncertainty files

This procedure is generally the simpler of the two possibilities since most network analyzers are capable of automatically generating measurement data in Touchstone format. You only need to create the measurement uncertainty file with its very simple format and import the data. The import requires the installation of the R&S ZVX_RECAL program module, see Section 8.1.1, "Program-controlled reflection measurement with R&S ZVX_RECAL", on page 65.

To import the data

1. Save the measurement data of the network analyzer on a storage medium that the R&S Recal+ software can access.
2. Create the measurement uncertainty file.
3. Save the measurement uncertainty file on a storage medium that the R&S Recal+ software can access.
4. Start the R&S Recal+ software.
5. In the toolbar, click to open the "Measurement with Recal+" dialog.
6. Select the "Reflection/S-Parameter" tab.
7. Select the sensor that the reflection data is associated with:
   - If this sensor is connected to an initialized base unit, click the corresponding option.
   - Otherwise, under "File", select the sensor from the list that appears. Of course, the second possibility assumes that the sensor has been plugged in at least once and its data was read out.
8. In the "S1P Data File (Reflection)" field, click "Browse" to select the file with the measurement data of the network analyzer.

9. In the "S1P Data File (Reflection)" field, click "Browse" to select the measurement uncertainty file.
10. Click "Import Reflection Data".

    The R&S Recal+ software automatically generates a file in the RF format based on the two starting files and saves it in the …`\recal+\measure.dat` directory. The filename consists of the sensor type designation, its variant identifier and the serial number.

Structure of a file to import the measurement data of the network analyzer

Save the reflection coefficients measured at the individual frequencies with the real and imaginary parts in the Touchstone format (`*.s1p`), see Figure 8-4. Use a period as a decimal separator. In the header indicated with #, provide all the information needed to interpret the data:

- Frequency unit (HZ|KHZ|MHZ|GHZ)
- Identification of S-parameter data (S)
- Data format real/imaginary (RI)
- Reference impedance of 50 Ω (R 50)

You can insert comments directly after the header following an exclamation mark (!). Except for the mandatory file extension `s1p`, you can use any desired filename.

```
# HZ  S  RI  R 50
! Rohde & Schwarz ZVA/B
!
! Frequency      Real part      Imaginary part
1.00000E+07      1.57630E-03    -2.22580E-03
5.00000E+07      1.37430E-03    -4.56010E-04
1.00000E+08      8.08320E-04    -1.36200E-04
3.00000E+08      1.45920E-04    -2.67880E-04
....
....
```

Figure 8-4: ASCII file with reflection data in Touchstone format

Save the reflection coefficients always with the real and imaginary parts. Other formats are not supported.

Structure of a file with the uncertainties of the reflection measurement

Save the expanded linear uncertainties with k = 2 as a function of the frequency. Use a period as a decimal separator. The left column defines the starting frequency of the interval in which the measurement uncertainty specified in the right column is valid. The interval ends with the starting frequency specified in the next row. The value in the last row is logically valid up to the upper frequency limit of the sensor. Usually, only a few entries are needed, and the measurement uncertainty file can be applied universally. The header indicated with # only needs to contain the frequency unit used in the table (HZ|KHZ|MHZ|GHZ) and the identifier for the measurement uncertainty file (*U*). You can insert comments directly after the header following an exclamation mark (!). You can select any desired filename.

```
# HZ U
!
! Frequency    Uncertainty (k=2)
   1.00E+07    0.005
   2.41E+09    0.007
   8.01E+09    0.009
  12.41E+09    0.010
```

Figure 8-5: ASCII file with measurement uncertainties

8.1.5.1 Creating, editing and saving a file in RF format

Measurement files in RF format contain all the information needed for matching of a sensor. Besides the measurement data and measurement uncertainties, they also contain information about the sensor and calibration. Table 8-2, Table 8-3 and Table 8-4 show examples of the format and content of these files. All mandatory entries are in bold, and all user-specific entries in normal font. The column on the right explains the various entries, i.e. these explanations are not included in the files.

The three examples differ in the presentation of the reflection-measured values. The preferred format with all the necessary information is shown in Table 8-3. If the measurement data is available only in scalar form, use the format in Table 8-4. You can use such files only for reporting and calculating the mismatch uncertainty in the calibration of absolute accuracy. A file like the one in Table 8-2 provides the same information as one in the preferred format, but also includes the magnitudes of the reflection coefficients.

Save the files in the RF format in the ...`\recal\measure.dat` directory. The filename must contain the type of the sensor and its serial number in the following format:

```
rf (<type>) <serial no.>
```

For a sensor of type R&S NRV-Z15 with serial number 102972, the filename is as follows:

```
rf(NRP-Z21)102972
```

After importing the Touchstone and measurement uncertainty file, it is sometimes helpful to edit an RF file created by R&S Recal+. Thus, you can add information that is not contained in the original files. For example, information about the instruments that were used, the name of the technician and data on the temperature and humidity, see Table 8-2 to Table 8-4.

Table 8-2: rf(NRP-Z21)102972 measurement file for checking reflection (R&S power sensors, variant 1)

`[SENSOR-MEAS-DATA-FILE]`	Designation as measurement file
`CalDataType = REFLECTION_DATA`	Designation as reflection data
`DeviceList =` `"VNA, HP, 8510, 8430F9241, 199710A4435, 1998-05"` `"..."` **`DataBlockEnd`**	List of measuring devices; a separate line is to be provided for each component: "<designation>, <manufacturer>, <type>, <serial no.>, <certificate no.>, <calibration expiry date>" The list is terminated with `DataBlockEnd`.
`TestEngineer` `= "Peter Schmidt"`	Name of test engineer

Humidity = "40 to 60" // % r.H.	Rel. humidity in % Comment line
Temperature = "20 to 26" // °C	Temperature range in °C Comment line
SerialNo = "102972"	Serial number
StockNo = "1081.2305.02"	Material number
SensorType = "NRP-Z11"	Type designation
Date = "2004-05-12"	Calibration date (12 May 2004)
DataPoints = 45	Number of frequencies
ValuesPerPoint = 5	Number of values per measurement point
Value = // Reflection coefficient of DUT // f/Hz | Magnitude | Uncert. | Real part | Imaginary part 5.000E+7 0.8783E-1 0.40E-2 0.7350E-1 0.4808E-2 1.000E+8 0.2650E-1 0.40E-2 0.1584E-2 0.2645E-1 5.000E+8 0.9632E-2 0.40E-2 0.2937E-2 0.9173E-2 .... 8.000E+9 0.32506E-1 1.20E-2 0.1742E-2 0.3245E-1 **DataBlockEnd**	Assignment of calibration values Comment line Comment line List of values, with columns separated by at least one space. The list is terminated with `DataBlockEnd`. `Reflection coefficient`: absolute value of the reflection coefficient `Uncertainty`: expanded measurement uncertainty (k=2) for the reflection coefficients

Table 8-3: rf(NRP-Z21)102972 measurement file for checking reflection (R&S power sensors, variant 2)

[SENSOR-MEAS-DATA-FILE]	Designation as measurement file
CalDataType = REFLECTION_DATA	Designation as reflection data
DeviceList = "VNA, HP, 8510, 8430F9241, 199710A4435, 1998-05" "..." DataBlockEnd	List of measuring devices; a separate line is to be provided for each component: "<designation>, <manufacturer>, <type>, <serial no.>, <certificate no.>, <calibration expiry date>" The list is terminated with `DataBlockEnd`.
TestEngineer = "Peter Schmidt"	Name of test engineer
Humidity = "40 to 60" // % r.H.	Rel. humidity in % Comment line
Temperature = "20 to 26" // °C	Temperature range in °C Comment line
SerialNo = "102972"	Serial number
StockNo = "1081.2305.02"	Material number

SensorType = "NRP-Z21"	Type designation
Date = "2004-05-12"	Calibration date (12 May 2004)
DataPoints = 45	Number of frequencies
ValuesPerPoint = 4	Number of values per measurement point
Value = // Reflection coefficient of DUT //f/Hz | Real part | Imaginary part | Uncertainty 5.000E+7 0.7350E-1 0.4808E-2 0.40E-2 1.000E+8 0.1584E-2 0.2645E-1 0.40E-2 5.000E+8 0.2937E-2 0.9173E-2 0.40E-2 .... 4.000E+10 0.1742E-2 0.3245E-1 1.20E-2 **DataBlockEnd**	Assignment of calibration values Comment line Comment line List of values, with columns separated by at least one space. The list is terminated with `DataBlockEnd`. `Uncertainty`: expanded measurement uncertainty (k=2) for the reflection coefficients

Table 8-4: rf(NRV-Z15)843275.034 measurement file for checking reflection (R&S NRV-Z and R&S URV5-Z sensors)

[SENSOR-MEAS-DATA-FILE]	Designation as measurement file
CalDataType = REFLECTION_DATA	Designation as reflection data
DeviceList = "VNA, HP, 8510, 8430F9241, 199710A4435, 1998-05" "..." **DataBlockEnd**	List of measuring devices; a separate line is to be provided for each component: "<designation>, <manufacturer>, <type>, <serial no.>, <certificate no.>, <calibration expiry date>" The list is terminated with `DataBlockEnd`.
TestEngineer = "Peter Schmidt"	Name of test engineer
Humidity = "40 to 60" // % r.H.	Rel. humidity in % Comment line
Temperature = "20 to 26" // °C	Temperature range in °C Comment line
SerialNo = "843275/034"	Serial number
StockNo = "1081.2305.02"	Material number
SensorType = "NRV-Z15"	Type designation
Date = "2004-05-12"	Calibration date (12 May 2004)
DataPoints = 45	Number of frequencies

`ValuesPerPoint = 3`	Number of values per measurement point
`Value =` `// Reflection coefficient of DUT` `//f/Hz | Magnitude | Uncertainty` `5.000E+7 0.8783E-2 0.40E-2` 1.000E+8 0.8820E-2 0.40E-2 `5.000E+8 0.9124E-2 0.40E-2` `......` `......` `4.000E+10 8.7455E-2 1.20E-2` `DataBlockEnd`	Assignment of calibration values Comment line Comment line List of values, with columns separated by at least one space. The list is terminated with `DataBlockEnd`. `Uncertainty`: expanded measurement uncertainty (k=2) for the reflection coefficients

8.2 S-parameter file for sensors with attenuators

In the sensor data memory of the R&S NRP18S-xx and R&S NRP-Z22/23/24/92 power sensors, two calibration data sets are saved. The first data set in the sensor data memory the power sensor. The second data set in the sensor data memory the attenuator in the form of all four S-parameters. You can refresh the data for the attenuator by providing R&S Recal+ with a file with current measurement data.

Table 8-5 shows the structure of this file type in RF format for a power sensor of type R&S NRP-Z22. Beside general information, this file contains a complete set of complex S-parameters for the attenuator. Provide the S-parameters exclusively in linear notation. For the measurement uncertainties, distinguish between the reflection and transmission parameters. For the reflection coefficients s_{11} and s_{22}, the absolute uncertainties are necessary, while for the transmission coefficients s_{12} and s_{21} the relative uncertainties (in dB) are necessary. Expand the uncertainties by the factor k = 2 and refer in each case to the magnitudes.

The complex reflection coefficients of the power attenuators change faster vs. frequency than the reflection coefficients at the input of the power sensors. This fact is related to the longer line lengths inside the attenuators. Therefore, the measurement frequencies in the calibration data set for an attenuator are more tightly spaced than the calibration frequencies of the power sensor. If the spacing between the frequency points is too large, significant errors arise in gamma correction between the power sensor and attenuator. In general, a frequency spacing of 50 MHz is adequate. It is best to select the frequency points in the existing calibration data set that you can read out in the "Create NRP View file" dialog and save as an ASCII file in the …`\recal+\config32.dat` directory. The parameters for the attenuator are listed under "S-Parameter Calibration Data".

The R&S ZVX_RECAL program module does not support the calibration of the attenuators since the possibility of significant measurement errors is greater compared to power calibration. Accordingly, we recommend only experienced personnel performing calibration of attenuators using suitable measurement setups.

Table 8-5: SP(NRP-Z22.002)100042 measurement data file for the S-parameters for the attenuator of an R&S NRP-Z22 sensor

[SENSOR-MEAS-DATA-FILE]	Designation as measurement file
CalDataType = S_PARA_DATA	S-parameter measurement data
DeviceList = //"<designation>, <manufacturer>, <type>, <serial no.>, <certificate no.>, <calibration expiry date>" "VNA, HP, 8510, 8430F9241, 199710A4435, 1998-05" "..." **DataBlockEnd**	List of measuring devices; a separate line is to be provided for each component. The list is terminated with `DataBlockEnd`.
TestEngineer = "Peter Schmidt"	Name of test engineer
Humidity = "40 to 60" // % r.H.	Rel. humidity in % Comment line
Temperature = "20 to 26" // °C	Temperature range in °C Comment line
SerialNo = "654321"	Component serial number
StockNo = "1234.5678.90"	Material number of component
ComponentType = "Weinschel 10 dB attenuator"	Component type designation
Date = "2001-10-21"	Calibration date
CalibrationLab = "R & S Messgerätebau Memmingen"	Calibration location
Family = ALL	Not a member of any specific sensor family
DataPoints = 360	Number of measurement frequencies
ValuesPerPoint = 13	Number of columns per frequency point
ComplexData = TRUE	Indicates that the measurement values are real and imaginary components of a complex value
Value = //f/Hz re_s11 im_s11 unc_s11 re_s12 im_s12 unc_s12 re_s21 im_s21 unc_s21 re_s22 im_s22 unc_s22 5.0E7 0.88E-2 0.40E-2 0.005 3.161E-1 0.240E-4 0.04 3.180E-1 0.861E-4 0.04 0.12E-1 0.11E-3 0.005 .... 18.0E9 0.88E-1 0.22E-1 0.010 0.111E-2 2.462E-1 0.07 0.263E-2 2.501E-1 0.07 0.72E-1 0.41E-1 0.010 **DataBlockEnd**	Assignment of calibration values Comment line (no line break!) List of values, one line per measurement frequency, with columns separated by at least one space. The list is terminated with `DataBlockEnd`.

8.3 Linearity calibration

You can perform the calibration of the linearity on a separate power calibration measurement setup.

Transfer the measurement results to the R&S Recal+ software in an ASCII file in accordance with Table 8-6. The ASCII file contains the following:

- General information
- Measured power value pairs for the standard and the DUT at each frequency point with the expanded (k = 2) measurement uncertainty U_{lin} in dB as the third quantity

You can obtain the measurement levels from the DUT configuration file:

```
...
linFilter = 7
...
linLevel  =
    1.00E-006
    1.58E-006
    ...
    ...
    2.51E-2
DataBlockEnd
...
freqLevel = 1.0E-6
...
```

Figure 8-6: Extract from nrv-z15.002 configuration file (linearity)

linFilter = DUT filter setting
linLevel = Power steps (± 0.5 dB)
freqLevel = Power (±0.5 dB) at the reference point

Table 8-6: ln(NRP-Z11.002)900123 measurement file for checking the linearity

[SENSOR-MEAS-DATA-FILE]	Designation as measurement file
CalDataType = LIN_RESPONSE	Designation as linearity data
Family = NRP	NRP (value for all R&S power sensors) or NRV (value for R&S NRV and R&S URV5-Z)
DeviceList = "Power Sensor, R&S, NRV-Z1, 856345/011, 199A5, 1998-05" "Power Meter, R&S, NRVD, 845123/018, 567B221, 1999-10" "..." **DataBlockEnd**	List of measuring devices; a separate line is to be provided for each component: "<designation>, <manufacturer>, <type>, <serial no.>, <certificate no.>, <calibration expiry date>;" The list is terminated with DataBlockEnd.
TestEngineer = "Peter Schmidt"	Name of test engineer
Humidity = "40 to 60" // % r.H.	Rel. humidity in % Comment line
Temperature = "20 to 26" // °C	Temperature range in °C Comment line
SerialNo = "900123"	Serial number

StockNo = "1138.3004.02"	Material number
SensorType = "NRP-Z11"	Type designation
CalibrationLab = "SE2 Service Dept"	Name of Calibration Lab
Date = "2004-05-12"	Calibration date (12 May 2004)
RefValue = 1.0024	P_{DUT} / P_{ref} for the reference point
RefUnit = -1	Reference value code
TestFrequency = 500.0E6	Measurement frequency
DataPoints = 24	Number of frequencies
ValuesPerPoint = 3	Number of values per measurement point
ValueUnit = W	Unit of `Value`, `V` for sensors that are marked as `VoltageSensor` in the config file
Value = // P_ref/W P_DUT/W uncertainty U_lin/dB 9.95123E-7 9.9751E-7 2.50E-2 1.57230E-6 1.5761E-6 2.50E-2 .... 2.46220E-2 2.4631E-2 2.50E-2 **DataBlockEnd**	Assignment of calibration values Comment line List of values, columns separated by at least one space. `Uncertainty U_lin/dB`: expanded measurement uncertainty (k=2) in dB for power ratio measurements. The list is terminated with `DataBlockEnd`.
SubstrateTemperature = 0.300000000E+3	Only `NRP` and `FSH`, fixed value.

8.4 Absolute accuracy calibration

You can perform the calibration of the absolute accuracy on a separate power calibration measurement setup.

Transfer the measurement results to the R&S Recal+ software in an ASCII file in accordance with Table 8-7 for R&S NRV-Z or R&S URV5-Z sensors, or in accordance with Table 8-8 for R&S power sensors. In addition to general information, this file contains the measured power value pairs for the standard and the DUT at each frequency point. You can obtain the measurement frequencies and the calibration power levels from the DUT configuration file:

```
...
FRQREF = 2
frequencyresponse=
    50E6 , 1.0
    100E6  , 1.0
    500E6  , 1.0
      ...
      ...
     40E9  , 1.0
DataBlockEnd
...
freqLevel  = 1.0E-6
freqFilter = 7
...
```

Figure 8-7: Extract from configuration file nrv-z15.002 (absolute accuracy)

FRQREF	= Reference frequency index
frequencyresponse	= Measurement frequencies
freqLevel	= Meas. power (±1.0 dB)
freqFilter	= Filter setting

For every frequency point, state the expanded (k = 2) measurement uncertainty U_{abs} in dB as the fourth quantity in the measurement file. The expanded (k = 2) measurement uncertainty $U_{ref,abs}$ of the calibration system includes:

- Mismatch uncertainty
- Component for the base unit
- Ambient temperature
- Component that considers the effect of harmonics for the R&S NRV-Z6 and R&S NRV-Z15 diode sensors.

$$U_{\mathrm{abs}} = 2 \cdot \sqrt{\left(\frac{U_{\mathrm{ref,abs}}}{2}\right)^2 + u_{\mathrm{NRVD,1}}^2 + \left[\alpha_{\mathrm{T,DUT}}\,(T - 296.15\,\mathrm{K})\right]^2 + u_{\mathrm{h,one}}^2}$$

$u_{NRVD,1}$ = 0.0039 dB

$$\alpha_{\mathrm{T,DUT}} = 0.0015 \;\; \mathrm{dB/K} \quad [\mathrm{R\&S\,NRV-Z6/-Z15}]$$
$$0.0005 \;\; \mathrm{dB/K} \quad [\mathrm{R\&S\,NRV-Z52/-Z55}]$$

T = sensor temperature in K

$$\frac{u_{\mathrm{h,one}}}{\mathrm{dB}} = \sqrt{\frac{P_{\mathrm{DUT}}}{4\,\mu\mathrm{W}}} \cdot 10^{-\frac{S}{20\mathrm{dB}}}$$

P_{DUT} is the power at the DUT, S the harmonic ratio. At a measurement power of 1 µW and a harmonic ratio of 25 dB, for example, the uncertainty $u_{h,one}$ = 0.028 dB.

Enter the default frequency defined for the sensor type in question must be entered as the reference frequency `RefValue`. The default frequency is the frequency that is accepted by the base unit when the frequency response correction is turned off.

You can find the default frequency in the corresponding configuration file, where the index `FRQREF` indicates the corresponding value in the frequency table (index 0 = 1st measurement frequency). In the example above (`FRQREF = 2`), `RefValue = 5E8` is the value to enter.

Table 8-7: fr(NRV-Z15.002)843275.034 measurement file for checking absolute accuracy

[SENSOR-MEAS-DATA-FILE]	Designation as measurement file
CalDataType = FREQ_RESPONSE	Designation as measurement data for absolute accuracy
Family = NRV	Also R&S NRV-Z for R&S URV5-Z sensors
DeviceList = "Power Sensor, HP, 8478B, 3318A2465, 199A5, 1998-05" "Power Meter, HP, 432A, 1234A10012, 199A6, 1999-10" "..." **DataBlockEnd**	List of measuring devices; a separate line is to be provided for each component: "<designation>, <manufacturer>, <type>, <serial no.>, <certificate no.>, <calibration expiry date>" The list is terminated with `DataBlockEnd`.
TestEngineer = "Peter Schmidt"	Name of test engineer
Humidity = "40 to 60" // % r.H.	Rel. humidity in % Comment line
Temperature = "20 to 26" // °C	Temperature range in °C Comment line
SerialNo = "843275/034"	Serial number
StockNo = "1081.2305.02"	Material number
SensorType = "NRV-Z15"	Type designation
Date = "2004-05-12"	Calibration date (12 May 2004)
FKF = TRUE	Measurement done with frequency correction turned on, is always `TRUE`.
RefValue = 500.00000E+6	Reference frequency
RefUnit = Hz	Reference frequency unit
TestLevel = 1.000000000E-6	Nominal level for Measurement
GammaCorrection = TRUE	Measurement with/without gamma correction
DataPoints = 45	Number of frequencies
ValuesPerPoint = 4	Number of values per measurement point

ValueUnit = W	Unit of Value and TestLevel, V for sensors that are marked as VoltageSensor in the config file.
Value = // f/Hz Ref. pwr./W DUT pwr./W Uncertainty U_abs/dB 5.00000E7 1.0034E-6 9.9987E-7 1.44E-2 1.00000E8 1.0141E-6 1.0187E-6 1.46E-2 5.00000E8 1.0273E-6 1.0337E-6 1.51E-2 .... 4.00000E10 9.0114E-7 8.8547E-7 2.88E-1 **DataBlockEnd**	Assignment of calibration values Comment line List of values, columns separated by at least one space. Uncertainty U_abs/dB: Expanded measurement uncertainty (k=2) for calibration of absolute accuracy. The list is terminated with DataBlockEnd.

Table 8-8: fr(NRP-Z11.002)900123 measurement file for checking absolute accuracy

[SENSOR-MEAS-DATA-FILE]	Designation as measurement file
CalDataType = FREQ_RESPONSE	Designation as measurement data for absolute accuracy
Family = NRP	Also NRP for R&S FSH-Z sensors
DeviceList = "Power Sensor, HP, 8478B, 3318A2465, 199A5, 1998-05" "Power Meter, HP, 432A, 1234A10012, 199A6, 1999-10" "..." **DataBlockEnd**	List of measuring devices; a separate line is to be provided for each component: "<designation>, <manufacturer>, <type>, <serial no.>, <certificate no.>, <calibration expiry date>" The list is terminated with DataBlockEnd.
TestEngineer = "Peter Schmidt"	Name of test engineer
Humidity = "40 to 60" // % r.H.	Rel. humidity in % Comment line
Temperature = "20 to 26" // °C	Temperature range in °C Comment line
SerialNo = "900123"	Serial number
StockNo = "1138.3004.02"	Material number
SensorType = "NRP-Z11"	Type designation
Date = "2004-05-12"	Calibration date (12 May 2004)
CalibrationLab = "SE2 Service Dept"	Name of calibration laboratory
FKF = TRUE	Always TRUE for R&S power sensors
RefValue = 500.00000E+6	Reference frequency
RefUnit = Hz	Reference frequency unit
GammaCorrection = TRUE	Measurement with/without gamma correction

TestLevels = 10.00E-6 1.00E-3 1.00E-3 **DataBlockEnd**	Nominal levels of measurements for 3-path sensors For R&S NRP-Z51: `TestLevel =` ... without `DataBlockEnd`
DataPoints = 45	Number of frequencies
ValuesPerPoint = 4	Number of values per meas. point
ValueUnit = W	Unit of `Value` and `TestLevel` (always `W` for R&S power sensors).
Value = // f/Hz Ch1_Ref_Pwr/W Ch1_DUT_Pwr/W Ch1_unc/dB Ch2_Ref_Pwr/W Ch2_DUT_Pwr/W Ch2_unc/dB Ch3_Ref_Pwr/W Ch3_DUT_Pwr/W Ch3_unc/dB 10.00000E+6 0.012600394E-3 0.012583287E-3 0.02949060 1.26928072E-3 1.2674270E-3 0.0267329 1.269419463E-3 1.268397333E-3 0.027131145 .... 8.0000000E+9 0.0101924E-3 0.01018197E-3 0.04508305 1.0275804E-3 1.02591166E-3 0.0363610 1.02847939E-3 1.027831333E-3 0.036797888 **DataBlockEnd**	Assignment of calibration values Comment line, data must be given in this order List of values (here NRP), number of columns must be `ValuesPerPoint`, columns separated by at least one space. `Uncertainty U_abs/dB`: Expanded measurement uncertainty (k=2) for calibration of absolute accuracy. The list is terminated with `DataBlockEnd`.
SubstrateTemperature = 0.300000000E+3	Only for R&S power sensors, fixed value.

