R&S®QAR50
Automotive Radome Tester
User Manual

ROHDE&SCHWARZ

Make ideas real

This document describes the following R&S®QAR50 models and options:

- R&S®QAR50 (1343.0099K02/03)
- R&S®QAR50-K10 Frequency response measurements (1343.2091.02)
- R&S®QAR50-K11 Faster frequency response measurements (1343.2840.02)
- R&S®QAR50-K20 Phase mask measurements (1343.2110.02)
- R&S®QAR50-K30 HD reflection image (1343.2133.02)
- R&S®QAR50-K80 Real-time imaging (reflection) (1343.2904.02)
- R&S®QAR50-Z44 Verification set (1343.0082.02)
- R&S®QAR50-U02 Polarization change to vertical (1343.0060.02)
- R&S®QAR50-U03 Polarization change to horizontal (1343.0076.02)

Throughout this manual, products from Rohde & Schwarz are indicated without the ® symbol, e.g. R&S®QAR50 is indicated as R&S QAR50.

Contents

1 Safety and regulatory information

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

Intended use

The product is intended for the development, production and verification of electronic components and devices in industrial, administrative, and laboratory environments. Use the product only for its designated purpose. Observe the operating conditions and performance limits stated in the data sheet.

Where do I find safety information?

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

● In Chapter 1.1, "Safety instructions", on page 7. The same information is provided in many languages as printed "Safety Instructions". The printed "Safety Instructions" are delivered with the product.

● Throughout the documentation, safety instructions are provided when you need to take care during setup or operation.

1.1 Safety instructions

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

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

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

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

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

Lifting, carrying and installing the product

The product is heavy and must be installed and set up by trained staff. Always use appropriate lifting equipment when you lift or carry the product, like a forklift when the R&S QAR50 is still packed in its original box or a crane when it is unpacked.

Lifting and carrying heavy items can cause structural or muscular injuries. Heavy items can also cause other physical injuries like crushed body parts when they fall or tip over.

Because of its weight, at least two strong people are required to move or install the R&S QAR50. During the installation, make sure that the installation site is only accessible to people working on the installation.

During transport, installation or repair, wear appropriate protective clothing that complies with your local rules and regulations. If you are unsure of which equipment to use, ask your safety inspector.

We recommend to wear:

● Safety shoes with toe cap and ESD protection.
● Protective gloves

Always place the product on a stable, flat and level surface with the bottom of the product facing down. If the product is designed for different positions, secure the product so that it cannot fall over.

Choosing the operating site

Only use the product indoors. The product casing is not waterproof. Water that enters can electrically connect the casing with live parts, which can lead to electric shock, serious personal injury or death if you touch the casing.

If Rohde & Schwarz provides accessories designed for outdoor use of your product, e.g. a protective cover, you can use the product outdoors.

You can operate the product up to an altitude of 2000 m above sea level. If a higher altitude is permissible, the value is provided in the specifications document. The product is suitable for pollution degree 2 environments where nonconductive contamination can occur. For more information on environmental conditions such as ambient temperature and humidity, see the specifications document.

Connecting to power

The product is an overvoltage category II product. Connect the product to a fixed installation used to supply energy-consuming equipment such as household appliances and similar loads. Keep in mind that electrically powered products have risks, such as electric shock, fire, personal injury or even death. Replace parts that are relevant to safety only by original parts, e.g. power cables or fuses.

Take the following measures for your safety:

● Before switching on the product, ensure that the voltage and frequency indicated on the product match the available power source. If the power adapter does not adjust automatically, set the correct value and check the rating of the fuse.

- Only use the power cable delivered with the product. It complies with country-specific safety requirements. Only insert the plug into an outlet with protective conductor terminal.
- Only use intact cables and route them carefully so that they cannot be damaged. Check the power cables regularly to ensure that they are undamaged. Also ensure that nobody can trip over loose cables.
- Only connect the product to a power source with a fuse protection of maximum 20 A.
- Ensure that you can disconnect the product from the power source at any time. Pull the power plug to disconnect the product. The power plug must be easily accessible. If the product is integrated into a system that does not meet these requirements, provide an easily accessible circuit breaker at the system level.

Cleaning the product

Use a dry, lint-free cloth to clean the product. When cleaning, keep in mind that the casing is not waterproof. Do not use liquid cleaning agents.

Meaning of safety labels

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

	Electrical hazard
	Indicates live parts. Risk of electric shock, fire, personal injury or even death.

	Heavy product
	Be careful when lifting, moving or carrying the product. Carrying the product requires a sufficient number of persons or transport equipment.

1.2   Labels on the product

Labels on the casing inform about:

- Personal safety, see "Meaning of safety labels" on page 9
- Product and environment safety, see Table 1-1
- Device information is provided on a sticker attached to the connector board. For details, see Chapter 5.2.6, "Device ID", on page 33.

Table 1-1: Labels regarding product and environment safety

	Labeling in line with EN 50419 for disposal of electrical and electronic equipment after the product has come to the end of its service life.
	For more information, see "Disposing of electrical and electronic equipment" on page 110.

1.3 Warning messages in the documentation

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

WARNING

Potentially hazardous situation. Could result in death or serious injury if not avoided.

CAUTION

Potentially hazardous situation. Could result in minor or moderate injury if not avoided.

NOTICE

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

1.4 Regulatory information

The R&S QAR50 complies with the following regulations.

1.4.1 Regulations for the USA

FCC compliance

This equipment has been tested and found to comply with the limits for Industrial, Scientific and Medical Equipment (ISM), pursuant to part 18 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in an industrial installation. This equipment generates, uses, and can radiate radio frequency energy, and if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference other devices, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Consult Rohde & Schwarz customer service for help.

1.4.2 Regulations for Canada

ICES-001 compliance

This class A ISM device complies with Canadian ICES-001.

Cet appareil ISM de la classe A est conforme à la norme NMB-001 du Canada.

1.5 Korea certification class A

이 기기는 업무용(A급) 전자파 적합기기로서 판매자 또는 사용자는 이 점을 주의하시기 바라며, 가정외의 지역에서 사용하는 것을 목적으로 합니다.

