R&S®RFPAL, R&S®SMW-K545
RF Ports Alignment
User Manual

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Version 03

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This manual describes the following application and software option:

- R&S®RFPAL (1414.7019.02)

- R&S®SMW-K545 (1414.6429.02)

This manual describes R&S®RFPAL, version 1.2 and later. Related firmware version of the R&S®SMW200A: FW 5.20.043.xx and later.

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

Contents

1 Documentation overview

This manual contains two main parts:

- All information about the R&S RFPAL application which determines correction data for RF ports alignment, see Chapter 3, "R&S RFPAL", on page 11
- RF Ports alignments option for R&S SMW signal generator in a multi-instrument setup on basis of the results of R&S RFPAL, see Chapter 4, "RF ports alignment at the signal generator", on page 49

Chapter 2, "About RF ports alignment", on page 6 describes the principle and common aspects of RF ports alignment.

RF ports alignment at the signal generators is embedded in the generators multi-instrument capabilities. See the R&S SMW user manual for comprehensive information about multi-instrument usage, general operation and SCPI handling.

Unless specified otherwise, you find the documents on the R&S SMW product page at:

www.rohde-schwarz.com/manual/smw200a

2 About RF ports alignment

RF ports alignment refers to test setups where the DUT gets several RF signals which have to be coherent. The RF signals come from several R&S SMW signal generators (multi-instrument setup). Due to own signal processing in the signal generators, the resulting RF signals at the out ports of the instruments can differ in phase, time delay and power in dependency to the signal frequency and power. RF ports alignment corrects such signal deviations. Consequently, the DUT receives coherent RF signals.

RF ports alignment consists of two processes:

- Measurement of the signal deviations (or misalignments) of the RF signals from the signal generators and creation of correction data. This task is done by R&S RFPAL. S-parameter files (s<n>p files) are included to compensate signal deviations by RF components in the RF paths like cables. The measurements are carried out with the test setup for testing the DUT but with additional measurement equipment. One signal generator is the primary instrument and its first used RF port is the reference port. R&S RFPAL measures the signal differences between the reference port and the other ports to calculate the required correction data.

- Application of the correction data at the signal generators. The primary instrument distributes correction data to the other signal generators. During test execution, the signal generators modify their RF signals according to the correction data and transmit the corrected signals synchronously. This functionality is enabled by the R&S SMW-K545 option.
  Correction data is applied in real time (not by predistorting given waveforms) and can therefore be used in real time applications such as PDW streaming.

R&S RFPAL delivers the correction data to the primary instrument. It does not take part in the second process. See Chapter 3, "R&S RFPAL", on page 11 for the detailed description of the application.

When correction data has been provided to the primary instrument and the R&S SMW-K545 option is available, the configurations for RF ports alignment are automatically carried out. You can inspect the configurations via the primary instrument's graphical user interface or via SCPI commands. To apply RF ports alignment, you only have to enable it at the primary instrument. See Chapter 4, "RF ports alignment at the signal generator", on page 49 for the detailed description.

2.1 Aligned RF signals from coupled signal generators

The figure shows the testing situation when alignment of the RF signals is applied by the signal generators using the alignment data from R&S RFPAL.
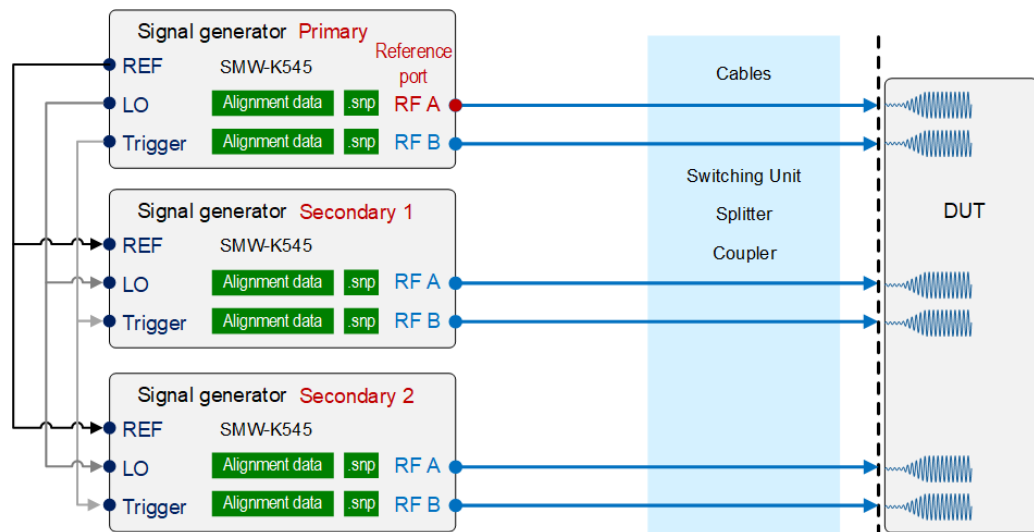
Figure 2-1: Aligned RF signals

Characteristics:

- The RF signals originate from several signal generators and are denoted by the RF ports. Each RF port is the source for one signal path to the DUT.

- To create reproducible relations between the RF signals (that nevertheless experience misalignments), the signal generators are coupled. One signal generator is the primary instrument. The other signal generators act as secondary instruments. The signal generators share several signals; here the primary instrument provides them to the secondary instruments:

  – Reference signal (REF)

  – Baseband synchronization and trigger signal

  – Local oscillator (LO)

  So all instruments are synchronized using the same reference signals, trigger signals and local oscillator.
  Alternatively, the reference signal and the local oscillator can be provided by external sources.

- The first RF port of the primary instrument serves as reference port. The alignment of the RF signals from other ports is done relative to the RF signal from the reference port.

- The primary signal generator gets the correction data (alignment data and `s<n>p` data) from R&S RFPAL. The other signal generators get their correction data from the primary one. Alignment data compensates misalignments between the RF signals at the different RF ports. `s<n>p` data compensates signal deviations in the RF paths caused by RF components such as cables and splitters.

2.2 Misaligned RF signals and alignment in signal generators

Alignment only works fine if the relations between the RF signals from the different RF ports are reproducible. Therefore, trigger, clock signal and local oscillator are coupled for the signal generators. The trigger coupling avoids trigger jitter. Misalignments still occur regarding LO phase, time delay and signal amplitude. The figure illustrates the different contributions to misalignments of signals and the effect of alignment with R&S RFPAL.
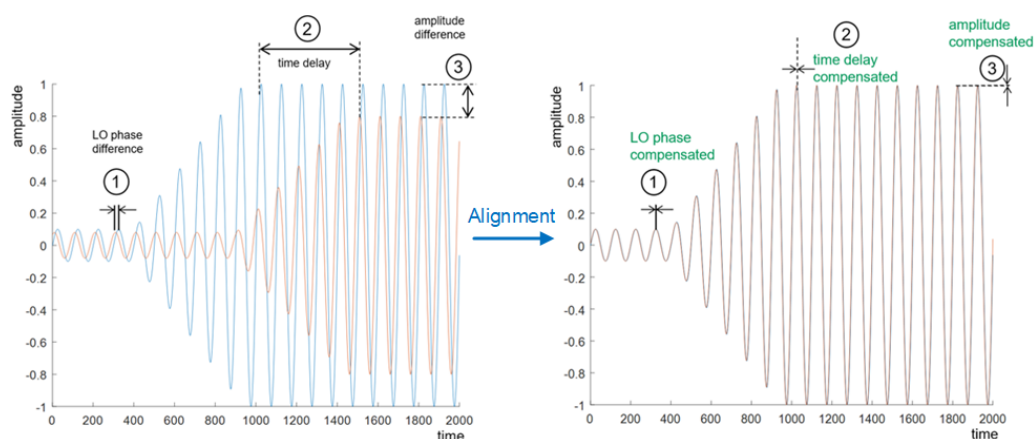
Figure 2-2: Contributions to misalignments and alignment effects

The table describes causes of misalignments and how misalignments are compensated in the signal generators.

Table 2-1: Causes for misalignment and their compensation

Effect	Caused by	Compensated by
LO phase difference	Length of the cables used for the distribution of the LO signal Phase errors in splitters or amplifiers	Offsetting the signal in the baseband (digital domain)
Level difference	Attenuation in the RF path	Adjusting the RF level
Time delay	Length of the cables used for the distribution of the trigger signal	Applying I/Q delay

The compensations require different settings if carried out manually. R&S RFPAL supports an integrated compensation process.

Alignment over frequency and power

The phase/power/delay differences between the RF signals of the different ports depend on the frequency and the signal power. Figure 2-3 schematically shows the phase over frequency for two RF ports before alignment (upper left part) and after alignment (lower left part).

Figure 2-3: Phase responses and relative compensation

bw = Modulation bandwidth

RF A is the reference port. The phase values vary over frequency for both RF ports but with different courses. Using the alignment data derived from the measurements of the network analyzer, RF ports alignment adjusts the phase course for port RF B to that of port RF A. This alignment is relative (as are the measurements of the network analyzer): The RF signals for RF A and RF B are in phase but no compensation is done to get a constant phase over frequency. Power levels and delays are aligned accordingly, that is, alignment is done relative to the reference port.

Also, the signal power over frequency can be measured for the reference port by a power sensor (absolute power measurement). In this case, an additional power compensation step is carried out. For a constant power level over frequency for all RF ports, the power variations measured at the reference port are compensated for the reference port and all other RF ports.
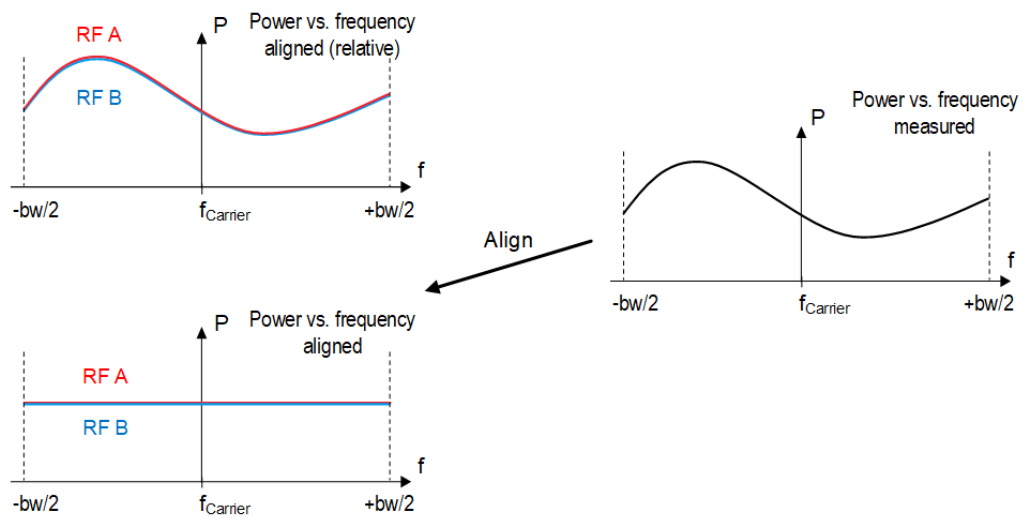
Figure 2-4: Power compensation with data from the power sensor

2.3 Required options

R&S RFPAL is not related to a software option. Instead, options are required for the R&S SMW to interplay with RFPAL and to use the alignment data according to the following list.

- R&S SMW-K545 (for each signal generator): RF ports alignment
- R&S SMW-K544 (per signal path): User-defined frequency response correction
- R&S SMW-K61 (per signal path): Multi-carrier continuous wave
- R&S SMW-B9 (per signal path): Wideband baseband generator
- R&S SMW-B13XT: Wideband baseband main module two I/Q paths to RF
- R&S SMW-B90: Phase coherence
- R&S SMW-B1003 (for example): RF frequency from 100 kHz to 3 GHz

If only standard baseband signals are required, you can use R&S SMW-B10 and R&S SMW-B13T instead of R&S SMW-B9 and R&S SMW-B13XT.

Note that R&S RFPAL includes an R&S®QuickStep standard option to perform the alignment procedures.

3 R&S RFPAL

3.1 About R&S RFPAL

R&S RFPAL is useful for test scenarios where one or more R&S SMW signal genera-
tors provide several RF signals that have to be coherent. Because RF signals at the
R&S SMW RF outputs can differ in phase, time delay and power depending on the RF
signal frequency and power. Where this difference is due to signal processing and tim-
ing in the signal generators.

R&S RFPAL assists in providing coherent RF signals over all RF paths at the DUT: It
measures relative signal deviations between RF paths and provides correction data for
the R&S SMW. The R&S SMW apply the correction data to compensate the deviations.
The RF signals of the different paths are aligned in this way. R&S RFPAL is short for
RF ports alignment. For applying the correction data at the signal generators, they
have to be equipped with the R&S SMW-K545 option.

Correction data is applied in real time (not by predistorting given waveforms) and can
therefore be used in real time applications such as PDW streaming.
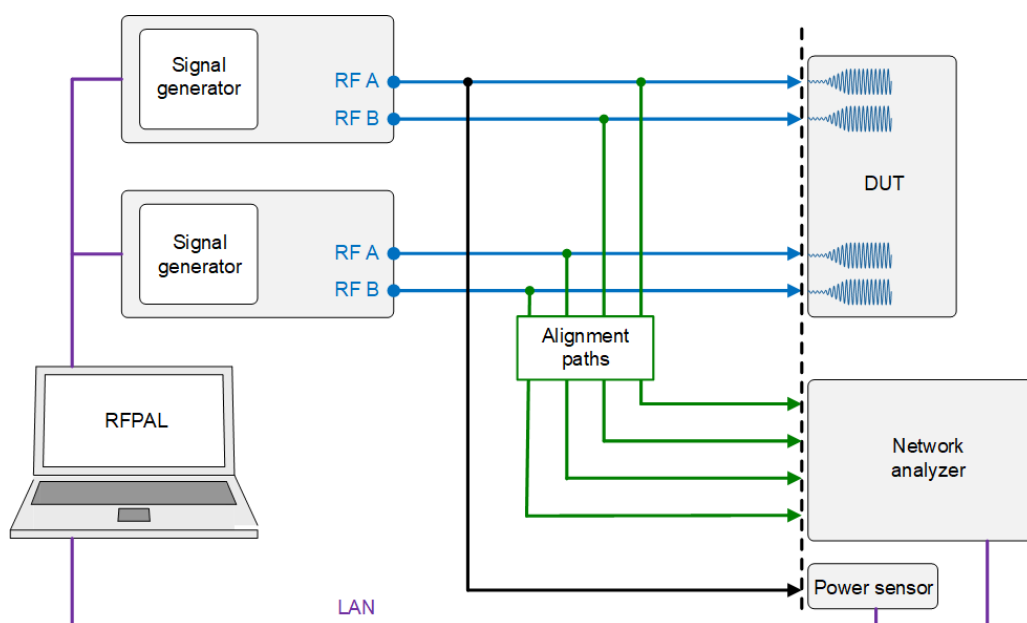
Figure 3-1: RF paths to be aligned

R&S RFPAL is an application that runs on a PC which is LAN-connected to the signal
generators. For alignment measurements, the test setup includes a network analyzer
and often a power sensor. R&S RFPAL controls the signal generators and the mea-
surement instruments.

If there are other RF components in the RF paths from the RF ports to the measure-
ment instruments than to the DUT, the measurement results of the measurement
instruments would not reflect the situation at the DUT. The different RF components

(for example splitters and cables) would cause different signal deviations. R&S RFPAL supports compensation of such signal deviations by S-parameter files (s<n>p files) which have to be provided.

Without R&S RFPAL, alignment of the RF signals in a test setup with several signal generators can be time-consuming and erroneous. First, the test and measurement instruments have to be controlled manually in a coordinated way for the alignment measurements. Second, the resulting corrections have to be provided manually in different parameters at the signal generators. Usually, you also have to ensure that all RF-related parameters of the generator are maintained.

R&S RFPAL uses R&S QuickStep to control the signal generators and to perform the alignment procedures.

Key facts

RFPAL interplays with one or several generators R&S SMW, a network analyzer and optionally a power meter.

RFPAL provides:

- Representation of the test setup and configuration of the alignment measurements
- Coordinated control of the R&S SMW and measurement instruments during alignment measurements; control of an R&S OSP RF switching unit, if used, is included
- Measurement of alignment data for correcting deviations in delay, phase, power level (PEP)
- Calibration support for an R&S network analyzer
- Integration of S-parameter files (s<n>p files) for RF path components and of calibration files for R&S network analyzer and R&S OSP
- Check of alignment results (by applying correction data)
- Provision of correction data (alignment data and s<n>p files) to the primary R&S SMW

3.2 GUI overview
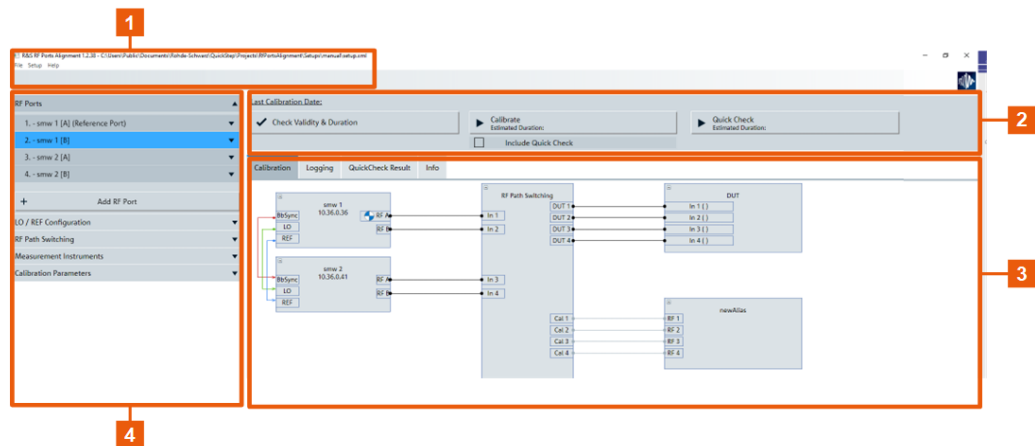
Figure 3-2: R&S RFPAL user interface

1 = Top menues
2 = Controls area
3 = Content area
4 = Configuration area

In the configuration area, you configure the setup for alignment measurements. The settings can be saved via the top menu "File > Save Setup" or previous settings can be loaded via "File > Load Setup".

You start and control the alignment measurements via "Calibrate" in the control area.

The information in the content area is distributed in several tabs:

- The "Calibration" tab shows a graphical representation of the setup as configured in the configuration area and used for the alignment measurements.

- The "Logging" tab contains processing and status information and event reports. You see what is going on. If errors occur, the information in this tab helps you to understand the problem and how to solve it.

- The "QuickCheck Result" displays charts for magnitude/phase/delay errors detected with a "QuickCheck" action.
  The "QuickCheck" runs the signal generators with correction data applied and measures the remaining misalignments.