9 R&S NRV-Z, R&S URV5-Z sensors and R&S NRVD power meter

This section describes the measurement equipment and setup for the discontinued R&S NRV-Z and R&S URV5-Z power sensor families.

9.1 Power calibration of R&S NRV-Z and R&S URV5-Z sensors

9.1.1 Requirements for all R&S NRV-Z, R&S URV5-Z sensors

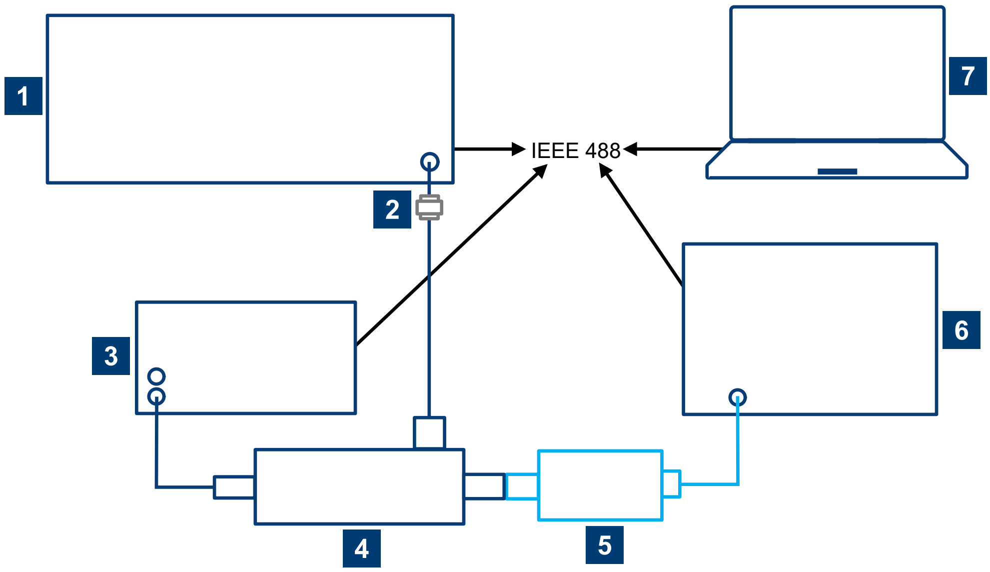


Figure 9-1: Setup for calibrating absolute accuracy

1 = Generator
2 = Depending on the generator used, an adapter for connecting the RF cable can be required.
3 = R&S NRX power meter; configure the R&S NRX as "Meter2", see Section 9.3, "Configuring the R&S NRVD power meter", on page 91.
4 = R&S NRPC; depending on the sensor type, an attenuator or termination is also required, see Table 9-1.
5 = DUT; R&S NRV-Z32/33/53/54 are measured with the corresponding attenuator.
6 = R&S NRVD
7 = Controller, a computer with R&S Recal+ installed

Generator, power meters and computer are connected via their IEEE-488 interfaces.

For details on the measurement equipment, see:

- Section 5.1, "Supported R&S power sensors", on page 25
- Section 5.2, "Controller", on page 28

- Section 5.3.2, "R&S NRX power meter", on page 31
- Section 5.3.3, "Generators for calibration of absolute accuracy", on page 31
- Section 5.3.4, "Generators for calibration of linearity", on page 33
- Section 5.3.5, "Vector network analyzers for calibration of matching", on page 33

9.1.2 Further equipment for the sensor types

Table 9-1: Further equipment for the sensor types

Sensor type	Reference attenuator (20 dB)	Precision termination	Calibration kit	See also
R&S NRV-Z2/5/8/51	-	-	R&S NRPC18	Table 5-1
R&S NRV-Z32/33/53/54	-	-	R&S NRPC18	Table 5-1
R&S NRV-Z1/4/7/31	x	-	R&S NRPC18	Table 5-1
R&S URV5-Z2	x	x	R&S NRPC18	Table 5-2
R&S URV5-Z4	-	x	R&S NRPC18	Table 5-2
R&S URV5-Z7	x *)	-	R&S NRPC18	Table 5-2
R&S NRV-Z52	-	-	R&S NRPC33	Table 5-3
R&S NRV-Z6	x	-	R&S NRPC33	Table 5-3
R&S NRV-Z55	-	-	R&S NRPC40	Table 5-4
R&S NRV-Z15	x	-	R&S NRPC40	Table 5-4
*) Two adapters are required: 50 Ω adapter (R&S URV5-Z50) and adapter for R&S URV5-Z50 adapter; the order is shown in Figure 9-2				

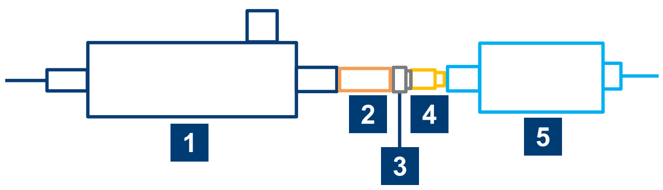


Figure 9-2: Adapter setup for R&S URV5-Z7

1 = R&S NRPC
2 = Reference attenuator
3 = Adapter N (male) to BNC (male)
4 = 50 Ω adapter (R&S URV5-Z50)
5 = DUT

9.2 Linearity calibration of R&S NRV-Z and R&S URV5-Z sensors

The calibration of linearity is not supported for R&S URV5-Z2 (55, 56), R&S URV5-Z4 (55, 56) and R&S URV5-Z7.

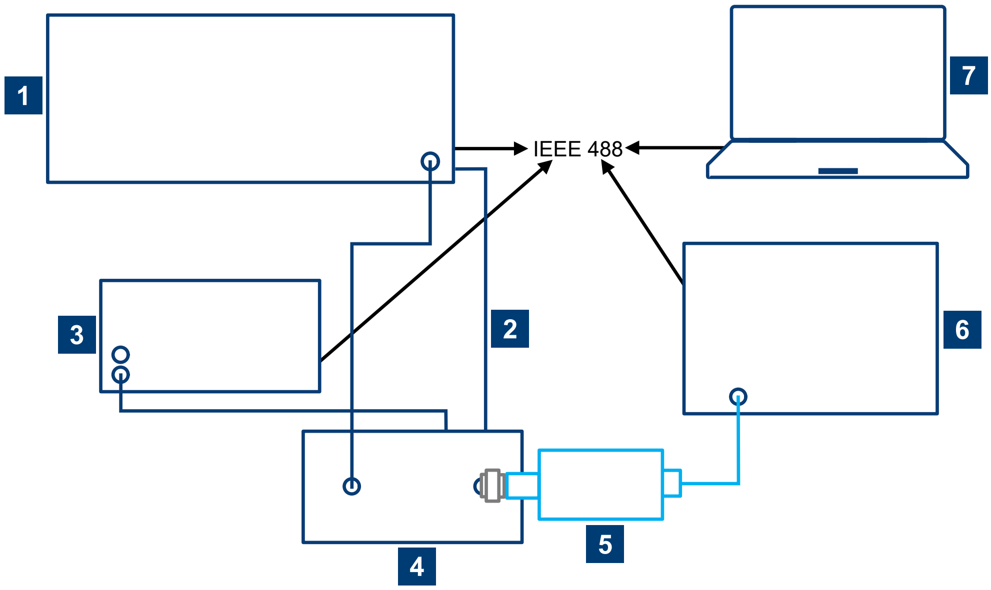


Figure 9-3: Setup for linearity calibration of R&S NRV-Z and R&S URV5-Z sensors

1 = R&S SMA100B generator
2 = 10 MHz reference; connect the internal reference oscillator of the generator to the reference clock of the R&S NRPC-LS.
3 = R&S NRX power meter; for connecting R&S NRPC-LS, use an R&S NRP-ZK8 interface cable.
4 = R&S NRPC-LS
5 = DUT; depending on the DUT used, an adapter for connecting to the test port of the R&S NRPC-LS can be required. See Table 9-2.
6 = R&S NRVD power meter
7 = Controller, a computer with R&S Recal+ installed

Table 9-2: Adapter for connecting the DUT to the R&S NRPC-LS

Connector of DUT	Calibration kit	Adapter included in calibration kit
3.5 mm	R&S NRPC33	N (male) to SMA (female)
2.92 mm	R&S NRPC40	N (male) to SMA (female)

Additional requirements for R&S URV5-Z sensors

- R&S SMA100B options
  Frequency option up to 20 GHz and the output power options "High output power" and "Ultra high output power" are required.
- Matched termination is required with a maximum input power of at least 2 W.
  We recommend using the attenuator included in the R&S NRPC18 calibration kit.
  You can also use an attenuator with an attenuation of at least 20 dB.

For details on the measurement equipment, see:

- Section 5.1, "Supported R&S power sensors", on page 25
- Section 5.2, "Controller", on page 28
- Section 5.3.2, "R&S NRX power meter", on page 31
- Section 5.3.3, "Generators for calibration of absolute accuracy", on page 31
- Section 5.3.4, "Generators for calibration of linearity", on page 33
- Section 5.3.5, "Vector network analyzers for calibration of matching", on page 33

9.3 Configuring the R&S NRVD power meter

For calibrating the R&S NRV-Z and R&S URV5 sensors, an R&S NRVD base unit is also required. Overall, you can control two base units:

- Basic power meter for connecting to the DUT
- R&S NRX for connecting to one or up to four power standards from the R&S NRPC calibration kit

The following tables show the possible combination.

Basic power meter	**Meter2**
R&S NRVD A / B	R&S NRX A / B / C / D
DUT (R&S NRV-Z or R&S URV5-Z)	Up to four R&S NRPC

9.3.1 Initializing the R&S NRVD

1. In the "Options" menu, open the "Remote Devices…" dialog.
2. Select the "Meter" tab.
3. Under "Basic Power Meter" panel, click "Search NRVD".

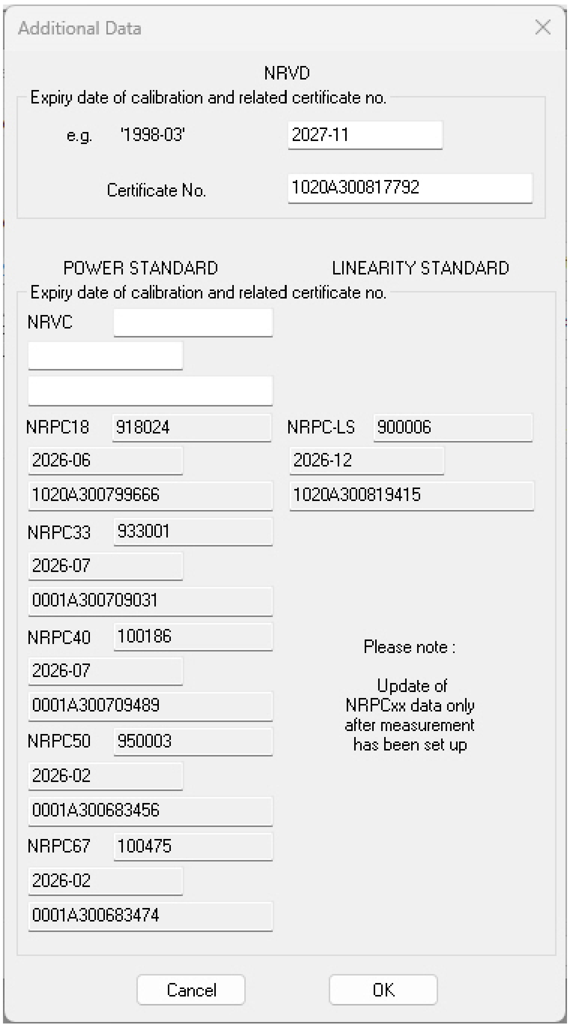
   The calibration software searches for an R&S NRVD that is connected to the IEC/IEEE bus. If the search is successful, the address of the R&S NRVD is displayed in the address field.

   Tip: If you already know the IEC/IEEE bus address of the R&S NRVD, the search is not necessary. You can simply enter the address.
4. If necessary, click "Search NRVD" again to find a second R&S NRVD base unit.
5. Click "Initialize".

   The R&S Recal+ calibration software initializes the R&S NRVD that was found at the specified address.
6. Click "Add data ...".

7. Enter the calibration expiry date and the "Certificate No." for the addressed R&S NRVD.
8. Click "OK".
9. If a second R&S NRVD is available, click "Use Meter 2" and proceed accordingly.
10. If an R&S NRX base unit is connected to the measurement setup:
    a) Under "Basic Power Meter" panel, select "NRX".
    b) Click "Search NRX".
    c) Click "Initialize".
    d) Initialize the R&S NRVD base unit connected to the setup as "Meter2".

Use "Meter2" exclusively to connect the standards during measurements.



10 Firmware update

10.1 Downloading the firmware update file

Firmware update files of these R&S products have an RSU extension, RSU meaning Rohde & Schwarz update.

To download the RSU file

1. Download the most recent firmware version from the Rohde & Schwarz homepage on the internet. The latest firmware update files are available at: www.rohde-schwarz.com/firmware/nrpc
2. Save the RSU file on the computer.
3. If the RSU file is packed in a `*.zip` archive, extract it.

10.2 Updating the firmware

Do not interrupt the firmware update because an interruption can lead to missing or faulty firmware. Take special care not to disconnect the power supply while the update is in progress. Interrupting the power supply during the firmware update most likely leads to an unusable sensor that needs to be sent in for maintenance.

You can choose from several methods to update the firmware installed on the sensor.

If you want to downgrade to an older version, you cannot use an RSU file downloaded from the Rohde & Schwarz homepage on the internet. Contact our costumer support to receive a special downgrade file for your sensor. See Section 15.5, "Contacting customer support", on page 186.

10.2.1 Using the Firmware Update program

The Firmware Update program is part of the R&S NRP-Toolkit. See also Section 5.2.1, "R&S NRP-Toolkit", on page 28.

You can use the Firmware Update program only if the sensor is recognized as a VISA device.

To check the prerequisites

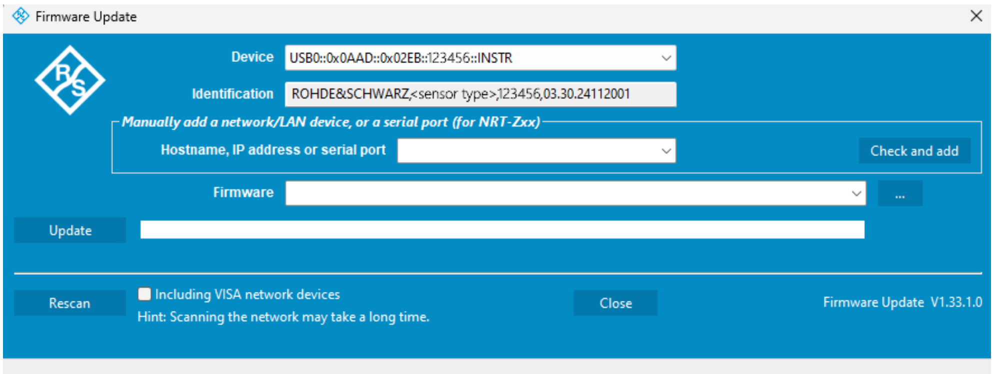
1. Ensure that a recent VISA software is installed on the computer.
   The latest version is provided on the Rohde & Schwarz website at www.rohde-schwarz.com/rsvisa.
2. Ensure that the R&S NRP-Toolkit for Windows is installed on the computer. See Section 5.2.1, "R&S NRP-Toolkit", on page 28.

To update the firmware over USB

A firmware update can take up to 5 minutes. Ensure that the update is not interrupted.

1. Ensure that the prerequisites are fulfilled. See "To check the prerequisites" on page 94.
2. Connect the sensor to the computer.
3. Start the Firmware Update program:
   "Start" menu > "NRP-Toolkit" > "Firmware Update".

   The program automatically starts scanning for R&S sensors connected via USB. When the scan is completed, all recognized sensors are listed under "Device".

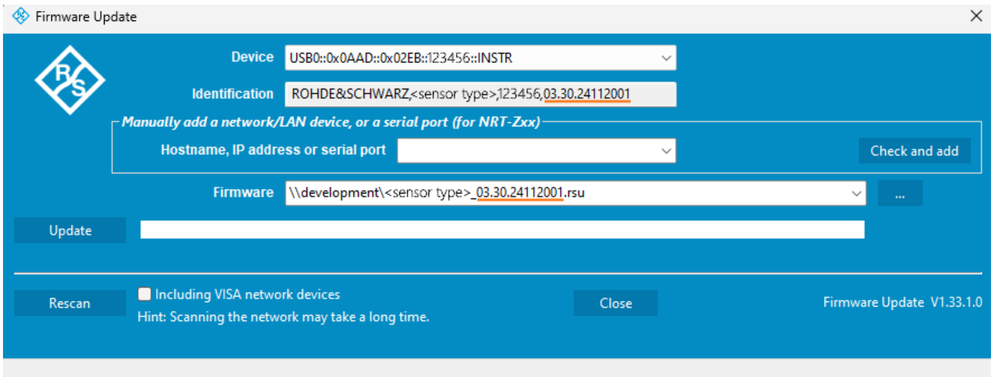
4. If the sensor you want to update is not listed, perform one of the following actions:
   - Click "Rescan" to search for attached sensors.
   - Check whether all necessary drivers are installed on the computer.
     For example, if the VISA library is not installed on the computer, no VISA sensor is accessible.
     See also Section 15.3, "Problems during a firmware update", on page 185 .
5. Under "Device", select the sensor you want to update.

   Note: The "Hostname, IP Address or Serial Port" field is not used during this procedure. Therefore, leave it empty.
6. Under "Firmware", enter the full path and filename of the update file. Alternatively, click ... next to the field.
7. Click "Update".

   During the update process, a progress bar is displayed.

The update sequence can take a couple of minutes, depending on the sensor model and the size of the selected file.

8. Check if the update was successful. The firmware version in the "Identification" field must match the version you selected in the "Firmware" field.



10.2.2 Using remote control

If you want to integrate a firmware update function in an application, use `SYSTem:FWUPdate` on page 148.

Example:

You want to update the sensor with the `NRPCx_03.50.25102101.rsu` file. This file has a size of 10242884 bytes.

To send the file to the sensor for updating the firmware, your application has to assemble a memory block containing:

`SYST:FWUP <block_data>`

The `<block_data>` are definite length-arbitrary block data.

See `SYSTem:FWUPdate` on page 148.

The size of the file is 10242884. This number has 8 digits. Thus, the `<block_data>` consist of the following:

- #
- 8
  How many digits follow to specify the file size.
- 10242884
  The number that specifies the file size.
- <file_contents>
  Contents of the RSU file, byte-by-byte
- 0x0a
  Delimiter

In this example, you write exactly 10242905 bytes to the sensor, for example by using a 'viWrite()' function.

The 10242905 bytes result from the values of the list above:

9 + 1 + 1 + 1 + 8 + 10242884 + 1

In a (pseudo) string notation, the memory block looks like this:

```
SYST:FWUP #810242884<file_contents>0x0a,
```

11 Remote control commands

In the following, all implemented commands are listed according to the command system and then described in detail. Mostly, the notation used complies with SCPI specifications.

For general information on remote control of Rohde & Schwarz products via SCPI, refer to www.rohde-schwarz.com/rc-via-scpi.

Further information:

- Section 13.1, "Remote control interfaces and protocols", on page 164
- Section 13, "Remote control basics", on page 164

11.1 Conventions used in SCPI command descriptions

The following conventions are used in the remote command descriptions:

- *Command usage*
  If not specified otherwise, commands can be used both for setting and for querying parameters.
  If a command can be used for setting or querying only, or if it initiates an event, the usage is stated explicitly.
- *Parameter usage*
  If not specified otherwise, a parameter can be used to set a value, and it is the result of a query.
  Parameters required only for setting are indicated as "Setting parameters".
  Parameters required only to refine a query are indicated as "Query parameters".
  Parameters that are only returned as the result of a query are indicated as "Return values".
- *Conformity*
  Commands that are taken from the SCPI standard are indicated as "SCPI confirmed". All commands used by the R&S NRPC follow the SCPI syntax rules.
- *Asynchronous commands*
  A command which does not automatically finish executing before the next command starts executing (overlapping command) is indicated as an "Asynchronous command".
- *Reset values (*RST)*
  Default parameter values that are used directly after resetting the instrument (`*RST` command) are indicated as "*RST" values, if available.
- *Default unit*
  The default unit is used for numeric values if no other unit is provided with the parameter.

Units

Units and prefixes, as defined by the international system of units (SI), are allowed and recognized. If you need decimal multiples and submultiples of a unit, you can use SCPI prefixes. Because SCPI uses only capital letters, it cannot distinguish between upper and lower case characters. Therefore, if SI prefixes use the same letter in upper and lower case, SCPI defines the meaning. An example is milli (m) and mega (M). In SCPI, M means milli for all units except Hz and Ohm - MHZ means mega Hz, 10^6 Hz.

Table 11-1: SCPI prefixes

Factor	SI name	SI symbol	SCPI prefix
10^3	kilo	k	K
10^6	mega	M	MA; also allowed are MOHM and MHZ
10^9	giga	G	G
10^{12}	tera	T	T
10^{-3}	milli	m	M Exception: Hz and Ohm
10^{-6}	micro	µ	U
10^{-9}	nano	n	N
10^{-12}	pico	p	P

11.2 Common commands

The common commands are taken from the IEEE 488.2 (IEC 625–2) standard. The headers of these commands consist of an asterisk * followed by three letters.

***CLS**

Clear status

Resets the following:

- Status byte (STB)
- Standard event register (ESR)
- EVENt part of the QUEStionable and the OPERation register
- Error/event queue

The command does not alter the ENABle and TRANsition parts of the registers.

Usage: Event

***ESE** <register>

Event status enable

Sets the event status enable register to the specified value. The query returns the contents of the event status enable register in decimal form.

Parameters:

<register> Range: 0 to 255
*RST: 0

***ESR?**

Event status read

Returns the contents of the event status register in decimal form (0 to 255) and then sets the register to zero.

Usage: Query only

***IDN?**

Identification

Returns a string containing information on the identity of the sensor (device identification code). In addition, the version number of the installed firmware is indicated.

Usage: Query only

***IST?**

Individual status

Returns the current value of the IST flag in decimal form. The IST flag is the status bit which is sent during a parallel poll.

Usage: Query only

***OPC**

Operation complete

Sets bit 0 in the event status register when all preceding commands have been executed. Send this command at the end of a program message. It is important that the read timeout is set sufficiently long.

The query always returns `1` because the query waits until all previous commands are executed.

`*OPC?` basically functions like `*WAI`, but also returns a response. The response is an advantage, because you can query the execution of commands from a controller program before sending new commands. Thus preventing overflow of the input queue when too many commands are sent that cannot be executed.

***OPT?**

Option identification

Returns a comma-separated list of installed options.

Usage: Query only

***PRE** <register>

Parallel poll register enable

Sets the parallel poll enable register to the specified value or queries the current value.

Parameters:

<register>	Range:	0 to 255
	*RST:	0

***RCL** <number>

Recall

Calls the device state which has been stored with the `*SAV` command under the specified number.

Setting parameters:

<number>	Range:	0 to 9
	*RST:	0

Usage: Setting only

***RST**

Reset

Sets the instrument to a defined default status. The default settings are indicated in the description of commands.

The command corresponds to the `SYSTem:PRESet` command.

Usage: Event

***SAV** <number>

Save

Stores the current device state under the specified number.

Setting parameters:

<number>	Range:	0 to 9
	*RST:	0

Usage: Setting only

***SRE** <register>

Service request enable

Sets the service request enable register to the specified value. This command determines under which conditions a service request is triggered.

Parameters:

<register>	Range:	0 to 255
	*RST:	0

***STB?**

Status byte

Returns the contents of the status byte in decimal form.

Usage: Query only

***TRG**

Trigger

Triggers a measurement if the following conditions are met:

- Sensor is in the waiting for trigger state.
- Trigger source is set to `BUS`.

See `TRIGger:SOURce BUS`.

Usage: Event

***TST?**

Self-test

Triggers a self-test of the sensor and outputs the result. `0` indicates that no errors have occurred.

Usage: Query only

***WAI**

Wait to continue

Prevents the execution of the subsequent commands until all preceding commands have been executed and all signals have settled.