2 Documentation overview

The user documentation for the R&S QAR50 consists of several documents.

Getting started

Introduces the R&S QAR50 and describes how to set up and start working with the product. A printed version is included in the delivery.

Download the manual from: https://www.rohde-schwarz.com/manual/qar50/

User manual

Contains a description of the R&S QAR50 system, including the features available in the R&S QAR50 application.

A digital version of the user manual in html format is available in the measurement application.

Download the manual from: https://www.rohde-schwarz.com/manual/qar50/

Safety instructions

Contains safety instructions, operating conditions and further important information. The printed safety instructions are part of the delivery.

Specifications and brochure

The specifications document (also called data sheet) contains the technical specifications of the R&S QAR50, its options and accessories.

The brochure provides an overview of the R&S QAR50 and its characteristics.

Download the documents from: https://www.rohde-schwarz.com/product/qar50

Open-source acknowledgment (OSA)

The open-source acknowledgment documents provide verbatim license texts of the used open source software.

The OSAs is available in the measurement application ("Info" > "Open Source Acknowledgement") and on the SSD in the folder `C:\OpenSourceAgreement`.

Application videos

The application video series provides information about the capabilities and features of the R&S QAR50.

Watch the videos at: http://www.rohde-schwarz.com/product/QAR50-application-videos

3 Welcome

The R&S QAR50 is the ideal tool for accurately testing the quality of radomes and bumpers in the automotive radar frequency range at the end-of-line (EOL). It features sufficient space to easily accommodate bulky bumpers combined with spatially resolved measurements to evaluate the homogeneity of design emblems. Its innovative hardware concept enables impressively fast measurement times whereas the modular software concept allows adaptation to your particular requirements.

Measurements:

- Precise reflection measurements from both sides for two frequency bands.
- Frequency-resolved reflection and transmission loss measurement.
- Transmission phase measurement.
- High-resolution reflection image.

The R&S QAR50 is based on the microwave imaging technology that can give immediate feedback about DUT (device under test) alignment and positioning.

Millimeter wave signals are electromagnetic waves with wavelengths that range from some millimeters down to one millimeter. These wavelengths correspond to a frequency range from a few tens of GHz up to 100 GHz. Millimeter wave (mmW) measurement devices require no direct contact and can penetrate the DUT to deliver an image of its content.

4 Preparing for use

Here, you can find basic information about setting up the product for the first time.

4.1 Choosing the operating site

Specific operating conditions ensure proper operation and avoid damage to the product and connected devices. For information on environmental conditions such as ambient temperature and humidity, see the specifications document.

For safety information, see "Choosing the operating site" on page 8.

▶ **NOTICE!** Overheating can damage the product.

Prevent overheating as follows:

- Keep a minimum distance of 10 cm between the fan openings of the product and any object in the vicinity to provide sufficient airflow and ventilation. Several fan openings are located on either side of the R&S QAR50.
- Do not place the product next to heat-generating equipment such as radiators or other products.

Electromagnetic compatibility classes

The electromagnetic compatibility (EMC) class indicates where you can operate the product. The EMC class of the product is given in the specifications document.

- Class B equipment is suitable for use in:
  - Residential environments
  - Environments that are directly connected to a low-voltage supply network that supplies residential buildings
- Class A equipment is intended for use in industrial environments. It can cause radio disturbances in residential environments due to possible conducted and radiated disturbances. It is therefore not suitable for class B environments.
  If class A equipment causes radio disturbances, take appropriate measures to eliminate them.

4.2 Unpacking and checking

The R&S QAR50 is a large and heavy device. Unpacking, moving and installing the R&S QAR50 requires special arrangements. Follow the instructions provided here when you unpack the R&S QAR50.

Also see "Lifting, carrying and installing the product" on page 8.

If you do not have appropriate lifting equipment, contact your Rohde & Schwarz representative.

Unpacking the R&S QAR50

1. **WARNING!** Risk of physical injury caused by heavy items. See "Lifting, carrying and installing the product" on page 8.

    Move the delivery box to a place near the installation site.

2. Remove the top lid of the wooden box the R&S QAR50 is delivered in.
    Disassembling the box requires a screwdriver, because the box parts are screwed to one another.

3. Remove the bars that hold secure the R&S QAR50 inside the box.

4. Remove the four side parts of the box.

5. Using the delivery notes, check the equipment for completeness.

6. Check the equipment for damage.

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

7. **WARNING!** Risk of physical injury caused by heavy items. See "Lifting, carrying and installing the product" on page 8.
    Carefully lift the R&S QAR50 out of the box.

Lifting the R&S QAR50 out of the transport box

Use a crane or similar lifting device to lift the R&S QAR50 out of its transport box.

1. Unpack the R&S QAR50 as described in Chapter 4.2, "Unpacking and checking", on page 14.

    Included in the delivery are four eye bolts. The eye bolts serve as lifting points. Use these bolts to attach appropriate lifting equipment. We recommend using a crane to lift and move the R&S QAR50.

2. Screw the four eye bolts into the mounting holes on top of the R&S QAR50.
    Make sure that the bolts sit tight in the mounting holes. They sit tight if you cannot screw them any further into the mounting holes.

3. **WARNING!** Risk of physical injury caused by heavy items. See "Lifting, carrying and installing the product" on page 8.
    The product is heavy. Moving the R&S QAR50 safely is only possible with appropriate lifting equipment (like a crane) and a suitable lifting harness (like a four leg rope). Commission personnel that is qualified to safely attach the R&S QAR50 to the lifting equipment, to operate the lifting equipment and take the necessary safety measures.