3.3 Concepts

3.3.1 Test setup for alignment measurements
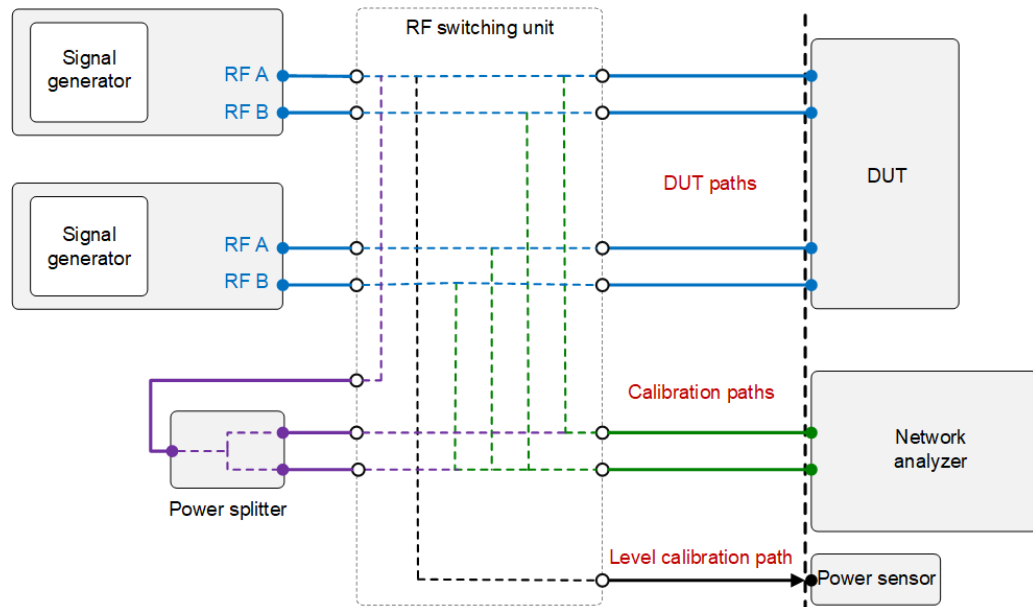
Figure 3-3: Test setup including an RF switching unit and relevant paths

The figure shows a useful instrument setup for R&S RFPAL alignment measurements.

Characteristics:

- The measurements instruments, a network analyzer and a power sensor, are embedded in the test setup that is used for executing tests after alignment. No test setup changes are required after alignment.

- Optionally, an RF switching unit connects the RF signal path sections at the signal generator side and the signal path sections at the DUT side. R&S RFPAL controls the switching unit. It can select the paths to be used for measurements, so the paths are switched automatically during R&S RFPAL operations. A configuration file is required at the switching unit that defines the required paths.
  If no switching unit is used, the required connections between RF ports and network analyzer have to be established manually (assisted by dialogs) during the measurement procedures.

- The components in the RF signal paths to the DUT can differ from the components to the measurement instruments. So, DUT paths are distinguished from the corresponding calibration paths to the network analyzer and from the level calibration path (corresponding paths: same signal generator's RF port). See in Integration of S-parameter files how the different path types are used.
  Always use cables of the same length and type for corresponding paths and all RF ports. Consequently, the relative signal deviations are minimized.

- The power sensor is used for measuring the RF signal power at the reference port.

- For calibration of the network analyzer, a power splitter can be integrated in the test setup. If an RF switching unit is used, connect the input and the output ports of the power splitter to the switching unit. The configuration file for the switching unit defines the RF paths through the power splitter. R&S RFPAL commands the unit to select the right RF paths to and from the power splitter for the calibration of the network analyzer. So, no change of the test setup and no manual connection establishment is required when proceeding from network analyzer calibration to alignment measurements.

3.3.2 Integration of S-parameter files

The network analyzer carrying out the alignment measurements experiences the same misalignments as the DUT if the DUT paths and the corresponding calibration paths are equivalent. This is the case if the RF connections to both devices consist of the same RF components, for example cables of the same type and lengths are used. So the alignment measurements match the situation at the DUT, and applying RF port alignment with the produced alignment data exactly aligns the RF signals at the DUT. In other words, alignment is required at the DUT reference plane, and the measurement plane of the network analyzer matches the DUT reference plane, see Figure 3-4.
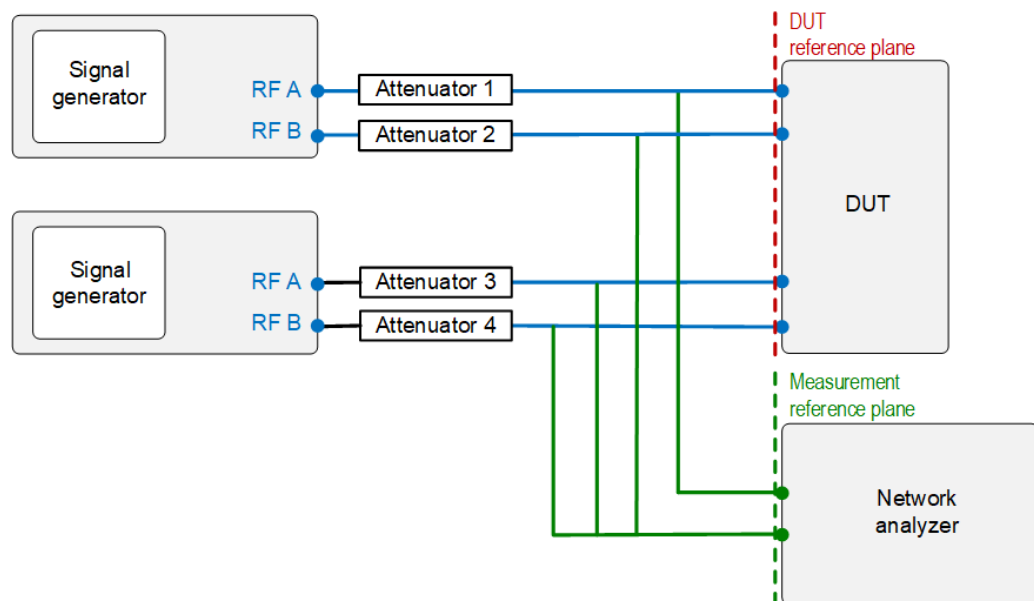
Figure 3-4: Equivalent DUT and calibration paths

The DUT paths and calibration paths often contain different RF components, which cause different signal deviations. We need to compensate these deviations for matching the situations at the measurement reference plane and the DUT reference plane. Figure 3-5 shows typical conditions.
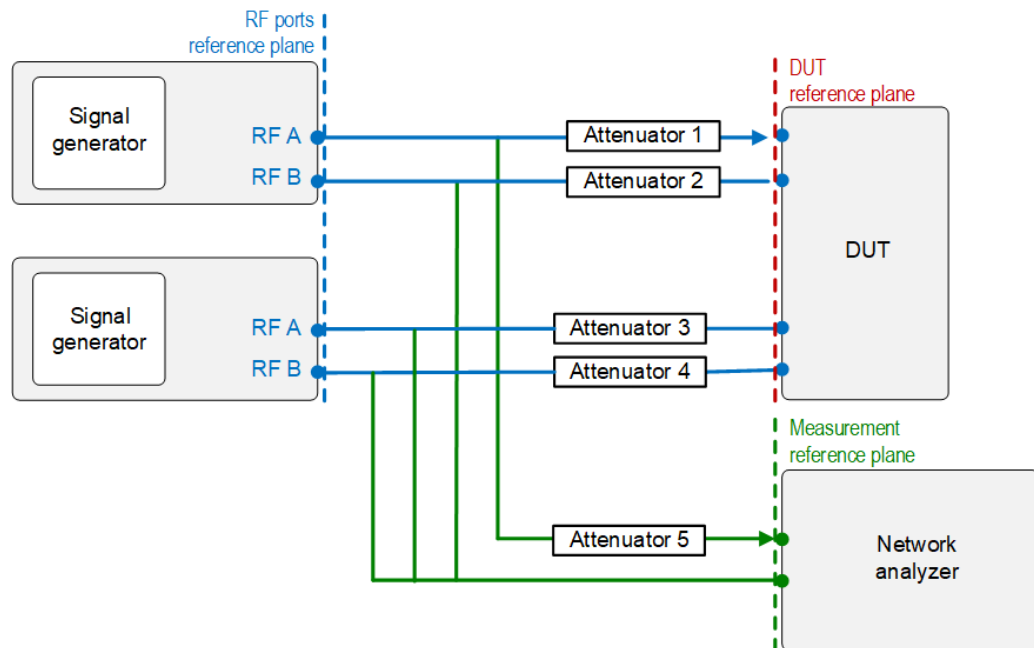
Figure 3-5: Different DUT paths and calibration paths that require S-parameter compensation

R&S RFPAL integrates compensation of signal deviations from RF components in the RF paths by S-parameter files (s<n>p files). The different RF path types are handled as follows:

- Calibration path:
  Gets the S-parameter files for the components in the RF signal path between RF port and network analyzer, particularly for the switching unit. R&S RFPAL uses these S-parameter files for compensating deviations in these paths during the alignment measurements. So alignment data is produced as if the measurements were carried out in the RF ports reference plane. Applying the S-parameter files shifts the measurement reference plane to the RF ports reference plane.

- DUT path:
  Gets the S-parameter files for cables, splitters and other components in that path. R&S RFPAL forwards these calibration files to the primary signal generator after the alignment measurements. They are applied by the signal generators to compensate the signal deviations in the DUT paths. In combination with alignment data related to the RF ports reference plane, the DUT gets aligned RF signals. Applying the S-parameter files can be seen as deembedding of the DUT. By removing the signal deviations between the RF ports of the signal generators and the DUT, the reference plane is shifted from the RF ports to the DUT reference plane.

- Level calibration path:
  Gets the S-parameter files for the components in the RF signal path between reference port and power sensor. R&S RFPAL uses these S-parameter files in the same way as the files for the calibration paths.

Measuring the frequency responses of the RF components in the different RF paths is not part of R&S RFPAL. Usually, the frequency responses of the RF components are known and s<n>p calibration files for them are already available.

3.3.3 Alignment measurements

Figure 3-6 shows schematically how misalignments between two RF ports of one or two signal generators are measured with a network analyzer.
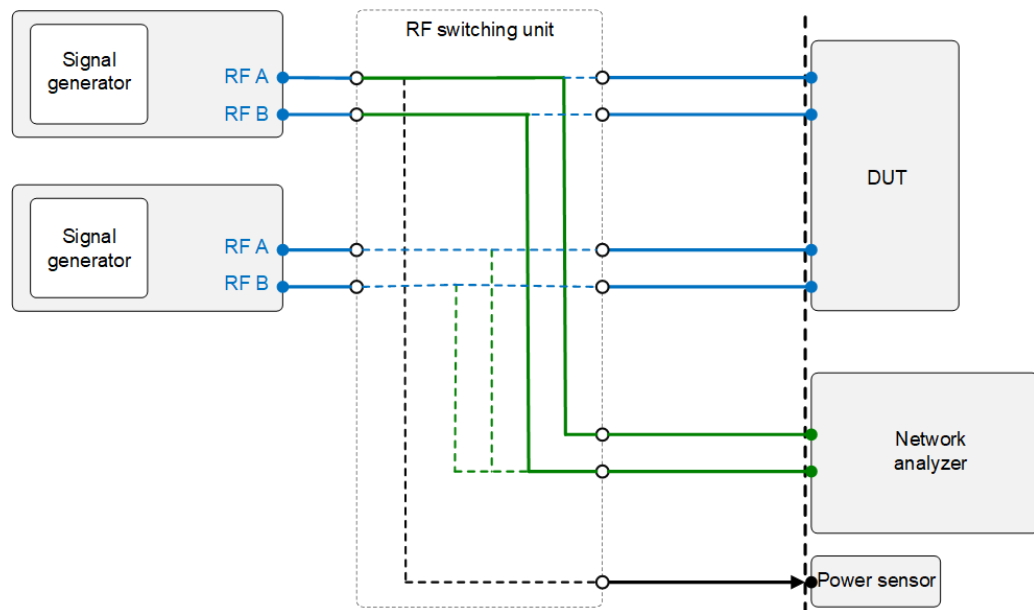
Figure 3-6: Alignment measurement for RF A and RF B

With connections between the reference port and a second RF port to the network analyzer established, R&S RFPAL commands the signal generators to generate appropriate RF signals. Instead of continuous-wave signals to be swept over the signal bandwidth, multi-carrier continuous wave (MCCW) signals are used. The network analyzer measures the differences between the RF signals over the frequencies and over signal power levels as configured in R&S RFPAL.

If more than two RF ports have to be aligned, the second RF port is changed. Then the same alignment measurement is performed for the new pair of reference port and second RF port. The process repeats until all RF ports are aligned. So, the reference port is always connected to the same input port of the network analyzer and the second port changes for each measurement. The connection to the next RF port is changed either automatically via RF switching box under control of R&S RFPAL or manually.

Power measurement with the power sensor is performed only for the reference port. Relative power differences between the reference port and the other RF ports are already covered by the network analyzer measurements.

3.3.4 Calibration of the network analyzer

R&S RFPAL supports calibration of the network analyzer. Two ports of the network analyzer are used to measure the signal differences of two RF ports of the signal generators. Calibration of the network analyzer makes sure that any differences in the frequency responses of the receivers behind the ports are compensated and do not influence the alignment measurements. For determining the differences of frequency responses in the network analyzer, the same RF signal is fed to the two ports. The network analyzer measures and evaluates the differences between the responses.

If direct receiver access is enabled for the network analyzer, its "Ref" and "Meas" connectors can alternatively be used (there is a receiver behind "Ref" and one behind "Meas"). Notice that when using direct receiver access, the standard calibration of the network analyzer is no more valid.

Two methods for calibration of the network analyzer are supported:

- Power splitter method:
  The primary signal generator generates appropriate RF signals and transmits them to a power splitter where they are split. The resulting two identical RF signals are fed to the two network analyzer receivers to be calibrated. RFPAL controls both the primary signal generator and the network analyzer and applies the s<n>p calibration file of the power splitter. This method fits to the test setup that is later used for testing. Only the power splitter is added to the test setup and you have to establish its connections.
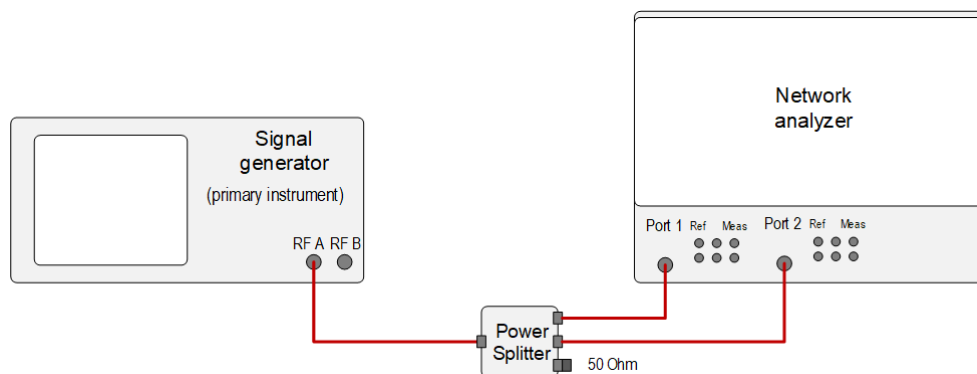
Figure 3-7: Calibration of network analyzer with power splitter and signal generator

Use the power splitter method for the R&S ZVA. The following method is not valid for this instrument.

- TOSM (Through – Open – Short – Match) method:
  This calibration type yields the most accurate calibration results (reflection and transmission measurements; 12-term error correction model). It relies on automatic calibration procedures of the network analyzer. Equivalent VNA standard calibration is also possible.
  TOSM calibration can be done in two ways.

For both, the network analyzer generates RF signals, transmits them to and through standard units, measures the responses and evaluates the differences between generated RF signals and responses:

  – Using a calibration kit for the network analyzer:

The Short, Open and Match standard from the kit are connected to one port, the Through standard is put between this port and the second one. See the network analyzer's documentation. R&S RFPAL is not involved. This calibration must be done at the network analyzer before R&S RFPAL is used. R&S RFPAL just gets the name of the resulting calibration file.

– Using a calibration unit:
It replaces the standards from a calibration kit, and full automation is possible. Refer to the documentation of the network analyzer.
Though the calibration procedures are carried out completely at the network analyzer, R&S RFPAL assists for this type of calibration. If the calibration unit is integrated in the test setup at R&S RFPAL, R&S RFPAL can control not only the network analyzer but also the calibration unit and the calibration. The results of the calibration are stored in a calibration file which you have to specify in R&S RFPAL. Later on, R&S RFPAL loads this file onto the network analyzer.
The calibration unit is supported only if its number of ports is at least equal to the number of ports of the network analyzer. Otherwise, you must first calibrate the network analyzer by following the build-in calibration wizard. For details, Refer to the documentation of the network analyzer.

3.3.5 Delivery of correction data

Having completed the alignment measurements, R&S RFPAL delivers the alignment data and s<n>p files for the DUT paths for all RF ports to the primary signal generator (via `*.rfsa` archive file). The combination of alignment and s<n>p data is called correction data. Further distribution of the correction data and application of the correction data, which aligns the RF signals, is done at the signal generators without participation of R&S RFPAL.

3.3.6 R&S QuickStep behind the scene

R&S QuickStep is an application that configures test procedures, runs test plans – sequences of individual tests together with scheduling and execution information – and evaluates the results. During test execution, R&S QuickStep controls the test equipment via SCPI commands. R&S QuickStep also provides the calibration and alignment procedures. The alignment procedures cover the typical use cases.

3.4 Preparing for use

3.4.1 Preliminaries

3.4.1.1 Required hardware

R&S RFPAL is intended to be used on a PC. No special hardware and other software is required. The tool runs on Windows 10.

3.4.1.2 Required options

R&S RFPAL is not related to a software option. Instead, options are required for the R&S SMW to interplay with R&S RFPAL and to use the alignment data, particularly R&S SMW-K545 RF ports alignment.

R&S RFPAL also includes an R&S QuickStep standard option to perform the alignment procedures.

3.4.2 Installing and starting R&S RFPAL

Installing R&S RFPAL

The tool is provided as `.exe` installation file. You install the tool on the PC that controls the alignment procedures.

1. Download the installation file from the following destination.
   https://www.rohde-schwarz.com/software/rfpal

2. Double-click the file.
   An installation dialog guides you through the installation process.

3. Accept the license conditions and click "Next".

   R&S RFPAL is installed on your PC. An "R&S RFPAL" icon is added on the desktop for starting the tool.

Starting the tool

► Double-click the "R&S RFPAL" icon on the desktop.

   The application starts and its graphical user interface opens with a start page. Either click "New setup" to create a setup file that has only some default settings and that you fill with configuration data. Or click "Load setup" to load a setup file from an earlier R&S RFPAL session.
   Then, the actual R&S RFPAL GUI is opened representing the settings stored in the setup file.

3.5 Operation

R&S RFPAL is operated by a sequence of steps.