Usage: Event

11.3 Preparing for the measurement

Before starting a measurement, you need to do the following:

11.3.1 Selecting the reference source

The `ROSCillator` subsystem contains commands for configuring the reference source.

[SENSe<Sensor>:]ROSCillator:SOURce <source>

Sets the source of the reference oscillator.

Refers typically to a precision, stabilized timebase.

Suffix:
<Sensor> 1

Parameters:
<source> INTernal | EXTernal | HOST

INTernal
Internal precision oscillator

EXTernal | HOST
External signal that is supplied at the host interface connector.

*RST: If the sensor boots or reboots, the source is set to INTernal. If the sensor is reset, the source setting is kept unchanged.

Example: `ROSC:SOUR INT`

11.3.2 Selecting a measurement

Before starting a measurement, select the measurement.

Further information:

- The available measurements and how to configure them are described in Section 11.5, "Configuring the measurements", on page 116.

[SENSe<Sensor>:]FUNCtion <function>

Sets the measurement.

Suffix:

<Sensor> 1

Parameters:

<function> **"POWer:AVG"**
Continuous average measurement
See Section 11.5.1, "Continuous average measurement", on page 116.
*RST: "POWer:AVG"

11.4 Controlling the measurement

The sensor offers a bunch of possibilities to control the measurement:

- Do you want to start the measurement immediately after the initiate command or do you want to wait for a trigger event?
- Do you want to start a single measurement cycle or a sequence of measurement cycles?
- Do you want to output each new average value as a measurement result or do you want to bundle more measured values into one result?

11.4.1 Starting and ending a measurement

In a basic continuous measurement, the measurement is started immediately after the continuous measurement is enabled. If you want to start the measurement only if a specific condition is fulfilled, define a trigger.

Further information:

- Section 11.4.2, "Triggering", on page 104

ABORt

Immediately interrupts the current measurement.

If the measurement has been started as a single measurement (`INITiate[:IMMediate]`), the sensor goes into the idle state.

If a continuous measurement is in progress (`INITiate:CONTinuous ON`), the trigger system of the sensor enters the waiting for trigger state. When the trigger condition is met, a new measurement is immediately started.

See also Section 11.4, "Controlling the measurement", on page 103.

Usage: Event

INITiate:ALL
INITiate[:IMMediate]

Starts a single measurement cycle. The sensor changes from the idle state to the waiting for trigger state. When the trigger condition is fulfilled, the sensor begins the measurement. Depending on the number of trigger events that are required, e.g. for averaging, the sensor enters the waiting for trigger state several times. Once the entire measurement is completed, a measurement result is available, and the sensor enters the idle state again.

Use this command only after the continuous measurement has been disabled using `INITiate:CONTinuous OFF`.

See also Section 11.4, "Controlling the measurement", on page 103.

Example: See Section 12.2, "Performing a buffered continuous average measurement", on page 161.

Usage: Event

INITiate:CONTinuous <state>

Enables or disables the continuous measurement. In a continuous measurement, the sensor does not go into the idle state after a measurement has been completed, but immediately executes another measurement cycle.

See also Section 11.4.2, "Triggering", on page 104.

Parameters:

<state>

ON
Measurements are performed continuously. If a measurement is completed, the sensor does not return to the idle state but enters the waiting for trigger state again.

OFF
Ends the continuous measurement, and sets the sensor to the idle state.

*RST: OFF

Example: See Section 12.2, "Performing a buffered continuous average measurement", on page 161.

11.4.2 Triggering

If you want to start the measurement only if a specific condition is fulfilled, define a trigger. For example, if a signal level is exceeded, or in certain time intervals.

Further information:
- Section 11.4.5, "Configuring the trigger", on page 110

11.4.2.1 Trigger states

The sensor has trigger states to define the exact start and stop time of a measurement and the sequence of a measurement cycle. The following states are defined:
- Idle
  The sensor performs no measurement. After powering on, the sensor is in the idle state.
- Waiting for trigger
  The sensor waits for a trigger event that is defined by the trigger source. When the trigger event occurs, the sensor enters the measuring state.
- Measuring
  The sensor is measuring data. It remains in this state during the measurement. When the measurement is completed, it exits this state immediately.

11.4.2.2 Waiting for a trigger event

Before a trigger can be executed, the sensor has to be set to the waiting for trigger state. Depending on the required number of measurement cycles, you use one of the following commands:
- `INITiate:CONTinuous`
  A new measurement cycle is started automatically after the previous one has been terminated.
- `INITiate[:IMMediate]`
  The number of measurement cycles is restricted.
  If `TRIGger:COUNt 1` is set, the command starts a single measurement cycle that renders one result. Every time you send this command, a new measurement cycle is started.
  Otherwise, as many measurement cycles are performed as determined by the trigger count.

11.4.2.3 Trigger sources

The possible trigger conditions and the execution of a trigger depend on the selected trigger source.

If the signal power exceeds or falls below a reference level set by the trigger level, the measurement is started after the defined delay time. Waiting for a trigger event can be skipped.

Trigger source	Description	Remote commands to initiate the measurement
"Hold"	Triggered by the remote command.	`TRIGger:IMMediate`
"Immediate"	Measures immediately, does not wait for a trigger condition.	-

Trigger source	Description	Remote commands to initiate the measurement
"Internal"	Uses the input signal as the trigger signal.	TRIGger:IMMediate
"External 1"	Uses the digital input signal supplied using a differential pair in the 8–pin sensor cable.	TRIGger:IMMediate
"External 2"	Supported for R&S NRPC-B1 verification sensors, but not applicable for R&S NRPC power standards.	TRIGger:IMMediate
"Bus"	Triggered by the remote command.	*TRG TRIGger:IMMediate

11.4.2.4 Dropout time

The dropout time is useful when dealing with signals with several active slots, for example GSM signals, see Figure 11-1. When measuring in sync with the signal, a trigger event is to be produced at A, but not at B or C.

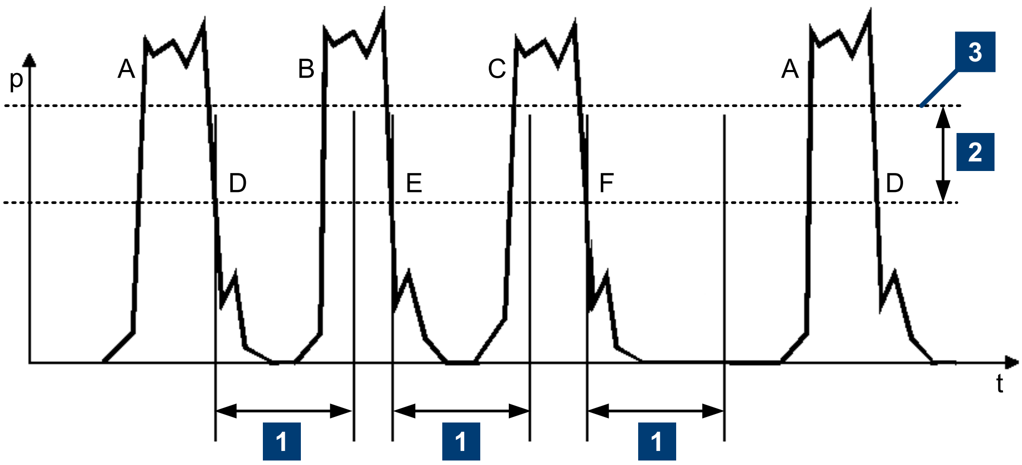


Figure 11-1: Significance of the dropout time

1 = Dropout time
2 = Trigger hysteresis
3 = Trigger level

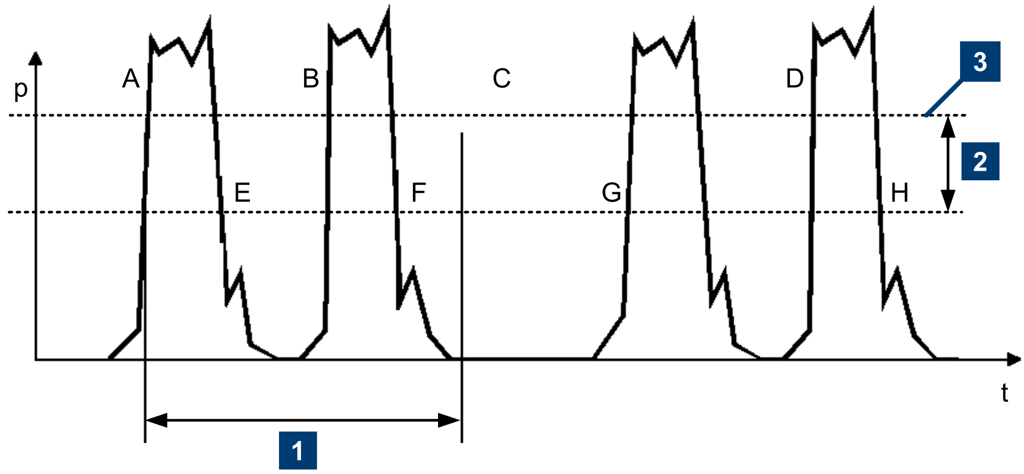
The RF power between the slots is below the threshold defined by the trigger level and the trigger hysteresis. Therefore, the trigger hysteresis alone cannot prevent triggering at B or at C. Therefore, set the dropout time greater than the time elapsed between points D and B and between E and C, but smaller than the time elapsed between F and A. Thus, you ensure that triggering takes place at A.

Because the mechanism associated with the dropout time is reactivated whenever the trigger threshold is crossed, you can also obtain unambiguous triggering for many complex signals.

If you use a holdoff time instead of a dropout time, you can obtain stable triggering conditions, regular triggering at the same point. But you cannot achieve exclusive triggering at A.

11.4.2.5 Holdoff time

During the holdoff time, a period after a trigger event, all trigger events are ignored.



1 = Holdoff time
2 = Trigger hysteresis
3 = Trigger level

11.4.3 Controlling the measurement results

The sensor can cope with the wide range of measurement scenarios with the help of the "termination control". Depending on how fast your measurement results change, you can define how the measurement results are output.

In a continuous average measurement, use `[SENSe<Sensor>:]AVERage:TCONtrol`.

Repeating termination control

Outputs a measurement result when the entire measurement has been completed. This means that the number of measurement cycle repetitions is equal to the set average count. If the average count is large, the measurement time can be long.

Useful if you expect slow changes in the results, and you want to avoid outputting redundant data.

Moving termination control

Outputs intermediate values to facilitate early detection of changes in the measured quantity. This means that for each partial measurement, a new average value is output as a measurement result. Thus, the measurement result is a moving average of the last partial measurements. How many of the partial measurements are averaged is defined by the average count.

Useful if you want to detect trends in the result during the measurement.

11.4.4 Interplay of the controlling mechanisms

In the following examples, continuous measurement scenarios are used. But these scenarios also apply to single measurements. The only difference is that a single measurement is not repeated.

11.4.4.1 Continuous average measurement

General settings for these examples:

- `INITiate:CONTinuous ON`
- `[SENSe<Sensor>:]AVERage:COUNt 4`
- `[SENSe<Sensor>:]AVERage:COUNt:AUTO OFF`

Example: Repeating termination control

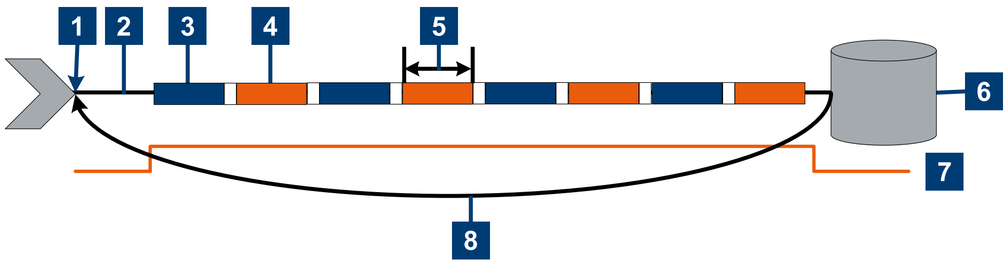
Further settings for this example:

- `[SENSe<Sensor>:]AVERage:TCONtrol REPeat`

The measurement is started by the trigger event.

Due to the chopper phases, one measurement lasts twice the defined aperture time.

As defined by the average count, after 4 measurements, the result is averaged and available. During the whole measurement cycle, the trigger synchronization is high (`TRIGger:SYNC:STATe ON`).



1 = Start of the measurement cycle
2 = Trigger event
3 = Noninverted chopper phase
4 = Inverted chopper phase
5 = Duration of one aperture time (1 x t_{AP}) ≙ length of one chopper phase
6 = Measurement result
7 = Trigger synchronization
8 = Return to the start of the measurement cycle

Example: Moving termination control

Further settings for this example:

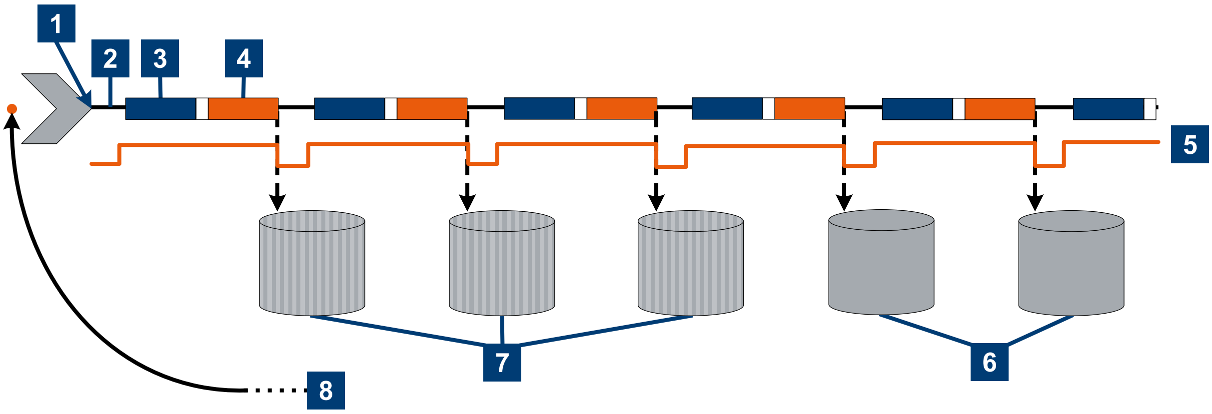
- [SENSe<Sensor>:]AVERage:TCONtrol MOVing
- TRIGger:COUNt 16

Every measurement is started by a trigger event.

Due to the chopper phases, one measurement lasts twice the defined aperture time.

During each measurement, the trigger synchronization is high (TRIGger:SYNC:STATe ON). Every measurement provides a result. During the settling phase, the amount of the result is already correct, but the noise is higher. After 4 measurements, when the average count is reached, settled data is available.

When the trigger count is reached (TRIGger:COUNt on page 111), the sensor returns to the idle state.

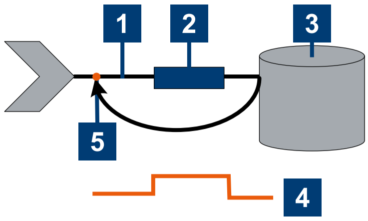


1 = Start of the measurement cycle
2 = Trigger events
3 = Noninverted chopper phase
4 = Inverted chopper phase
5 = Trigger synchronization
6 = Averaged measurement result after the average count is reached
7 = Measurement result before average count is reached
8 = Return to idle state after the trigger count (= 16 in this example) is reached

Example: Average count = 1

[SENSe<Sensor>:]AVERage:COUNt 1

For average count 1, the setting of the termination control has no impact. In both cases, the measurement runs for the duration of one aperture time. Then, settled data is available, and the sensor returns to the idle state.



1 = Trigger event
2 = Noninverted chopper phase
3 = Measurement result
4 = Trigger synchronization
5 = Return to idle state

11.4.5 Configuring the trigger

Further information:

- Section 11.4, "Controlling the measurement", on page 103

Remote commands:

TRIGger:ATRigger:DELay <delay>

Effective only if TRIGger:ATRigger[:STATe] is set to ON.

Sets the delay between the artificial trigger event and the beginning of the actual measurement

Parameters:

<delay>	Range:	0.1 s to 5.0 s
	*RST:	2.0 s
	Default unit:	s

TRIGger:ATRigger:EXECuted?

Queries the number of measurements that were triggered automatically since `TRIGger:ATRigger[:STATe]` was set to `ON`.

In normal scalar measurements, this number can only be 0 or 1. If a buffered measurement was executed, this number indicates how many results in the returned array of measurement data were executed without a real trigger event.

Usage: Query only

TRIGger:ATRigger[:STATe] <state>

Controls the automatic trigger function. If enabled, an artificial trigger is generated if the delay time has elapsed after the measurement start, and no trigger event has occurred.

The delay time is set using `TRIGger:ATRigger:DELay`.

Parameters:

<state>	*RST:	OFF

TRIGger:COUNt <count>

Sets the number of measurement cycles to be performed when the measurement is started using `INITiate[:IMMediate]`.

This number equals the number of results that can be obtained from the sensor after a single measurement. As long as the defined number of measurements is not executed, the sensor automatically initiates another measurement internally when the current result is available.

This command is particularly useful in conjunction with buffered measurements. For example, to fill a buffer with a predefined size with measurements that have been triggered externally or by `*TRG` without having to start the measurement multiple times.

Parameters:

<count>	Range:	1 to 8192
	*RST:	1

Example: See Section 12.2, "Performing a buffered continuous average measurement", on page 161.

TRIGger:DELay <delay>

Sets the delay between the trigger event and the beginning of the actual measurement (integration).

Note: In a continuous average measurement, a negative trigger delay is not supported.

Parameters:

<delay> Range: -5.0 s to 10.0 s
*RST: 0.0 s
Default unit: s

TRIGger:DELay:AUTO <state>

If `TRIGger:DELay:AUTO ON` is set, no measurement is started until the sensor has settled. For this purpose, the delay value is automatically determined.

If a longer period is set using `TRIGger:DELay`, the automatically determined delay is ignored.

Parameters:

<state> *RST: OFF

TRIGger:DTIMe <dropout_time>

Sets the dropout time for the internal trigger source. During this time, the signal power must exceed (negative trigger slope) or undercut (positive trigger slope) the level defined by the trigger level and trigger hysteresis. At least, this time must elapse before triggering can occur again.

See Section 11.4.2.4, "Dropout time", on page 106.

Parameters:

<dropout_time> Range: 0.00 s to 10.00 s
*RST: 0.00 s
Default unit: s

TRIGger:EXTernal<2...2>:IMPedance <impedance>

Effective only if `TRIGger:SOURce EXTernal2` is set.

Sets the termination resistance of the second external trigger input. Choose the setting that fits the impedance of the trigger source to minimize reflections on the trigger signals.

Suffix:

<2...2> 1..n

Parameters:

<impedance> HIGH | LOW

HIGH
~10 kΩ

LOW
50 Ω

*RST: HIGH

TRIGger:HOLDoff <holdoff>

Sets the holdoff time, see Section 11.4.2.5, "Holdoff time", on page 107.

Parameters:

<holdoff> Range: 0.00 s to 10.00 s
*RST: 0.00 s
Default unit: s

TRIGger:HYSTeresis <hysteresis>

Sets the hysteresis. A trigger event occurs, if the trigger level:

- Falls below the set value on a rising slope.
- Rises above the set value on a falling slope

Thus, you can use this setting to eliminate the effects of noise in the signal for the edge detector of the trigger system.

Parameters:

<hysteresis> Range: 0.00 dB to 10.00 dB
*RST: 0.00 dB
Default unit: dB

TRIGger:IMMediate

Causes a generic trigger event. The sensor leaves the waiting for trigger state immediately, irrespective of the trigger source and the trigger delay, and starts the measurement.

This command is the only way to start a measurement if the trigger source is set to hold, `TRIGger:SOURce HOLD`. Only one measurement cycle is executed, irrespective of the averaging factor.

Usage: Event

TRIGger:LEVel <level>

Effective only if `TRIGger:SOURce INTernal`.

Sets the trigger threshold for internal triggering derived from the test signal.

If the S-parameter and/or the offset correction are enabled, the trigger threshold is referenced to the correction data.

If the S-parameter and/or the offset correction are disabled, the trigger threshold and its input limits are adjusted as necessary.

Parameters:

<level> If you enter a value without unit, the unit is defined by `TRIGger:LEVel:UNIT`.

Range: 300e-9 W to 100.0e-3 W
*RST: 3.0e-5 W
Default unit: As defined by TRIGger:LEVel:UNIT.

TRIGger:LEVel:UNIT <unit>

Defines the unit of the trigger level if this value is entered without a unit. See also `TRIGger:LEVel` on page 113.

Parameters:

<unit> DBM | W | DBUV

*RST: W

TRIGger:SENDer:PORT <sender_port>

Effective only if the R&S NRPC is trigger sender:

- `TRIGger:SENDer:STATe ON`

Selects the port where the sensor outputs a digital trigger signal.

If the sensor is the trigger sender, it can output its trigger signal either on the `EXTernal<1>` or `EXTernal2`.

If the sensor triggers itself, the trigger source of the sensor must be assigned to the other external port, as shown in the examples.

Parameters:

<sender_port> EXT1 | EXTernal1 | EXT2 | EXTernal2

*RST: EXT1

Example:
```
TRIG:SEND:PORT EXT1
TRIG:SOUR EXT2
TRIG:SEND:STAT ON
```

Example:
```
TRIG:SEND:PORT EXT2
TRIG:SOUR EXT1
TRIG:SEND:STAT ON
```

TRIGger:SENDer:STATe <state>

Enables or disables the trigger sender mode of the sensor. In this state, the sensor can output a digital trigger signal in sync with its own trigger event.

If enabled, select the output port for the trigger signal using `TRIGger:SENDer:PORT`.

Typically, the trigger sender uses its internal trigger source. But you can also trigger the trigger sender externally, because the sensor has two external trigger connectors. If you trigger the trigger sender externally, use `EXTernal1` as external trigger input port (trigger source) and `EXTernal2` as trigger sender output port or vice versa.

Parameters:

<state> *RST: OFF

TRIGger:SLOPe <slope>

Effective only if `TRIGger:SOURce` is set to `INTernal` or `EXTernal`.

Determines which edge of the envelope power, with internal triggering, or increasing voltage, with external triggering, is used for triggering.

Parameters:

<slope> POSitive | NEGative

POSitive
Rising edge

NEGative
Falling edge

*RST: POSitive

TRIGger:SOURce <source>

Selects the source for the trigger event.

Parameters:

<source> HOLD | IMMediate | INTernal | BUS | EXTernal | EXT1 | EXTernal1 | EXT2 | EXTernal2

See Section 11.4.2.3, "Trigger sources", on page 105.

*RST: IMMediate

TRIGger:SYNC:PORT <sync_port>

Selects the external connection for the sync output of the sensor. For more information, see `TRIGger:SYNC:STATe`.

Parameters:

<sync_port> EXT1 | EXTernal1 | EXT2 | EXTernal2

*RST: EXT1

TRIGger:SYNC:STATe <state>

Available in the following measurements:

- Continuous average measurement if `TRIGger:SOURce IMMediate` is set.

Enable the synchronization state if you want to synchronize several sensors connected to a base unit. The synchronization works as follows.

The external trigger bus is blocked as long as a sensor is in the "measuring" state. The external trigger bus is enabled only when all sensors are in the "waiting for trigger" or "idle" state. Thus, the sensors start to measure simultaneously.

Make sure that the measurement time is the same for all sensors involved in the measurement. Otherwise, the trigger bus is blocked by any sensor that has completed its measurement before the others and has returned to the "idle" state.

1 = measurement time

During the measurement, the trigger synchronization is high.

For details on trigger states, see Section 11.4.2.1, "Trigger states", on page 105.

Parameters:
<state> *RST: OFF

11.5 Configuring the measurements

In the following, the settings needed for configuring a measurement are described.

Further information:
- Section 11.6, "Configuring basic measurement parameters", on page 118
- Section 11.4, "Controlling the measurement", on page 103
- Section 11.8, "Querying measurement results", on page 141

11.5.1 Continuous average measurement

In a continuous average measurement, the sensor measures the signal average power asynchronously within definable time intervals (sampling windows). The aperture (width of the sampling windows) can be defined.

Further information:
- Section 11.8, "Querying measurement results", on page 141

11.5.1.1 Defining the sampling window

[SENSe<Sensor>:][POWer:][AVG:]APERture <integration_time>

Sets the duration of the sampling window. During this time interval, the average signal power is measured.

Suffix:
<Sensor> 1

Parameters:

<integration_time>	Range:	0.5e-3 s to 0.3 s
	*RST:	0.005 s
	Default unit: s	

11.5.1.2 Reducing noise and zero offset

The smoothing filter can reduce result fluctuations caused by modulation. But activating it increases the inherent noise of the sensor by approx. 20 %, so do not activate if it unless required.