    Attach the the lifting device.
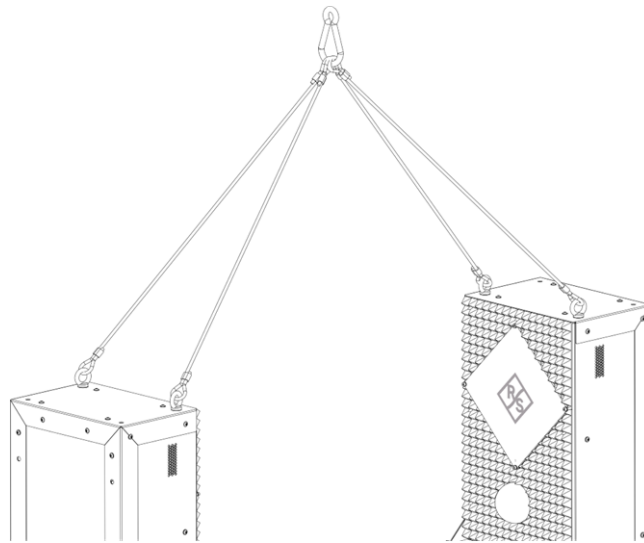
Figure 4-1: Attachment of lifting equipment, for example a rope harness

● Use lifting equipment and harness that can carry the weight of the R&S QAR50 (see datasheet).
● Connect the eye bolts securely to the harness, for example with shackles.
● Distribute the weight equally over all four eye bolts.
● Mount the harness legs at a maximum angle of 45° per eye bolt.

Figure 4-2: Eye bolt load limit

4. Move the R&S QAR50 carefully to its operating site and put it firmly onto the ground.

5. Remove the lifting equipment.

6. Remove the eye bolts from the mounting holes.

7. Proceed with the installation as described in Chapter 4.3, "Installing the R&S QAR50", on page 17.

8. Retain the original packing material. Use it when transporting or shipping the R&S QAR50 later.
    See also Chapter 18, "Transporting", on page 112.

4.3 Installing the R&S QAR50

The R&S QAR50 is a large and heavy device. Unpacking, moving and installing the R&S QAR50 requires special arrangements. Follow the instructions provided here when you install the R&S QAR50.

See also:

Parts of delivery required for installation

- 1 x R&S QAR5050
- 2 x supporting feet, incl. screws (M8X45) and washers
- 16 x mounting hole caps (M8X16 screws)
- 1 x power cable
- 2 x Allen wrench (1x size 5 and 1 x size 6)

Other required tools for installation

- Open-ended wrench size 19
- Spirit level

Setting up the R&S QAR50

You can set up the R&S QAR50 in two different ways: lying on its long side ("lying position") or standing upright on one of its short sides ("upright position"). By default, the R&S QAR50 is designed to stand on a pair of feet that are part of the delivery.

For the upright position, make sure that the side with the connector board is at the bottom.

The R&S QAR50 must be placed on a level surface. This is important not only for safety reasons, but also to get valid measurement results. If the body of the R&S QAR50 is not at a right angle to the floor, measurement results can be invalid.
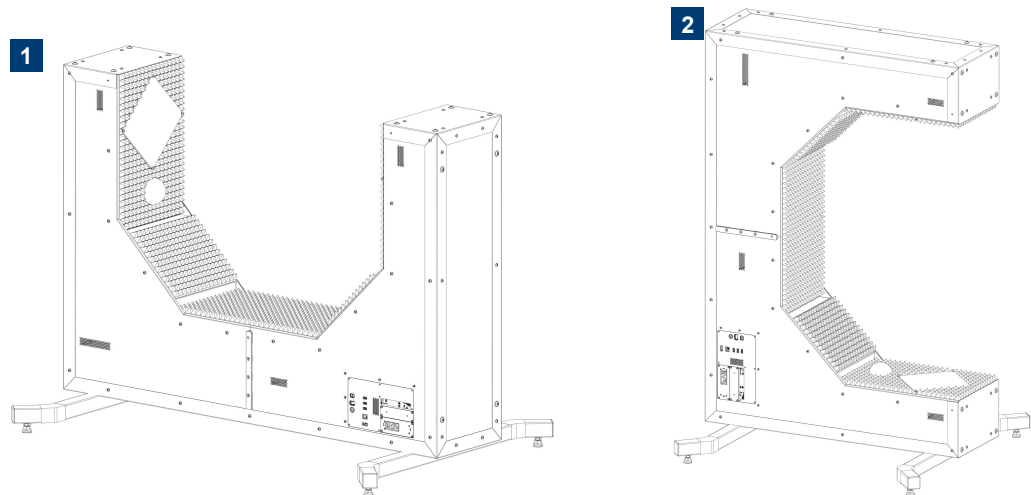
Figure 4-3: Possible operation positions for the R&S QAR50

1 = Lying position
2 = Standing position

ⓘ   Instead of using the supporting feet, you can also integrate the R&S QAR50 in a production line system. For these special setups, contact your Rohde & Schwarz representative.

Attaching the supporting feet

The R&S QAR50 is delivered with a pair of feet that you can attach to the R&S QAR50. All required parts (feet, screws and washers) are part of the delivery.

The supporting feet are bent at their ends to make the R&S QAR50 more stable. Make sure to align the feet correctly with the bent parts facing away from the ends of the main body.

Figure 4-4: Correct alignment of the supporting feet

After you have unpacked the R&S QAR50, it usually rests in lying position on the floor. The way to attach the feet depends on the way you set up the R&S QAR50 (lying position or upright position).

1. **WARNING!** Risk of physical injury caused by heavy items. See "Lifting, carrying and installing the product" on page 8.
   Attaching the feet requires you to tilt the R&S QAR50 by 90° at least once.

To tilt the R&S QAR50, you can attach a suitable aid like a handle to the mounting holes not needed for the feet. While tilting the R&S QAR50, be careful not to damage the R&S QAR50 or the supporting feet. One person must secure the R&S QAR50 while another person tilts the R&S QAR50.

For the lying position, proceed as follows to attach the supporting feet.

a) Tilt the R&S QAR50 by 90° to an upright position (make sure that the side with the connector board is on the bottom).

Figure 4-5: Tilting the R&S QAR50 into an upright position

b) Screw the two feet to the mounting holes indicated in Figure 4-6 with an Allen wrench. The screws and wrench are part of the delivery (M8X45).
Put the washers between screw heads and feet.