- Configure the setup
- Configure RF path switching and the measurement instruments
- Configure the alignment measurements
- Execute the measurements and transfer correction data

Prerequisites

Before applying the following procedures:

- Make sure that the cabling connections have been established. Particularly, R&S RFPAL needs LAN connections to the instruments to be controlled.
- Switch on the instruments.

Set up all instruments at once in the connection configuration dialog when opening it the first time during the R&S RFPAL configuration (see Connection configuration dialog). Then, you only have to select the right instruments in the later R&S RFPAL configuration steps.

3.5.1 Configure the setup

The setup of the signal generators and the connections is configured by parameters in the "RF Ports" and "LO/REF Configuration" sections of the configuration area on the left side. After saving the configuration, the "Calibration" tab displays a schematic diagram of the instruments and paths as configured.

Use case

No setup is loaded. Instead, a new setup is built by configurations in the "Calibration" area.

Prerequisites

- S-parameter files for the components in the RF paths (between RF ports and the DUT and the measurement instruments) are available if needed (see Integration of S-parameter files).

To configure the RF ports (including signal generators and RF paths)

1. From the top menu, select "File > New Setup". Enter a filename for the `.xml` file that describes the setup and store the file.

2. In the configuration area, select "RF Ports".

3. For each RF port in your physical test setup, select "+ Add RF Port" to add an RF port section.

4. For each section, enter an RF port name from the loaded test setup for "RF Port Name".

    Note: The first RF port is always the reference port. The signal generator with that port is the primary instrument.

5. Open the "Config" dialog. Add the signal generator for the RF port.
    For example, use "Search Instrument" if the instrument is connected and running in the LAN.

6. Select "Save & Select" while the row for the signal generator is highlighted.

    The dialog closes and the device name of the signal generator from the "Config" dialog is displayed in the "Device Name" field.

7. Select the used "RF Port".

8. For all components in the signal path from the signal generator's RF port to the DUT:
    In the"DUT Path" section, select "Add Row". Add the related S-parameter files.

9. For the components in the signal path from the signal generator's RF port to the calibration instrument, for example a network analyzer:
    In the "Calibration Path" section, select "Add Row". Add the related S-parameter files.

10. For the reference port of the primary instrument, the "Level Calibration Path" section is available.
    For the components in the signal path from the reference port to the level calibration instrument (power sensor):
    In the "Calibration Path" section, select "Add Row". Add the related S-parameter files.

To configure the local oscillator and the reference signal

This example assumes that the primary signal generator provides the local oscillator and the REF signal, all secondary signal generators get the LO and REF signals from the primary instrument.

Default settings are provided for this use case. So, if you decide to operate with this use case, you can omit the following procedure. Nevertheless, the procedure illustrates exemplarily how to configure in this section.

1. Select "LO / REF Configuration" in the configuration area on the left.

2. Configure the parameters according to your physical test setup.

    ● Enable "LO Coupling".
    ● Select "Star" for the "LO Configuration".
    ● Select "Internal" for the "LO Source".
    ● Select "Internal" for the "REF Source from Primary".

To save the configuration

► From the top menu, select "File > Save Setup".

Vice versa, you get the saved configuration via "File > Load Setup".

3.5.2 Configure RF path switching and the measurement instruments

RF path switching means changing one connection between an RF port of a signal generator and the network analyzer (the other connection to the reference RF port is kept).

Measurement instruments are the network analyzer and the power sensor.

To configure the RF path switching

If an RF switching unit is integrated in the test setup, you can use automatic switching: R&S RFPAL commands the switching unit to establish the required connections.

Else, manual switching is required where you reconnect manually.

1. Select "RF Path Switching" in the configuration area on the left.

2. Select the "Switching Mode" according to your needs.

3. If "Switching Mode = Automatic":
   - Configure and select the RF switching unit via the "Config" dialog.
   - Enter the name of the configuration file that defines the mapping between the ports of the RF switching unit and the RF path sections. This file must be available on the RF switching unit.

To configure the network analyzer

Calibration of the network via power splitter is included. See Calibration of the network analyzer for details.

1. In the configuration area, expand "Measurement Instruments". Select the checkbox at the "Vector Network Analyzer" field is and expand the field.

2. Get the "Device Name" of the network analyzer via the Config dialog and "Save & Select".
   If the network analyzer is not yet available in the "Config" dialog, add the instrument in the dialog and select it.

   "Number of Ports" indicates how many ports of the network analyzer are used for the alignment measurements.

3. Keep "Direct Receiver Access" disabled.

4. Select "Calibration Mode = Power Splitter".

   A table for S-parameter files is displayed.

5. Select the S-parameter file for compensating signal deviations by the power splitter (only for calibration).

To configure the power meter

1. In the "Measurement Instruments" area, select "Power Meter" and expand the field.

2.   Get the "Device Name" of the power meter via the "Config" dialog and "Save & Select".

To save the configuration

► Select "File > Save Setup" from the top menu.

3.5.3 Configure the alignment measurements

The configurations for the alignment measurements are done in the "Calibration Parameters" section in the configuration area on the left.

To configure the RF signals for alignment measurements

The frequency configurations are related to the maximum usable bandwidth at the R&S SMW. See Chapter 3.5.3.1, "Setting appropriate calibration frequencies", on page 24 for details.

1.   Select "Calibration Parameters" in the configuration area on the left.

2.   Specify the carrier frequencies used for the calibration measurements.

3.   Specify the power levels (peak envelope power, PEP) used for the calibration measurements.

4.   Specify the modulation bandwidth of the signal.

     Alignment measurements are carried out with two independent loops for frequency and power level as specified above.

3.5.3.1 Setting appropriate calibration frequencies

The upper part of the following figure graphically represents a set of calibration frequencies and levels configured in the "Calibration Parameters" area. The light-blue background color shows the frequency ranges covered for alignment. R&S RFPAL determines alignment data for each frequency range defined by the calibration frequency in the center and the modulation bandwidth around the calibration frequency. In the middle part of the figure, you see that the aligned frequency ranges overlap without gaps. Therefore the distance between two selected calibration frequencies has to be smaller than the modulation bandwidth.
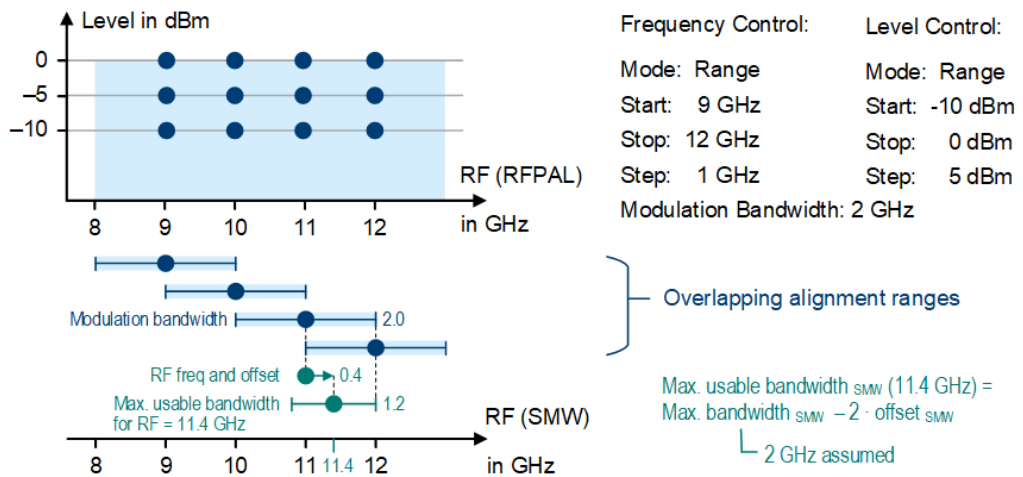
Figure 3-8: Calibration set and relations to the RF signal at the R&S SMW

The lower part of the figure illustrates the resulting situation at the R&S SMW. The R&S SMW automatically selects the correction data for the frequency range whose calibration frequency is nearest to the RF center frequency (largest overlap of aligned frequency range and RF signal). Accordingly, the R&S SMW uses the calibration frequency as RF frequency and adds a frequency offset to reach the center frequency f of the RF signal to be generated. Due to this frequency offset, the maximum usable bandwidth at the R&S SMW is reduced in dependency to f:

[1] Maximum usable bandwidth $_{SMW}$ (f) = Maximum bandwidth $_{SMW}$ − 2 · Offset to calibration frequency $_{SMW}$ (f)

See Example: calibration settings for signal set and usage at the R&S SMW for an example and illustrations.

Figure 3-9 shows how the maximum usable bandwidth at the R&S SMW depends on the RF frequency and the calibration frequencies for a given maximum bandwidth at the R&S SMW. Here 2 GHz; values from the example on Figure 3-8.
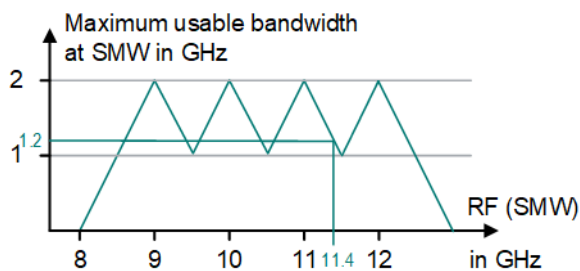

Figure 3-9: Maximum usable bandwidth for the RF signal at the R&S SMW

You can control the maximum offset between RF frequency at the R&S SMW and the nearest calibration frequency by the distance between two calibration frequencies:

[2] Offset$_{SMW}$(f) < calibration step size $_{RFPAL}$ / 2

The RF signal with its center frequency and bandwidth has to be located within an aligned frequency range. Particularly, the maximum usable bandwidth at the R&S SMW must be larger than the bandwidth of the RF signal to be created:

[3] RF signal bandwidth < Maximum usable bandwidth $_{SMW}$ (f)

To achieve that the bandwidth requirements, select a smaöö enough calibration step size at R&S RFPAL. Consequently, the frequency offset at the R&S SMW is small enough. With the following setting, the maximum usable bandwidth at the R&S SMW is large enough even for the largest possible frequency offset (using equations [3] and [2] in equation [1]):

[4] RF signal bandwidth = Maximum bandwidth $_{SMW}$ − Calibration step size $_{RFPAL}$

Hence:

[5] Calibration step size $_{RFPAL}$ = Maximum bandwidth $_{SMW}$ − RF signal bandwidth

Often, you set the modulation bandwidth to the maximum bandwidth which the R&S SMW in the test setup support (lowest value of the included R&S SMW). Having in mind the maximum bandwidth of the RF signal to be generated, use the formula [5] to determine the required step size for the calibration frequencies. More conveniently, use the Range Mode Wizard to configure the frequency parameters.

3.5.3.2　Setting appropriate calibration levels

The R&S SMW automatically selects the correction data for the calibration level that is equal or the first that is higher than the RF signal level (best dynamic range). The R&S SMW uses that calibration level as attenuator value. The difference between the RF signal power level and the attenuator value is automatically set as digital attenuation. Due to the digital attenuation, the usable dynamic range is reduced.

See Example: calibration settings for signal set and usage at the R&S SMW for an example and illustration of the situation at the R&S SMW.

3.5.3.3　Example: calibration settings for signal set and usage at the R&S SMW

Use Case

Signals to be aligned:

- Signal S1: Frequency agile radar centered at 11.8 GHz with a total bandwidth of 400 MHz and a peak envelope power of -6 dBm
- Signal S2: FMCW radar centered at 10 GHz with a chirp bandwidth of 200 MHz and a peak envelope power of 0 dBm
- Signal S3: Pulsed radar centered at 8.4 GHz with a pulse width of 100 ns, that means a bandwidth of about 20 MHz, and a peak envelope power of -10 dBm
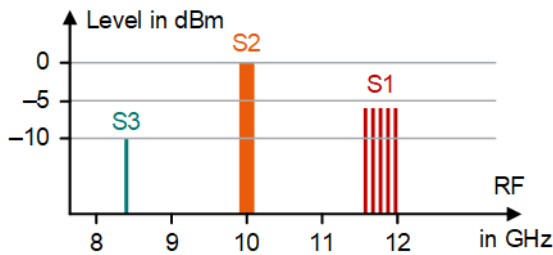
Figure 3-10: Signals to be aligned

The R&S SMW is equipped with R&S SMW-K527 supporting a signal bandwidth of up to 2 GHz.

Appropriate RFPAL calibration settings

Frequency Control:

Mode: Range
Start: 9 GHz
Stop: 11 GHz
Step: 2 GHz
Modulation Bandwidth: 2 GHz

Level Control:

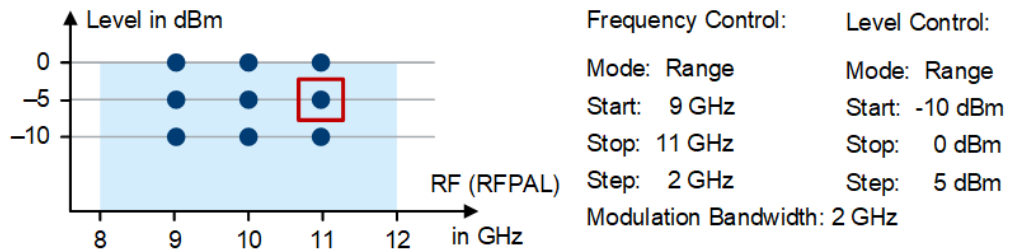Mode: Range
Start: -10 dBm
Stop: 0 dBm
Step: 5 dBm

Figure 3-11: Calibration set (highlighting corresponds to the following figure)

Settings used at the R&S SMW

The R&S SMW selects the correction data for the frequency range:

● whose calibration frequency is nearest to the RF center frequency (largest overlap of aligned frequency range and RF signal) and

● the first calibration level that is higher than the RF signal level (best dynamic range).

Figure 3-12: Settings and calibration parameters at the R&S SMW for Signal S1

The calibration frequency from R&S RFPAL used by the R&S SMW is displayed as value of the "Calibrated Frequency" parameter under "RF Ports Alignment > Info" >

"Current Corrections". The difference between RF frequency and calibration frequency is reflected in the "Baseband Frequency Offset" parameter.

The used calibration level is displayed in the "Calibrated Level (PEP)" parameter. The difference between RF signal level and calibration level is reflected in the "Digital Attenuation" parameter.

Maximum usable bandwidth at 11.8 GHz: 400 MHz ("Modulation Bandwidth" − 2 · "Baseband Frequency Offset"). This value is as high as required.

3.5.4 Execute the measurements and transfer correction data

Use case: Calibration of the network analyzer is included as well as power measurements with a power sensor. The RF paths are switched manually (no RF switching unit used).

1. In the control area above the main display area, select "Calibrate" to launch the measurements.

   The estimated duration of the measurement procedures is shown.

2. Confirm with "Ok".

   A calibration dialog for the network analyzer opens.

3. Follow the instructions.

   The two ports of the network analyzer used for the alignment measurements are calibrated.
   A dialog opens requesting to connect the power sensor to RF port 1.

4. Follow the instructions.

   The power meter measures the output power of the reference port over the configured signals.

5. Check that the reference port and the second RF port are connected with the network analyzer. If a low signal level is detected, establish the connections.

   The network analyzer measures the differences of the frequency responses at the two ports.
   A calibration dialog opens that requests you to establish the next required RF connection.

6. Establish the RF path connections as requested. Select "Ok".

   The network analyzer measures the alignment for the two ports.
   For all remaining configured RF ports: The calibration dialog opens again. The first RF port is the same as before, the second RF port is the next one not measured yet.

7. Connect the RF paths as requested. Select "Ok".

   The network analyzer measures the alignment for the two ports.

When measurements are complete for all RF ports, a distribute corrections dialog opens.

8. Select "Ok".

the calibration and correction data are delivered to the primary instrument. An `*.rfsa` archive file is transferred to the `/var/user/` directory on the primary signal generator. It includes the alignment data derived from the alignment measurements, the `*.s<n>p` files for the DUT paths and the setup configuration.

3.6 GUI description

The graphical user interface (GUI) is structured by the following areas:
- Top menus on top of the GUI
- Control area above the main content area
- Configuration area on the left
- Content area structured with tabs

3.6.1 Top menus

3.6.1.1 File

New Setup [Ctrl + n]
Opens a file explorer for creating and saving a new `setup.xml` setup file. A folder is created which has the name you specify and which contains `setup.xml` where the configurations are saved.

Load Setup [Ctrl + l]
Opens a file explorer for navigating to an `.xml` setup file. Select the file of interest and click "OK" to have it loaded. The settings of the setup file are loaded in the configuration area, a graphical representation is displayed in the "Calibration" area.

Default directory for setup files:

```
C:\Users\Public\Documents\Rohde-Schwarz\QuickStep\Projects\
RfPortsAlignment\Setups
```

Save Setup [Ctrl + s]
Saves the current configuration in the new or loaded setup file.

Save Setup As [Ctrl + Shift + s]
Opens a file explorer and lets you save the current configuration under the path you select and with the filename you enter.

Import Corrections

Loads correction data from a file explorer into RFPAL. The correction data is contained in an `*.rfsa` file. If the current setup fits to the correction data, you can do a "Quick-Check" to control the quality of the corrections.

Export Corrections

Saves the current corrections in an `*.rfsa` file under a selectable path. Afterwards, you can import them on an R&S SMW.

Default directory for correction files:

`C:\Users\Public\Documents\Rohde-Schwarz\QuickStep\Projects\`
`RfPortsAlignment\Results`

Create Debug Info

Creates a `.zip` archive containing the current configuration − particularly the setup folder and its content − and results. You can select the archive's filename and directory. The archive helps to understand the cause of a problem.
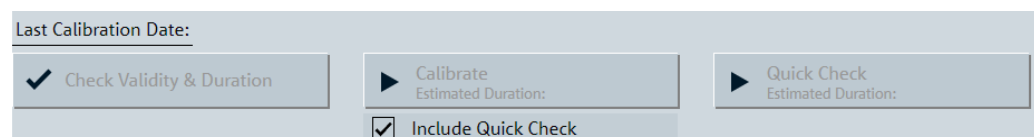
Exit [Ctrl + q]

Closes the application.

3.6.1.2 Help

Provides version information about the tool and the operating help.

3.6.2 Control area

Controls the execution of alignment measurements.

Figure 3-13: Control area

Last Calibration Date

Displays the date and time when the last "Calibrate" procedure has been executed for the loaded (current) setup.

Check Validity & Duration

Checks the validity of the configuration parameter settings, like:

- The values of the parameters are within the value ranges supported by the test instruments.
- The VISA resource strings allow access to the test instruments.
- The specified calibration files are available.

To perform the checks, R&S RFPAL accesses the test instruments, gets their relevant parameter ranges and compares them with the parameter settings in R&S RFPAL. The performed actions, events and validity findings are reported in the "Logging" tab. The "Info" tab contains a condensed listing of the validity findings.

Sections and parameters with invalid settings are indicated by an icon in the configuration area. Hover the mouse over an icon to get short information about the detected failure.

Once the duration of the calibration process is estimated, the value is displayed as "Estimated Duration".

Calibrate, Estimated Duration
Starts automatic validity check and indicates the estimated duration of the alignment measurements.

The alignment procedure can include the calibration of the network analyzer.