[SENSe<Sensor>:][POWer:][AVG:]SMOothing:STATe <state>

Enables or disables the smoothing filter, a steep-edge digital lowpass filter. If you cannot adjust the aperture time exactly to the modulation period, the filter reduces result fluctuations caused by modulation.

Suffix:

<Sensor>	1

Parameters:

<state>	ON | OFF	
	*RST:	OFF

Example: `SMO:STAT OFF`

11.5.1.3 Measuring modulated signals

When measuring modulated signals in a continuous average measurement, the measurement can show fluctuation due to the modulation. If that is the case, adapt the size of the sampling window exactly to the modulation period to get an optimally stable display. If the modulation period varies or is not precisely known, you can also activate the smoothing function.

With smoothing activated, the selected sampling window has to be 5 to 9 times larger than the modulation period so that the fluctuations caused by modulation are sufficiently reduced. The sampling values are subjected to weighting (raised-von-Hann window), which corresponds to video filtering.

If you deactivate the smoothing filter, 300 to 3000 periods are required to obtain the same effect. The sampling values are considered equivalent and are averaged in a sampling window, which yields an integrating behavior of the measuring instrument. To obtain optimum suppression of variations in the result, exactly adapt the modulation period to the size of the sampling window. Otherwise, the modulation can have a considerable influence, even if the sampling window is larger than the modulation period.

11.5.1.4 Calculating the measurement time

Normally, the measurement time is calculated as follows:

$MT = 2 * AC * APER + (2 * AC - 1) * 100\ \mu s$

With:

MT: overall measurement time

AC: average count

APER: aperture time

100 µs is the time for switching the chopper phase.

11.6 Configuring basic measurement parameters

The following section describes the settings common for several measurements.

11.6.1 Configuring auto averaging

Describes the automatic averaging commands for the following measurements:

- Continuous average measurement

Remote commands:

[SENSe<Sensor>:]AVERage:COUNt <count>

Sets the number of readings that are averaged for one measured value. The higher the count, the lower the noise, and the longer it takes to obtain a measured value.

Average count is often also called averaging factor, but it designates the same thing, i.e. the number of measured values that have to be averaged for forming the measurement result.

Averaging is only effective if `[SENSe<Sensor>:]AVERage[:STATe] ON` is set.

Suffix:

<Sensor>	1

Parameters:

<count>	Range:	1 to 65536
	*RST:	4

Example: `AVER:COUN 1`

[SENSe<Sensor>:]AVERage:COUNt:AUTO <state>

Sets how the average count is determined.

Suffix:
<Sensor> 1

Parameters:
<state>

ON
Auto averaging: the averaging factor is continuously determined and set depending on the power level and other parameters.

OFF
Fixed filter: the previous, automatically determined averaging factor is used.

ONCE
Automatically determines an averaging factor under the current measurement conditions. Then changes to the fixed filter setting (see `OFF`) and uses this averaging factor.

*RST: ON

[SENSe<Sensor>:]AVERage:COUNt:AUTO:MTIMe <maximum_time>

Sets an upper limit for the settling time of the auto-averaging filter if `[SENSe<Sensor>:]AVERage:COUNt:AUTO:TYPE` is set to `NSRatio`. Thus it limits the length of the filter.

If auto-averaging exceeded the maximum time, a notice is issued.

Suffix:
<Sensor> 1

Parameters:
<maximum_time>
Range: 0.01 s to 999.99 s
*RST: 4.00 s
Default unit: s

[SENSe<Sensor>:]AVERage:COUNt:AUTO:NSRatio <nsr>

Determines the relative noise component in the measurement result for the measurements with scalar results. These measurements are the continuous average, burst average and timeslot measurements, provided the particular sensor supports them.

This command is only effective if the auto average calculation is enabled:

- `[SENSe<Sensor>:]AVERage:COUNt:AUTO ON`
- `[SENSe<Sensor>:]AVERage:COUNt:AUTO:TYPE NSR`

The noise component is defined as the magnitude of the level variation in dB caused by the inherent noise of the sensor (two standard deviations).

The query returns the relative noise component in the measured value.

Suffix:
<Sensor> 1

Parameters:
<nsr> Range: 100.000e-6 dB to 1.00 dB
*RST: 0.01 dB
Default unit: dB

[SENSe<Sensor>:]AVERage:COUNt:AUTO:RESolution <resolution>

Defines the number of significant places for linear units and the number of decimal places for logarithmic units that are likely free of noise in the measurement result.

The setting is only considered if the following applies:

- `[SENSe<Sensor>:]AVERage:COUNt:AUTO` ON
- `[SENSe<Sensor>:]AVERage:COUNt:AUTO:TYPE` RES

Suffix:
<Sensor> 1

Parameters:
<resolution> Range: 1 to 4
*RST: 3

[SENSe<Sensor>:]AVERage:COUNt:AUTO:TYPE <type>

Sets the automatic averaging filter.

Suffix:
<Sensor> 1

Parameters:
<type> RESolution | NSRatio

RESolution
Usually used.

NSRatio
Predefines the compliance to an exactly defined noise component. Enter this value using `[SENSe<Sensor>:]AVERage:COUNt:AUTO:NSRatio`.

*RST: RESolution

[SENSe<Sensor>:]AVERage:RESet

Deletes all previous measurement results that the averaging filter contains and initializes the averaging filter. The filter length gradually increases from 1 to the set averaging factor. Thus, trends in the measurement result become quickly apparent. Note that the measurement time required for the averaging filter to settle completely remains unchanged.

Use this command if:

- High averaging factor is set.
  [SENSe<Sensor>:]AVERage:COUNt
- Intermediate values are output as measurement results.
  [SENSe<Sensor>:]AVERage:TCONtrol MOVing
- Power has significantly decreased since the previous measurement, for example by several powers of 10.

In this situation, previous measurement results, which are still contained in the averaging filter, strongly affect the settling of the display. As a result, the advantage of detecting trends in the measurement result while the measurement is still in progress is lost.

Suffix:
<Sensor> 1

Example: AVER:RES

Usage: Event

[SENSe<Sensor>:]AVERage[:STATe] <state>

Available in the following measurements:

- Continuous average measurement

Enables or disables the averaging filter.

Suffix:
<Sensor> 1

Parameters:
<state> *RST: ON

[SENSe<Sensor>:]AVERage:TCONtrol <mode>

Defines how the measurement results are output. This is called termination control.

See also Section 11.4.3, "Controlling the measurement results", on page 107.

Suffix:
<Sensor> 1

Parameters:
<mode> MOVing | REPeat

MOVing
Outputs intermediate values to facilitate early detection of changes in the measured quantity. In the settled state that means when the number of measurements specified by the average count has been performed, a moving average is output.

REPeat
Specifies that a measurement result is not output until the entire measurement has been completed. This means that the number of measurement cycle repetitions is equal to the set average count. If the average count is large, the measurement time can be long.
The average count is set using `[SENSe<Sensor>:]AVERage:COUNt` on page 118.

*RST: REPeat

Example: `AVER:TCON REP`

11.6.2 Setting the frequency

The frequency of the signal to be measured is not automatically determined. For achieving better accuracy, the carrier frequency of the applied signal must be set.

[SENSe<Sensor>:]FREQuency <frequency>

Transfers the carrier frequency of the RF signal to be measured. This frequency is used for the frequency response correction of the measurement result.

The center frequency is set for broadband signals, e.g. spread spectrum signals, multicarrier signals.

Suffix:
<Sensor> 1

Parameters:
<frequency> Range: 0.0 Hz to Depends on the model. See the specifications document.
*RST: 50.0e6 Hz
Default unit: Hz

Example: `FREQ 18000000`

11.6.3 Configuring corrections

It is possible to set some parameters that compensate for a change of the measured signal due to fixed external influences.

11.6.3.1 Duty cycle corrections

The duty cycle is the percentage of one period during which the signal is active, when pulse-modulated signals are corrected. The duty cycle is only evaluated in the continuous average measurement.

Remote commands:

[SENSe<Sensor>:]CORRection:DCYCle <duty_cycle>

Available in a continuous average measurement.

Sets the duty cycle for measuring pulse-modulated signals. The duty cycle defines the percentage of one period during which the signal is active. If the duty cycle is enabled, the sensor considers this percentage when calculating the signal pulse power from the average power.

Suffix:

<Sensor>	1	

Parameters:

<duty_cycle>	Range:	0.001 percent to 100.00 percent
	*RST:	1.00 percent
	Default unit:	PCT

[SENSe<Sensor>:]CORRection:DCYCle:STATe <state>

Enables or disables the duty cycle correction for the measured value.

Suffix:

<Sensor>	1	

Parameters:

<state>	*RST:	OFF

11.6.3.2 Offset corrections

The offset accounts for external losses by adding a fixed level offset in dB.

Using S-parameters instead of a fixed offset allows more precise measurements, because the interaction between the sensor and the component can be considered. See also Section 11.6.3.3, "S-parameter correction", on page 124.

Remote commands:

[SENSe<Sensor>:]CORRection:OFFSet <offset>

Sets a fixed offset that is added to correct the measured value.

Suffix:
<Sensor> 1

Parameters:
<offset> Range: -200.00 dB to 200.00 dB
*RST: 0 dB
Default unit: dB

[SENSe<Sensor>:]CORRection:OFFSet:STATe <state>

Enables or disables the offset correction.

Suffix:
<Sensor> 1

Parameters:
<state> *RST: OFF

Example: `CORR:OFFS:STAT ON`

11.6.3.3 S-parameter correction

S-parameter correction compensates for the losses and reflections introduced by a component — such as an attenuator, directional coupler, or matching pad — that is attached to a sensor. Using S-parameters instead of a fixed offset increases measurement accuracy by accounting for the interaction between the sensor and the component. It shifts the reference plane of the sensor from its RF connector to the input of the device that is being applied externally.

The S-parameter correction works differently for the power standard than for the verification sensor. The power standard allows compensating for the influence of any two-port device between the power standard test port and signal sink (DUT). The verification sensor allows compensating for the influence of any two-port device between the signal source and the sensor input. As a result, the firmware can calculate the power that the power standard test port/signal source actually delivers. Examples of such two-port devices include attenuators, matching pads, minimum-loss pads and waveguide adapters. One precondition for such compensation is that you provide a complete set of S-parameter data for the two-port device in the frequency range required by the application.

Configuring the S-parameter correction

[SENSe<Sensor>:]CORRection:SPDevice:LIST?

Queries the list of the S-parameter data sets that have been downloaded to the sensor. Returns the consecutive number and mnemonic of each data set, separated by line feeds.

Suffix:
<Sensor> 1

Usage: Query only

[SENSe<Sensor>:]CORRection:SPDevice:SELect <num>

Selects a downloaded data set for S-parameter correction.

Suffix:
<Sensor> 1

Parameters:
<num> Range: 1 to 1999
*RST: 1; can differ if a calibration set defines another value.

[SENSe<Sensor>:]CORRection:SPDevice:STATe <state>

Enables or disables the S-parameter correction. If activated, uses the S-parameter data set selected by [SENSe<Sensor>:]CORRection:SPDevice:SELect.

Suffix:
<Sensor> 1

Parameters:
<state> *RST: OFF; can differ if a calibration set defines another value.

Example:
```
CORR:SPD:SEL 1
```
Selects an S-parameter correction data set.
```
CORR:SPD:STAT ON
```
Enables the S-parameter correction.

11.6.3.4 S-gamma corrections

The S-gamma correction works differently for the power standard than for the verification sensor.

Power standard

Using the complex reflection coefficient, you can determine the power delivered by the power standard test port with considerably greater accuracy.

The coefficient of the signal sink Γ_{Sink} is defined by its magnitude and phase:

- [SENSe<Sensor>:]SGAMma:MAGNitude
- [SENSe<Sensor>:]SGAMma:PHASe

The complex reflection coefficient Γ_{NRPC} of the power standard, which is also required for the correction, is prestored in the calibration data memory for many frequencies.

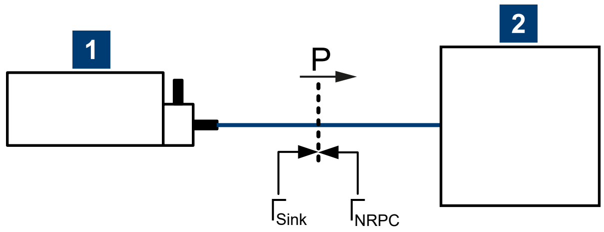


Figure 11-2: Correction of interactions between power standard test port and signal sink (DUT)

1 = R&S NRPC power standard
2 = Sink

If the gamma correction is performed in combination with an S-parameter correction ([SENSe<Sensor>:]CORRection:SPDevice:STATe ON), the following is considered:

- Interaction of the signal sink with the S-parameter device reflection of port 1, expressed by S_{11}.
- Interaction of the signal sink with input of the power standard test port, depending on the transmission, expressed by the term $S_{12}S_{21}$.

If the S-parameter correction is enabled, the interaction between the complex reflection coefficient Γ_{NRPC} of the power standard and the reflection of port 2, expressed by S_{22}, is always considered, regardless whether gamma correction is performed or not. See Figure 11-3.

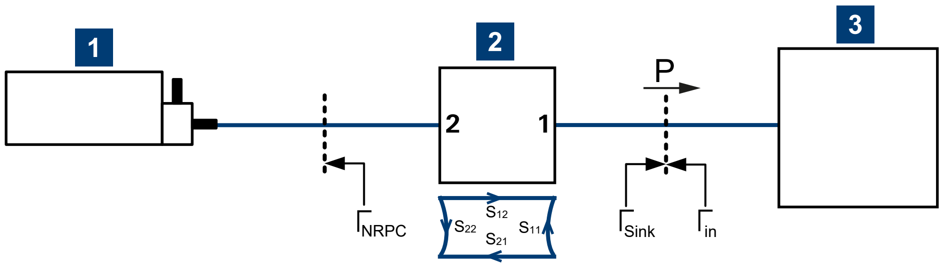


Figure 11-3: Correction of interactions between power standard test port, S-parameter device and signal sink (DUT)

1 = R&S NRPC power standard
2 = S-parameter device
3 = Sink

Verification sensor

Using the complex reflection coefficient, you can determine the power delivered by the signal source with considerably greater accuracy.

The coefficient of the signal source Γ_{Source} is defined by its magnitude and phase:

- [SENSe<Sensor>:]SGAMma:MAGNitude
- [SENSe<Sensor>:]SGAMma:PHASe

The complex reflection coefficient Γ_{Sensor} of the sensor, which is also required for the correction, is prestored in the calibration data memory for many frequencies.

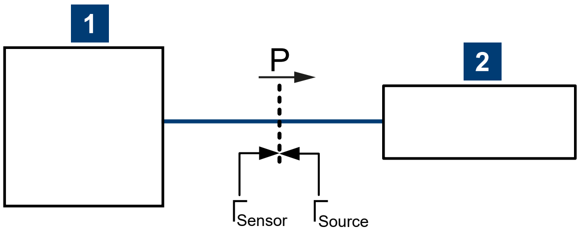


Figure 11-4: Correction of interactions between signal source and sensor

1 = Signal source
2 = Sensor

If the gamma correction is performed in combination with an S-parameter correction (`[SENSe<Sensor>:]CORRection:SPDevice:STATe ON`), the following is considered:

- Interaction of the signal source with the S-parameter device reflection of port 1, expressed by S_{11}.
- Interaction of the signal source with input of the sensor, depending on the transmission, expressed by the term $S_{12}S_{21}$.

If the S-parameter correction is enabled, the interaction between the complex reflection coefficient Γ_{Sensor} of the sensor and the reflection of port 2, expressed by S_{22}, is always considered, regardless whether gamma correction is performed or not. See Figure 11-5.

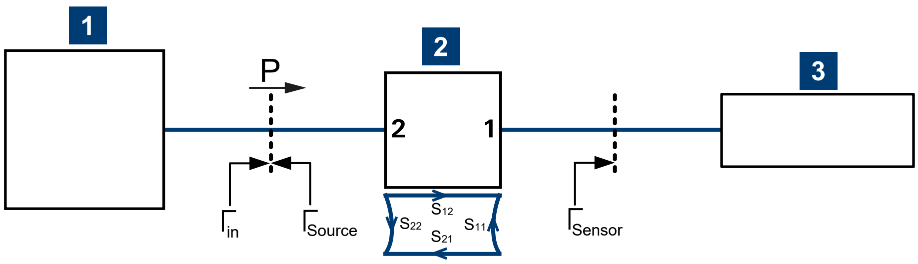


Figure 11-5: Correction of interactions between signal source, S-parameter device and sensor

1 = Signal source
2 = S-parameter device
3 = Sensor

Remote commands:

[SENSe<Sensor>:]SGAMma:CORRection:STATe <state>

Power standard:

Enables or disables the use of the complex reflection coefficient to correct the interactions of sensor test port and signal sink (DUT).

Verification sensor:

Enables or disables the use of the complex reflection coefficient to correct the interactions of sensor and signal source.

Suffix:
<Sensor> 1

Parameters:
<state> *RST: OFF

[SENSe<Sensor>:]SGAMma:MAGNitude <magnitude>

Power standard:

Sets the magnitude of the complex reflection coefficient of the sink, Γ_{sink}.

Verification sensor:

Sets the magnitude of the complex reflection coefficient of the source, Γ_{source}.

Suffix:
<Sensor> 1

Parameters:
<magnitude> 0.0 ≙ ideal matched source
1.0 ≙ total reflection
Range: 0.0 to 1.0
*RST: 0.0

[SENSe<Sensor>:]SGAMma:PHASe <phase>

Power standard:

Sets the phase angle of the complex reflection coefficient of the sink, Γ_{sink}.

Verification sensor:

Sets the phase angle of the complex reflection coefficient of the source, Γ_{source}.

Suffix:
<Sensor> 1

Parameters:
<phase> Range: -360.0 degrees to 360.0 degrees
*RST: 0.0 degrees
Default unit: degrees

11.6.3.5 I-gamma queries

For the current frequency, queries the complex input reflection coefficient Γ_{in} of the following:

- Sensor if the S-parameter correction is disabled.
(`[SENSe<Sensor>:]SGAMma:CORRection:STATe OFF`)

- S-parameter device if the S-parameter correction is enabled.
  ([SENSe<Sensor>:]SGAMma:CORRection:STATe ON)

[SENSe<Sensor>:]IGAMma:MAGNitude?

Queries the magnitude of the complex input reflection coefficient Γ_{in}.

Suffix:
<Sensor> 1

Example: `IGAM:MAGN?`
Query
`1.739179E-02`
Response

Usage: Query only

[SENSe<Sensor>:]IGAMma:PHASe?

Queries the phase angle of the complex input reflection coefficient Γ_{in}. The result is provided in degrees. Range: -180 degrees to +180 degrees.

Suffix:
<Sensor> 1

Example: `IGAM:PHAS?`
Query
`-1.327654E+02`
Response

Usage: Query only

[SENSe<Sensor>:]IGAMma:EUNCertainty?

Queries the expanded (k = 2) uncertainty of the magnitude of the complex input reflection coefficient Γ_{in}. Following gamma correction, the residual mismatch uncertainty becomes so small that it is practically negligible.

Suffix:
<Sensor> 1

Example: `IGAM:EUNC?`
Query
`5.000000E-03`
Response

Usage: Query only

11.6.3.6 Using the S-Parameters program

The S-Parameters program helps loading an S-parameter table into the sensor. The S-Parameters program is part of the R&S NRP-Toolkit, see Section 5.2.1, "R&S NRP-Toolkit", on page 28.

To start the S-Parameters program

► In Windows, search for "S-Parameter Update Multi".

User interface of the S-Parameters program

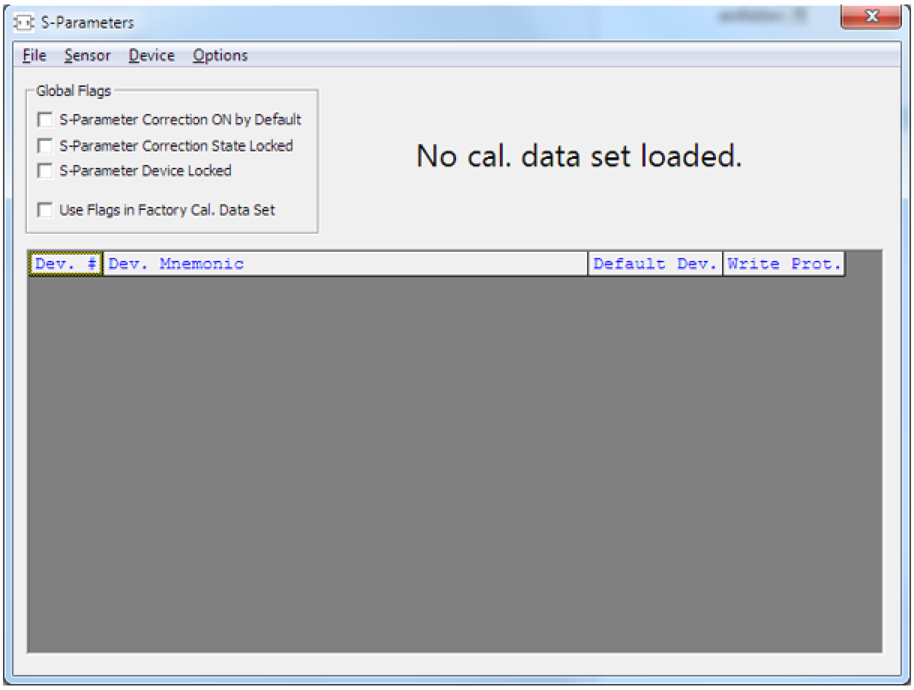


Figure 11-6: S-Parameters dialog

Menu bar
Contains the following submenus.

File ← Menu bar
Provides options for loading and saving calibration data files, see:
- "To change the S-parameter data" on page 135
- "To load an uncertainty parameter file" on page 136

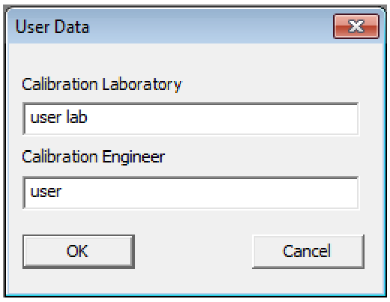
Sensor ← Menu bar
Provides options for loading and saving calibration data directly from or to the sensor, see:
- "To load a calibration data set from a sensor" on page 133
- "To save the calibration data on the sensor" on page 137

Device ← Menu bar
Provides functions for editing the table of S-parameter devices.

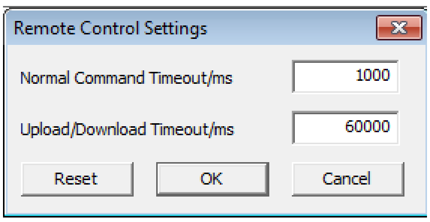
Options ← Menu bar
Provides functions for editing user data, changing remote control timeouts, and displaying calibration data as plain text.

User Data ← Options ← Menu bar
Opens the "User Data" dialog.

Here, you can enter the name of the calibration laboratory and the calibration engineer that is stored in the calibration data set if changes are made.



Remote ← Options ← Menu bar
Opens the "Remote Control Settings" dialog. It is normally not necessary to change timeouts.



Show Cal. Data ← Options ← Menu bar
Displays the content of the calibration data set that has been loaded either from a file of directly from a sensor as a plain text.

You can copy the text output to the clipboard by clicking "Copy to Clipboard."

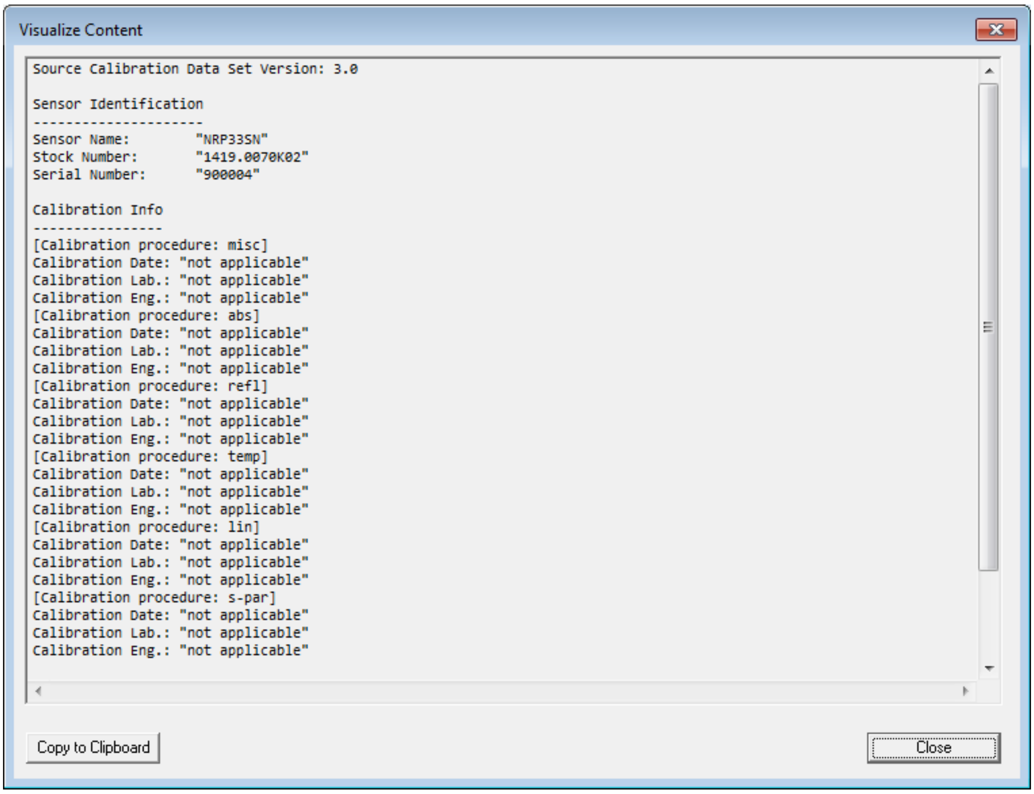


Figure 11-7: Example

Global Flags

Groups the settings for the sensor behavior regarding S-parameter corrections.