Figure 4-6: Attaching the supporting feet for lying position

c) Screw in the caps of the mounting holes (M8X16 screws). The caps are part of the delivery.

d) Tilt the R&S QAR50 back to the lying position.
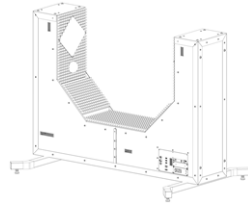
Figure 4-7: Final lying position

2. For the upright position, proceed as follows to attach the supporting feet.
In the upright position, make sure to install the feet on the side of the R&S QAR50 that contains the connector board.

a) Screw the two feet to the mounting holes indicated in Figure 4-8 with an Allen wrench. The screws and wrench are part of the delivery (M8X45).
Put the washers between screw heads and feet.
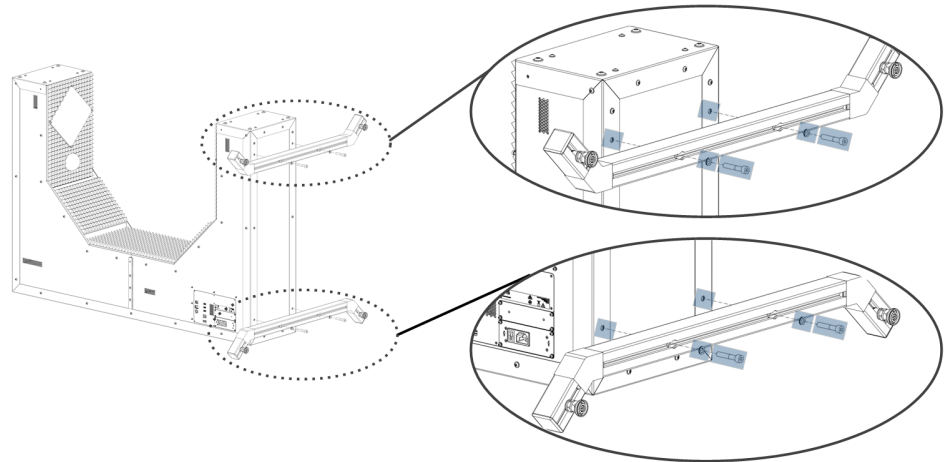
Figure 4-8: Attaching the supporting feet for upright position

b) Screw in the caps of the mounting holes (M8X16 screws). The caps are part of the delivery.

c) Tilt the R&S QAR50 by 90° to an upright position (make sure that the side with the connector board is on the bottom).
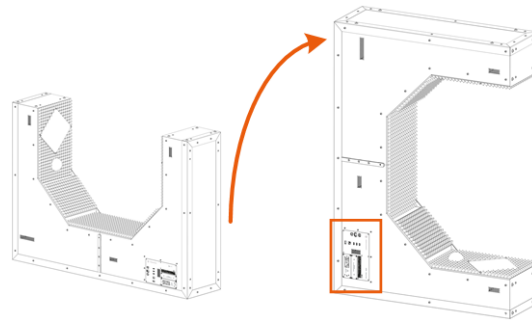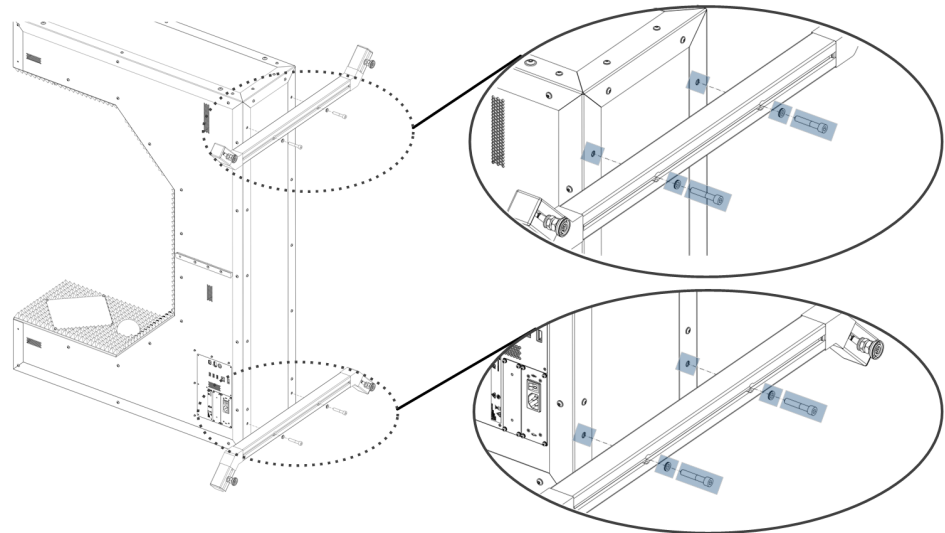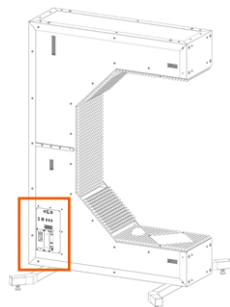

Figure 4-9: Final upright position

3. For both positions, make sure that the R&S QAR50 is in a stable position.

   a) Check with a spirit level if the R&S QAR50 itself is level.
   b) If necessary, remove any irregularities by adjusting the height of the feet with the open-ended wrench until the R&S QAR50 is level.
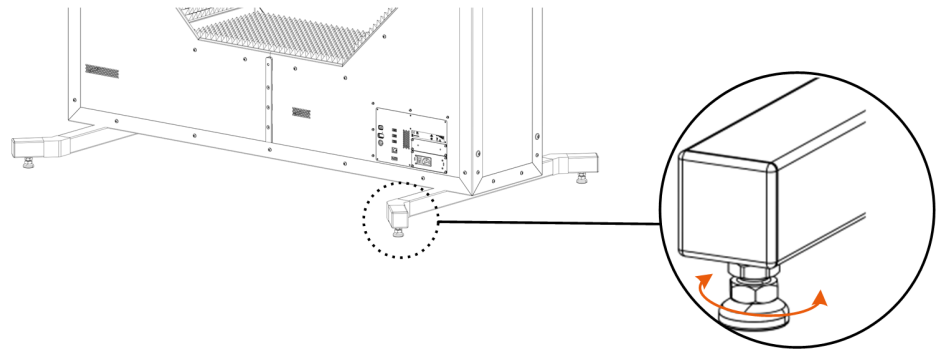
Figure 4-10: Adjusting feet height

   ● A clockwise movement lowers the corresponding foot.
   ● A counterclockwise movement raises the corresponding foot.
   c) Tighten the feet with the check nuts using the open-end wrench.