"Estimated Duration" displays the expected duration of the "Calibrate" procedure for the loaded (current) setup.

Include Quick Check
If enabled, a quick check starts automatically after the calibration process is completed.

Quick Check
Makes the signal generators generate RF signals with alignment applied using the current R&S RFPAL correction data and measures the remaining misalignments. The results of the "Quick Check" are shown in the "Quick Check Result" tab. The "Quick Check" measures the quality of alignment with the current correction data. The measurements are carried out for the carrier frequencies and power values (the calibration points) configured in the "Calibration Parameters" section.

Run the "Quick Check" to check if earlier correction data leads to sufficiently aligned signals.

Abort
Stops the currently running alignment measurement without saving the results.

3.6.3   Configuration area

This area contains configuration menus. The settings are applied on the loaded setup.

3.6.3.1   RF ports

Specifies the sources for the RF signals at the RF ports and the calibration files for the RF paths. Each RF path gets an own, numbered section denoted by an RF port name and is defined by an RF signal generator and an RF port of that generator. DUT paths are distinguished from calibration paths due to different path components and related s<n>p calibration files.

The first port in the configuration area is always the reference port.

Figure 3-14: RF Ports

RF Port Name

A descriptive name for the RF port and the related RF paths. It appears in the headline of the section for the RF port and path.

Device Name

The name of the instrument as displayed in the connection configuration dialog and in the setup figure. Select the device name via the connection configuration dialog.

Config

Opens the connection configuration dialog where you specify the RF signal generator for remote control by RFPAL. See Common configurations.

RF Port

Selects an RF port of the signal generator, for example, "RF A" or "RF B" for a signal generator.

DUT Path

A table imports the S-parameter files for compensating signal deviations by RF compo-
nents in the signal path between RF port and DUT. Each table row displays one S-
parameter file.

- Add or delete a row with the "Add Row" and "Delete Row" buttons.
  A default file name and a file explorer icon are shown in the new row.
- The "S-Parameter File" column displays the filename of an imported S-parameter file. This S-parameter file is transmitted to the primary signal generator at the end of the alignment procedure.
- Click the file icon in the "File Manager" column to open a file explorer. Then select the S-parameter file and click the "Import ..." button to import the file.

- In the "Ports to" and "Ports from" columns, describe the start and end point of the DUT path section that is covered with the imported S-parameter file (information only).

Calibration Path

A table imports the S-parameter files for compensating signal deviations by RF components in the signal path between RF port and network analyzer. Each table row displays one S-parameter file. S-parameter handling is the same as for the "DUT Path".

Level Calibration Path

Only available for the first, the reference, RF port. A table imports the S-parameter files for compensating signal deviations by RF components in the signal path between reference port and power measurement instrument. Each table row displays one S-parameter file. Handling in the table is the same as for the "DUT Path".

Delete RF Port

Removes the complete RF port section (beginning with the number and RF port name).

3.6.3.2 LO / REF configuration

Configures the source of the LO local oscillator and the REF reference signal and how these signals are utilized. The configured connections from the local oscillator to the signal generators and the REF connections are displayed in the "Calibration" tab of the content area.
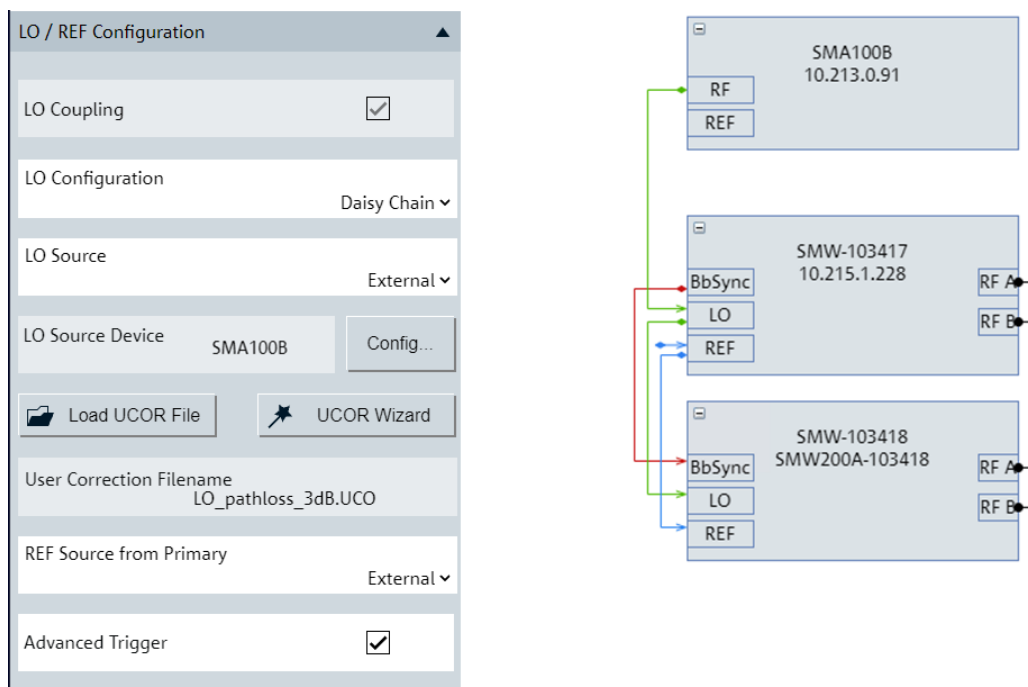

Figure 3-15: LO / REF configuration and its graphical representation

LO Coupling

Enable LO coupling so that the signal generators get the local oscillator signals from the same source. Disabling is not possible to avoid phase differences of the local oscillators which cause RF signal misalignments.

LO Configuration

- Select "Star" if the signal generators get the local oscillator signals directly (with a direct connection) from the same source.
- Select "Daisy Chain" if the local oscillator signal is forwarded from one signal generator to the next one.

LO Source

Sets the source for the local oscillator

"Internal"　　　　The local oscillator from one of the signal generators is used.

"External"　　　　The local oscillator from an additional instrument, selected as "LO Source Device", is used.

LO Source Device

For "LO Source = External", specifies the device name of the instrument in the setup that provides the local oscillator signals. Select this device name via the "Config" dialog.

Config

For "LO Source = External", opens the connection configuration dialog where you specify the local oscillator instrument for remote control by R&S RFPAL.

See Common configurations.

Load UCOR File

For "LO Source = External", opens a file explorer where you select a user correction `.uco` correction file. The file is loaded in R&S RFPAL and compensates the pathloss between LO source instrument and the signal generators. The correction file is provided to the LO device which adjusts its transmission power according to the correction data.

If the setup already contains a `.uco` file, you have to confirm the loading of the specified correction. The old `.uco` file is replaced by the one which is loaded.

A `.uco` file uses comma-separated value (CSV) format. Each row contains two values: a frequency [Hz] and a path loss [dB]. A positive path loss value increases the output power of the LO instrument by that value. A negative path loss value results in a path gain and reduces the LO output power.

For more details about `.uco` files, see the documentation of the LO instrument, for example R&S SMA100B user manual.

UCOR Wizard

For "LO Source = External", opens `.uco` correction file for compensating a constant (frequency-independent) pathloss between LO source instrument and signal generators.

Select "User Input Field" and enter an integer pathloss value. Click "Select". The correction file is automatically created with file name `LO_pathloss_<value>dB.uco`. It contains rows for LO frequencies from 200 MHz to 6.5 GHz in steps of 10 MHz, all rows with the same pathloss value.

Example: "User Input Field = 3 dB" produces `LO_pathloss_3dB.uco` with the following content:

```
200000000,3
210000000,3
220000000,3
...
6490000000,3
6500000000,3
```

REF Source from Primary

Specifies the source instrument for the REF reference signal used by the primary signal generator.

"Internal"　　　　Reference frequency is generated at the primary signal generator.

"External"　　　　Reference frequency is generated at an additional instrument and is fed into the primary signal generator.

Advanced Trigger

If enabled, the signal provided at the ADV TRIG interface is used. The signal comprises both, a synchronization and a trigger signal and is used as synchronization signal in multi-instrument setups.

Using this signal requires dedicated cables. Check if your instrument is equipped with the ADV TRIG connectors and ensure the proper cabling, i.e. ADV TRIG to ADV CLK connections.

If all R&S SMW signal generators support ADV TRIG signal, an additional external reference signal is not needed for the secondary instruments, see Figure 3-19.

For details, see the R&S SMW user manual.

3.6.3.3　RF path switching

Specifies how the signal paths are switched during the alignment measurements.
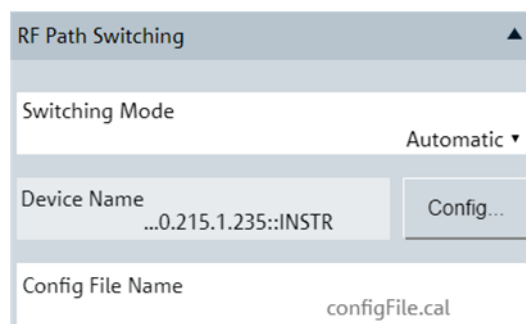
Figure 3-16: RF path switching

Switching Mode

Specifies how the second RF port is changed for the next alignment measurement (the first port is the reference port which is kept for all measurements).

"Manual"   After one alignment measurement, a dialog requests two RF ports to be connected to the network analyzer. Establish the connections manually. This mode is required if the test setup does not contain a switching unit.

"Automatic"   Requires that an RF switching unit is contained in the test setup that can control the RF paths used for the measurements. R&S RFPAL controls the switching unit. For example, when proceeding from one to the next alignment measurement, R&S RFPAL automatically commands the switching unit to establish the required connections.

Device Name

For "RF switching = Automatic", specifies the name of the switching unit as displayed in the connection configuration dialog. Select this device name via the "Config" dialog.

Config

For "RF switching = Automatic", opens the "Config" dialog where you configure the switching unit for remote control by R&S RFPAL. See Common configurations.

Config File Name

For "RF switching = Automatic", sets the filename of the configuration file to be used by the RF switching unit. The file defines the paths used within the RF switching unit. R&S RFPAL expects the configuration file to be available at the switching unit.

Figure 3-17 shows an example for a configuration file. In1, In2, In3, In4 refer to the Input ports of the RF switching unit. In1 is related to the reference port of the primary signal generator. Cal1, Cal2, Cal3, Cal4 refer to the output ports of the RF switching unit connecting to the network analyzer. Cal0 refers to the Output port to the power meter. These port names are also displayed in the test setup figure in the "Calibration" tab of the content area.

```
In1_Cal1_Cal2_Cal3_Cal4
1100111,1100112,1200011,1300014,1300013,1300015,
In1_Cal1
1100111,1100012,1200111,
In2_Cal2
1100115,1300114,
In3_Cal3
1200113,1100113,
In4_Cal4
1300111,1200115,
In1_Cal0
1100011,1100116,1200014,1300013,1300012,
In2_Cal0
1100015,1100016,1200114,1300013,1300012,
In3_Cal0
1200013,1100016,1200014,1300113,1300012,
In4_Cal0
1300011,1100016,1200014,1300013,1300112,
```

Figure 3-17: Content of RF switching configuration file (example)

The first line in the configuration file denotes the signal routing from the In1 port to the Out ports Cal1, Cal2, Cal3, Cal4. The signal from In1 is split and distributed to all these output ports. This routing is related to the calibration of the network analyzer by using RF signals from the reference port. The second line defines the internal connections for that signal routing.

See the "R&S OSP Open Switch and Control Unit" user manual for details. The following pairs of lines define individual paths. For example, In1_Cal0 connects the reference port with the power meter, the path is realized within the switching unit by the internal connection configuration 1100011,1100116,1200014,1300013,1300012.

3.6.3.4 Measurement instruments

This area configures the instruments which carry out the alignment measurements.
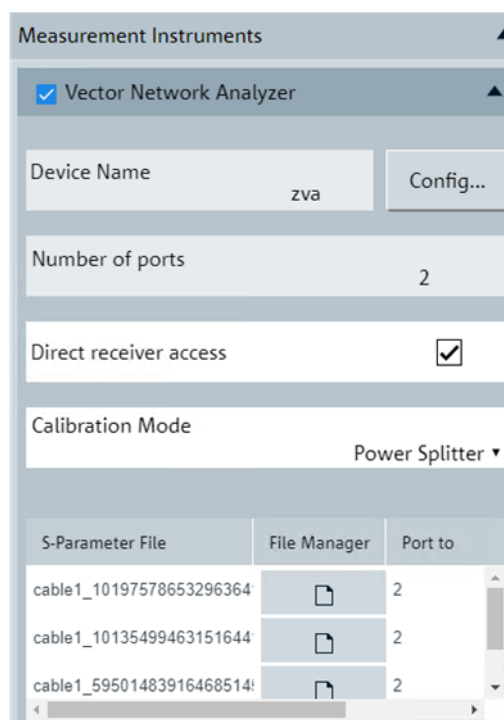

Figure 3-18: Measurement instruments

Vector network analyzer

The network analyzer measures the differences between the signals from the reference port and from other signal generator RF ports.

Vector Network Analyzer checkbox
Enables or disables the network analyzer for alignment measurements.

Device Name
The name of the measurement instrument as displayed in the "Config" dialog and in the setup figure. Select the device name via the "Config" dialog.

Config

Opens the connection configuration dialog where you specify the calibration instrument for remote control by R&S RFPAL. See Common configurations.

Number of ports

Number of ports of the measurement instrument that are used for alignment measurements. For example, two ports of a network analyzer are used: "Port 1" connected to RF port A of the primary instrument, "Port 2" connected to RF port B of the primary instrument.

Direct receiver access

Direct receiver access is only possible if the network analyzer is equipped with "Ref", "Source" and "Meas" pairs of SMA connectors for each port according to hardware option R&S ZNAxx-B16. If enabled, "Ref" and "Meas" of one port of the network analyzer is used for alignment measurements ("Number of ports" = 1 in this case). "Ref" is connected to the RF path of the reference RF port (of the primary instrument) "Meas" to the second RF port.

The SMA connectors give direct access to the RF input and output signal paths, here to the "Ref" and "Meas" receivers.

Calibration mode

Defines the calibration method of the network analyzer.

"Standard Calibration"

> The calibration of the network analyzer is done with Through – Open – Short – Match (TOSM) standards connected to the network analyzer or with a calibration unit that integrates all standards.

"Power splitter"   Select this option if a power splitter is used to get the same RF signal from a signal generator twice for the two ports of the network analyzer. See Calibration of the network analyzer for details.

The power splitter is an additional (passive) device in the test setup, so specify the S-parameter file to compensate errors from this device. See DUT Path for a description of the S-parameter table.

If direct receiver access is enabled, two S-parameter files can be specified per network analyzer port since each port offers two separate RF paths. The two path "Ref" and "Meas" can include error-causing components to be compensated.

Calibration Instrument ← Calibration mode

For "Calibration mode = Standard Calibration", defines how the calibration of the network analyzer is performed:

"VNA is calibrated"

> The calibration data of the network analyzer is used.
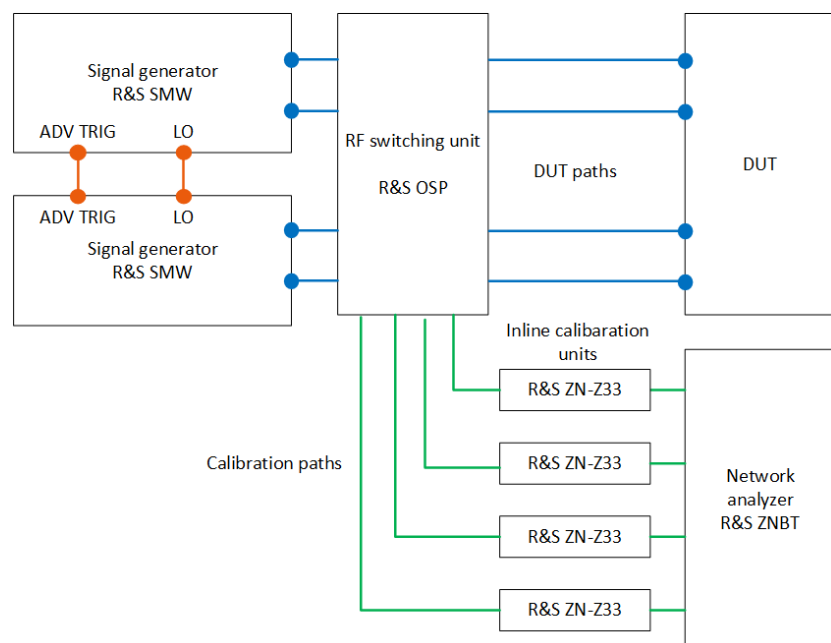
"Calibration unit"

Select if you use a calibration unit like for example R&S ZN-Z15x for calibration of the network analyzer.

A calibration unit enables the automatic calibration of several network analyzer ports in one simple procedure. The calibration unit is directly connected with the network analyzer's ports to be used for the later alignment measurements. At least two network analyzer ports are required.

The calibration unit contains calibration standards that are electronically switched by the analyzer firmware, when a calibration is performed. The characteristic data of these standards is stored in the calibration unit, so that the analyzer can calculate the error terms and apply the calibration without any further input.

"Inline claibration unit"

Inline calibration units like for example R&S ZN-Z33 allows recalibrating a running measurement setup without mechanically changing the measurement setup. For each DUT port, an inline calibration unit is inserted between the corresponding VNA test port and the DUT. The inline calibration unit remains within the signal path throughout the measurement (low-loss through path) and, on request of the VNA, performs a full one-port calibration in-situ.

Figure 3-19: Example: test setup with inline calibration units

The setup on Figure 3-19 requires extending the configuration file of R&S OSP, see Figure 3-17.

To extend the file for this example, add the following lines in the file:

```
InlineCal_P1_P2 : Unknown through path from VNA port 1 to port 2
InlineCal_P1_P3 : Unknown through path from VNA port 1 to port 3
InlineCal_P1_P4 : Unknown through path from VNA port 1 to port 4
```

Calibration filename ← Calibration mode

For "Calibration mode = Standard Calibration", specifies the filename of the `.cal` cali-
bration file for the measurement instrument.

- If calibration is carried out under control of R&S RFPAL, R&S RFPAL generates the
  calibration file and forwards it to the network analyzer.
- If calibration was carried out beforehand without R&S RFPAL, the calibration file is
  expected to be available at the network analyzer.