S-Parameter Correction ON by Default ← Global Flags

If this option is enabled, the S-parameter correction is activated automatically when the sensor is started.

S-Parameter Correction State Locked ← Global Flags

If enabled, the state that is selected with "S-Parameter Correction ON by Default" is locked and cannot be changed using:

- `[SENSe<Sensor>:]CORRection:SPDevice:STATe`
- Base unit

S-Parameter Device Locked ← Global Flags

If enabled, the S-parameter device that is selected as the default device in the table of S-parameter devices is locked and cannot be changed using:

- `[SENSe<Sensor>:]CORRection:SPDevice:SELect`
- Base unit

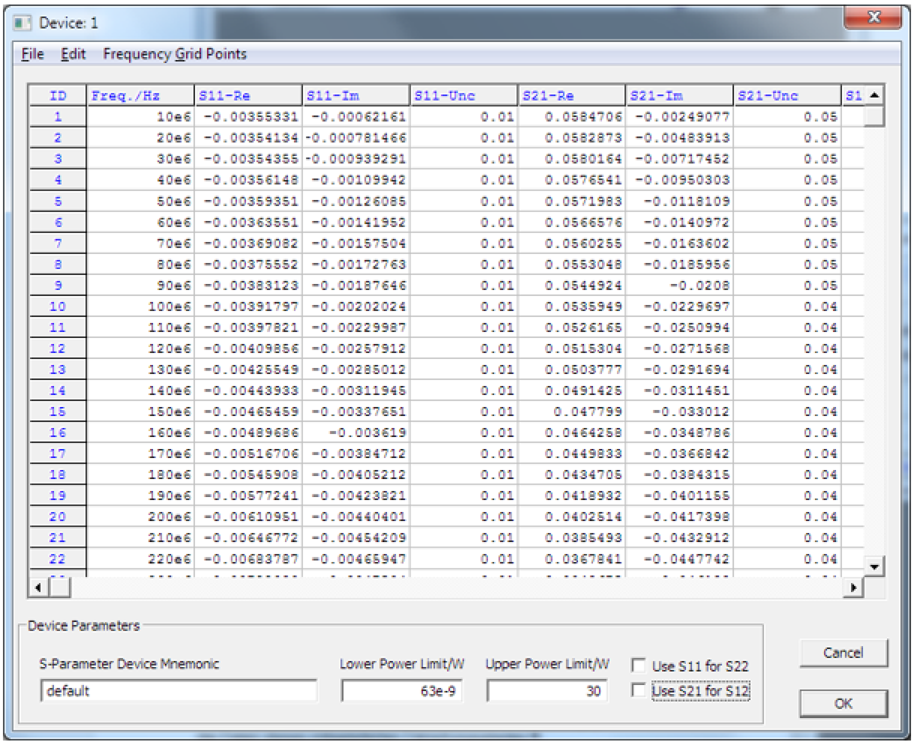
The default S-parameter device is the S-parameter device that you have selected when the sensor is started.

Use Flags in Factory Cal. Data Set ← Global Flags
Available if the sensor supports two different calibration data sets:
- Factory calibration data set containing all factory calibration data.
- User calibration data set that contains the S-parameter devices you have loaded.

Note: After you have added S-parameter devices and configured the global flags, disable this option. Otherwise, it is not possible to enable S-parameter correction because the flags in the factory calibration data set prevent it.

Device table
Shows a list of all S-parameter devices that are available in the calibration data set.

If you double-click an entry, a dialog for the device is opened that allows to import, export, and edit S-parameter data. See "To change the S-parameter data" on page 135.



ID	Freq./Hz	S11-Re	S11-Im	S11-Unc	S21-Re	S21-Im	S21-Unc	S1
1	10e6	-0.00355331	-0.00062161	0.01	0.0584706	-0.00249077	0.05	
2	20e6	-0.00354134	-0.000781466	0.01	0.0582873	-0.00483913	0.05	
3	30e6	-0.00354355	-0.000939291	0.01	0.0580164	-0.00717452	0.05	
4	40e6	-0.00356148	-0.00109942	0.01	0.0576541	-0.00950303	0.05	
5	50e6	-0.00359351	-0.00126085	0.01	0.0571983	-0.0118109	0.05	
6	60e6	-0.00363551	-0.00141952	0.01	0.0566576	-0.0140972	0.05	
7	70e6	-0.00369082	-0.00157504	0.01	0.0560255	-0.0163602	0.05	
8	80e6	-0.00375552	-0.00172763	0.01	0.0553048	-0.0185956	0.05	
9	90e6	-0.00383123	-0.00187646	0.01	0.0544924	-0.0208	0.05	
10	100e6	-0.00391797	-0.00202024	0.01	0.0535949	-0.0229697	0.04	
11	110e6	-0.00397821	-0.00229987	0.01	0.0526165	-0.0250994	0.04	
12	120e6	-0.00409856	-0.00257912	0.01	0.0515304	-0.0271568	0.04	
13	130e6	-0.00425549	-0.00285012	0.01	0.0503777	-0.0291694	0.04	
14	140e6	-0.00443933	-0.00311945	0.01	0.0491425	-0.0311451	0.04	
15	150e6	-0.00465459	-0.00337651	0.01	0.047799	-0.033012	0.04	
16	160e6	-0.00489686	-0.003619	0.01	0.0464258	-0.0348786	0.04	
17	170e6	-0.00516706	-0.00384712	0.01	0.0449833	-0.0366842	0.04	
18	180e6	-0.00545908	-0.00405212	0.01	0.0434705	-0.0384315	0.04	
19	190e6	-0.00577241	-0.00423821	0.01	0.0418932	-0.0401155	0.04	
20	200e6	-0.00610951	-0.00440401	0.01	0.0402514	-0.0417398	0.04	
21	210e6	-0.00646772	-0.00454209	0.01	0.0385493	-0.0432912	0.04	
22	220e6	-0.00683787	-0.00465947	0.01	0.0367841	-0.0447742	0.04	

Performing configuration tasks

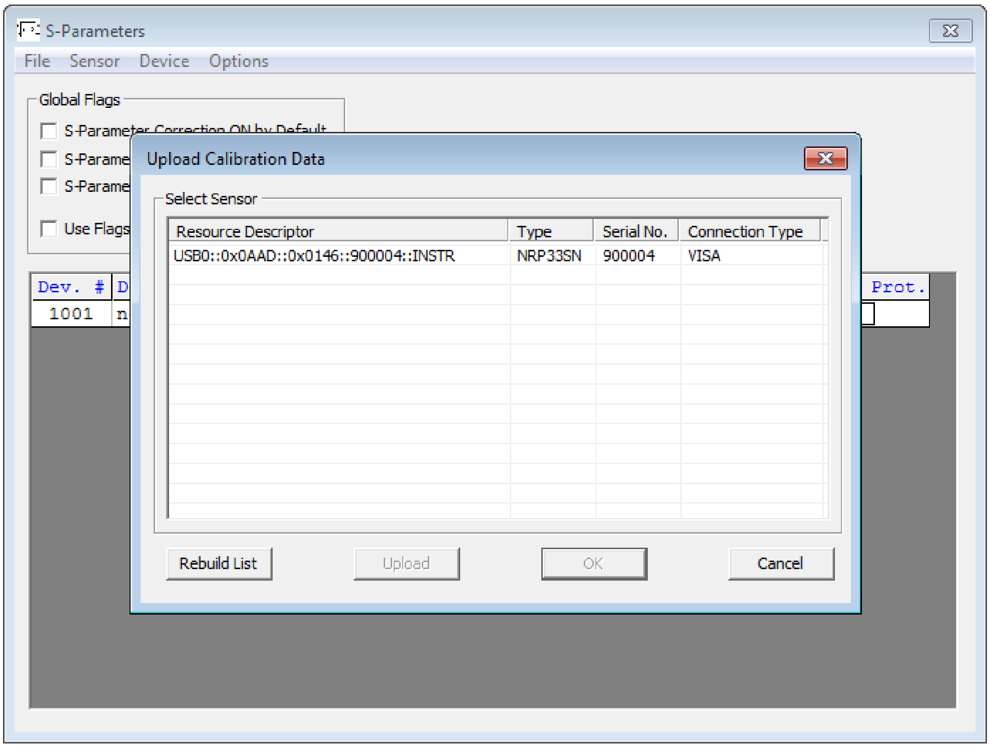
In this section, different configuration tasks performed with the sensor and the "S-Parameter Update Multi" tool are described.

To load a calibration data set from a sensor

Prerequisites: The sensor is connected to the computer and a connection is established.

1. Open the "S-Parameter Update Multi" program.
2. Select "Sensor" > "Load Calibration Data".

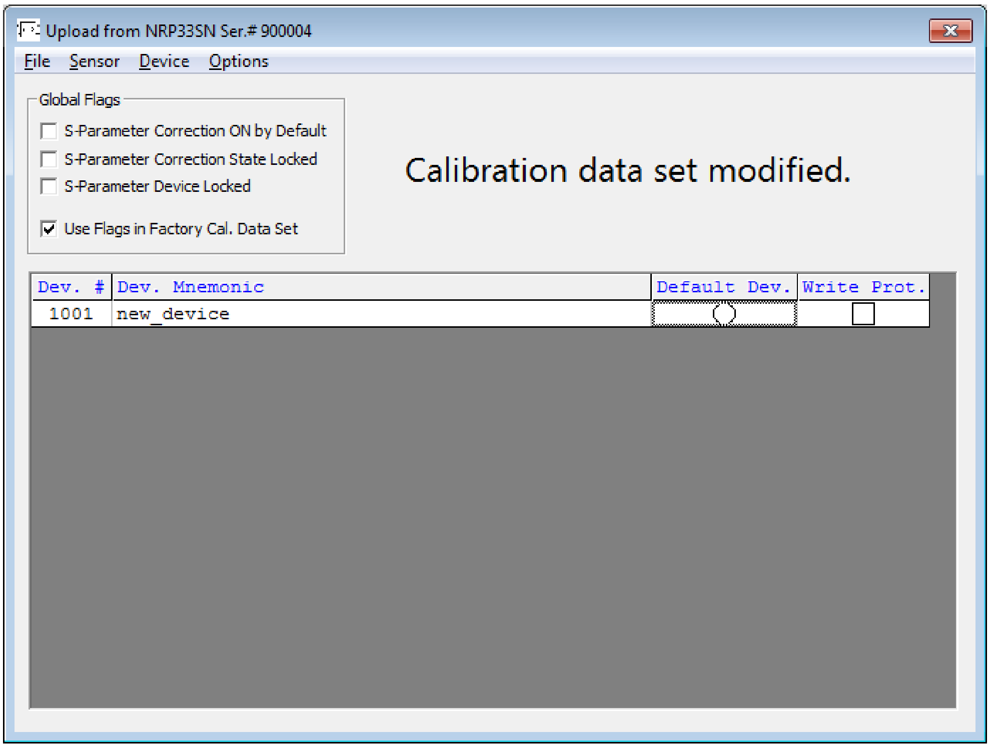
The "Upload Calibration Data" dialog opens. It shows a list of the available sensors.



3. If you cannot find your sensor in the list, for example because of reconnecting the sensor, you can reload the list by clicking "Rebuild List".
4. Click "Upload" to load calibration data from the sensor.

   After the upload is finished, the "OK" button is enabled.
5. Click "OK" to apply the changes.
   If you want to discard the changes, exit the dialog by clicking "Cancel".

   After a successful upload, the name and serial number are shown in the name of the main dialog.



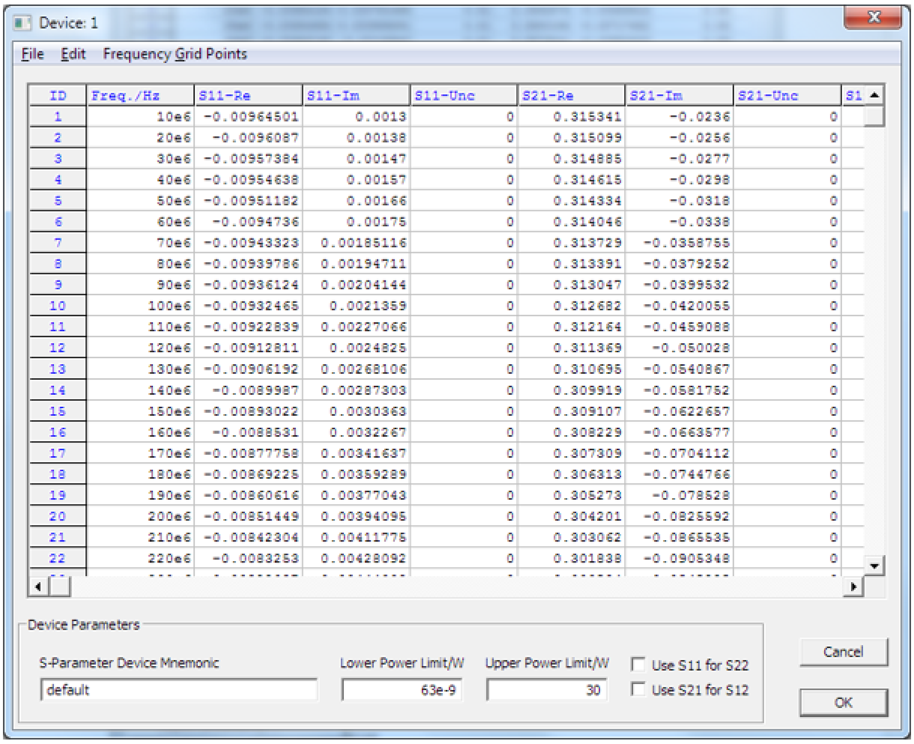
6. Create a backup of the calibration data set before making any changes.
   Select "File" > "Save Calibration Data".

   A dialog opens where you can select the location to save the calibration data.

To change the S-parameter data

1. In the device table, double-click an entry. See also "Device table" on page 133.
2. Select "File" > "Import S2P".
3. Select the `*.S2P` file that you want to import.
4. Confirm with "Open".

   The data from the selected file is loaded in the device table.
   All uncertainties are set to zero.



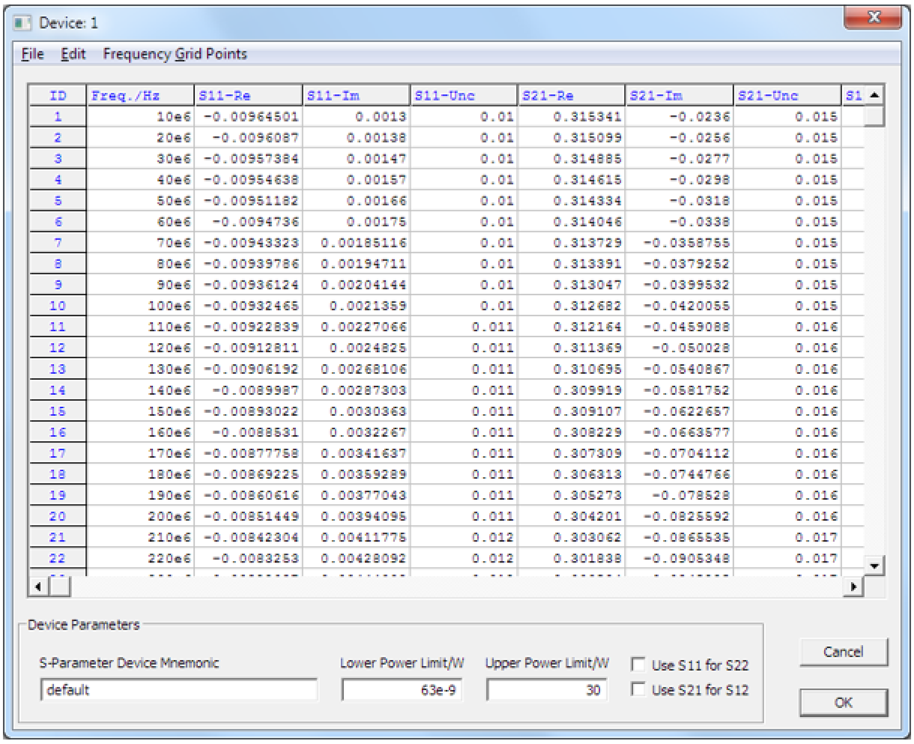
5. If needed, load uncertainty data. See "To load an uncertainty parameter file" on page 136.
6. Check the entries in the "S-Parameter Device Mnemonic", "Lower Power Limit/W" and "Upper Power Limit/W" fields
7. If necessary, change the entries.

   For example, the lower and upper power limits are deduced from the power limits of the sensor itself and the minimum attenuation of the S-parameter device. If the "Upper Power Limit/W" entry is higher than the power dissipation rating of the attenuator, reduce it accordingly.
8. Click "OK" to apply the changes.
   If you want to discard the change, click "Cancel".

To load an uncertainty parameter file

1. In the device table, double-click an entry. See also "Device table" on page 133.
2. Select "File" > "Import uncertainties".
3. Select the file that you want to import.
4. Confirm with "Open".

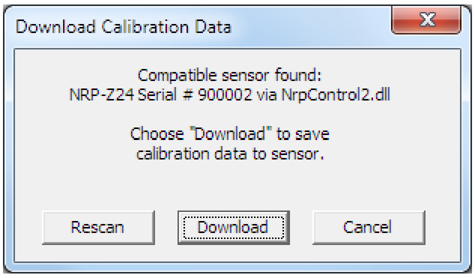
   The data from the selected file is loaded in the device table.



To save the calibration data on the sensor

1. Select "Sensor" > "Save Calibration Data".

   The "Download Calibration Data" dialog opens.

2. Confirm that the correct sensor is selected by clicking "Download".

   After a successful transfer of the data to the sensor, a confirmation message is displayed.
   The sensor can be used with the new S-parameter data.

S2P measurement data files

S2P files are human-readable text files that contain header information and the complex S-parameters of the device under test in columns. This section briefly describes the format of the S2P file.

An S2P measurement data file has the following structure (square brackets indicate that the enclosed content is optional):

- **Option line**
  The option line has the format *#[<frequency unit>][<parameter>][<format>][<R n>]*, where:
  - #
    Identifies the option line.
  - *<frequency unit>*
    Possible values are Hz, kHz, MHz or GHz. If a frequency unit is not specified, GHz is implicitly assumed.
  - *<parameter>*
  - *<format>*
    Possible values are MA (linear magnitude and phase in degree), DB (magnitude in dB, phase in degree) or RI (real and imaginary part). If a format is not specified, MA is implicitly assumed.
  - *<R n>*
    R is optional and followed by the reference impedance in Ω. If no entry is made, R50 is implicitly assumed.

  The option line therefore reads:
  # [HZ | KHZ | MHZ | GHZ] [S] [MA | DB | RI] [R 50].
- **Measurement frequencies**
  The measurement frequencies are listed in ascending order and are specified as follows:
  Where f_i is the i-th frequency and $s_{jk}(f_i)$ is the display format as specified in the option line:
  - $|s_{jk}(f_i)| \arg s_{jk}(f_i)$
    Display format for linear magnitude and phase in degree (MA)
  - $20.lg| s_{jk}(f_i)| \arg s_{jk}(f_i)$
    Display format for magnitude in dB and phase in degree (DB)
  - $Re|s_{jk}(f_i)| Im|s_{jk}(f_i)|$
    Display format for real and imaginary part (RI)
- **Comments**
  Any line starting with an exclamation mark (*!*) is interpreted as a comment line.

Uncertainty data files

An uncertainty data file has the following structure (square brackets indicate that the enclosed content is optional):

- **Option line**
  The option line has the format *#[<frequency unit>]<parameter>[<format>][<R n>]*, where:
  - #
    Identifies the option line.
  - *<frequency unit>*
    Possible values are Hz, kHz, MHz or GHz. If a frequency unit is not specified, GHz is implicitly assumed.
  - *<parameter>*

U must be specified for uncertainty data files. If a parameter is not specified, S is implicitly assumed and as a result an error message is triggered.

– *<format>*
  This value is ignored in uncertainty measurement files. The entry is therefore irrelevant.
– *<R n>*
  R is optional and followed by the reference impedance in Ω. If no entry is made, R50 is implicitly assumed.

The option line therefore reads:
[HZ | KHZ | MHZ | GHZ] U [MA | DB | RI] [R 50].

- **Measurement frequencies**
  The measurement frequencies are listed in ascending order and are specified as follows:
  f_i $unc[s_{11}(f_i)]$ $unc[s_{21}(f_i)]$ $unc[s_{12}(f_i)]$ $unc[s_{22}(f_i)]$
  Where f_i is the i-th frequency and $unc[s_{jk}(f_i)]$ is the uncertainty of the S-parameters that is forwarded as follows:
  – As extended absolute uncertainty (k = 2) for the magnitude of reflection parameters s_{11} and s_{22}
  – As extended uncertainties (k = 2) in dB for the magnitude of transmission parameters s_{21} and s_{12}
- **Comments**
  Any line starting with an exclamation mark (*!*) is interpreted as a comment line.

11.7 Configuring measurement results

See also:

- Section 11.8, "Querying measurement results", on page 141

11.7.1 Setting the power unit

The `UNIT` subsystem contains commands for setting up the power unit.

UNIT:POWer <unit>

Sets the output unit for the measured power values.

Parameters:

<unit> DBM | W | DBUV
*RST: W

Example: `UNIT:POW DBM`

11.7.2 Setting the result format

The FORMat subsystem sets the format of numeric data (measured values) that is exchanged between the remote control computer and the sensors if high-level measurement commands are used.

Remote commands:

FORMat:BORDer <border>

Selects the order of bytes in 32-bit or 64-bit binary data.

Parameters:

<border> NORMal | SWAPped

NORMal
The 1st byte is the least significant byte, the 4th/8th byte the most significant byte.
Fulfills the Little Endian (little end comes first) convention, used by x86/x64 CPUs, for example.

SWAPped
The 1st byte is the most significant byte, the 4th/8th byte the least significant byte.
Fulfills the Big Endian (big end comes first) convention.

*RST: NORMal

Example: `FORM:BORD NORM`

FORMat[:DATA] [<data,length>, <length>]

Specifies how the sensor sends the numeric data to the controlling host/computer.

Parameters:

<data,length> <REAL,32 | 64>

REAL
Block of binary values, 32-bit or 64-bit each; also called "SCPI definite length block"

32 | 64
32-bit or 64-bit
If you omit the length, the sensor sets the last used length.
Example for `REAL,32` format:
`#6768000....<binary float values>....`
Example for `REAL,64` format:
`#71536000....<binary float values>....`

<data[,length]> <ASCii[,0 to 12]>

ASCii
List of comma-separated, readable values.

[,0 to 12]
Defines the number of decimal places.
The reset value 0 does not restrict the number of decimal places.
Example for `ASCii,4` format:
`1.2938e-06, -4.7269e-11, ...`
*RST: ASCii,0

FORMat:SREGister <sregister>

Specifies which format is used for the return value of `*STB?`.

Parameters:
<sregister> ASCii | HEXadecimal | OCTal | BINary
*RST: ASCii

Example: `FORM:SREG ASC`

11.8 Querying measurement results

After the measurement, you can query the measurement results.

11.8.1 Continuous average measurement results

Commands for querying the continuous average measurement results and configuring the result buffer.

FETCh<Sensor>:ARRay[:POWer][:AVG]?

Queries the last valid measurement result of a buffered continuous average measurement.

Suffix:
<Sensor> 1

Usage: Query only

FETCh<Sensor>[:SCALar][:POWer][:AVG]?

Queries the last valid measurement result of the measurand that was configured before.