Moving the R&S QAR50

Use a crane or similar device to move the R&S QAR50 from one location to another.

The process is similar to lifting the R&S QAR50 out of the transport box ("Lifting the R&S QAR50 out of the transport box" on page 15).

During the whole process, the feet can remain attached to the R&S QAR50.

1. **WARNING!** Risk of physical injury caused by heavy items. See "Lifting, carrying and installing the product" on page 8.
   The product is heavy. Moving the R&S QAR50 safely is only possible with appropriate lifting equipment (like a crane) and a suitable lifting harness (like a four leg rope). Commission personnel that is qualified to safely attach the R&S QAR50 to the lifting equipment and to operate the lifting equipment.
   Unscrew the caps of the mounting holes you need (M8X16 screws).
   Depending on the setup (lying or upright position), use the mounting holes indicated in Figure 4-11 to lift the R&S QAR50. Do not use different mounting holes and always use four mounting holes to distribute the weight equally.

   ● For the lying position: Use the mounting holes on top of the R&S QAR50. Use either the four outer mounting holes (variant 1 in Figure 4-11) **or** the inner mounting holes (variant 2 in Figure 4-11).
   ● For the upright position: Use the mounting holes on the opposite side of the connector board. The side with the connector board must always be on the bottom.
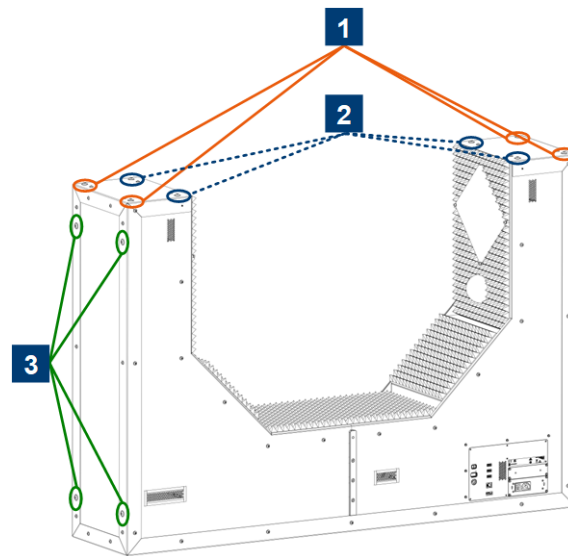
Figure 4-11: Attachment points for lifting equipment

1 = Attachment points for lying position (variant 1)
2 = Attachment points for lying position (variant 2)
3 = Attachment points for upright position

2. Screw the eye bolts that were part of the delivery securely into the mounting holes. They sit tight if you cannot screw them any further into the mounting holes.

3. Attach lifting equipment as described in "Lifting the R&S QAR50 out of the transport box" on page 15.

4. Carefully move the R&S QAR50 to its new location.

5. Remove the lifting equipment from the R&S QAR50.

6. Remove the eye bolts from the mounting holes.

7. Screw the caps of the mounting holes back in (M8X16 screws).

4.4 Considerations for test setup

Integration of the R&S QAR50 at the workplace

The R&S QAR50 has several edges that are required by its functionality. To avoid physical injuries like head lacerations, take care of an appropriate ergonomic integration of the device at the workplace, especially if frequent human interaction with the device is expected.

Cable selection and electromagnetic interference (EMI)

Electromagnetic interference (EMI) can affect the measurement results.

To suppress electromagnetic radiation during operation:

- Use high-quality shielded cables, for example, double-shielded RF and LAN cables.
- Always terminate open cable ends.
- Ensure that connected external devices comply with EMC regulations.

4.5 Connecting the R&S QAR50

The following overview shows the possible connections for the R&S QAR50.
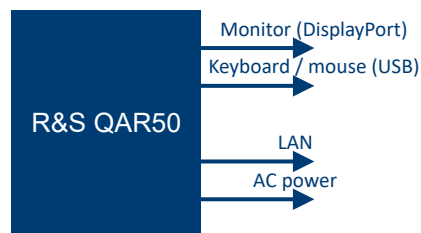
Figure 4-12: Connections for the R&S QAR50

1. Connect a monitor to the DisplayPort port on the R&S QAR50.
    As a power source, you can use a household AC outlet to supply the monitor with power (for monitors with a light-current extension cable).

    Note: We recommend using a monitor with a resolution of at least 1920 x 1080. Lower resolutions can lead to an incorrect display of the measurement data.

2. Connect a keyboard and a mouse to two of the USB ports.

3. Optional: Establish a connection to your LAN via the LAN interface.

    Note: Always connect all devices before connecting the R&S QAR50 to the mains supply.

Network connections

Before connecting the product to a local area network (LAN), consider the following:

- Install the latest software to reduce security risks.
- For internet or remote access, use secured connections if applicable.
- Ensure that the network settings comply with the security policies of your company. Contact your local system administrator or IT department before connecting your product to your company LAN.
- When connected to the LAN, the product can potentially be accessed from the internet, which can be a security risk. For example, attackers might misuse or damage the product.

Connecting to power

The R&S QAR50 contains an AC power supply on the connector board.

For safety information, see "Connecting to power" on page 8.

1. Plug the AC power cable into the AC power connector on the connector board. Only use the AC power cable delivered with the product.

2. Plug the AC power cable into a power outlet with ground contact.

   The required ratings are listed next to the AC power connector and in the data sheet.

4.6 Switching on or off

Table 4-1: Overview of power states

Status	LED	Position of power switch
Off	Off	[0]
Standby	🟠 orange	[I]
Ready	🟢 green	[I]

Turning on the R&S QAR50

The product is off but connected to power.