Power meter

A power meter, for example, an R&S NRP, is used for measuring the output power lev-
els for the reference port of the primary signal generator.
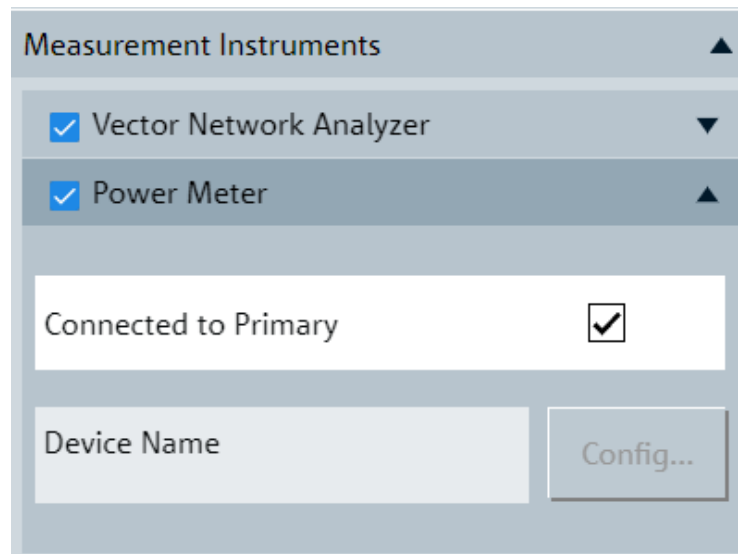
Power Meter checkbox

Enables or disables the power meter for alignment measurements.

Connected to Primary

Enable the checkbox if the power meter is directly connected to the primary signal gen-
erator. RFPAL controls the power meter via the primary instrument.

Keep the checkbox unticked if the power meter is connected to the primary signal gen-
erator via RF cables (and RF switching box if used). In this case, `*.s<n>p` files have
to be provided at the "Level Calibration Path" for the reference port configuration to
compensate the signal errors caused by the RF connection.

Device Name

The name of the measurement instrument as displayed in the "Config" dialog and in
the setup figure. Select the device name via the "Config" dialog.

Config

Opens the connection configuration dialog where you specify the instrument for remote
control by RFPAL. See Common configurations.

3.6.3.5 Calibration parameters

Alignment measurements are performed over a set of RF signals characterized by their center frequencies and the modulation bandwidth of a signal and by the power levels. Frequency and level settings are configured separately. Figure 3-20 and Figure 3-21 visualize settings in R&S RFPAL and consequences at the R&S SMW for the case that frequencies are defined in a list ("Mode" = "List") where the frequencies need not to be equally spaced.
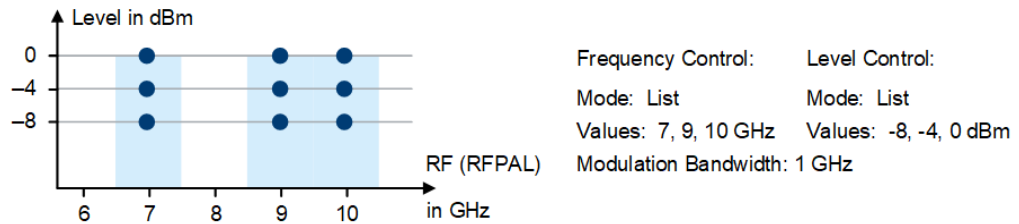
Figure 3-20: Graphical representation of calibration frequencies, levels and modulation bandwidth (colored area)
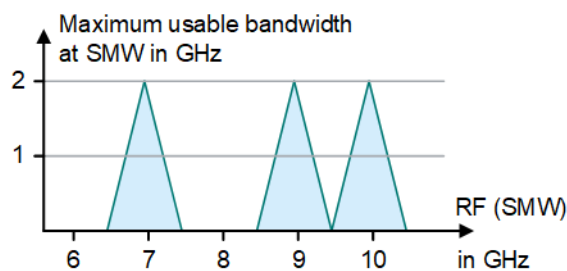
Figure 3-21: Maximum usable bandwidth for the RF signal at the R&S SMW

Frequency settings in RFPAL are related to the maximum usable bandwidth at the R&S SMW where the alignments are carried out. For a detailed description and an example for setting the calibration parameters on basis of a set of signals to be aligned, see Configure the alignment measurements.

Frequency control

This section specifies the center frequencies of the RF signals used for the alignment measurements and the modulation bandwidth for the RF signals at R&S RFPAL. You can define the frequencies as a range of equally spaced frequencies or as a list of frequencies. For the first case, a "Range Mode Wizard" is provided.

Range Mode Wizard
Click the field to open the wizard in an additional window. The wizard allows you to set the range of RF frequencies used for alignment measurements and dynamically visualizes the consequences of the settings in charts over the RF frequencies.
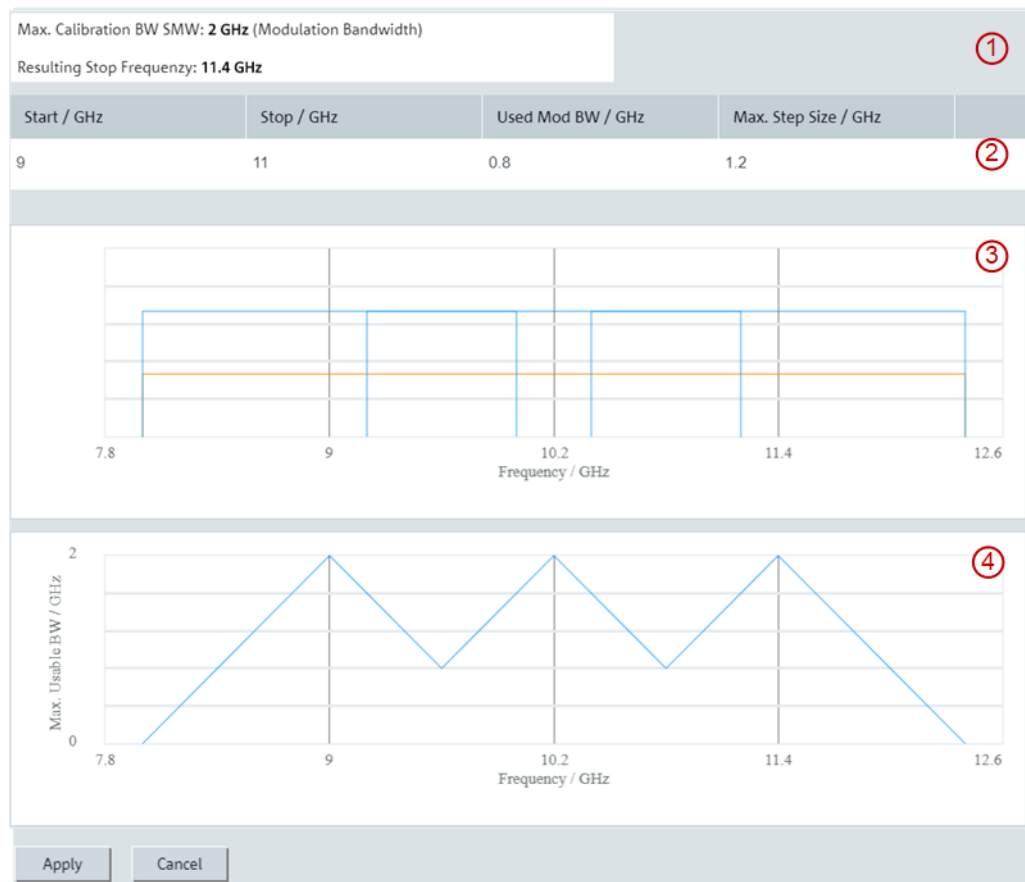
Figure 3-22: Range Mode Wizard

Sections of the "Range Mode Wizard":

- **1**: Starting situation and resulting configuration. The Max. Calibration Bandwidth is a property of the R&S SMW. It is fetched from the test setup, the smallest value of the R&S SMW in the test setup is taken. The value is used for calculating the lower chart.
  The resulting stop frequency is calculated from the start frequency and step size configured in the 2nd section (thus can deviate from the stop frequency configured there).
- **2**: Frequency configuration. "Start", "Stop" and "Max. Step Size" correspond to frequency control parameters on the left for "Mode" = "Range". "Used Mod BW" is the maximum usable bandwidth at the R&S SMW. This value should be greater than the maximum bandwidth of the RF signal to be generated and corrected at the R&S SMW.
  Settings of "Used Mod BW" and "Max. Step Size" are coupled, so that their sum equals the max. calibration bandwidth of the R&S SMW.
- **3**: Frequency coverage at R&S RFPAL. For each configured RF frequency, a left and right vertical blue line indicates the borders of the covered frequency range. Where the frequency range is the modulation bandwidth for which the max. calibration bandwidth of the R&S SMW is used. You can see if and to which extent the frequency ranges overlap.

- **4**: Maximum usable bandwidth over RF frequency at the R&S SMW. The RF frequency at the horizontal axis is the center frequency of the RF signal to be generated at the R&S SMW. The maximum usable bandwidth at the center frequency of the RF signal has to be equal or greater than the required RF signal bandwidth. The curves depend on the start frequency, the step size and the maximum calibration bandwidth of the R&S SMW. The maximum usable bandwidth depends on the offset between a calibration frequency and the center frequency of the RF signal to be generated.

For a detailed description of the relations, see Setting appropriate calibration frequencies.

If you change a value in the frequency configuration section, the charts are immediately adjusted.

By clicking the "Apply" button, the settings are transferred to the Frequency Control parameters on the left below the "Range Mode Wizard" field: Transferred are the values of the "Start" frequency, of the "Max. Step Size" and the "Resulting Stop Frequency".

Mode
Specifies how the RF frequencies are provided for the alignment measurements.

Range ← Mode
Define the RF frequencies by the "Start", "Stop" and "Step" parameters.

Start ← Range ← Mode
The first RF frequency used in the loop of alignment measurements with varied RF frequency.

Stop ← Range ← Mode
The last RF frequency used in the loop of alignment measurements with varied RF frequency.

Step ← Range ← Mode
The frequency increment to get the next RF frequency.

List ← Mode
Define the RF frequencies via a file that contains a list of frequencies.

Values ← List ← Mode
Displays the frequencies contained in the imported list of frequencies.

Import Values ← List ← Mode
Opens a file explorer to select a `.csv` file that contains the comma-separated list of frequencies (in GHz, units not included in the file) for which alignment measurements are executed.

Modulation Bandwidth
Specifies the frequency range of the RF signal around the carrier frequency. For each carrier frequency specified in the "Frequency Control" section, the alignment measurements cover the modulation bandwidth around the carrier frequency.

You get a higher resolution for the frequency response measurements if you reduce the modulation bandwidth.

Level control

Alignment measurements are performed over a range of power levels, one loop over power levels for each RF frequency defined in the "Frequency Control" section. Here, the power levels refer to the peak envelope power (PEP) of the RF signal received at the DUT.

ⓘ Level settings have an impact on the dynamic range when alignment is applied at the signal generators. See Setting appropriate calibration levels for details.

Mode

Specifies how the power levels are provided for the alignment measurements.

- Value "Range" displays the "Start", "Stop"and "Step" parameters to define the power range.
- Value "List" displays the "Value" parameter and the "Import Values" field to define the power values via a file.

Range

Define the power levels by the "Start", "Stop" and "Step" parameters.

Start ← Range

The first power level used in the loop of alignment measurements with varied RF power.

Stop ← Range

The last power level used in the loop of alignment measurements with varied RF power.

Step ← Range

The increment to get the next power level.

List

Define the power levels via a file that contains a list of power values.

Values ← List

Displays the power levels contained in the imported list of power values.

Import Values ← List

Opens a file explorer to select a `.csv` file that contains the list of power values (in dBm; units not included in the file) for which alignment measurements are executed.

High Quality Phase

If activated, the R&S RFPAL automatically selects the maximum output level to obtain a better phase value and thus improve the residual phase error.

3.6.3.6　Common configurations

Figure 3-23: Connection configuration dialog

Connection configuration table

The table contains the following columns:

- "Device Name": A descriptive name for the instrument. That name appears in the setup figure.
- "VISA Resource": The VISA resource string used to connect to the instrument.
- "Timeout [ms]": The maximum waiting time for the instrument to respond to a connection attempt.
- "Hostname/IP": The hostname or IP address of the signal generator to be accessed via VISA.
- "Check Connection": Click the "Check" button to attempt to establish the connection to the target instrument using the string in the "VISA Resource" column. An *IDN? request is sent to the instrument and the result of the attempt is reported.
- "Status": The connection status to the instrument.

Buttons

The buttons above the table on the left side filter for device types. The buttons below the table provide VISA utilities.

SMW
Filters the table for instruments of type R&S SMW (signal generators).

ZNA/ZVA
Filters the table for instruments of type ZNA and ZVA (vector signal analyzers).

All Devices
Removes previous filtering of the table. All table rows are displayed.

Clear List
Removes all entries in the table.

Search Instrument
Searches for connected VISA instruments in the LAN and displays them in a dialog.
Select a detected instrument and click the "Add" button to add it to the table.

Add Instrument
Appends a new row in the table with default settings.

Remove Instrument
Removes the currently selected row in the table.

Save & Select
Saves the changes in the table and copies the device name of the currently selected
row into the "Device Name" in the current section of the RFPAL configuration area.

3.6.4 Content area

This area contains a graphical representation of the setup, logging data from calibra-
tion and alignment measurements and results.

3.6.4.1 Calibration

This area shows a schematic test setup which is a graphical representation of the con-
figuration in the configuration area. If the configuration is changed, the graphical repre-
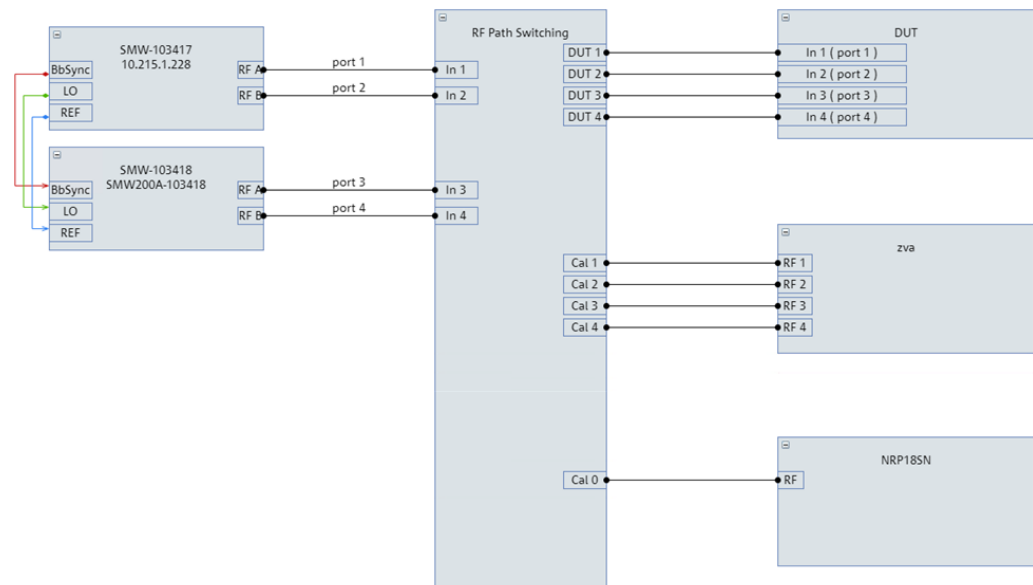sentation is adapted accordingly.

Figure 3-24: Calibration tab

The "RF Path Switching" field between signal generators and DUT and measurement instruments represents the RF switching unit if this device is contained in the physical test setup. Else, the crossbar has no physical counterpart but structures the different paths.

3.6.4.2 Logging

This area lists processing and status information, error and event reports. Each logged message includes a timestamp.

| Calibration | Logging | QuickCheck Result | Info |

Date	Time	Source	Message
2022-02-24	9:10:30	QS Engine	StartCommunication test message 2
2022-02-24	9:10:30	QS Engine	Received value: 123
2022-02-24	9:10:30	QS Engine	Current time: 2/24/2022 9:10:30 AM
2022-02-24	9:10:30	QS Engine	Elapsed time: 75 ms
2022-02-24	9:10:30	QS Engine	Starting TestStep with Id: 3. Test Procedure: 'Parse setup'
2022-02-24	9:10:30	QS Engine	Setup: Last Calibration started at 2022_02_24__09_10

Figure 3-25: Logging tab

The "Source" column indicates the component where the reported information has its origin. "QS Engine" is the R&S QuickStep software that executes the procedures.

Click the "Clear" button to remove all displayed log information.

3.6.4.3 QuickCheck result

This area displays charts for magnitude/phase/delay errors vs. power resulting from a "QuickCheck". This action runs the signal generators with alignment applied and measures the remaining signal errors. Each chart shows errors versus the power values configured in the "Calibration Parameters" section, and error curves are provided for each carrier frequency configured in "Calibration Parameters" section. So, you can see magnitude/phase/delay errors for all configured carrier frequencies and power values. The error curves for the different carrier frequencies are color-coded. See the "Filter" section to relate the color to the frequency.
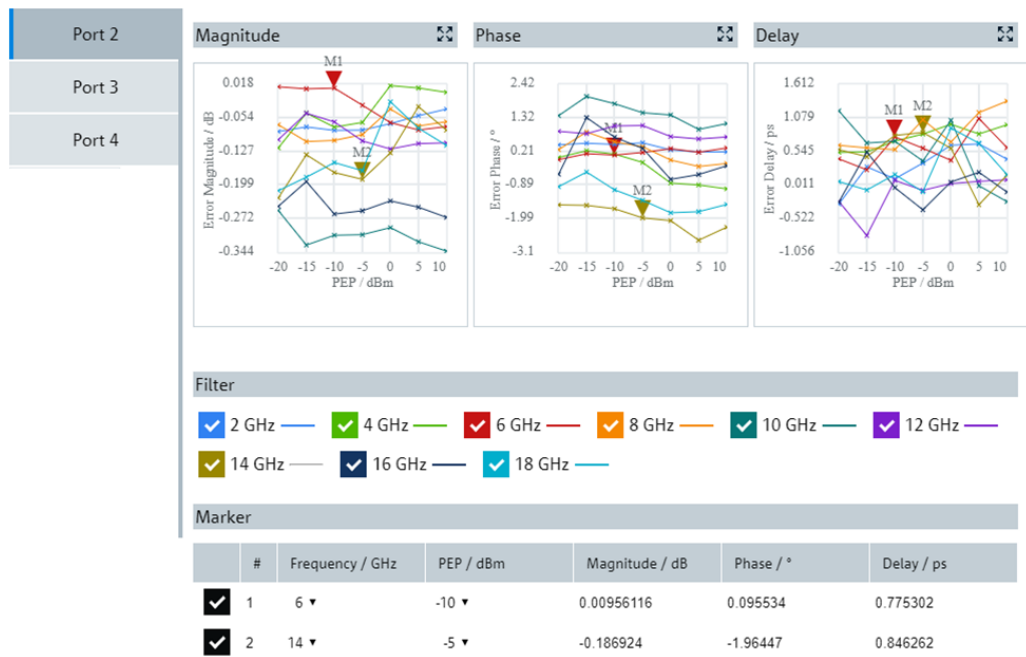
Figure 3-26: QuickCheck Result tab

Filter

In the "Filter" section, you select the carrier frequencies for which error curves are displayed in the charts.

Marker

You tick a checkbox in the left column of the displayed table to activate a marker. And you select the carrier frequency and power for the marker in the "Frequency" and "PEP" columns. Consequently, in each chart, a marker is displayed at the measurement value for the selected PEP power and at the curve related to the selected frequency. In the columns to the right side, the table rows show the values for the magnitude, phase and delay errors at the marker position.