Suffix:
<Sensor> 1

Usage: Query only

[SENSe<Sensor>:][POWer:][AVG:]BUFFer:CLEar

Clears the contents of the result buffer.

Suffix:
<Sensor> 1

Example: `BUFF:CLE`

Usage: Event

[SENSe<Sensor>:][POWer:][AVG:]BUFFer:COUNt?

Queries the number of results that are currently stored in the result buffer.

Suffix:
<Sensor> 1

Example: `BUFF:COUN?`

Usage: Query only

[SENSe<Sensor>:][POWer:][AVG:]BUFFer:DATA?

Queries the results of the continuous average result buffer and returns them even if the buffer is not full.

In contrast, `FETCh<Sensor>[:SCALar][:POWer][:AVG]?` returns a result only if the buffer is full.

Suffix:
<Sensor> 1

Usage: Query only

[SENSe<Sensor>:][POWer:][AVG:]BUFFer:SIZE <count>

Sets the size of the result buffer.

You can enable the buffer using `[SENSe<Sensor>:][POWer:][AVG:]BUFFer:STATe`.

Suffix:
<Sensor> 1

Parameters:
<count> Range: 1 to 8192
*RST: 1

Example: `BUFF:SIZE 1`
See Section 12.2, "Performing a buffered continuous average measurement", on page 161.

[SENSe<Sensor>:][POWer:][AVG:]BUFFer:STATe <state>

Enables or disables a buffered continuous average measurement. If enabled, the sensor collects all results generated by trigger events until the buffer is filled.

You can set the size of the buffer using `[SENSe<Sensor>:][POWer:][AVG:]BUFFer:SIZE`.

Suffix:
<Sensor> 1

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

Example: `BUFF:STAT OFF`

11.9 Calibrating, zeroing

Zeroing removes offset voltages from the analog circuitry of the sensor, so that there are only low powers displayed if no power applied. The zeroing process can take more than 8 s to complete.

Zeroing is recommended if:

- The temperature has varied by more than 5 K.
- The sensor has been replaced.
- No zeroing was performed in the last 24 hours.
- Signals of very low power are to be measured, for instance, if the expected measured value is less than 10 dB above the lower measurement range limit.

Turn off all test signals before zeroing. An active test signal during zeroing causes an error.

Remote commands:

CALibration:DATA <caldata>

Writes a binary calibration data set in the memory of the sensor.

Parameters:

<caldata> <block_data>

Block of binary calibration data, structured in a so-called "SCPI definite length block".

CALibration:DATA:LENGth?

Queries the length in bytes of the calibration data set currently stored in the flash memory. Programs that read out the calibration data set can use this information to determine the capacity of the buffer memory required.

Example: `CAL:DATA:LENG?`

Query

`57392`

Response

Usage: Query only

CALibration:TEST?

The thermal sensors are equipped with an additional test heater.

Queries the power difference when measuring with the test heater enabled and disabled. Unit: W.

Usage: Query only

CALibration:TEST:DEViation?

The thermal sensors are equipped with an additional test heater.

Queries the relative deviation of the current power difference from the reference value stored in the calibration data set. The relative deviation is calculated as follows:

<relative deviation> = (<current power difference> / <reference value>) - 1

with

<current power difference>: `CALibration:TEST?`

<reference value>: `CALibration:TEST:REFerence?`

Usage: Query only

CALibration:TEST:REFerence?

The thermal sensors are equipped with an additional test heater.

Queries the reference value of the power difference when measuring with the external heater enabled and disabled. The reference value is determined during the calibration process and stored in the calibration data set. Unit: W.

Usage: Query only

CALibration:USER:DATA <caldata>

Transfers the user calibration data set, which mainly contains S-parameter sets for user-specific devices. The query returns the data as it was downloaded to the sensor before.

After downloading of a new user calibration data set to the sensor, the current S-parameter correction settings become invalid. Safe operation of the sensor is only possible if the `SELect` and `STATe` commands are repeated after download. See also:

- `[SENSe<Sensor>:]CORRection:SPDevice:STATe`
- `[SENSe<Sensor>:]CORRection:SPDevice:SELect`

Parameters:
<caldata> <block_data>

CALibration:USER:DATA:LENGth?

Queries the length of the user calibration data block.

Usage: Query only

CALibration<Channel>:ZERO:AUTO <state>

Performs zero calibration.

Turn off all test signals before zeroing. An active test signal during zeroing causes an error.

While zero calibration is in progress, no queries or other setting commands are allowed, since the command is synchronous. Any communication attempt can run into a timeout.

After zero calibration, query the static error queue (`SYSTem:SERRor?`). The following responses are possible:

- `0`
  No error, the zero calibration was successful.
- `-240`
  Warning, zero calibration failed.

Suffix:
<Channel> 1 to 4
Measurement channel if more than one channel is available.

Parameters:
<state> **ONCE**
Only valid parameter for this command.
OFF
Return value if no calibration is in progress.

Example:
```
*CLS
CAL1:ZERO:AUTO ONCE
```
Performs zeroing. Takes several seconds.

11.10 Running a self-test

The self-test allows a test of the internal circuitry of the sensor.

Do not apply a signal to the sensor while the self-test is running. If the self-test is carried out with a signal being present, error messages can erroneously be output for the following test steps:

- Offset Voltages
- Noise Voltage

TEST:SENSor? [<Item>]

Starts a self-test of the sensor.

In contrast to `*TST?`, this command returns detailed information that you can use for troubleshooting. If one test step or a part of it fails, the overall result is FAIL.

For result examples and interpretation of the results, see Section 15.2, "Performing a self-test", on page 183.

Query parameters:
<Item> String

Usage: Query only

11.11 Configuring the system

The `SYSTem` subsystem contains a series of commands for general functions that do not directly affect the measurement.

11.11.1 Preset and initialize

SYSTem:PRESet

Resets the sensor.

The command essentially corresponds to the `*RST` command, with the exception that the settings of the following commands are persistently held:

- `INITiate:CONTinuous`
- `[SENSe<Sensor>:]AVERage:TCONtrol`

Usage: Event

SYSTem:INITialize

Sets the sensor to the standard state.

The sensor loads the default settings for all test parameters in the same way as when using `*RST`. The sensor outputs a complete list of all supported commands and parameters. The remote control software can automatically adapt to the features of different types of sensors with different functionality.

Usage: Event

11.11.2 Reboot and restart

SYSTem:REBoot

Reboots the sensor.

Usage: Event

SYSTem:RESTart

Restarts the firmware of the sensor.

Usage: Event

11.11.3 Firmware update

See also Section 10, "Firmware update", on page 93.

SYSTem:FWUPdate <fwudata>

Loads new operating firmware into the sensor. Rohde & Schwarz provides the update file. For further details, see Section 10, "Firmware update", on page 93.

If you want to integrate a firmware update function in an application, see the example given in Section 10.2.2, "Using remote control", on page 95.

Setting parameters:

<fwudata> <block_data>

Definite length arbitrary block data containing the direct copy of the binary `*.rsu` file in the following format:
#
Single digit indicating how many digits follow to specify the size of the binary file.
Number that specifies the size of the binary file.
Binary data
0x0a as appended delimiter (single '\n' character) for line feed

Usage: Setting only

SYSTem:FWUPdate:STATus?

Reads the result of the firmware update performed using `SYSTem:FWUPdate` on page 148.

While a firmware update is in progress, the LED of the sensor flashes in bright white color. When the firmware update is completed, you can read the result.

The result of the query is a readable string.

Example: `SYST:FWUP:STAT?`
Query
`"Success"`
Response

Usage: Query only

11.11.4 Remote settings

SYSTem:HELP:HEADers? [<Item>]

Returns a list of all SCPI commands supported by the sensor.

Query parameters:

<Item> <block_data>

Usage: Query only

SYSTem:HELP:SYNTax? [<Item>]

Queries the relevant parameter information for the specified SCPI command.

Query parameters:

<Item>

Example: `SYST:HELP:SYNT? 'sens:aver:coun'`

Usage: Query only

SYSTem:HELP:SYNTax:ALL?

Queries the implemented SCPI commands and their parameters. Returns the result as a block data.

Usage: Query only

SYSTem:LANGuage <language>

Selects an emulation of a different command set.

Parameters:

<language> SCPI

*RST: SCPI

SYSTem:PARameters?

Returns an XML-output containing all commands with the following information, if available for the command:

- Default value
- Minimum value
- Maximum value
- Parameters
- Limits

Each command is shortened to a command token, consisting only of the mnemonics short form. For example, `CALibration:DATA` is shortened to `CALDATA` as command token.

Usage: Query only

SYSTem:PARameters:DELTa?

Returns an XML-output containing all commands that differ from the defined default status set by `*RST` on page 100.

The commands are accompanied by the same information as for `SYSTem:PARameters?`.

Usage: Query only

SYSTem:TRANsaction:BEGin

Starts a series of settings.

Usage: Event

SYSTem:TRANsaction:END

Ends a series of settings.

Usage: Event

SYSTem:VERSion?

Queries the SCPI version that the command set of the sensor complies with.

Example: `SYST:VERS?`
Query
`1999.0`
Response: SCPI version from 1999.

Usage: Query only

11.11.5 Sensor information

Device footprint

The device footprint contains information about the sensor hardware, the installed software, and license data.


```
#41905<?xml version="1.0" encoding="utf-8" ?>
<DeviceFootprint formatVersion="03.05" creationDate="1970-01-01T00:00:07"
 checksum="140271acac7f19bf2efd69cb559ff4fb">
  <DeviceData deviceId="1418.1573.02-100753-Cd" partChangeIndex="--.--"
  type="NRPC67" upgradeType="NRPC67" upgradePartNumber="1418.1573.02"
  hostName="NRPC67-100753"/>
  <HardwareData cpu="ARMv7 Processor rev 0 (v7l)" ramSize="129642496">
    <HardwareList>
      <Hardware id="12001" partNumber="1424.5719.02" sn="101369"
       partName="ZE SENSORKOPF 67 GHZ NRPXXT"/>
```

```
      <Hardware id="12002" partNumber="1424.5725.00" sn="000000"
       partName="BD DETEKTOR NRPXX" parentId="12001"/>
      <Hardware id="12003" partNumber="1419.0464.02" sn="106067"
       partName="ED ANALOG BOARD NRP18T"/>
      <Hardware id="12004" partNumber="1419.0541.02" sn="128775"
       partName="ED DIGITALBOARD NRPXXS"/>
      <Hardware id="12005" partNumber="1419.0529.02" sn="135048"
       partName="ED INTERFACE BOARD"/>
    </HardwareList>
  </HardwareData>
  <SoftwareData>
    <Bios name="U-Boot" version="2013.01.01 (Oct 19 2021 - 17:34:26)"/>
    <OperatingSystem name="Linux - Linux Platform Kit 2.3.4-6 (pyro)"
     version="2.3.4-6" imageName="Linux Platform Kit 2.3.4-6 (pyro)"
     imageVersion="2.3.4-6" systemWordSize="32-Bit" systemLanguage="C"
     kernelRelease="3.14.34"
     kernelVersion="#1 SMP PREEMPT Thu Apr 13 17:17:00 UTC 2023"/>
    <SoftwareList>
      <Software name="RSU build" version="03.10.24022101.beta"
       vendorName="Rohde&amp;Schwarz"/>
      <Software name="SW build" version="24.02.21 19:26"
       vendorName="Rohde&amp;Schwarz"/>
      <Software name="FPGA image" version="1.0.6"
       vendorName="Rohde&amp;Schwarz"/>
    </SoftwareList>
  </SoftwareData>
  <LicenseData conformToTvr320="false">
    <ActiveLicenseList>
      <ActiveLicense type="NRPS-K1" partNumber="1419.0135.02"
       keyCode="25c4efdfd70f74f86d0f011ac919823e"/>
    </ActiveLicenseList>
  </LicenseData>
</DeviceFootprint>
```


SYSTem:DFPRint<Channel>?

Queries the current device footprint.

See "Device footprint" on page 150.

Suffix:

<Channel> 1...4
Measurement channel if more than one channel is available.

Usage: Query only

SYSTem:DFPRint:HISTory:COUNt?

Queries the number of device footprints in the history.

Return values:
<Count>

Usage: Query only

SYSTem:DFPRint:HISTory:ENTRy? <index>

Queries a device footprint from the history.

Query parameters:
<index> **0**
Most recent device footprint

Return values:
<XmlDeviceFootprint><dblock>

Usage: Query only

SYSTem:INFO? [<item>]

Queries information about the sensor.

If queried without parameters, the command returns all available information in the form of a list of strings separated by commas.

If you want to query specific information, add the query parameter:

```
SYST:INFO? "<string>"
```

Query parameters:
<item> "Manufacturer", "Type", "Stock Number", "Serial", "SW Build", "Sensor Name", "Hostname", "IP Address", "Technology", "Function", "MinPower", "MaxPower", "MinFreq", "MaxFreq", "Resolution", "Impedance", "Coupling", "Cal. Due Date", "Cal. Abs.", "Cal. Refl.", "Cal. S-Para.", "Cal. S-Para. (User)", "Cal. Misc.", "Cal. Temp.", "Cal. Lin.", "SPD Mnemonic", "TestLimit", "TestLimit pd", "Uptime"

Usage: Query only

SYSTem:INFO:SUPPort?

Queries the diagnostic and troubleshooting data. Returns the results as a definite length-arbitrary block data containing a compressed archive (`.tar.gz`) of the diagnostic and troubleshooting data in the following format:

- #
- Single digit indicating how many digits follow to specify the size of the compressed archive.
- Number that specifies the size of the compressed archive.

- Compressed archive data
- 0x0a as appended delimiter (single '\n' character) for line feed

See also Section 15.4, "Collecting information for technical support", on page 186.

Usage: Query only

SYSTem[:SENSor]:NAME <sensorname>

Sets the name of the sensor according to your requirements.

The name that you specify here is independent from the host name of the sensor. However, if you do not specify a name, the host name is used as default.

Parameters:
<sensorname>

Example: `SYST:NAME "InputModule-X5"`

11.11.6 Status display and update

The power standard has no status LED. Therefore, not all commands are applicable for the power standard.

SYSTem:LED:COLor <color>

Effective if the status LED is user-controlled, see `SYSTem:LED:MODE USER`.

Sets the color and the flash code of the status LED.

Parameters:
<color> Hexadecimal code: #H0<emitting type><color>
With
<emitting type>: 0 = steady on; 1 = slowly flashing; 2 = fast flashing
<color>: FF0000 = red, 00FF00 = green, 0000FF = blue

Range: 0 to #H0FFFFFFF
*RST: #H00A0A0A0

Example:
`SYST:LED:MODE USER`
The status LED is user-controlled.

`SYST:LED:COL #H01FF0000`
The LED flashes slowly in red.

`SYST:LED:MODE SENS`
The status LED is controlled by the sensor firmware.

SYSTem:LED:MODE <mode>

Sets whether the color and flash code of the status LED are controlled by the sensor firmware or by the user settings.

For more information, see SYSTem:LED:COLor.

Parameters:

<mode>	USER | SENSor	
	*RST:	SENSor

SYSTem:RUTime <update_time>

Effective only in the NRP legacy mode. Relevant only for continuous measurements, INITiate:CONTinuous ON.

Sets the result update time. The result update time is the maximum rate in which the sensor can output measurement results.

Parameters:

<update_time>	Range:	0.0 s to 10.0 s
	*RST:	0.1 s
	Default unit:	s

SYSTem:SUTime <update_time>

Effective only in the NRP legacy mode. Relevant only for continuous measurements, INITiate:CONTinuous ON.

Sets the status update time. The status update time is the maximum rate in which the sensor can output measurement results.

Parameters:

<update_time>	Range:	0.0 s to 10.0 s
	*RST:	10e-3 s
	Default unit:	s

11.11.7 Measurement limits and levels

SYSTem:MINPower?

Queries the lower power measurement limit. Use this query to determine a useful resolution for the result display near the lower measurement limit.

This value changes if [SENSe<Sensor>:]CORRection:SPDevice:STATe is set to ON.

The lower measurement limit refers to the sensor or to the combination of a sensor and the components connected ahead of it.

Set the unit using `SYSTem:MINPower:UNIT`.

Usage: Query only

SYSTem:MINPower:UNIT <unit>

Sets the unit for the lower power measurement limit, queried by `SYSTem:MINPower?`.

Parameters:

<unit> DBM | W | DBUV

*RST: W

SYSTem:TLEVels?

Queries the possible power test levels of the sensor.

Usage: Query only

11.11.8 Errors

See also Section 15.1, "Error messages", on page 183.

SYSTem:ERRor:ALL?

Queries all unread entries in the SCPI communication error queue and removes them from the queue.

Returns a comma-separated list of error numbers and a short error description in the first-in first-out order.

Example:

`SYST:ERR:ALL?`
Query
`0,"No error"`
Response

Usage: Query only

SYSTem:ERRor:CODE:ALL?

Queries all unread entries in the SCPI communication error queue and removes them from the queue.

Returns a comma-separated list of error numbers, but no error description.

Example: `SYST:ERR:CODE:ALL?`
Query
`0`
Response: No errors have occurred since the error queue was last read out.

Usage: Query only

SYSTem:ERRor:CODE[:NEXT]?

Queries the SCPI communication error queue for the oldest entry and removes it from the queue.

Returns the error number, but no error description.

Example: `SYST:ERR:CODE?`
Query
`0`
Response: No errors have occurred since the error queue was last read out.

Usage: Query only

SYSTem:ERRor:COUNt?

Queries the number of entries in the SCPI communication error queue.

Example: `SYST:ERR:COUN?`
Query
`1`
Response: One error has occurred since the error queue was last read out.

Usage: Query only

SYSTem:ERRor[:NEXT]?

Queries the SCPI communication error queue for the oldest entry and removes it from the queue.

Returns an error number and a short description of the error.

Example: `SYST:ERR?`
Query
`0, 'no error'`
Response: No errors have occurred since the error queue was last read out.

Usage: Query only

SYSTem:SERRor?

Queries the next static error, if available.

Static errors, as a rule, prevent the execution of normal measurements.

Errors in SCPI communication are queried using `SYSTem:ERRor[:NEXT]?`.

Usage: Query only

SYSTem:SERRor:LIST:ALL?

Queries all changes in the static error queue that have not been read yet and removes them from the queue.

Example:
`SYST:SERR:LIST:ALL?`
Query
`0,"reported at uptime:2942; notice; auto-averaging exceeded maximum time; Notification",0,"removed at uptime:2944; notice; auto-averaging exceeded maximum time; Notification"`
Response

Usage: Query only

SYSTem:SERRor:LIST[:NEXT]?

Queries the list of static error changes for the oldest entry and removes it from the queue.

Returns an error number and a short description of the error.

Example:
`SYST:SERR:LIST?`
Query
`0,"reported at uptime:2942; notice; auto-averaging exceeded maximum time; Notification"`
Response

Usage: Query only

11.12 Using the status register

Further information:

- Section 13.2, "Status reporting system", on page 166

Contents:

11.12.1 General status register commands

STATus:PRESet

Resets the edge detectors and `ENABle` parts of all registers to a defined value.

Usage: Event

STATus:QUEue[:NEXT]?

Queries the most recent error queue entry and deletes it.

Positive error numbers indicate sensor-specific errors. Negative error numbers are error messages defined by SCPI.

If the error queue is empty, the error number 0, "No error", is returned.

Usage: Query only

11.12.2 Reading the CONDition part

STATus:DEVice:CONDition?
STATus:OPERation:CALibrating:CONDition?
STATus:OPERation:CONDition?
STATus:OPERation:LLFail:CONDition?
STATus:OPERation:MEASuring:CONDition?
STATus:OPERation:SENSe:CONDition?
STATus:OPERation:TRIGger:CONDition?
STATus:OPERation:ULFail:CONDition?
STATus:QUEStionable:CALibration:CONDition?
STATus:QUEStionable:CONDition?
STATus:QUEStionable:POWer:CONDition?
STATus:QUEStionable:WINDow:CONDition?

Usage: Query only

11.12.3 Reading the EVENt part

STATus:DEVice[:EVENt]?
STATus:OPERation:CALibrating[:SUMMary][:EVENt]?
STATus:OPERation[:EVENt]?
STATus:OPERation:LLFail[:SUMMary][:EVENt]?
STATus:OPERation:MEASuring[:SUMMary][:EVENt]?
STATus:OPERation:SENSe[:SUMMary][:EVENt]?
STATus:OPERation:TRIGger[:SUMMary][:EVENt]?
STATus:OPERation:ULFail[:SUMMary][:EVENt]?
STATus:QUEStionable:CALibration[:SUMMary][:EVENt]?
STATus:QUEStionable[:EVENt]?
STATus:QUEStionable:POWer[:SUMMary][:EVENt]?
STATus:QUEStionable:WINDow[:SUMMary][:EVENt]?

Usage: Query only

11.12.4 Controlling the ENABle part

STATus:DEVice:ENABle <value>
STATus:OPERation:CALibrating:ENABle <value>
STATus:OPERation:ENABle <value>
STATus:OPERation:LLFail:ENABle <value>
STATus:OPERation:MEASuring:ENABle <value>
STATus:OPERation:SENSe:ENABle <value>
STATus:OPERation:TRIGger:ENABle <value>
STATus:OPERation:ULFail:ENABle <value>
STATus:QUEStionable:CALibration:ENABle <value>
STATus:QUEStionable:ENABle <value>
STATus:QUEStionable:POWer:ENABle <value>
STATus:QUEStionable:WINDow:ENABle <value>

Parameters:

<value> *RST: 0

11.12.5 Controlling the negative transition part

STATus:DEVice:NTRansition <value>
STATus:OPERation:CALibrating:NTRansition <value>
STATus:OPERation:NTRansition <value>
STATus:OPERation:LLFail:NTRansition <value>
STATus:OPERation:MEASuring:NTRansition <value>
STATus:OPERation:SENSe:NTRansition <value>
STATus:OPERation:TRIGger:NTRansition <value>
STATus:OPERation:ULFail:NTRansition <value>
STATus:QUEStionable:CALibration:NTRansition <value>
STATus:QUEStionable:NTRansition <value>

STATus:QUEStionable:POWer:NTRansition <value>
STATus:QUEStionable:WINDow:NTRansition <value>

Parameters:

<value>	*RST:	0

11.12.6 Controlling the positive transition part

STATus:DEVice:PTRansition <value>
STATus:OPERation:CALibrating:PTRansition <value>
STATus:OPERation:PTRansition <value>
STATus:OPERation:LLFail:PTRansition <value>
STATus:OPERation:MEASuring:PTRansition <value>
STATus:OPERation:SENSe:PTRansition <value>
STATus:OPERation:TRIGger:PTRansition <value>
STATus:OPERation:ULFail:PTRansition <value>
STATus:QUEStionable:CALibration:PTRansition <value>
STATus:QUEStionable:PTRansition <value>
STATus:QUEStionable:POWer:PTRansition <value>
STATus:QUEStionable:WINDow:PTRansition <value>

Parameters:

<value>	*RST:	65535

12 Performing measurement tasks - programming examples

If you install the optional software development kit (SDK) of the R&S NRP-Toolkit, programming examples are provided. See Section 5.2.1, "R&S NRP-Toolkit", on page 28.

Under Windows, these examples are installed under:

`C:\ProgramData\Rohde-Schwarz\NRP-Toolkit-SDK\examples`

This section gives programming examples for measurement tasks performed with the NRP sensors.

12.1 Performing the simplest measurement

The simplest way to obtain a result is to use the following sequence of commands:

```
*RST
INITiate
FETCh?
```

The `*RST` sets the continuous average measurement.

`INITiate` initiates the measurement.

After `*RST`, the trigger system is set to `TRIGger:SOURce IMMediate`. That means the sensor starts measuring when the measurement is started without waiting for a trigger condition.

After the measurement has been completed, `FETCh<Sensor>[:SCALar][:POWer][:AVG]?` delivers the result to the output queue from which it can be fetched.