1. Set the switch on the power supply to position [I]. See Chapter 5.2.1, "AC power supply", on page 31.

   The LED of the [Power] key is orange. See Chapter 5.2.2, "Power button", on page 32.

2. Press the [Power] key.

   The LED turns green. The R&S QAR50 boots.

Warming up the hardware

Before using the R&S QAR50, let it warm up to its operating temperature. If the hardware does not reach its operating temperature, measurement results can be invalid. The operating temperature depends on the ambient temperature.

After turning on the R&S QAR50 for the very first time, let it warm up for at least 90 minutes.

Each subsequent start of the software automatically heats the hardware to the temperature it had during the last normalization. This fast warm-up can take up to 20 minutes. After that time period, you can start measuring with your R&S QAR50.

You can interrupt the fast warm-up. If you do so, normalize the measurement. Otherwise, measurements results can be invalid.

If the operating temperature of the last normalization has not been reached after 20 minutes, the R&S QAR50 automatically aborts the fast warm-up. In that case, you cannot start measurements. To be able to measure again, normalize the measurement.

Before normalizing measurements, we recommend to let the R&S QAR50 warm up to its operating temperature. If in doubt, let the R&S QAR50 warm up for 90 minutes (or until the temperature display is stable).

Shutting down the product

The product is in the ready state.

► Press the [Power] key.

The operating system shuts down. The LED changes to orange.

Disconnecting from power

The product is in the standby state.

1. **NOTICE!** Risk of data loss. If you disconnect the product from power when it is in the ready state, you can lose settings and data. Shut it down first.

   Set the switch on the power supply to position [0].

   The LED of the Power key is switched off.

2. Disconnect the product from the power source.

4.7 Operating system

The R&S QAR50 contains a Microsoft Windows 10 operating system which has been configured according to the R&S QAR50's features and needs.

The drivers and software installed on the R&S QAR50 are adapted to the R&S QAR50. Only install software updates released by Rohde & Schwarz.

Service packs and updates

Microsoft regularly creates security updates and other patches to protect Windows-based operating systems. They are released through the Microsoft Update website and associated update server. Update instruments using Windows regularly, especially instruments that connect to a network.

Firewall settings

A firewall protects an instrument by preventing unauthorized users from gaining access to it through a network. Rohde & Schwarz highly recommends using the firewall on your instrument. Rohde & Schwarz instruments are shipped with the Windows firewall enabled. All ports and connections for remote control are enabled.

Note that changing firewall settings requires administrator rights.

Virus protection

Take appropriate steps to protect your instruments from infection. Use strong firewall settings and scan any removable storage device used with a Rohde & Schwarz instrument regularly. It is also recommended that you install anti-virus software on the instru-

ment. Rohde & Schwarz does NOT recommend running anti-virus software in the background ("on-access" mode) on Windows-based instruments, due to potentially degrading instrument performance. However, Rohde & Schwarz does recommend running it during non-critical hours.

For details and recommendations, see the following Rohde & Schwarz white paper:

● 1EF96: Malware Protection Windows 10

User accounts

The Windows 10 operating system installed on the R&S QAR50 has two predefined user accounts:

● Standard user account with standard windows rights.
  The user name for this account is `Operator`.
  The password is `operator<serialnumber>`, with `<serialnumber>` being a placeholder of the serial number of the R&S QAR50.
  Example: `operator123456`

● Administrator account with rights to install software or create user accounts.
  The user name for this account is `Admin`
  The password is `emodar8Administrator<serialnumber>`, with `<serialnumber>` being a placeholder of the serial number of the R&S QAR50.
  Example: `emodar8Administrator123456`

ⓘ **Changing the passwords**
For security reasons, we recommend that you to change the passwords after the first login.

5 Instrument tour

The R&S QAR50 is a millimeter wave imaging system operating in the frequency band of automotive radar sensors. With its support of spatially resolved reflection and transmission loss measurements, the R&S QAR50 provides an intuitive and powerful way to evaluate how radomes and bumpers influence the radar performance.

The R&S QAR50 contains the measuring electronics like transmitting and receiving antennas and a PC with dedicated software to operate and control the measurements.

The meanings of the labels on the product are described in "Meaning of safety labels" on page 9.

Additional equipment required to run measurements

- (Touchscreen) monitor
- Keyboard
- Mouse

Instrument variants

The R&S QAR50 is available in two variants.
- Variant 02: The antennas on the antenna clusters have a vertical polarization.
- Variant 03: The antennas on the antenna clusters have a horizontal polarization.