Up to two markers can be activated corresponding with the two rows of the table.

To change the horizontal position of a marker in the charts, drag it to the left or right via the mouse cursor.

4 RF ports alignment at the signal generator

For aligning the signals at the RF ports of the signal generators in the test setup, the signal generators apply the correction data from R&S RFPAL. R&S RFPAL delivers the correction data as `*.rfsa` archive file to the primary signal generator. The correction data include alignment and s<n>p data. The primary instrument takes over control of the own RF ports alignment and that of the secondary instruments. It distributes the correction data to the secondary instruments, and the secondary instruments are configured accordingly. At start of operation, the primary instrument checks the status of all secondary devices to check for errors and retrigger the instruments for synchronous update of the correction data.

No configurations are needed at the secondary instruments. The following descriptions refer to the primary signal generator only.

4.1 Using the RF ports alignment at the primary signal generator

When the `*.rfsa` file arrives at the primary instrument and it is valid, multi-instrument usage and RF ports alignment are automatically configured. At the primary instrument, you only need to activate RF ports alignment and execute "Align". No manual configurations are needed at the secondary instruments.
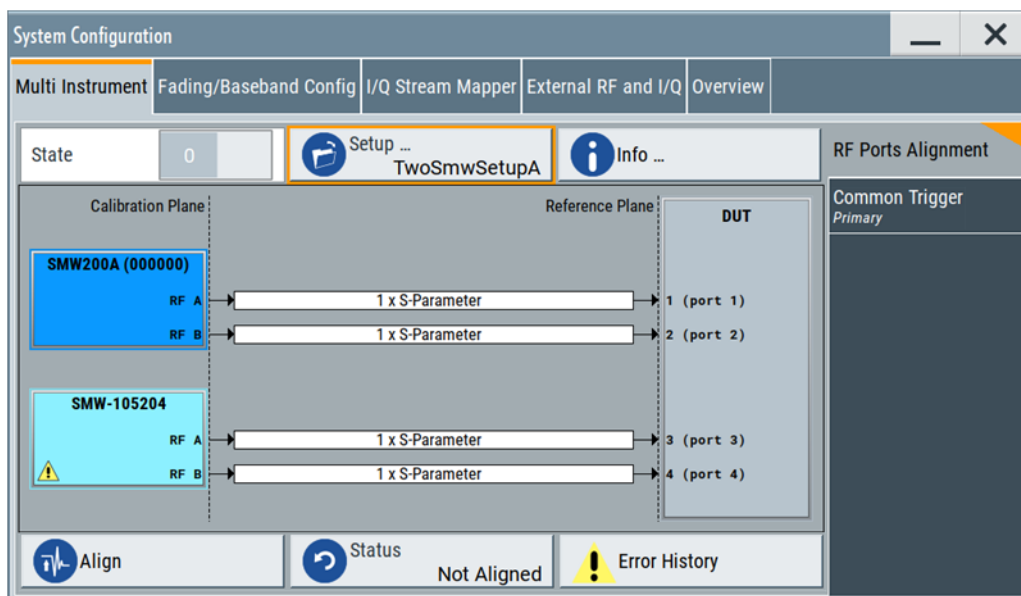

Figure 4-1: RF ports alignment within multi-instrument configuration

Configure and activate RF ports alignment

1. At the primary instrument, click the "System Config" field to open the "System Configuration" dialog.

2. In the "System Configuration" dialog, select the "Multi Instrument" tab.

3. If not already activated, select "RF Ports Alignment" at the right sidebar.

4. Select "Setup".
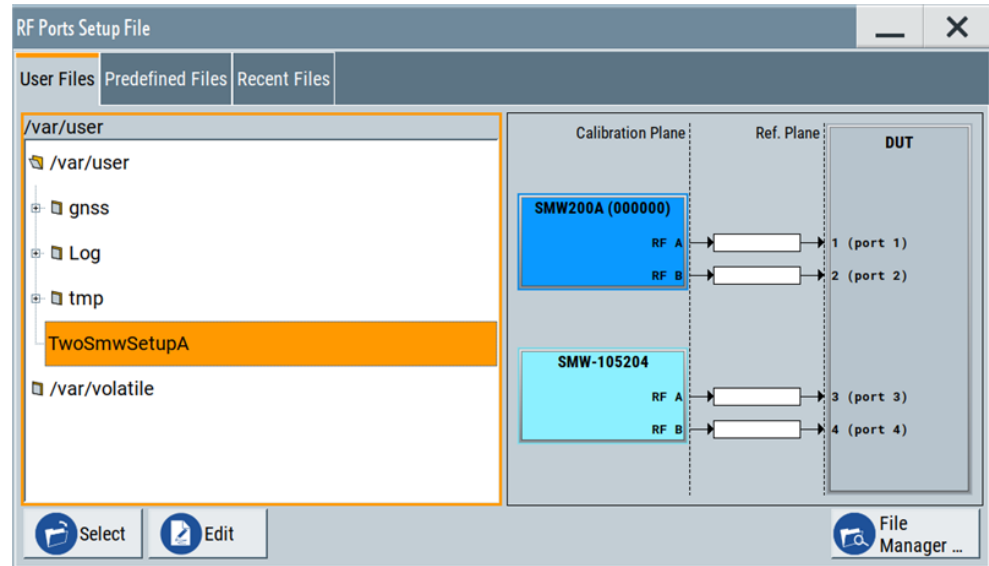
    The "RF Ports Setup File" dialog opens.

Figure 4-2: RF Ports Setup File > User Files

5. Select "User Files" and select the setup file received from R&S RFPAL.

    The test setup is displayed and you have access to the setup settings.

6. Check the settings:

    ● Set "Common Trigger = Primary".
      Check the related configuration.
      Make sure that the displayed baseband triggering information complies with the physical cabling and the calibrated setup.
    ● Check the correction data at "RF Ports Alignment > Info > Calibration".
    ● At "RF Ports Setup Info > Setup Overview", make sure that the current LO coupling indication complies with the physical cabling and the calibrated setup.
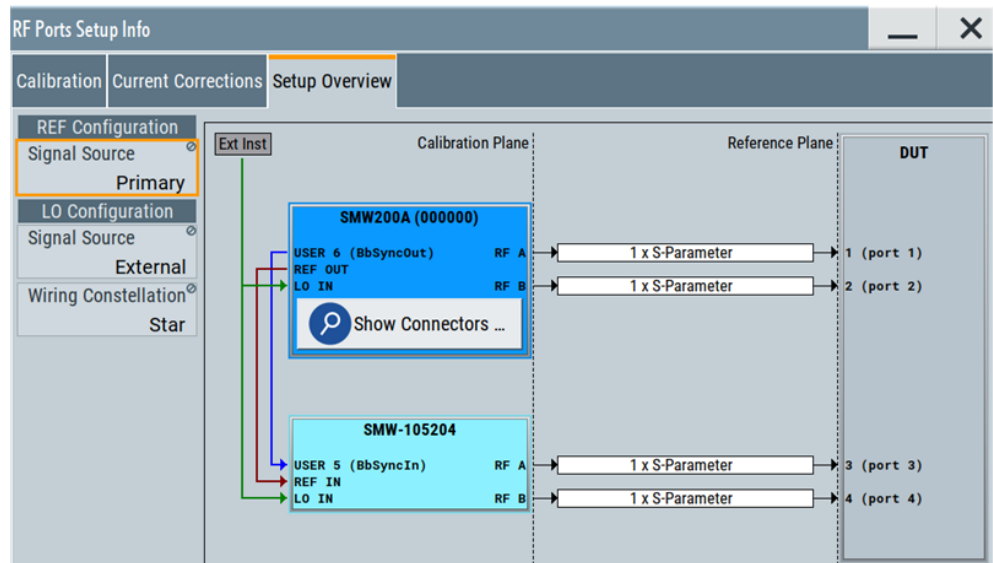
Figure 4-3: RF Ports Setup Info > Setup Overview

7. Back in the "RF Ports Alignment" view, select "Align" to synchronize the signal generators via multi-instrument trigger signal.

8. Select "RF Ports Alignment > State > On" to activate the RF ports alignment.

   All instruments in the setup are triggered simultaneously. Calibration files and correction data are automatically applied during test execution.

4.2 RF ports alignment configuration and settings

Access:

► Select "System Configuration > Multi Instrument > RF Ports Alignment".

Settings:

4.2.1 General settings
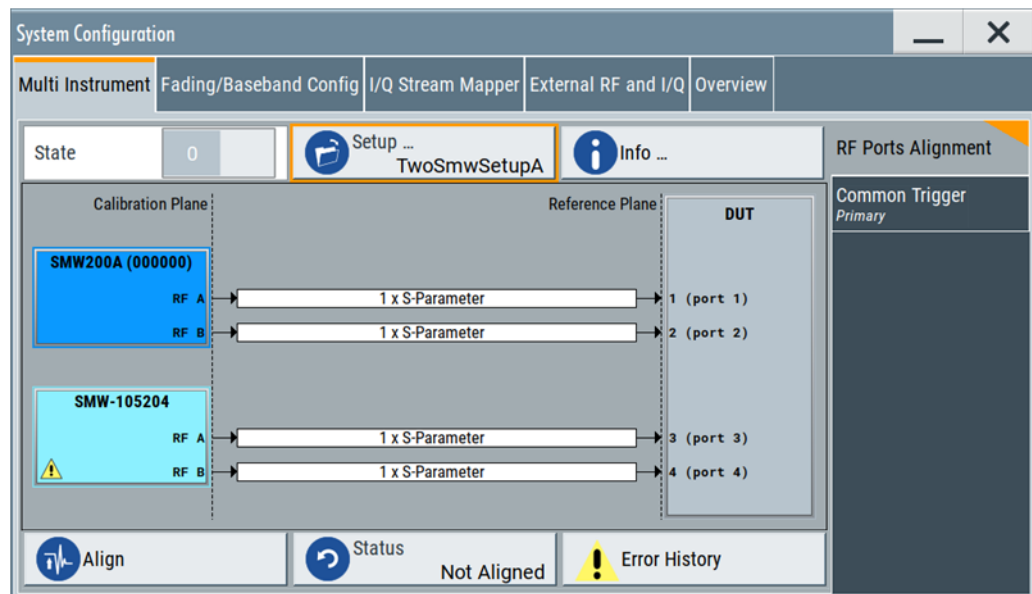
Figure 4-4: Multi Instrument > RF Ports Alignment

State

Activates the RF ports alignment function. Setup files with correction data are transferred to the secondary instruments. The following configurations are automatically set. Correction data is applied during signal generation using these configurations.

- "RF":
    – "Attenuator > Mode = Auto"
    – "ALC > Mode = Off (Table)" and "ALC > Driver Amplifier = Auto"
    – "UCOR > State = Off"
    – "LO Coupling > Mode" = "Internal" or "A Internal & A->B Coupled"
    – "LO Coupling > Out State = B On"; otherwise "Out State = Off"
- "I/Q Mod > Frequency Response":
    – "General > Optimization Mode = High Quality Table"
    – "General > Optimization Bandwidth = Auto"
    – "User Defined Corrections > State = On"
- "System Configuration > Multi Instrument > Common Trigger":
    – "State = On"
    – "Multi Instrument Trigger = Primary" on the primary instrument,
      "Multi Instrument Trigger = Secondary" on the secondary instruments

- "System Configuration > Multi Instrument > RF Ports Alignment > RF Ports Setup Info":
  - "Calibration > LO Coupling = Active"
  - "Setup Overview > REF Configuration > Signal Source" = "Primary" or "External"
  - "Setup Overview > LO Configuration > Signal Source" = "Primary" or "External"
  - "Setup Overview > Wiring Constellation" = "Daisy Chain" or "Star"

Remote command:
:SCONfiguration:RFALignment:STATe on page 71

Setup

Accesses the "Setup File" dialog, that is the standard instrument function for saving and loading setup files. The provided navigation possibilities in the dialog are self-explanatory.

The filename and the directory in which the settings are saved are user-definable; the file extension is predefined.

The setup file (*.rfsa) is an archive file containing setup description file (*.xml), the RF port correction files (*.rfcor), the frequency response correction files (*.rfresp) and the S-parameter files (*.snp). It is **created automatically** during calibration by RFPAL and can be **loaded only in the primary instrument**. Do not create or modify setup files manually.

On recall, the instrument checks if the current instrument is the reference instrument used during calibration with RFPAL. The dialog also displays the wiring diagram of the selected setup. If the setup file is loaded in a different instrument, a setting conflict appears.

The setup files in the secondary instruments are distributed by the primary instrument and loaded in the secondaries automatically.

Remote command:
:SCONfiguration:RFALignment:SETup:PREDefined:CATalog? on page 69
:SCONfiguration:RFALignment:SETup:FILE:PREDefined on page 69
:SCONfiguration:RFALignment:SETup:CATalog? on page 70
:SCONfiguration:RFALignment:SETup:FILE on page 70

Info

Accesses the "RF Ports Setup Info" dialog that displays summary information on the configured settings, see Chapter 4.2.2, "RF ports setup info", on page 55.

Test Setup

Displays the cabling diagram fo the current setup.

The diagram is interactive. Click an element to access further settings.

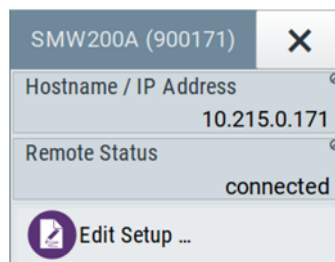Indicated are:

Primary instrument

        The primary instrument, incl. alias name, serial number and number of RF outputs.

        The primary instrument is the uppermost instrument displayed in dark blue color. Click the block to open a dialog with its "Hostname / IP Address" and for quick access to the RF Port Setup File Editor dialog ("Edit Setup").

Secondary instrument(s)

        The secondary instruments, incl. their remote connection status, alias name, serial number and number of RF outputs.

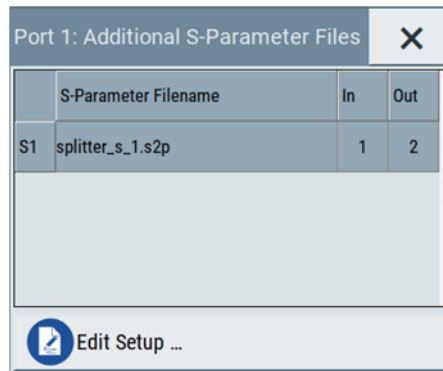   Click the block to open a dialog with information on the "Hostname / IP Address", "Remote Status" and for quick access to the RF Port Setup File Editor dialog ("Edit Setup").

Figure 4-5: Secondary instrument dialog

S-parameter files

        Indicates if and how many S-parameter files are loaded.

Figure 4-6: Additional S-Parameter Files dialog

DUT

        DUT, incl. the RF ports designation, as configured in the RF Port Setup File Editor dialog.

Align

Sends the multi-instrument trigger signal to all instruments to synchronize the basebands of the instruments if a valid setup is loaded ("RF Ports Alignment > Setup") and the "RF Ports Alignment > State" is "On".

Remote command:

:SCONfiguration:RFALignment:ALIGn on page 71

Status

Retrieves and displays information on the internal compensation status and the connected secondary instruments.

"No Setup" A setup file has not been loaded.

"Invalid Setup" Possible causes:
- The loaded setup file has been removed.
- The setup file is invalid (RF ports are not configured).
- Mismatch between the setup and the physical instrument (the setup is loaded in an instrument that is not the primary instrument).

"Not Active" The setup file is loaded but "RF Ports Alignment > State = Off".

"Not Aligned"

Indicates one of the following situations:
- Setup is loaded and "RF Ports Alignment > State = On", system is not triggered
  Execute "Align" to send the multi-instrument trigger signal to all instruments to synchronize the basebands of the instruments.
- Setup is loaded and active but frequency value is changed (in primary or in the secondary instrument).
  The instrument with changed frequency value waits for trigger event.

"Aligned" The setup is aligned and ready for operation.

"Error" Settings conflict or missing connection to secondary instruments.

"Warning" Indicates the following situations:
- Selected frequency or PEP value outside of the calibrated range.
- Temperature deviation (Temperature Offset to Last Calibration is greater than +/- 3K)
- Internal adjustment was performed since last calibration.
- "LO Coupling = On" but the secondary instrument cannot be synchronized.

A warning icon in the task bar indicates the erroneous situation.

Remote command:
:SCONfiguration:RFALignment:SETup:STATus? on page 70

Error History

Indicates the status of the alignment process.

4.2.2 RF ports setup info

Access:

1. Select "System Configuration > Multi Instrument > RF Ports Alignment".

2. Select "Setup > User files > <... .rfsa > > Select".

3.   Select "RF Ports Alignment" > **"Info"**.

4.2.2.1   Calibration settings

Access:

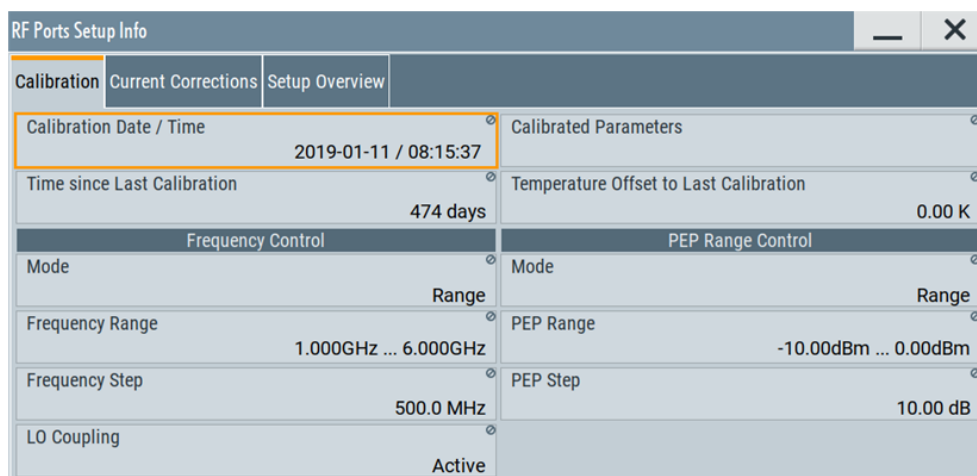►   Select "RF Ports Alignment > Info" > **"Calibration"**.

Figure 4-7: RF Ports Setup Info > Calibration

This dialog displays summary information on the calibration data as retrieved from the setup file.

Settings:

Calibration Date/Time
Indicates the date and time the calibration described in the loaded setup file is performed.

Remote command:
`:SCONfiguration:RFALignment:SETup:INFO:CALibration:DATE?`
on page 72
`:SCONfiguration:RFALignment:SETup:INFO:CALibration:TIME?`
on page 72

Calibrated Parameters
Summary information on the major calibrated parameters.

Remote command:
`:SCONfiguration:RFALignment:SETup:INFO:CALibration:PARameters?`
on page 73

Time since Last Calibration
Indicates the elapsed time since the moment the calibration described in the loaded
setup file is performed.