12.2 Performing a buffered continuous average measurement

This example, written in pseudo code, shows how to set up and execute a buffered continuous average measurement.

```
  //Select whether using
//    'BUS Trigger'     --> true
// or 'EXT Trigger'     --> false
bool   bUseBUSTrigger = true;

// Use the first NRP series sensor which is found
if ( VI_SUCCESS == SENSOR.openFirstNrpSensor( "USB?::0X0AAD::?*::INSTR" ) )
{
 //Start with a clean state
 SENSOR.write( "*RST" );
```

```
// Auto Averaging OFF and set Average Count = 4
SENSOR.write( "SENS:AVER:COUN:AUTO OFF" );
SENSOR.write( "SENS:AVER:COUN 4" );

// Select the trigger source
if ( bUseBUSTrigger )
{
 // We want to use '*TRG' to trigger a single physical measurement
 SENSOR.write( "TRIG:SOUR BUS" );
}
else
{
 // We get trigger pulses on the external input (SMB-type connector)
 SENSOR.write( "TRIG:SOUR EXT2" );
}
// Auto-Trigger OFF
SENSOR.write( "TRIG:ATR:STAT OFF" );

// Configure a buffered measurement
// Buffer size is randomly selected to 17
SENSOR.write( "SENS:BUFF:SIZE 17" );
SENSOR.write( "SENS:BUFF:STAT ON" );
SENSOR.write( "TRIG:COUN 17" );

// Read out all errors / Clear error queue
SENSOR.query( "SYST:ERR:ALL?", szBuf, sizeof( szBuf ) );
printf( szBuf );


// Start a 'single' buffered measurement
// Since 17 trigger-counts have been configured,
// the 'single' buffered measurement, which becomes
// initiated by INIT:IMM, is not over until
// 17 physical measurements have been triggered
SENSOR.write( "INIT:IMM" );


// The end of a physical measurement can be recognized
// by a transistion to 'NOT MEASURING' which is a
// negative transition on bit 1
SENSOR.write( "STAT:OPER:MEAS:NTR 2" );
SENSOR.write( "STAT:OPER:MEAS:PTR 0" );

// Collect 17 physical measurements
for ( int i = 0; i < 17; i++ )
{
 // As a pre-condition: clear the event register by reading it
 int iDummy;
 SENSOR.query( "STAT:OPER:MEAS:EVEN?", &iDummy );
```

```
  // Trigger a single physical measurement; either by '*TRG'
  // command or by an externally supplied pulse on the SMB-type connector
  if ( bUseBUSTrigger )
  SENSOR.write( "*TRG" );


  // Wait until the measurement is done
  int iMeasEvent = 0;
  while ( iMeasEvent != 2 )
  {
   SENSOR.query( "STAT:OPER:MEAS:EVEN?", &iMeasEvent );
   iMeasEvent &= 2;
  }
  printf( "Triggered!\n" );
 }
 // All 17 physical measurement have been executed.
 // That means, buffer is full and can be read
 SENSOR.query( "FETCH?", szBuf, sizeof( szBuf ) );
 printf( szBuf );
}
```

13 Remote control basics

For general information on remote control of Rohde & Schwarz products via SCPI, refer to www.rohde-schwarz.com/rc-via-scpi.

13.1 Remote control interfaces and protocols

For remote control, communication between the sensors and the controlling host is established based on various interfaces and protocols.

Depending on the sensor type, the sensors support different interfaces for remote control.

- USB sensors are always accessed using USB.
  See Section 13.1.1, "USB interface", on page 164.

13.1.1 USB interface

Connect the computer and the sensors as described in:

- Section 5, "Measurement equipment and setups", on page 25

13.1.1.1 USBTMC protocol

The USB test & measurement class specification (USBTMC) is a protocol that is built on top of USB for communication with USB devices from the test & measurement category. It defines a dedicated class code that identifies a device's functionality. The device also uses this class code to identify itself as a member of the test & measurement class. Using a VISA library, such devices support service request, trigger and other operations that are commonly found in GPIB devices.

Computer requirements

- VISA library
  VISA is a standardized software interface library providing input and output functions to communicate with instruments. A VISA installation on the controller is a prerequisite for remote control over USBTMC.
  VISA detects and configures the product automatically when the USB connection is established.
- USBTMC driver
  Apart from the USBTMC driver, which comes with the installation of VISA, you do not have to install a separate driver.

USB resource string

The VISA resource string for USBTMC device communication represents an addressing scheme that is used to establish a communication session with the product. It is based on the product address and some product- and vendor-specific information. The syntax of the used USB resource string is:

USB[board]::<vendor ID>::<product ID>::<serial number>[::INSTR]

- *<vendor ID>* is the vendor ID for Rohde & Schwarz, 0x0AAD.
- *<product ID>* is the product ID for the product.
- *<serial number>* is the individual serial number of the product, printed on the casing.

Example:

`USB0::0x0AAD::0x01A5::100001::INSTR`

0x0AAD is the vendor ID for Rohde & Schwarz.

0x01A5 is the product ID.

100001 is the serial number of the product.

Table 13-1: Power standard USB product IDs

R&S NRPC	Model	USB product ID
R&S NRPC18	02	0x00BF
	03	0x01B6
R&S NRPC33	02	0x00B6
	03	0x01B7
R&S NRPC40	02	0x008F
	03	0x01B8
R&S NRPC50	02	0x0090
	03	0x01B9
R&S NRPC67	02	0x01A5
For distinguishing models, see Section 3.4, "Recognizing power standard models", on page 20.		

Table 13-2: Verification sensor USB product IDs

R&S NRPC-B1	Model	USB product ID
R&S NRPC18-B1	03	0x00C1
	04	0x01B2
R&S NRPC33-B1	02	0x00C2
	03	0x01B3
R&S NRPC40-B1	03	0x00C3
	04	0x01B4
R&S NRPC50-B1	02	0x00C4
For distinguishing models, see Section 3.4, "Recognizing power standard models", on page 20.		

R&S NRPC-B1	Model	USB product ID
	03	0x01B5
R&S NRPC67-B1	02	0x01A6
For distinguishing models, see Section 3.4, "Recognizing power standard models", on page 20.		

13.1.1.2 NRP legacy protocol

The NRP legacy protocol is available to ensure the compatibility of the sensors with the R&S NRP-Z sensors. The usage of this protocol is not recommended for new applications.

Computer requirements

- VISA library
  VISA is a standardized software interface library providing input and output functions to communicate with instruments. A VISA installation on the controller is a prerequisite for remote control over USB.
  VISA detects and configures the product automatically when the USB connection is established.
- USB device drivers
  Apart from the USB device drivers that come with the installation of the R&S NRP-Toolkit, you do not have to install a separate driver.

13.2 Status reporting system

The status reporting system stores all information on the current operating state of the instrument, and on errors which have occurred. This information is stored in the status registers and in the error queue. You can query both with the commands of the `STATus` subsystem.

Here, the term "instrument" is used synonymous for "sensor".

13.2.1 Overview

Fig.13-1 shows the hierarchical structure of information in the status registers.

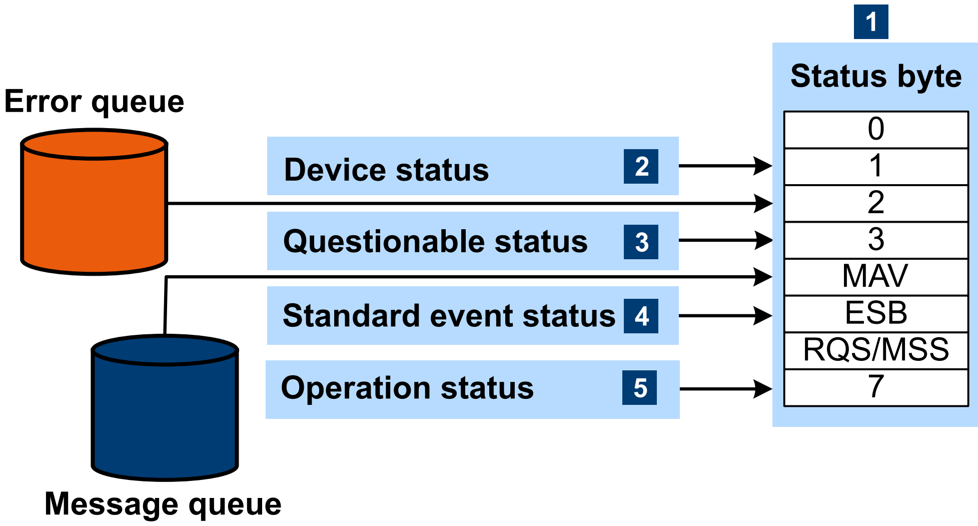


Figure 13-1: Status registers overview

1 = Status byte, see Table 13-3
2 = Section 13.2.2, "Device status register", on page 168
3 = Section 13.2.3, "Questionable status register", on page 170
4 = Section 13.2.4, "Standard event status and enable register (ESR, ESE)", on page 173
5 = Section 13.2.5, "Operation status register", on page 174

The highest level is formed by the status byte register (STB) and the associated service request enable (SRE) register.

The status byte register (STB) receives its information from:

- Standard event status register (ESR)
- Associated standard event status enable register (ESE)
- SCPI-defined operation status register
- Questionable status register, which contains detailed information on the device.

Table 13-3: Used status byte bits and their meaning

Bit no.	Short description	Bit is set if
1	Device status register summary	An instrument is connected or disconnected or when an error has occurred in an instrument, depending on the configuration of the instrument status register. Section 13.2.2, "Device status register", on page 168.
2	Error queue not empty	The error queue has an entry. If this bit is enabled by the service request enable register, each entry of the error queue generates a service request. An error can thus be recognized and specified in detail by querying the error queue. The query yields a conclusive error message. This procedure is recommended since it considerably reduces the problems of IEC/IEEE bus control.

Bit no.	Short description	Bit is set if
3	Questionable status register summary	An EVENt bit is set in the QUEStionable status register and the associated ENABLe bit is set to 1. A set bit denotes a questionable device status which can be specified in greater detail by querying the questionable status register. Section 13.2.3, "Questionable status register", on page 170.
4	MAV Message available	A readable message is in the message queue. This bit can be used to read data automatically from the instrument into the controller.
5	ESB Standard event status register summary	One of the bits in the standard event status register is set and enabled in the event status enable register. Setting this bit denotes a serious error which can be specified in greater detail by querying the standard event status register. Section 13.2.4, "Standard event status and enable register (ESR, ESE)", on page 173.
6	RQS/MSS Primary status summary	The instrument triggers a service request. The service request happens if one of the other bits of this register is set together with its enable bit in the service request enable register (SRE).
7	Operation status register summary	An EVENt bit is set in the operation status register and the associated ENABLe bit is set to 1. A set bit denotes that an action is being performed by the instrument. Information on the type of action can be obtained by querying the operation status register. Section 13.2.5, "Operation status register", on page 174.

Further information:

- See Figure 13-1.
- Set and read the service request enable register using *SRE.

13.2.2 Device status register

Shows whether static errors (SERR) exist and other sensor status information.

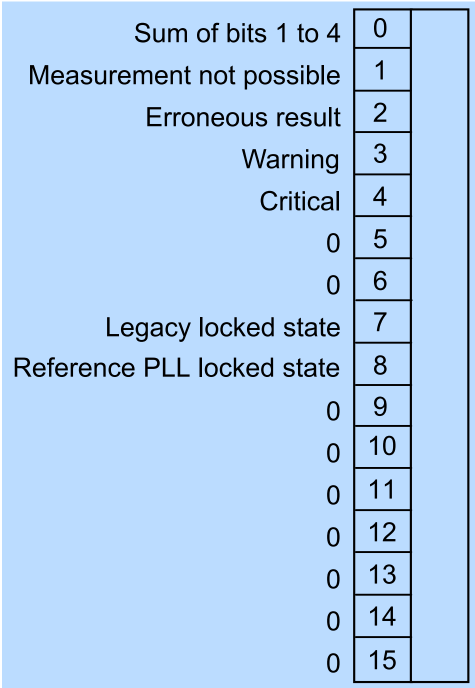


Figure 13-2: Device status register

Querying the register:

- `STATus:DEVice:CONDition?`
- `STATus:DEVice[:EVENt]?`

Querying the static errors:

- `SYSTem:SERRor?`

Table 13-4: Used device status bits and their meaning

Bit no.	Short description	Bit is set if
0	Sum of bits 1 to 4	Sum/combination of static error (SERR) bits 1 to 4.
1	Measurement not possible	Static error exists. Certain parameter settings could lead to a situation where subsequent measurements are not possible.
2	Erroneous results	Static error exists. The measurement result is possibly incor-rect.
3	Warning	Static error exists. The status LED of the sensor is slowly flashing red.
4	Critical	Critical static error exists. The status LED of the sensor is fast flashing red.

Bit no.	Short description	Bit is set if
7	Legacy locked state	The sensor is locked in the NRP legacy mode. Via the SCPI channels (USBTMC or TCP/IP), only query commands can be sent, but no setting commands. When the first setting command is sent, the NRP legacy interface takes precedence over all other command channels. This bit is set to `1`, and all other channels can only execute query commands. If a setting command is sent via a different channel, the sensor indicates an error: *-200,"Execution error; sensor in LEGACY mode"* To leave the NRP legacy mode, close the NRP legacy channel. Either close the application which opened the NRP legacy channel or close at least the connection to the sensor.
8	Reference PLL locked state	PLL for the clock reference is synchronized. The bit is useful when selecting an external clock source. The following states are possible: ● Internal clock (`[SENSe<Sensor>:]ROSCillator:SOURce INT`): – `1` (always) ● External clock (`[SENSe<Sensor>:]ROSCillator:SOURce EXT`): – `1` if the sensor was able to synchronize with external clock – `0` if the sensor could not synchronize with external clock

13.2.3 Questionable status register

Contains information on questionable sensor states that occur if the sensor is not operated in compliance with its specifications.

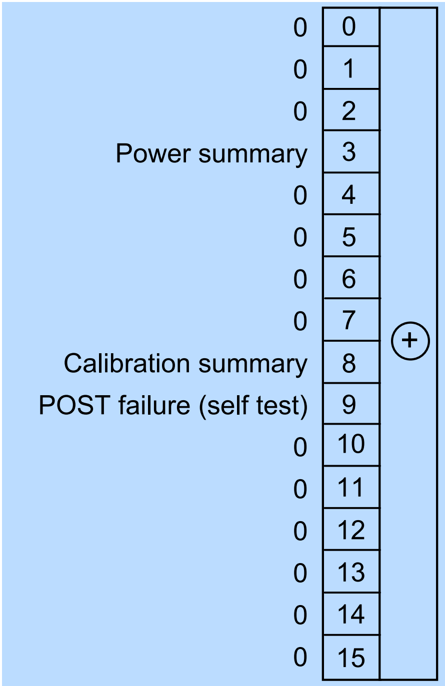


Figure 13-3: Questionable status register

Querying the register:

- `STATus:QUEStionable:CONDition?`
- `STATus:QUEStionable[:EVENt]?`

Table 13-5: Used questionable status bits and their meaning

Bit no.	Short description	Bit is set if
3	Power summary	Summary of Questionable power status register exists.
8	Calibration summary	Summary of Questionable calibration status register exists.
9	POST failure (self-test)	Built-in test of the R&S NRPC that is carried out automatically upon power-up has generated an error.

13.2.3.1 Questionable power status register

Contains information on whether the measured power values are questionable.

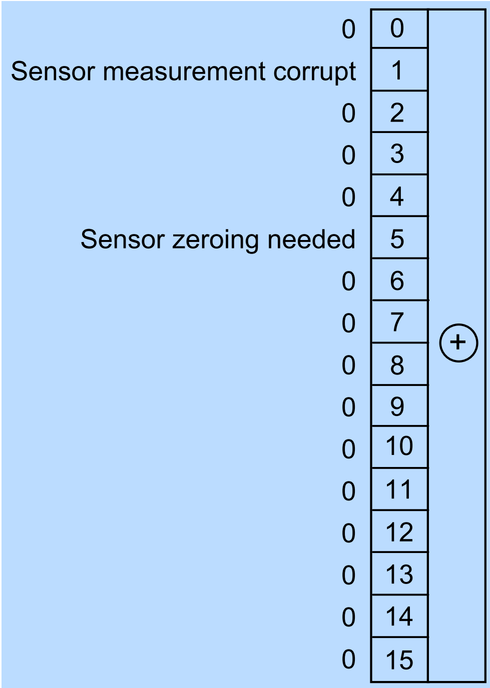


Figure 13-4: Questionable power status register

Querying the register:

- STATus:QUEStionable:POWer:CONDition?
- STATus:QUEStionable:POWer[:SUMMary][:EVENt]?

Table 13-6: Used questionable power status bits and their meaning

Bit no.	Short description	Bit is set if
1	Sensor measurement corrupt	Measurement data of the sensor is corrupt.
5	Sensor zeroing needed	Zero correction for the sensor is no longer correct. Perform a zero correction.

13.2.3.2 Questionable calibration status register

Contains information whether the zeroing of the sensor was successful.

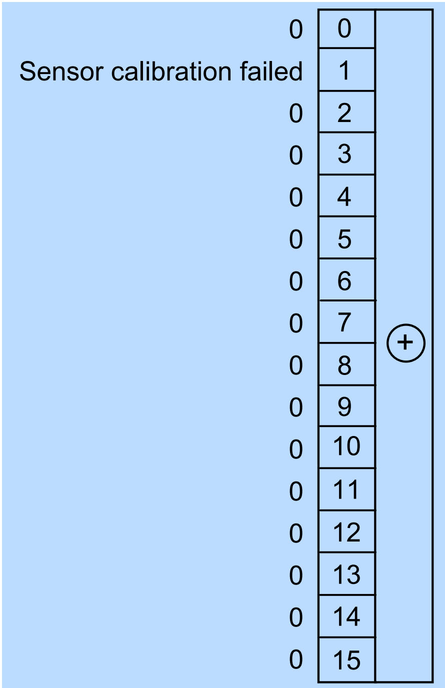


Figure 13-5: Questionable calibration status register

Querying the register:

- `STATus:QUEStionable:CALibration:CONDition?`
- `STATus:QUEStionable:CALibration[:SUMMary][:EVENt]?`

Table 13-7: Used questionable calibration status bits and their meaning

Bit no.	Short description	Bit is set if
1	Sensor calibration failed	Zeroing of the sensor was not successful.

13.2.4 Standard event status and enable register (ESR, ESE)

The `ESR` is already defined in the IEEE 488.2 standard. It is comparable to the `EVENt` register of a SCPI register. The standard event status register can be read out by `*ESR?`.

The `ESE` forms the associated `ENABle` register. It can be set and read by `*ESE`.

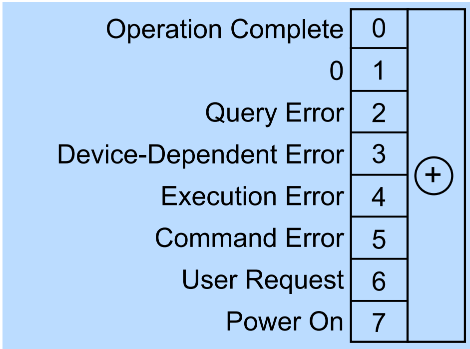


Figure 13-6: Standard event status register (ESR)

Table 13-8: Used standard event status bits and their meaning

Bit no.	Short description	Bit is set if
0	Operation complete	All previous commands have been executed and `*OPC` is received.
2	Query error	The controller wants to read data from the instrument but has not sent a query, or it sends new commands to the instrument before it retrieves existing requested data. A frequent cause is a faulty query which cannot be executed.
3	Device-dependent error	An instrument-dependent error occurs. An error message with a number between -300 and -399 or a positive error number denoting the error in greater detail is entered in the error queue.
4	Execution error	The syntax of a received command is correct but the command cannot be executed due to various marginal conditions. An error message with a number between -200 and -300 denoting the error in greater detail is entered in the error queue.
5	Command error	An undefined command or a command with incorrect syntax is received. An error message with a number between -100 and -200 denoting the error in greater detail is entered in the error queue.
6	User request	The instrument is switched over to manual control.
7	Power on	The instrument is switched on.

13.2.5 Operation status register

Contains information on current operations, `CONDition` register, or operations performed since the last query, `EVENt` register.

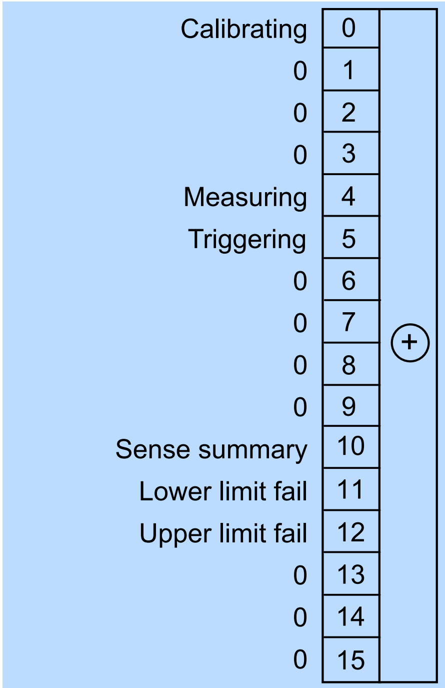


Figure 13-7: Operation status register

Querying the register:

- `STATus:OPERation:CONDition?`
- `STATus:OPERation[:EVENt]?`

Table 13-9: Used operation status bits and their meaning

Bit no.	Short description	Bit is set if
0	Calibrating	Summary of Operation calibrating status register exists.
4	Measuring	Summary of Operation measuring status register exists.
5	Triggering	Summary of Operation trigger status register exists.
10	Sense summary	Summary of Operation sense status register exists.
11	Lower limit fail	Summary of Operation lower limit fail status register exists.
12	Upper limit fail	Summary of Operation upper limit fail status register exists.

13.2.5.1 Operation calibrating status register

The `CONDition` register contains information on whether a sensor is being calibrated. The `EVENt` register contains information on whether a calibration was started or completed since the last query.

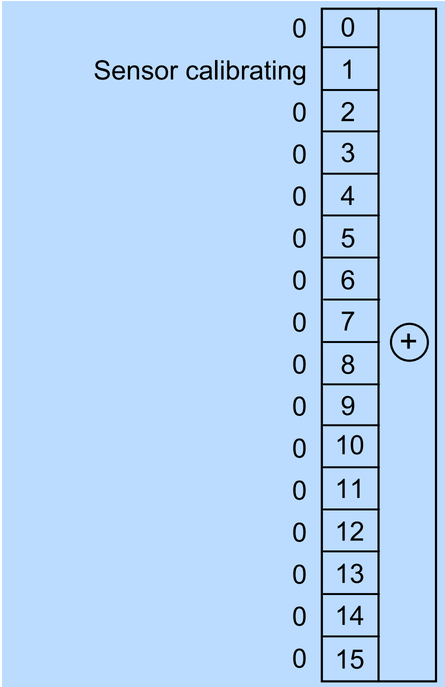


Figure 13-8: Operation calibrating status register

Querying the register:

- STATus:OPERation:CALibrating:CONDition?
- STATus:OPERation:CALibrating[:SUMMary][:EVENt]?

Table 13-10: Used operation calibrating status bits and their meaning

Bit no.	Short description	Bit is set if
1	Sensor calibrating	Sensor is being calibrated.

13.2.5.2 Operation measuring status register

The CONDition register contains information on whether a sensor is measuring. The EVENt register contains information on whether a measurement was started or completed since the last query.

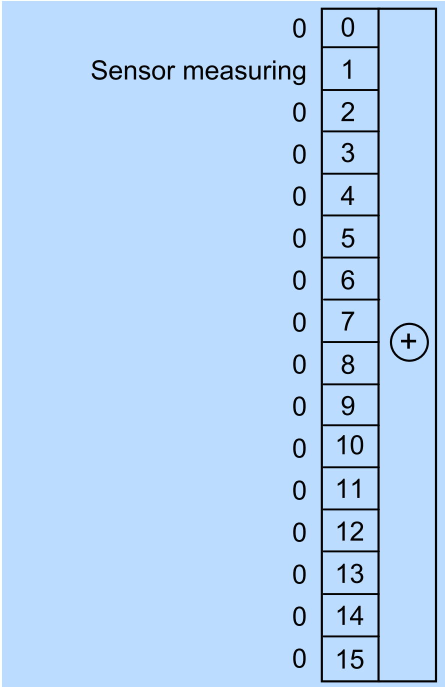


Figure 13-9: Operation measuring status register

Querying the register:

- STATus:OPERation:MEASuring:CONDition?
- STATus:OPERation:MEASuring[:SUMMary][:EVENt]?

Table 13-11: Used operation measuring status bits and their meaning

Bit no.	Short description	Bit is set if
1	Sensor measuring	Sensor is measuring.

13.2.5.3 Operation trigger status register

The CONDition register contains information whether a sensor is waiting for a trigger event. The EVENt register contains information on whether the sensor has been waiting for a trigger event since the last query.

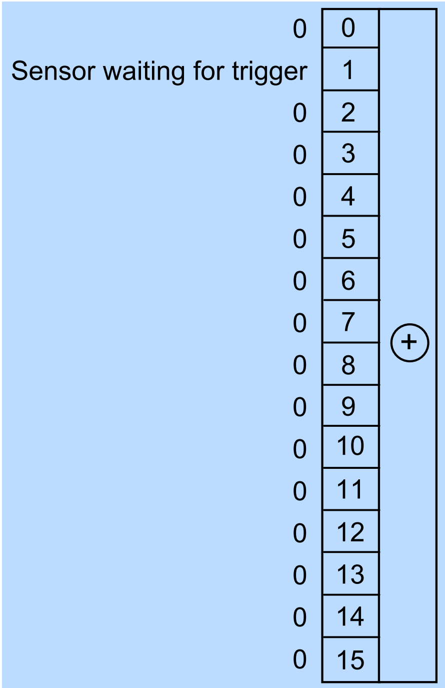


Figure 13-10: Operation trigger status register

Querying the register:

- STATus:OPERation:TRIGger:CONDition?
- STATus:OPERation:TRIGger[:SUMMary][:EVENt]?