5.1 System overview

The visible part of the R&S QAR50 system consists of several elements that you can either interact with or that are required for measurement applications.
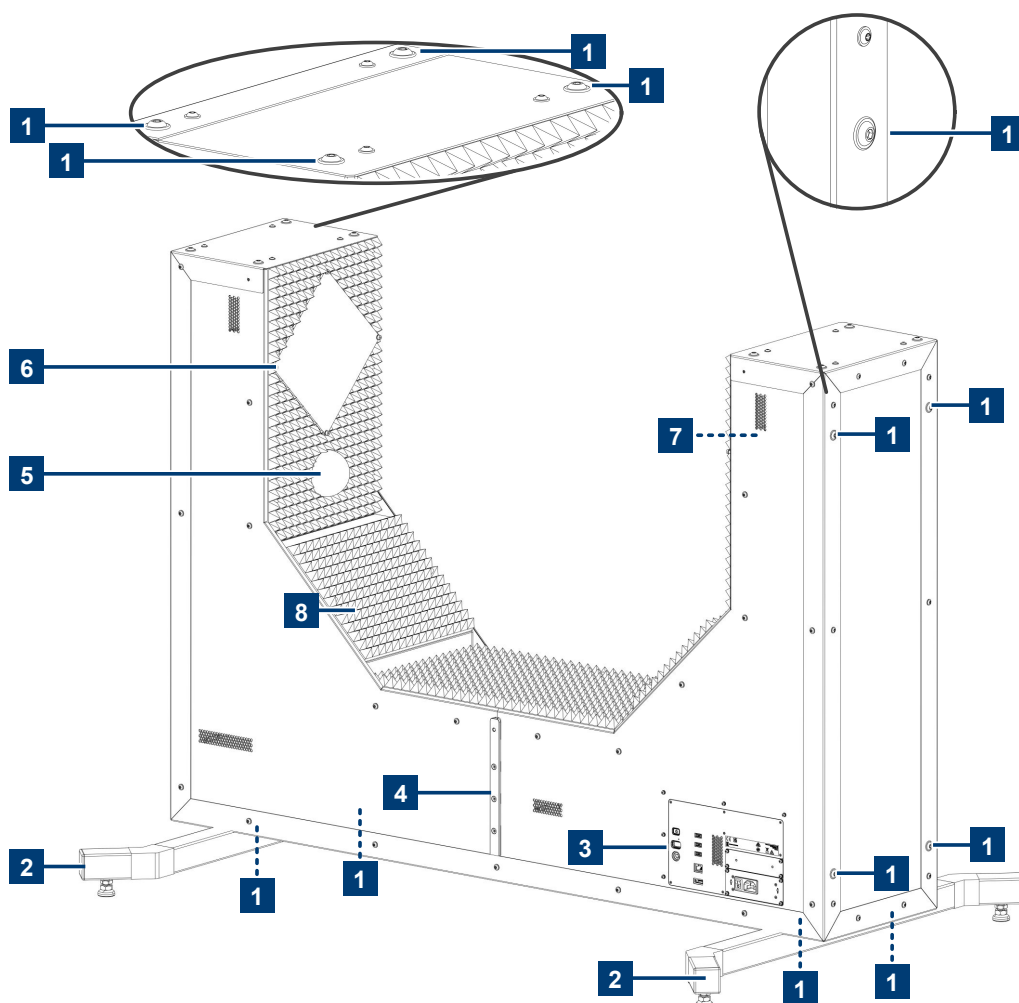
Figure 5-1: System overview

1 = Mounting holes
2 = Supporting feet
3 = Connector board
4 = Verification kit mounting rail
5 = Calibration sphere
6 = Antenna cluster 1
7 = Antenna cluster 2
8 = Absorbers

5.1.1 Connector board

Number of connector boards: 1

Function: The connector board provides various interfaces for external applications.

For more information about available connectors, see Chapter 5.2, "Connectors and labels", on page 30.

5.1.2 Antenna cluster

Number of clusters: 2

Function: The antenna clusters are located in the side body of the R&S QAR50. The antenna clusters contain the transmit and receive antennas. Each cluster contains 188 antennas, 94 transmit antennas and 94 receive antennas. These antennas transmit and receive the signals to and from the DUT and digitize the resulting incident wave quantities, which are in turn the source for the microwave imaging.

Depending on the system variant, the antennas have a vertical polarization or a horizontal polarization.

- The variant with a vertical antenna polarization is required for measurements on radar covers with a vertical polarization.
- The variant with a horizontal antenna polarization is required for measurements on radar covers with a horizontal polarization.

You can change the cluster polarization later on with one of the optional upgrade kits for a polarization change.

The R&S QAR50 contains two clusters:

- Cluster "2" is located on the side of the connector board.
- Cluster "1" is located on the other side.

For better orientation, the cluster numbers are printed on the corresponding cluster.

5.1.3 Absorbers

Number of absorber sheets: 5

Function: The absorber sheets on the inside of the R&S QAR50 eliminate electromagnetic interferences that would otherwise distort the reflection and transmission measurements.

5.1.4 Mounting rail for the verification kit

Number of mounting rails: 2 (one on each side of the main body)

Function: The mounting rails for the verification kit are located in the center of each side of the R&S QAR50 body. Use these rails to install the verification kit if you have to verify the system.

For a comprehensive description of the verification procedure, see Chapter 12, "System verification", on page 78.

5.1.5 Calibration sphere

Number of calibration spheres: 2

Function: The calibration spheres are located in the side body of the R&S QAR50. The calibration spheres are passive features required for instrument calibration. System calibration becomes necessary after a module has been replaced or if the verification returns a poor image quality.

For more information about system calibration, contact your service representative or refer to the service manual.

5.1.6   Supporting feet

Number of supporting feet: 2

Function: The supporting feet provide a means to support the R&S QAR50.

Depending on how you install the R&S QAR50, the supporting feet are either located on the bottom of the main body of the R&S QAR50 or on the side body that contains cluster "2".

For more information about installing the supporting feet, see "Attaching the supporting feet" on page 18.

5.1.7   Mounting holes

Number of mounting holes: 20

Location of mounting holes:

*   8 x mounting holes on the top of each of the side bodies.
    Function: These mounting holes provide a means to mount lifting equipment to the R&S QAR50.
*   4 x mounting holes on the outer side of each of the side bodies.
    Function: These mounting holes provide a means to mount the supporting feet or lifting equipment to the R&S QAR50.
*   4 x mounting holes on the bottom of the main body.
    Function: These mounting holes a means to mount the supporting feet to the R&S QAR50.

Caps (M8X16 screws) cover the mounting holes if the mounting holes are unused.

For more information about mounting supporting feet and lifting equipment, see "Attaching the supporting feet" on page 18 and "Lifting the R&S QAR50 out of the transport box" on page 15.