Remote command:
`:SCONfiguration:RFALignment:SETup:INFO:CALibration:AGE?`
on page 72

Temperature Offset to Last Calibration
Indicates the difference in temperature since the moment the calibration described in
the loaded setup file is performed.

The indication is color coded; if the temperature deviation exceeds +/- 3K, the value is
displayed in red.

Remote command:
`:SCONfiguration:RFALignment:SETup:INFO:CALibration:TEMPerature:`
`OFFSet?` on page 73

Frequency/PEP Control
Comprises the frequency and PEP-related settings.

The displayed values resemble the values you have set during the calibration process.

Mode ← Frequency/PEP Control
Indicates the method used to define the calibrated frequency and PEP ranges.

"Range"   By the min and max values of the range.

"List"   As a sequence of discrete frequency values.
               See Frequency Values/PEP Values.
               Consider that greater number of calibration points leads to longer cal-
               ibration time.

Remote command:
`:SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:`
`MODE?` on page 73
`:SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:MODE?`
on page 73

Frequency Range/PEP Range ← Frequency/PEP Control
Indicates the frequency and PEP ranges the calibrated values apply for.

This value is displayed if "Mode = Range" is used during the calibration, where the range is defined by the min and max values.

Remote command:

`:SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:`
`RANGe:LOWer?` on page 74

`:SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:`
`RANGe:UPPer?` on page 74

`:SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:RANGe:`
`LOWer?` on page 74

`:SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:RANGe:`
`UPPer?` on page 74

Frequency Step/PEP Step ← Frequency/PEP Control
This value is displayed if "Mode = Range" is used during the calibration. It indicates the frequency/PEP step size that is used to define the frequency and level values to be calibrated with the range, defined with the min and max values.

Remote command:

`:SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:`
`STEP?` on page 75

`:SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:STEP?`
on page 75

Frequency Values/PEP Values ← Frequency/PEP Control
This value is displayed if "Mode = List" is used during the calibration.

It indicates the calibrated values, that are defined as a sequence of comma-separated discrete values in the required units.

Remote command:

`:SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:`
`LIST:VALues?` on page 74

`:SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:LIST:`
`VALues?` on page 74

LO Coupling ← Frequency/PEP Control
Indicates whether the instruments use a common local oscillator (LO) signal or not.

"Active"

All instruments are connected to the same LO reference frequency.

"Inactive"

Each instrument uses its own local oscillator.

Remote command:

`:SCONfiguration:RFALignment:SETup:INFO:CALibration:LOCoupling?`
on page 75

4.2.2.2 Current corrections settings

Access:

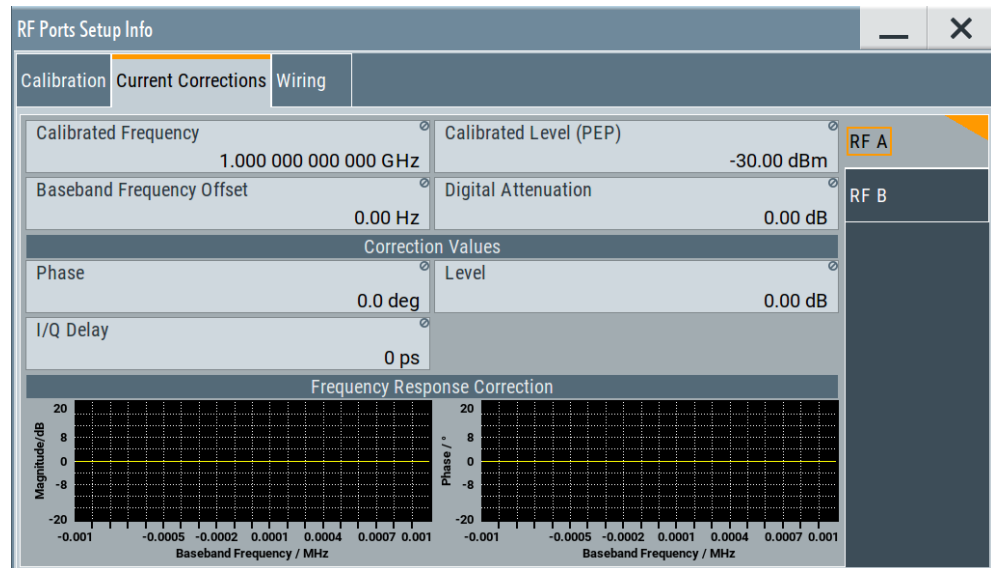► Select "RF Ports Alignment > Info" > **"Current Corrections"**.

Figure 4-8: RF Ports Setup Info > Current Corrections

This dialog displays summary information on the current correction values per RF path.

Settings:

Calibrated Frequency

Indicates the frequency f_{Cal} the calibration data is valid for.

This is the value you have set as RF frequency during the calibration process.

Remote command:

:SOURce<hw>:RFALignment:CALibrated:FREQuency? on page 77

Calibrated Level (PEP)

Indicates the level P_{Cal} the calibration data is valid for.

Remote command:
`:SOURce<hw>:RFALignment:CALibrated:POWer:PEP?` on page 77

Baseband Frequency Offset
Indicates the applied baseband frequency offset $f_{BB\ Offset}$, calculated as the difference between the current frequency $f_{RF\ Out}$ ("Status bar > Freq") and the calibrated frequency f_{Cal} ("Calibrated Frequency").

Remote command:
`:SOURce<hw>:RFALignment:FOFFset?` on page 77

Digital Attenuation
Indicates the applied digital attenuation $P_{Dig\ Att}$, calculated as the difference between the current level $P_{RF\ Out}$ ("Status bar > Level") and the calibrated level P_{Cal} ("Calibrated Level").

Remote command:
`:SOURce<hw>:RFALignment:DATTenuation?` on page 77

Correction Values
Displays the correction values retrieved from the S-parameter files and used for compensation of the complex frequency response of the signal.

Phase ← Correction Values
Indicates the delta phase applied for compensation of the frequency response of the signal.

The value is retrieved from the S-parameter files.

Remote command:
`:SOURce<hw>:RFALignment:CORRection:PHASe?` on page 78

Level ← Correction Values
Indicates the level correction applied to the signal of the selected path.

A level correction is required if a mismatch between the PEP values in the paths are detected.

The value is retrieved from the S-parameter files.

Remote command:
`:SOURce<hw>:RFALignment:CORRection:LEVel?` on page 78

I/Q Delay ← Correction Values
Indicates the I/Q delay applied for compensation of the frequency response of the signal.

The value is retrieved from the S-parameter files.

Remote command:
`:SOURce<hw>:RFALignment:CORRection:IQDelay?` on page 78

Frequency Response Correction
Graphical representation of magnitude and phase variations of the currently used compensation filter over the available baseband bandwidth.

4.2.2.3 Setup overview

Access:

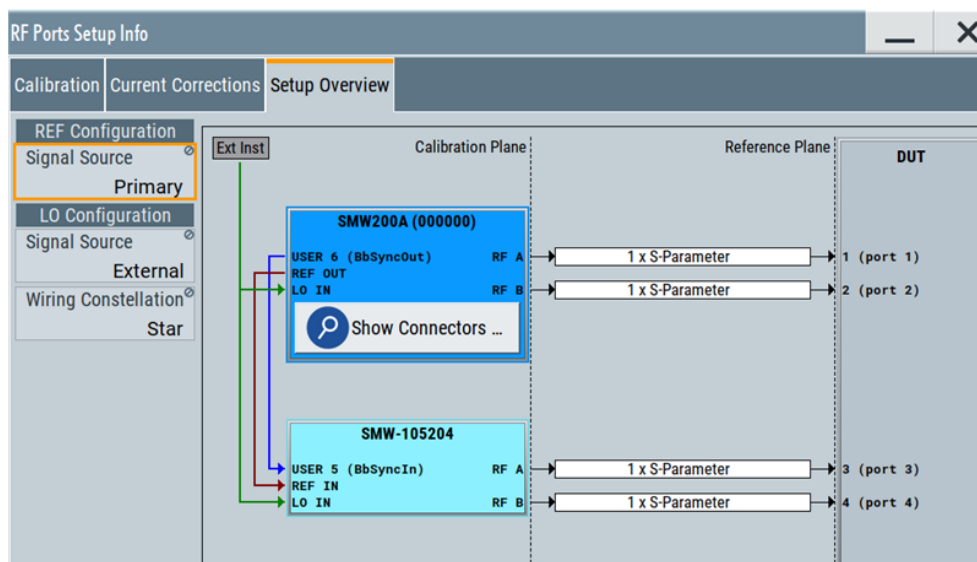► Select "RF Ports Alignment > Info" > **"Setup Overview"**.

Figure 4-9: RF Ports Setup Info > Setup Overview

This dialog displays the wiring diagram of the setup. The displayed information resembles the setup displayed in the "RF Ports Alignment" dialog.
See "Test Setup" on page 53.

Ref Configuration > Signal Source
Indicates if the current instrument uses its own or an external reference signal.

"Primary"   The instrument uses its reference signal and provides it to the other instruments.

"External"   The instrument uses an external reference frequency source, for example from other R&S SMW (the one with "Ref Configuration" > "Signal Source = Primary") or from R&S®SMA100B.

Remote command:
:SCONfiguration:RFALignment:SETup:INFO:WIRing:REF:SOURce?
on page 76

LO Configuration > Signal Source
Indicates if the current instrument uses its own or an external LO signal.

"Intern (Primary Instrument)"

The instrument uses its own LO frequency.

In a two-path instruments, the LOs of the two signal paths are coupled, where the LO signal of the first path is fed to the LO of the second one.

The block diagram indicates this connection, too.

"External Instrument"

The instrument acts as a secondary one regarding the LO frequency. It receives the LO frequency from the instrument that acts as an LO source in the setup.

The external LO signal is fed at the first signal path.

In a two-path instruments, the LOs of the two signal paths are coupled, where the LO signal of the first path is fed to the LO of the second one.

The block diagram indicates this connection, too.

Remote command:

:SCONfiguration:RFALignment:SETup:INFO:WIRing:LO:SOURce?
on page 76

LO Configuration > Wiring Constellation
Indicates the connection method used to distribute the LO frequency signal.

"Daisy Chain"   A connection scheme in which instruments are connected together in sequence, i.e. an output of the first one is the connected to an input of the second one, etc.

"Star"   A connection scheme for several instruments that consists of one primary instrument and several secondary instruments, all connected to the primary one.

The LO signal of the primary instrument or from an external LO source is split with a power combiner or splitter and fed to the secondary instruments.

Remote command:

:SCONfiguration:RFALignment:SETup:INFO:WIRing:LO:CONStellation?
on page 75

Test Setup
Displays the cabling diagram fo the current setup.

The diagram is interactive. Click an element to access further settings.

Indicated are:

Primary instrument

The primary instrument, incl. alias name, serial number and number of RF outputs.

The primary instrument is the uppermost instrument displayed in dark blue color. Click the block to open a dialog with its "Hostname / IP Address" and for quick access to the RF Port Setup File Editor dialog ("Edit Setup").

Secondary instrument(s)

The secondary instruments, incl. their remote connection status, alias name, serial number and number of RF outputs.

Click the block to open a dialog with information on the "Hostname / IP Address", "Remote Status" and for quick access to the RF Port Setup File Editor dialog ("Edit Setup").
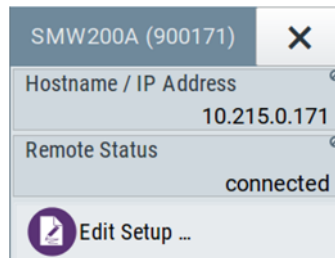

Figure 4-10: Secondary instrument dialog

S-parameter files

Indicates if and how many S-parameter files are loaded.
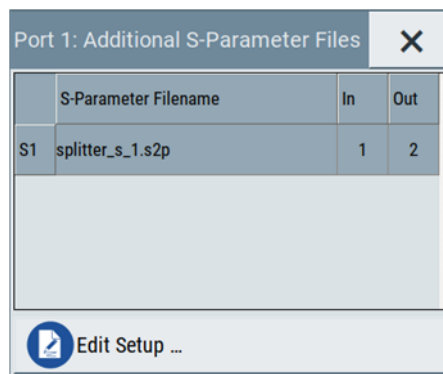
Figure 4-11: Additional S-Parameter Files dialog

DUT   DUT, incl. the RF ports designation, as configured in the RF Port Setup File Editor dialog.

4.2.3   RF ports setup file settings

Access:

1. Select "System Configuration > Multi Instrument > RF Ports Alignment" > **"Setup"**.

2. Select a setup file and select "Edit".

   The setup file (`*.rfsa`) is an archive file containing setup description file (`*.xml`), the RF port correction files (`*.rfcor`), the frequency response correction files (`*.rfresp`) and the S-parameter files (`*.snp`). Setup files are created automatically during the calibration process.

Do not create or edit setup files manually.

The "RF Ports Setup File Editor" dialog opens.

Figure 4-12: RF Ports Setup File Editor

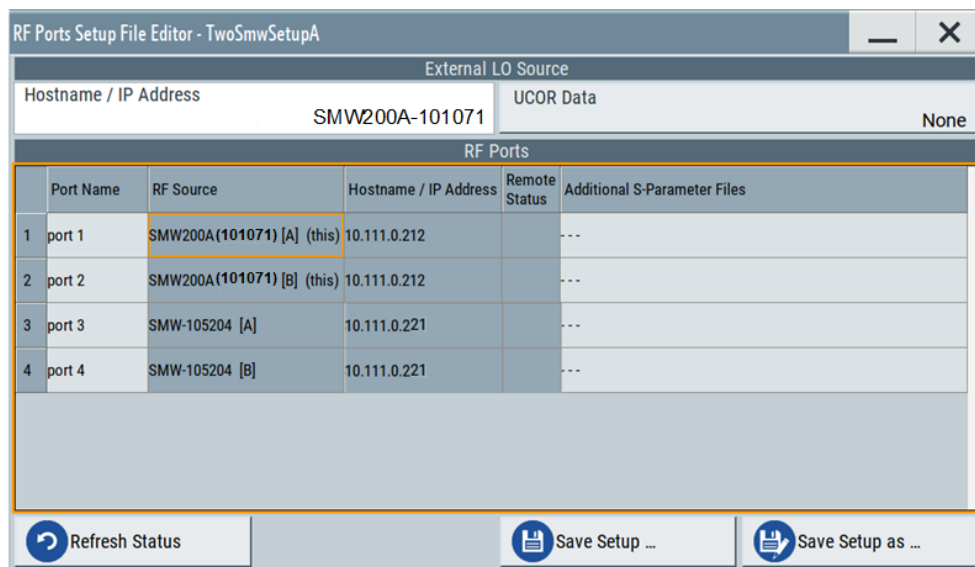The dialog displays an overview information on the following:
- Configured ports including user-defined port names
- The physical instruments on that the ports are located
- The filename of the files with calibration data
- If S-Parameter files are used during the calibration or loaded afterwards, the filenames of these files.

The "RF Ports Setup File Editor" dialog is the central point to reconfigure and control your setup. Here, you can rename ports, add, remove or exchange S-parameter files, retrieve information on connected external instruments, and save your settings in a loadable setup file.

RF port table
Represents the RF ports configuration; there is one table row per RF port.

Port Name ← RF port table
Add an alias name for the RF port.

RF Source ← RF port table
Indicates the physical instrument which the RF port belongs to.

Hostname / IP Address ← RF port table
Displays/sets the IP address or hostname of the connected external instrument.

Remote Status ← RF port table
Indicates the remote connection status.

⟳	The RF port belongs to a secondary instrument; the remote connection to the secondary instrument can be established. The remote connection is active during the time the correction files are transferred to the secondary instruments. The term **secondary** instrument describes a signal generator connected in a primary-secondary mode and receiving the multi-instrument trigger from the primary instrument (see "System Configuration > Multi Instrument > Common Trigger > Multi Instrument Trigger = Secondary")
⚠ and yellow background	At least one of the secondary instruments cannot be reached, that is the remote connection to it cannot be established. Check the "Hostname / IP Address" of the secondary instrument and select "Refresh" to check the status.

Additional S-Parameters Files ← RF port table
Indicates the filename of the S-Parameter files used during the calibration process or the S-Parameter files loaded subsequently.

During calibration, you may load S-Parameter files which describe the cables between the signal generator and the network analyzer. In this case, the correction data for the setup is calculated so that it excludes the correction values listed in the S-Parameter files. This allows you to exchange the S-Parameter files subsequently if you, for example, use different cables to connect the DUT to the outputs of the signal generator.

Click the filename to retrieve details on the loaded files or to select a different file, see Chapter 4.2.4, "Additional S-Parameter files settings", on page 65.

Save Setup .../Save Setup as ...
Saves the setup configuration in a file.

The "*" symbol behind the filename in the dialog header indicates unsaved settings. It appears whenever you change any of the settings in the dialog.

To overwrite the current file, select "Save Setup ...".
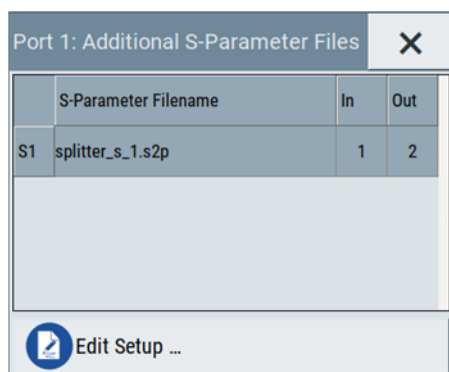
To retain the setup file content, select "Save Setup as ...".

4.2.4 Additional S-Parameter files settings

Access:

1. Select "System Configuration > Multi Instrument > RF Ports Alignment" > **"Setup"**.

2. Select a setup file and select "Edit".

3. Select "RF Ports / Instruments > RF ports table" > **"Additional S-Parameter Files"**.

In this dialog, you can load S-parameter files to compensate for exchanged cables or other components.

Settings:

Add S-Parameter File
Appends a row in the table with S-parameter files.

S-Parameter Filename
Indicates the filename of the loaded file.

Select the filed to open the standard "File Select" dialog for selecting and loading S-parameters (Touchstone) files. S-parameters files are files with predefined extension (`*.s<n>p`) and file format.

Use the standard "File Manager" function to transfer external data lists to the instrument.

In/Out
Sets the origin and destination ports, i.e. the port number from that the signal is coming and the port to that it is going. Use this parameter to change the orientation of the signal chain.

Delete
Removes the selected table row and the S-parameter file.

4.3 Remote control commands

The following commands are required to perform signal generation with the option R&S SMW-K545 in a remote environment. We assume that the R&S SMW has already

been set up for remote operation in a network as described in the R&S SMW documentation. A knowledge about the remote control operation and the SCPI command syntax are assumed.

ⓘ **Conventions used in SCPI command descriptions**

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

Common Suffixes

The following common suffixes are used in the remote commands:

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

The following commands specific to the R&S SMW-K545 option are described here:

4.3.1 Programming examples

This description provides simple programming examples. The purpose of the examples is to present **all** commands for a given task. In real applications, one would rather reduce the examples to an appropriate subset of commands.