Table 13-12: Used operation trigger status bits and their meaning

Bit no.	Short description	Bit is set if
1	Sensor waiting for trigger	Sensor is waiting for a trigger event. When the trigger event occurs, the sensor changes into the measuring state.

13.2.5.4 Operation sense status register

The CONDition register contains information whether a sensor is being initialized. The EVENt register contains information whether an initialization was started or completed since the last query.

A sensor is initialized if:

- Supply voltage is switched on (power-up).
- Sensor was connected.
- Reset was performed using:
  - *RST
  - SYSTem:PRESet

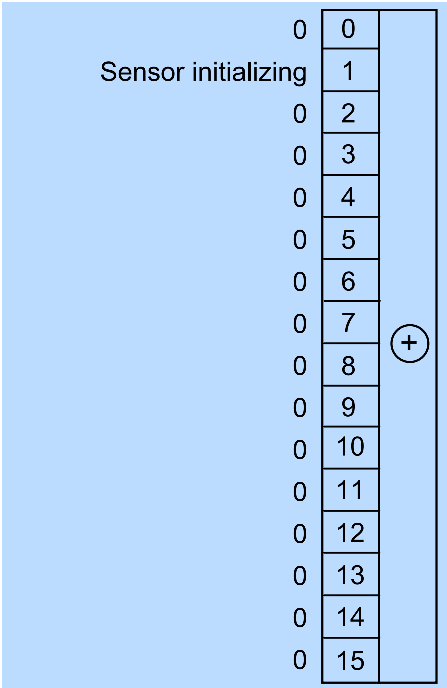


Figure 13-11: Operation sense status register

Querying the register:

- STATus:OPERation:SENSe:CONDition?
- STATus:OPERation:SENSe[:SUMMary][:EVENt]?

Table 13-13: Used operation sense status bits and their meaning

Bit no.	Short description	Bit is set if
1	Sensor initializing	Sensor is being initialized.

13.2.5.5 Operation lower limit fail status register

The CONDition registers contain information whether a measured value is below a configured lower limit. The EVENt registers contain information on whether a measured value dropped below a limit value since the last query.

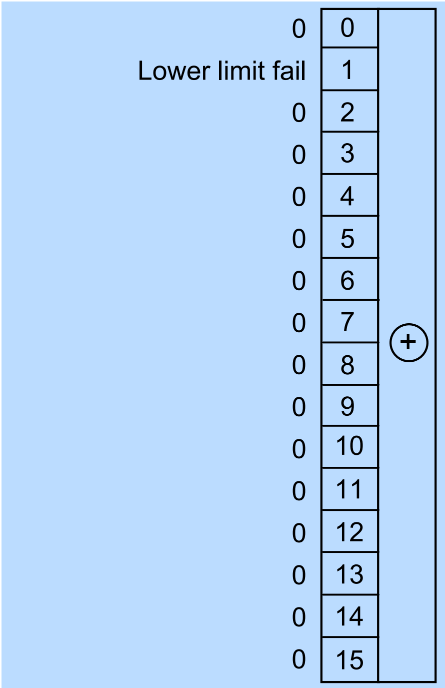


Figure 13-12: Operation lower limit fail status registers

Querying the register:

- STATus:OPERation:LLFail:CONDition?
- STATus:OPERation:LLFail[:SUMMary][:EVENt]?

Table 13-14: Used operation lower limit fail status bits and their meaning

Bit no.	Short description	Bit is set if
1	Lower limit fail	Measured value is below the lower limit value.

13.2.5.6 Operation upper limit fail status register

The CONDition registers contain information on whether a measured value currently exceeds a configured upper limit. The EVENt registers contain information on whether a measured value exceeded an upper limit value since the last query.

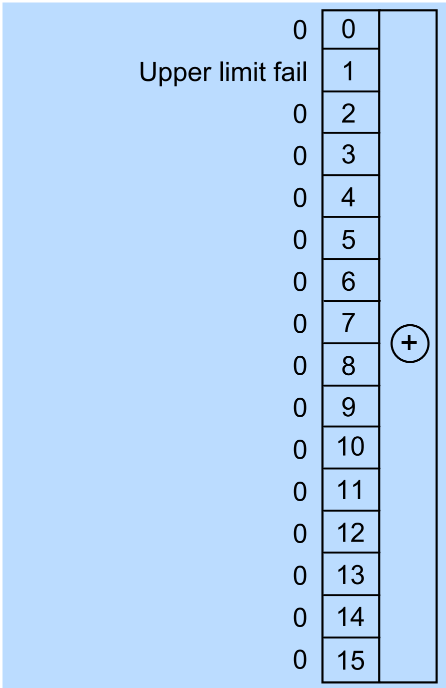


Figure 13-13: Operation upper limit fail status registers

Querying the register:

- `STATus:OPERation:ULFail:CONDition?`
- `STATus:OPERation:ULFail[:SUMMary][:EVENt]?`

Table 13-15: Used operation upper limit fail status bits and their meaning

Bit no.	Short description	Bit is set if
1	Upper limit fail	Measured value exceeds the upper limit value.

14 Data management

Depending on the origin and content, this description distinguishes between the following data types:

- Operational data
- Non-operational data

Operational data (data for intended use)

The power sensor uses and creates this data because of its intended use and according to the settings and configuration you have made. Thus, this data makes up most of the data that the R&S NRPC creates, such as user files that contain user-defined configurations or data, like sensor settings or measurement data.

Non-operational data (usage data)

The R&S NRPC creates this data during and through its use. Such data is collected e.g. for troubleshooting, to help our customer support center find solutions quickly.

The R&S NRPC generates this data continuously and in real-time. This data is saved on the power sensor. The power sensor is not capable of storing this data on a remote server.

The R&S NRPC generates the following data and saves it in the non-volatile memory:

- Diagnostic and troubleshooting data
  On demand, this data is returned as block data containing a compressed archive of files in text and binary format. The volume of the non-operational data depends on the usage of the product and typically amounts to about 20 kbyte.
  You can access, retrieve and delete this data. See Section 15.4, "Collecting information for technical support", on page 186.

The R&S NRPC generates the following data and saves it temporarily. When you disconnect the power sensor from its power source, this data is deleted.

- Environmental conditions
  You can access and retrieve this data using the `TEST:SENSor?` command.
- Hardware component metadata
  You can access and retrieve this data using the `SYSTem:DFPRint<Channel>?` command.

For additional information on the different memory types and on how to clear the internal memory to protect sensitive data, see the instrument security procedures document at:

www.rohde-schwarz.com/manual/nrpc

15 Troubleshooting

In this section, the troubleshooting for the R&S NRPC power standard and the R&S NRPC-B1 verification sensor is described. For information on solving measurement problems, see Section 6.3, "Troubleshooting measurement problems", on page 53.

15.1 Error messages

Querying errors (remote control)

In remote control, the commands querying errors are part of `SYSTem`.

See Section 11.11, "Configuring the system", on page 146.

The severity of the error is distinguished:

- Normal error
  Results from, for example, unknown commands or syntax errors and generally affect a single parameter or setting.
- Static error
  More severe than a normal error. Prevents the execution of normal measurements.

Positive error numbers are instrument-dependent. Negative error numbers are reserved by the SCPI standard.

You can query the error queue using:

- `SYSTem:ERRor:ALL?`
- `SYSTem:ERRor:COUNt?`
- `SYSTem:ERRor[:NEXT]?`

If you want to look only at static errors, use:

- `SYSTem:SERRor?`
- `SYSTem:SERRor:LIST[:NEXT]?`

15.2 Performing a self-test

The self-test gives you detailed information that you can use for troubleshooting.

The R&S Recal+ software supports a self-test of the calibration kit so that you can run the self-test in the measurement setup. For details, see Section 7.1, "Built-in self-test", on page 62 or the R&S Recal+ help.

Do not apply a signal to the sensor while the self-test is running. If the self-test is carried out with a signal being present, error messages can erroneously be output for the following test steps:

- Offset Voltages
- Noise Voltage

Using remote control

► For a quick check, send:
TEST:SENSor?

For each test step, PASS or FAIL is listed.

```
Operating Voltages:
   +3V3_VCC_MIO:      PASS (+3.31 V)
   +1V8_PS:           PASS (+1.79 V)
   +1V0_PS:           PASS (+0.99 V)
   +3V3_VCC_13:       PASS (+3.31 V)
   +2V5_VCC_34:       PASS (+2.51 V)
   +1V8_VCC_35:       PASS (+1.80 V)
   +1V8_PL:           PASS (+1.78 V)
   +1V0_PL:           PASS (+1.00 V)
   +1V8_LPDDR2_CORE:  PASS (+1.80 V)
   +1V2_LPDDR2:       PASS (+1.20 V)
   +0V6_VREF_LPDDR2:  PASS (+0.60 V)
   +1V25_VREF:        PASS (+1.25 V)
   +2V5_ANALOG:       PASS (+2.51 V)
   -2V5_ANALOG:       PASS (-2.55 V)
   VREF_ANALOG:       PASS (+4.096 V)
Temperatures:
   Detector Temperature:      PASS (+25.5 deg C)
   Analog Board Temperature:  PASS (+29.9 deg C)
   Digital Board Temperature: PASS (+45.9 deg C)
Offset Voltages: PASS (-0.0497 mV, -0.0498 mV)
Noise Voltage: FAIL (+8.64 uV)
Test Heater Power Drift: PASS (-0.07 %)
```

15.2.1 Interpreting the test results

If all test steps or parts pass, the overall result is PASS. If one test step or a part of it fails, the overall result is FAIL. What you need to do in this case is described in the following.

Operating Voltages, Reference Voltages, Offset Voltages, Noise Voltage

Checks the voltages.

If the test fails:

1. Disconnect all signal sources and connectors except LAN or USB.
2. Perform the self-test again.

   If it fails again, a hardware defect is probable.
3. Contact the customer support.

Temperatures

Checks the temperature at several measurement points, whether they are plausible and whether the limits are met.

Is the ambient temperature OK?

► Check whether the ambient temperature lies within the range rated in the specifications document of the R&S NRPC.

  If the ambient temperature is higher or lower, adjust the air conditioning of the room or move the test setup into a room with a fitting temperature.

15.3 Problems during a firmware update

Further information:

- Firmware update. See Section 10, "Firmware update", on page 93.

Sensor is not in the "Device" list

If you do not find the sensor in the "Device" list, the driver assigned to the sensor is the legacy driver.

► Install a recent VISA software.

Sensor is highlighted in the Windows device manager

If the sensor is highlighted by a yellow exclamation mark in the Windows device manager, Windows tries in vain to find a USB driver for the sensor.

► Install a recent VISA software.

Firmware update was interrupted

If for example, a power cut happened during the firmware update, problems can occur.

1. Perform the firmware update again. Sometimes, a further update fixes the problems.
2. If the sensor is not accessible anymore, contact the service.

Firmware update was aborted

If there is not enough free storage space, the firmware update is aborted. An error message is displayed, and the status LED of the sensor starts flashing red.

1. Perform a sanitization procedure, as described in the instrument security procedures. This document is available on the product page.
2. Perform the firmware update again.

15.4 Collecting information for technical support

If you encounter problems that you cannot solve yourself, contact your Rohde & Schwarz support center, see Section 15.5, "Contacting customer support", on page 186. Our support center staff is optimally trained to assist you in solving problems.

The support center finds solutions more quickly and efficiently if you provide them with information on the instrument and an error description.

Obtaining information from the sensor firmware

To create, collect and save the diagnostic and troubleshooting data, use the remote control. See `SYSTem:INFO:SUPPort?` on page 152.

Collect also the error information. See Section 15.1, "Error messages", on page 183.

Attach the collected information to an email in which you describe the problem.

If you need to transport or ship the product, see Section 16, "Transporting", on page 188.

15.5 Contacting customer support

Technical support – where and when you need it

For quick, expert help with any Rohde & Schwarz product, contact our customer support center. A team of highly qualified engineers provides support and works with you to find a solution to your query on any aspect of the operation, programming or applications of Rohde & Schwarz products.

Contact information

Contact our customer support center at www.rohde-schwarz.com/support, or follow this QR code:

Figure 15-1: QR code to the Rohde & Schwarz support page

16 Transporting

Packing

Use the original packaging material. It consists of antistatic wrap for electrostatic protection and packing material designed for the product.

If you do not have the original packaging, use similar materials that provide the same level of protection. You can also contact your local Rohde & Schwarz service center for advice.

Securing

When moving the product in a vehicle or using transporting equipment, make sure that the product is properly secured. Only use items intended for securing objects.

Transport altitude

The maximum transport altitude without pressure compensation is 15000 m above sea level.

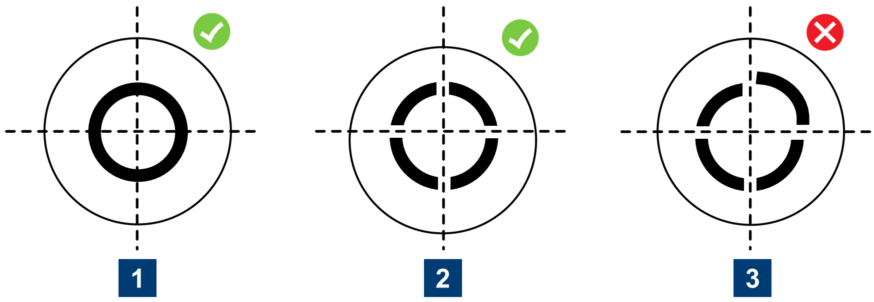
17 Maintenance, storage and disposal

Verify the power standard with the verification set before usage or daily. See Section 7, "Verification", on page 62.

17.1 Checking the RF connector

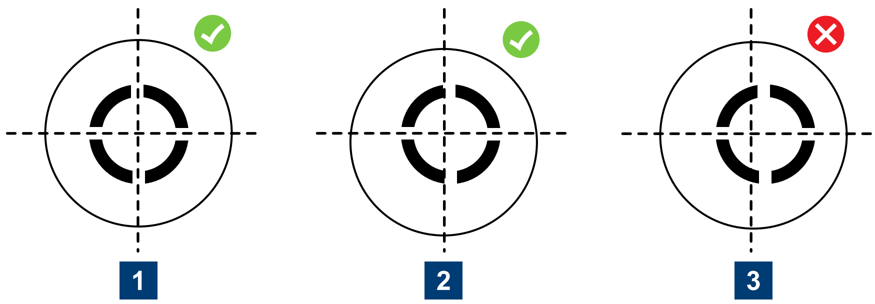
If the product is used frequently, check the RF connectors for visible damage - bent inner conductors, broken contact springs and so on. If the RF connectors are damaged, stop using the product. Contact Rohde & Schwarz customer support, see Section 15.5, "Contacting customer support", on page 186.

Checking the integrity of the RF connector



1 = Perfectly formed contacts
2 = Normal wear
3 = Damaged contacts

Checking the concentricity of the RF connector



1 = Perfectly concentric
2 = Slightly off-center
3 = Excessively off-center

17.2 Exchanging the test port RF connector

In the R&S NRPC33, R&S NRPC40, R&S NRPC50 and R&S NRPC67 power standards, there is an adapter between the test port and the output of the integrated power splitter. You can exchange the adapter if the RF connector of the test port becomes worn out. A replacement adapter is supplied for this purpose with each of the calibration kits mentioned here. The accuracy level is ensured even after the adapter is exchanged. Each power standard is calibrated with both adapters during manufacture and recalibration at German Accreditation Body (DKD) laboratory D-K-15195-01-01. The calibration certificate contains the calibration data for both configurations.

Exchange the adapter if the test port is damaged or in the following cases:

- Verification with the R&S NRPC-B1 verification sensor fails due to strong oscillations in the frequency response.
- High dependence on the angular position during calibration of absolute accuracy.

To exchange the test port RF connector

1. Remove the anti-turn device for the union nut of the adapter:
   a) Loosen the two grub screws using an Allen wrench with a 0.9 mm wrench opening.
2. Unscrew the adapter using a flat wrench with an 8 mm wrench opening.
3. Screw on the replacement adapter, tighten the union nut with a torque of 1.5 Nm, using a torque flat wrench with an 8 mm wrench opening.

   Note: The torque of the supplied torque wrench (0.9 Nm) is too small to prevent the adapter from turning during subsequent usage. If a suitable torque wrench is not available, tighten the adapter by feeling and then check whether the adapter turns when the sensor is screwed on and off.
4. Slide on the anti-turn device and tighten the grub screws.
5. Install the R&S NRP-Toolkit software, provided on the internet.
6. Connect the power standard to the USB port of a Windows computer. Requires an R&S NRP-ZKU or R&S NRP-ZKC USB adapter or an R&S NRP-Z5 sensor hub.
7. Load the calibration data set of the power standard for the replacement adapter using the S-Parameter Update Multi program module of the R&S NRP-Toolkit. See "To load the calibration data set of the power standard" on page 191.
8. Connect the verification sensor to the USB port of a Windows computer.
9. Load the calibration data set for the verification sensor to use on a power standard with the replacement adapter. Use the S-Parameter Update Multi program module of the R&S NRP-Toolkit.
   Also exchange the calibration data set for the verification sensor to obtain correct verification results from the start. The calibration data set is called `Caldata_NRPC-B1_T<serial no.>.bin`, located in the `Dataset/`

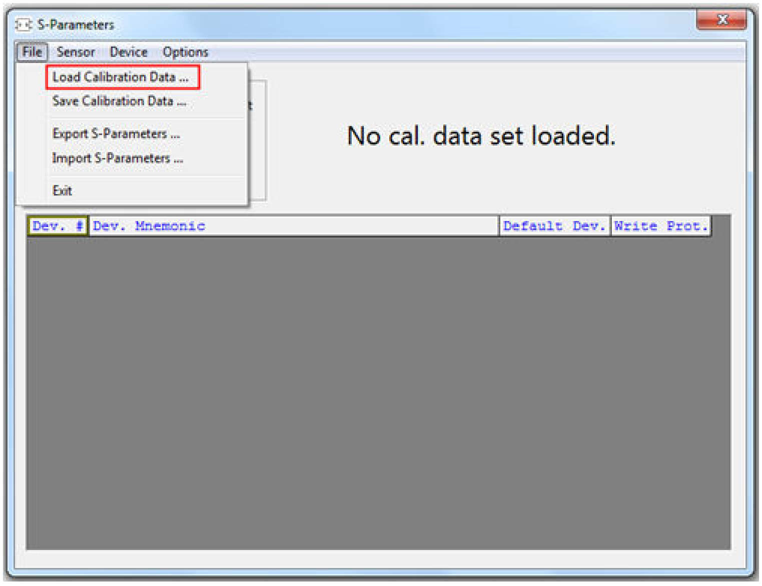
Exchange_Thru directory of the download. As before, the serial number at the end of the filename refers to the spare adapter.

10. Connect power standard and verification sensor to R&S NRX base unit.
11. Check identification of the loaded calibration data sets.
    After successfully loading the calibration data sets, the serial number of the spare adapter is displayed in info texts of the R&S NRX base unit ("System" > "Sensor Info: SPD Mnemonic").
    For the power standard, the letter "T" is followed by the serial number engraved on the spare adapter, e.g. 12387 in the entry T12387. An additional code "A####" stands for the supplied reference attenuator of the R&S NRPC33 and R&S NRPC40 power standards.
12. Perform a verification measurement. See Section 7.1, "Built-in self-test", on page 62.
    The measured values must lie well within the specified tolerance bands. If not, do the following:
    a) Check whether the correct calibration data sets were loaded.
    b) Unscrew the adapter and try remounting it in a different angular position.

To load the calibration data set of the power standard

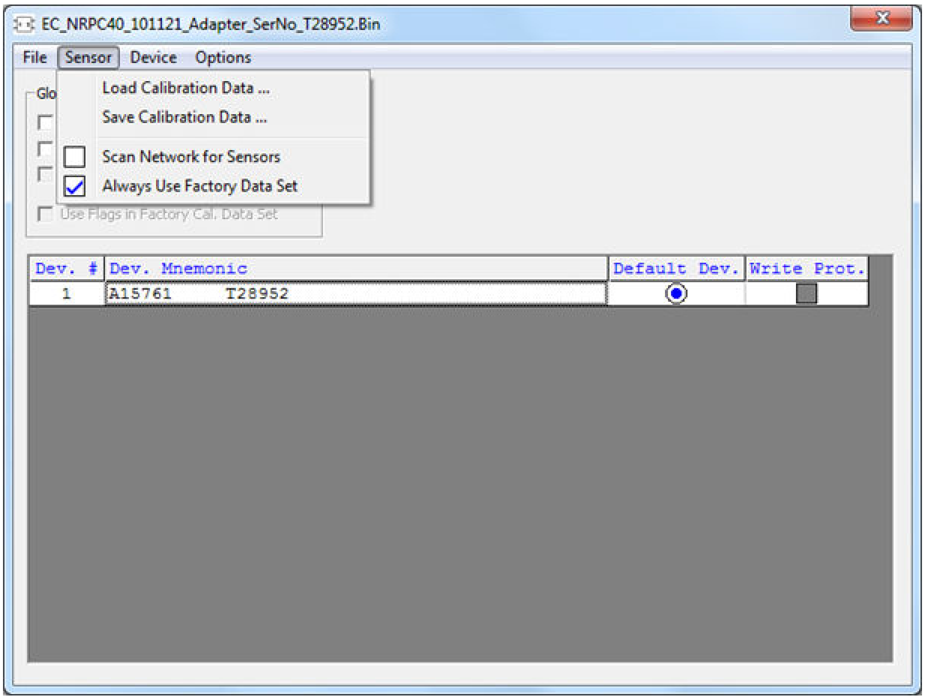
Exchange the calibration data for the power standard when you change the adapter. The data set called Caldata_NRPC_T<serial no.>.bin is located in the Dataset/Exchange_Thru directory of the download. The serial number at the end of the filename refers to the spare adapter. This number is also engraved on the adapter.

1. Open the S-Parameter Update Multi program module of the R&S NRP-Toolkit.



2. Under "File", select "Load Calibration Data". The calibration data for the power standard are in the above-named directory.

3. Under "Sensor", enable "Always Use Factory Data Set", if not already enabled.



17.3 Recalibration

We recommend returning the R&S NRPC and its options to Rohde & Schwarz for recalibration once a year. As part of recalibration, all components are checked, and the reference standards, the reference attenuators and the precision termination are recalibrated. The sensors from the verification set are adjusted to match the recalibrated standards and the data memories are updated.

How to get the recalibration done?

1. Contact your nearest Rohde & Schwarz representative. See Section 15.5, "Contacting customer support", on page 186.

2. Send in the complete calibration kit packed in its storage cases. See also "Packing" on page 188.

What to do when the recalibrated calibration kit comes back?

When you receive the calibrated kit, perform the following steps to ensure that it is functioning correctly.

1. If mentioned in the accompanying letter, update the R&S Recal+ software. For details, see the release note of the R&S Recal+ software.

2. Connect the R&S NRPC power standard to one channel of the R&S NRX.

3. Start the R&S Recal+ calibration software.

4. Initialize the R&S NRX.
5. Perform the verification as described in Section 7, "Verification", on page 62.

17.4 Cleaning

► Clean the outside of the product using a lint-free cloth. You can dampen the cloth with water but keep in mind that the casing is not waterproof. If you use 70% isopropyl alcohol instead of water, be careful not to damage the labeling. Do not use cleaning agents that can damage the instrument such as acetone, acids or alkalis.

Further information:

- Application note 1MA99: "Guidance on Selecting and Handling Coaxial RF Connectors used with Rohde & Schwarz Test Equipment"

17.5 Storage

Put plastic end caps on the RF connectors to protect them from damage. Protect the product against dust.

Ensure that the environmental conditions, e.g. temperature range and climatic load, meet the values specified in the specifications document.

17.6 Disposal

Rohde & Schwarz is committed to making careful, ecologically sound use of natural resources and minimizing the environmental footprint of our products. Help us by disposing of waste in a way that causes minimum environmental impact.

Disposing of electrical and electronic equipment

A product that is labeled as follows cannot be disposed of in normal household waste after it has come to the end of its life. Even disposal via the municipal collection points for waste electrical and electronic equipment is not permitted.

Figure 17-1: Labeling in line with EU directive WEEE

Rohde & Schwarz has developed a disposal concept for the eco-friendly disposal or recycling of waste material. As a manufacturer, Rohde & Schwarz completely fulfills its obligation to take back and dispose of electrical and electronic waste. Contact your local service representative to dispose of the product.

List of commands