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

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

Example: Loading and activating setup files

This example uses the predefined demo setup file.

```
// SCONfiguration:RFALignment:SETup:CATalog?
// SCONfiguration:RFALignment:SETup:FILE "/var/user/RfPortsSetup/setup"

SCONfiguration:RFALignment:SETup:PREDefined:CATalog?
// demo
SCONfiguration:RFALignment:SETup:FILE:PREDefined "demo"
SCONfiguration:RFALignment:SETup:STATus?
// NALign
SCONfiguration:RFALignment:ALIGn
SCONfiguration:RFALignment:SETup:STATus?
// ALIGned
SCONfiguration:RFALignment:STATe 1
```

Example: Retrieving details on the calibrated values

This example uses the predefined demo setup file.

```
SCONfiguration:RFALignment:SETup:PREDefined:CATalog?
// demo
SCONfiguration:RFALignment:SETup:FILE:PREDefined "demo"

SCONfiguration:RFALignment:SETup:INFO:CALibration:DATE?
// "2019-01-11"
SCONfiguration:RFALignment:SETup:INFO:CALibration:TIME?
// "08:15:37 "
SCONfiguration:RFALignment:SETup:INFO:CALibration:PARameters?
// "Level,Phase,Time"
SCONfiguration:RFALignment:SETup:INFO:CALibration:AGE?
// 52
SCONfiguration:RFALignment:SETup:INFO:CALibration:TEMPerature:OFFSet?
// 0
SCONfiguration:RFALignment:SETup:INFO:WIRing:LO:SOURce?
// PRIM
SCONfiguration:RFALignment:SETup:INFO:WIRing:LO:CONStellation?
// DCH
SCONfiguration:RFALignment:SETup:INFO:WIRing:REF:SOURce?
// PRIM

SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:MODE?
// RANG
SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:RANGe:LOWer?
// 1000000000
SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:RANGe:UPPer?
// 6000000000
SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:STEP?
// 500000000
SCONfiguration:RFALignment:SETup:INFO:CALibration:LOCoupling?
// ACT

SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:MODE?
```

```
// RANG
SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:RANGe:LOWer?
// -10
SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:RANGe:UPPer?
// 0
SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:STEP?
// 10

SOURce1:RFALignment:CALibrated:FREQuency?
// 1000000000
SOURce1:RFALignment:CALibrated:POWer:PEP?
// -30
SOURce1:RFALignment:DATTenuation?
// 0
SOURce1:RFALignment:FOFFset
// 0
SOURce1:RFALignment:CORRection:IQDelay?
// 0
SOURce1:RFALignment:CORRection:LEVel?
// 0
SOURce1:RFALignment:CORRection:PHASe?
// 0
```

4.3.2 General commands

:SCONfiguration:RFALignment:SETup:PREDefined:CATalog?

Queries the names of the existing predefined setup files.

Only files with extension `*.rfsa` are listed.

Example: See Example"Loading and activating setup files" on page 68.

Usage: Query only

Manual operation: See "Setup" on page 53

:SCONfiguration:RFALignment:SETup:FILE:PREDefined <Filename>

Loads the selected predefined file.

Setting parameters:

<Filename>	"<filename>"
	File extension can be omitted. Query the filenames of predefined setup files with the command :SCONfiguration:RFALignment:SETup: PREDefined:CATalog?.
Example:	See Example"Loading and activating setup files" on page 68.
Usage:	Setting only
Manual operation:	See "Setup" on page 53

:SCONfiguration:RFALignment:SETup:CATalog?

Queries the names of the existing setup files in the default directory.

Per default, the instrument saves user-defined files in the /var/user/ directory. Use the command :MMEM:CDIRectory to change the default directory to the currently used one.

Only files with extension *.rfsa are listed.

Example:	See Example"Loading and activating setup files" on page 68.
Usage:	Query only
Manual operation:	See "Setup" on page 53

:SCONfiguration:RFALignment:SETup:FILE <SetupFile>

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

Parameters:

<SetupFile>	"<filename>"
	Filename or complete file path; file extension can be omitted. Query the filenames of existing setup files with the command : SCONfiguration:RFALignment:SETup:CATalog?.
Example:	See Example"Loading and activating setup files" on page 68.
Manual operation:	See "Setup" on page 53

:SCONfiguration:RFALignment:SETup:STATus?

Queries information on the internal compensation status and the connected secondary instruments.

Return values:

<SetupStatus>	NALign | ALIGned | ERRor | WARNing | INACtive | NOSetup | INValid
	NOSetup = Setup is not loaded

`INValid` = Loaded setup does not match the current setup

`INACtive` = Setup loaded but RF port alignment not enabled

`NALign` = Setup is loaded but aligned not triggered

`ALIGned | ERRor | WARNing` = Setup is aligned, error, warning

*RST:　　　　n.a. (factory preset)

Example:	See Example"Loading and activating setup files" on page 68.
Usage:	Query only
Manual operation:	See "Status" on page 55

:SCONfiguration:RFALignment:ALIGn

If a valid setup is loaded and RF ports alignment is enabled, sends the multi instrument trigger signal to all instruments to synchronize the basebands of the instruments.

Example:	See Example"Loading and activating setup files" on page 68.
Usage:	Event
Manual operation:	See "Align" on page 54

:SCONfiguration:RFALignment:STATe <State>

If a valid setup file is selected, applies the specified correction data.

Load the setup file with the command `:SCONfiguration:RFALignment:SETup:FILE`.

Parameters:

<State>	1	ON	0	OFF
	*RST:　　　　n.a. (factory preset: 0)
Example:	See Example"Loading and activating setup files" on page 68.
Manual operation:	See "State" on page 52

4.3.3　RF port setup info commands

:SCONfiguration:RFALignment:SETup:INFO:CALibration:DATE?

Queries the time the calibration described in the loaded setup file is performed.

Return values:

<Date>	string

Example:	See Example"Retrieving details on the calibrated values" on page 68.
Usage:	Query only
Manual operation:	See "Calibration Date/Time" on page 56

:SCONfiguration:RFALignment:SETup:INFO:CALibration:TIME?

The date and time the calibration described in the loaded setup file is performed.

Return values:

<Time>	string

Example:	See Example"Retrieving details on the calibrated values" on page 68.
Usage:	Query only
Manual operation:	See "Calibration Date/Time" on page 56

:SCONfiguration:RFALignment:SETup:INFO:CALibration:AGE?

Queries how many days are passed since the moment the calibration described in the loaded setup file is performed.

Return values:

<Days>	integer
	Time since calibration in days

Example:	See Example"Retrieving details on the calibrated values" on page 68.
Usage:	Query only
Manual operation:	See "Time since Last Calibration" on page 57

:SCONfiguration:RFALignment:SETup:INFO:CALibration:TEMPerature:OFFSet?

Queries the difference in temperature since the moment the calibration described in the loaded setup file is performed.

Return values:

<TempOffset>	float
	Increment: 0.01

Example:	See Example"Retrieving details on the calibrated values" on page 68.
Usage:	Query only
Manual operation:	See "Temperature Offset to Last Calibration" on page 57

:SCONfiguration:RFALignment:SETup:INFO:CALibration:PARameters?

Queries information on the major calibrated parameters.

Return values:

<CalibratedParam>	string

Example:	See Example"Retrieving details on the calibrated values" on page 68.
Usage:	Query only
Manual operation:	See "Calibrated Parameters" on page 57

:SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:MODE?
:SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:MODE?

Queries the method used to be defined the calibrated frequency and PEP ranges.

Return values:

<Mode>	RANGe | LIST
	RANGe
	Range, see:
	`:SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:RANGe:LOWer?` on page 74
	`:SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:RANGe:UPPer?` on page 74
	`:SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:STEP?` on page 75
	`:SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:RANGe:LOWer?` on page 74
	`:SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:RANGe:UPPer?` on page 74
	`:SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:STEP?` on page 75

LIST

List, see:

`:SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:LIST:VALues?` on page 74

`:SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:LIST:VALues?` on page 74

Example:	See Example"Retrieving details on the calibrated values" on page 68.
Usage:	Query only
Manual operation:	See "Mode" on page 57

:SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:LIST: VALues?
:SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:LIST:VALues?

Return values:

<ListOfValues>	string

Example:	`SCONfiguration:RFALignment:SETup:INFO:CALibration:LOCoupling?`
	`// NACTive`
	`SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:MODE?`
	`// LIST`
	`SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:LIST:VALues?`
	`// -21,-15,-10`

Usage:	Query only
Manual operation:	See "Frequency Values/PEP Values" on page 58

:SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:RANGe: LOWer?
:SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:RANGe: UPPer?
:SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:RANGe: LOWer?
:SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:RANGe:UPPer?

Queries the min and max frequency and PEP values that define the calibrated range.

Return values:

<PEPmax>	float
	Increment: 0.01

Example:	See Example"Retrieving details on the calibrated values" on page 68.
Usage:	Query only
Manual operation:	See "Frequency Range/PEP Range" on page 57

:SCONfiguration:RFALignment:SETup:INFO:CALibration:FREQuency:STEP?
:SCONfiguration:RFALignment:SETup:INFO:CALibration:POWer:STEP?

Queries the frequency/PEP step size with that the calibration values are selected from the defined value range.

Return values:

<PEPstep>	float
	Increment:　0.01
Example:	See Example"Retrieving details on the calibrated values" on page 68.
Usage:	Query only
Manual operation:	See "Frequency Step/PEP Step" on page 58

:SCONfiguration:RFALignment:SETup:INFO:CALibration:LOCoupling?

Queries whether the instruments use a common local oscillator (LO) signal or not.

Return values:

<State>	ACTive | NACTive
	ACTive
	All instruments are connected to the same LO reference frequency.
	NACTive
	Each instrument uses its own local oscillator.
	*RST:　　　n.a. (factory preset)
Example:	See Example"Retrieving details on the calibrated values" on page 68.
Usage:	Query only
Manual operation:	See "LO Coupling" on page 58

:SCONfiguration:RFALignment:SETup:INFO:WIRing:LO:CONStellation?

Queries the connection method used to distribute the LO frequency signal.

Return values:

<Constellation>	DCHain | STAR
	DCHain
	Daisy chain
	STAR
	Star
Example:	See Example"Retrieving details on the calibrated values" on page 68.
Usage:	Query only
Manual operation:	See "LO Configuration > Wiring Constellation" on page 62

:SCONfiguration:RFALignment:SETup:INFO:WIRing:LO:SOURce?

Queries if the current instrument uses its own or an external LO signal.

Return values:

<Source>　　　　　　　PRIMary | EXTernal

PRIMary
The instrument uses its LO signal and provides it to the other instruments.

EXTernal
The instrument uses an external LO signal, for example from other R&S SMW (the one with
`SCONfiguration:RFALignment:SETup:INFO:WIRing: LO:SOURce PRIMary`).

Example:　　　　　See Example"Retrieving details on the calibrated values" on page 68.

Usage:　　　　　　Query only

Manual operation:　See "LO Configuration > Signal Source" on page 61

:SCONfiguration:RFALignment:SETup:INFO:WIRing:REF:SOURce?

Queries if the current instrument uses its own or an external reference signal.

Return values:

<Source>　　　　　　　PRIMary | EXTernal

PRIMary
The instrument uses its reference signal and provides it to the other instruments.

EXTernal
The instrument uses an external reference frequency source, for example from other R&S SMW (the one with
`SCONfiguration:RFALignment:SETup:INFO:WIRing: REF:SOURce PRIMary`) or from R&S®SMA100B.

Example:　　　　　See Example"Retrieving details on the calibrated values" on page 68.

Usage:　　　　　　Query only

Manual operation:　See "Ref Configuration > Signal Source" on page 61

4.3.4　Current corrections commands

:SOURce<hw>:RFALignment:CALibrated:FREQuency?

Queries the frequency for that the calibration data is valid.

Return values:

<CalibratedFreq>	float
	Increment: 0.01

Example:	See Example"Retrieving details on the calibrated values" on page 68.
Usage:	Query only
Manual operation:	See "Calibrated Frequency" on page 59

:SOURce<hw>:RFALignment:CALibrated:POWer:PEP?

Queries the PEP for that the calibration data is valid.

Return values:

<PEP>	float
	Increment: 0.01

Example:	See Example"Retrieving details on the calibrated values" on page 68.
Usage:	Query only
Manual operation:	See "Calibrated Level (PEP)" on page 59

:SOURce<hw>:RFALignment:FOFFset?

Queries the applied baseband frequency offset.

Return values:

<BbFreqOffset>	float
	Increment: 0.01

Example:	See Example"Retrieving details on the calibrated values" on page 68.
Usage:	Query only
Manual operation:	See "Baseband Frequency Offset" on page 60

:SOURce<hw>:RFALignment:DATTenuation?

Queries the applied digital attenuation.

Return values:

<Attenuation>   float

                                 Increment: 0.01

Example: See Example"Retrieving details on the calibrated values"
                                 on page 68.

Usage: Query only

Manual operation: See "Digital Attenuation" on page 60

:SOURce<hw>:RFALignment:CORRection:PHASe?

queries the delta phase applied for compensation of the frequency response of the signal.

Return values:

<Phase>   float

                                 Increment: 0.01

Example: See Example"Retrieving details on the calibrated values"
                                 on page 68.

Usage: Query only

Manual operation: See "Phase" on page 60

:SOURce<hw>:RFALignment:CORRection:LEVel?

Queries the level correction applied to the signal of the selected path.

Return values:

<Level>   float

                                 Increment: 0.01

Example: See Example"Retrieving details on the calibrated values"
                                 on page 68.

Usage: Query only

Manual operation: See "Level" on page 60

:SOURce<hw>:RFALignment:CORRection:IQDelay?

Queries the I/Q delay applied for compensation of the frequency response of the signal.

Return values:

<IQdelay>   float

                                 Increment: 1E-12

Example: See Example"Retrieving details on the calibrated values"
                                 on page 68.

Usage: Query only

Manual operation: See "I/Q Delay" on page 60

Annex

A Files and data

A.1 Supported file formats

The following file formats are supported.

Extension	File type	Description
`*.rfsa`	Archive file containing the setup description file, the RF port configuration files and the S-parameter files	Setup file (`*.rfsa`) are archive files in proprietary file format. They contain the setup description file (`*.xml`), the RF port correction files (`*.rfcor`), the frequency response correction files (`*.rfresp`) and the S-parameter files (`*.snp`). Setup files are created automatically during the calibration process. Do not edit setup files manually.
`*.xml`	Setup description file	Files in proprietary file format, created automatically during setup calibration.
`*.rfcor`	RF port correction files	The files are human-readable but should not be created or edited manually.
`*.rfresp`	frequency response correction files	
`*.s<n>p`	Touchstone S-parameters files	See Chapter A.2, "S-Parameters (Touchstone) files", on page 80.

A.2 S-Parameters (Touchstone) files

The R&S SMW can extract and apply scattering matrix corrections from S-parameters data files. These data files are also known as Touchstone files and exist in two format versions, V1.0 and V2.0.

R&S SMW-K545 supports Touchstone file format in version V1.0.

File extension

S-parameters files are files with predefined structure and file extension `*.s<n>p`, where $<n>$:

- Is an integer value and $<n> \geq 1$
- $<n>$ = number of measured ports
- $<n>^2$ = number of S-parameters the file contains

An `*.s1p` file, for example, contains a one-port measurement and one S-parameter while the file `*.s3p` contains a three-port measurement and nine S-parameters.

The most meaningful S-parameter for the frequency response compensation is the S21, because it characterizes the frequency response of a component.

S-parameters measurements are typically performed with a vector network analyzer, like, for example, the R&S®ZNB.

File format

Touchstone files contain a **header**, a **comment section**, and the **actual trace data**. The following is an extract of the file content of file created by the R&S®ZNB.

```
#  HZ   S   RI   R     50.00
! Rohde & Schwarz Vector Network Analyzer
! Rohde-Schwarz,ZNB8-4Port,1311601044100005,1.93.1.42
! Created: UTC 9/17/2013, 9:13:56 AM
! freq[Hz]               re:S11              im:S11
 1.000000000000000E5    -4.897128641605377E-1    3.767784312367439E-2
 4.259950000000000E7    -5.450598597526550E-1    3.608805686235428E-2
 ...
```

# indicates the beginning of the **header line**. It is required at the top of file and consists of the following data elements:

- <Frequency unit>: `HZ` / `KHZ` / `MHZ` / `GHZ`, Rohde & Schwarz analyzers usually use Hz.
- <Data file type>: `S` for S-parameter files
- <Data format>:
    - RI = Re/Im
    - MA = linear Magnitude-Phase
    - DB = Mag-Phase in decibels
- <Reference resistance>: specifies the impedance system underlying the trace data, given as a real, positive resistance (default 50 Ω)

Comment lines start with the exclamation mark **(!)** and can contain any text used for documentation of the trace data file. Any number of comment lines can be inserted before or after the header line.

The following information is displayed in the comments section:

- VNA identification (comment line 2 in above example)
- Timestamp (comment line 3)
- Port-specific renormalization information (comment lines 4ff, if applied)
- Headings for included data tables (comment lines right above the data tables, starting with `! freq`)

The **trace data** section corresponds to a set of single-ended S-parameters. It depends on the number of ports and the data format.

For real and imaginary values (<Data format> = `RI`) the trace data for each stimulus frequency is arranged as indicated in the lowermost comment lines:

- **1-port files (`*.s1p`)**

  `! freq[Hz] re:S11 im:S11`

  S_{11} can be replaced by any S-parameter.

  Thus, the `*.s1p` format can contain an arbitrary data trace representing an S-parameter.

- **2-port files (`*.s2p`)**

  `! freq[Hz] re:S11 im:S11 re:S21 im:S21 re:S12 im:S12 re: S22 im:S22`

  (all values arranged in 1 line)

- **n-port files (`*.snp`), 2 < n ≤ 4**

  `! freq[Hz] re:S11 im:S11 re:S12 im:S12 ... re:S1n im:S1n`
  `! re:S21 im:S21 re:S22 im:S22 ... re:S2n im:S2n`
  `! ...`
  `! re:Sn1 im:Sn1 re:Sn2 im:Sn2 ... re:Snn im:Snn`

  (values arranged in n lines)

- **n-port files (`*.snp`), n > 4**

  `! freq[Hz] re:S11 im:S11 ... re:S14 im:S14`
  `! re:S15 im:S15 ...`
  `! ...`
  `! ... re:Snn im:Snn`

  (values arranged in m = ⌈$n^2/4$⌉ lines, where the first —1 data lines contain exactly four value pairs)

The stimulus frequencies are arranged in ascending order. For linear Magnitude-Phase and Magnitude-Phase in decibels values (<Data format> = `MA or DB`), the trace data the real and imaginary S-parameter values `re:Sij  im:Sij` are replaced by `mag:Sij  ang:Sij` or `db:Sij  ang:Sij`, respectively.

Cascading files

If several S-parameter files are loaded, they are cascaded. Each S-parameters file is defined with its origin and destination ports. Thus, you can configure or reverse the orientation of the signal chain.

The first entry in the chain is the R&S SMW itself; it illustrates the chain orientation - form R&S SMW toward the DUT.