5.2   Connectors and labels

The R&S QAR50 has several connectors for various purposes. All connectors are located on the side of the R&S QAR50.
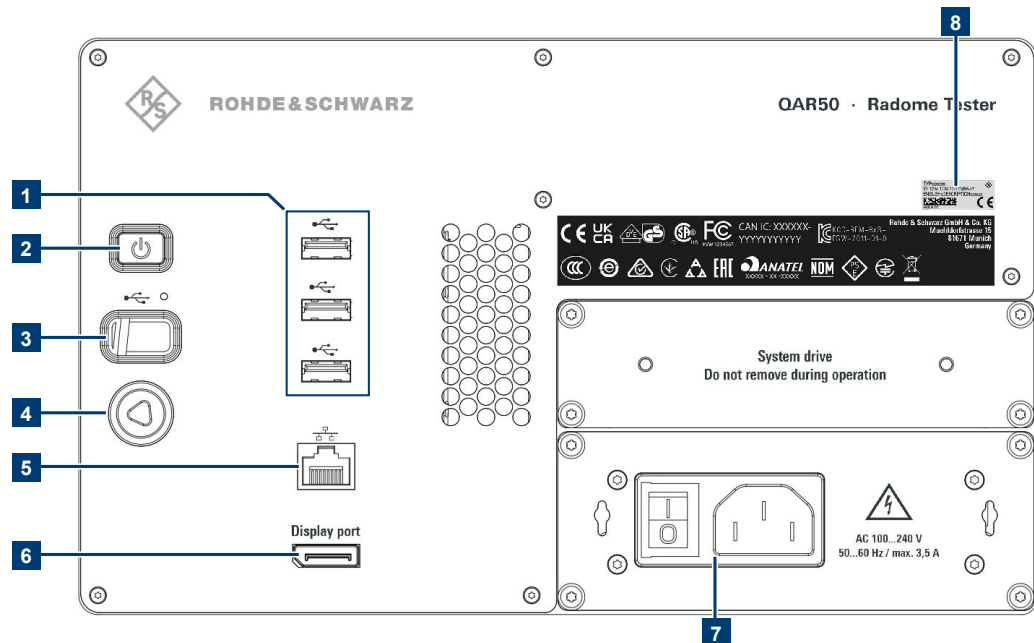
Figure 5-2: Connector overview

1 = USB ports
2 = Power button
3 = USB ports (behind protective cover)
4 = Lock for protected USB port
5 = LAN interface
6 = DisplayPort
7 = AC power supply
8 = Sticker with device ID

5.2.1 AC power supply

Connector type: IEC 60320-1 C14

Function: AC input for a connection to the AC mains supply. You can connect the R&S QAR50 to networks with different voltage levels (see datasheet for the supported voltage range). The power supply automatically adapts itself to the voltage level of the power source.

The power cord necessary to connect the panel to the power supply is part of the delivery (with country-specific plug).

For more information about using the AC power supply safely, see "Connecting to power" on page 8.

For more information about supplying the radio with power, see Chapter 4.5, "Connecting the R&S QAR50", on page 23.
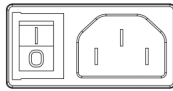
Figure 5-3: AC power supply

5.2.2 Power button

Function: A short press turns the R&S QAR50 on and off when it is connected to an AC power source

The power button contains an LED that indicates the state of the R&S QAR50. For more information about the power states, see Chapter 4.6, "Switching on or off", on page 24.

Figure 5-4: Power button

5.2.3 LAN interface

Connector type: RJ45

Function: LAN interface to connect the R&S QAR50 to a local network and for remote control via SCPI or OPC.

Figure 5-5: LAN interface

5.2.4 USB ports

Connector type: USB 3.0 type A

Number of ports: 4

Function: USB ports for various uses.

- Connection of a keyboard to operate the R&S QAR50.
- Connection of a mouse to operate the R&S QAR50.
- Connection of a memory stick, for example to update the software or export measurement results.

Note that the fourth USB port is located behind a protective cap that you can open with a triangular wrench.

(i) **Locked USB ports**

Some service and maintenance tasks require access to one of the USB ports. If you lock the USB ports, for example for security reasons, these tasks can no longer be performed.

Figure 5-6: USB port

5.2.5 DisplayPort connector

Connector type: DisplayPort

Function: DisplayPort for connection of a touchscreen or monitor that you can use to control the R&S QAR50 and view the measurement results.

Figure 5-7: DisplayPort connector

5.2.6 Device ID

The unique device identifier is provided as a barcode sticker on the connector board on the side of the R&S QAR50.

It consists of the device order number, the serial number and a checksum.

Example `1343.0099K02-123456-aa`.

6 Test setup

The test setup for measurements with the R&S QAR50 basically consists of a R&S QAR50 and a DUT located between the two measurement clusters.

There are, however, a few things that you need to consider for your specific measurement tasks that can have a big impact on the test setup.

Note that the verification process is the same for all test setups.

6.1 Cluster polarization

The R&S QAR50 is available in two variants. One variant that has vertically polarized clusters (order no. 1343.0099K02) and one variant that has horizontally polarized clusters (order no. 1343.0099K03). The variant you need depends on the DUT that you are measuring: radomes for radar sensors with vertical or horizontal polarization.

You can change the cluster polarization later on with one of the optional polarization change kits. Changing the polarization requires a trained service technician. Contact your R&S QAR50 representative for details.

Co-polarized measurements vs cross-polarized measurements

Most radomes are unpolarized. Therefore, the cluster polarization does not matter for most measurements. The polarization becomes important when you measure DUTs that contain polarized elements, for example DUTs coated with polarized paint or integrated heating wires.

In that case, using a R&S QAR50 with the incorrect polarization yields deviating measurement results.

- For co-polarized measurements, DUTs act like little antennas that influence the signals that the clusters transmit. If you test those DUTs with a co-polarization, measurement results show unwanted effects.
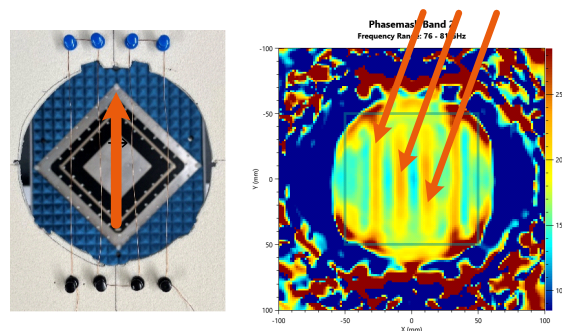
Figure 6-1: Image of a co-polarized DUT with unwanted effects (visible heating wires)

- Measurements with a cross-polarized setup do not show that effect on the signal. A cross-polarized setup is a R&S QAR50 with horizontal polarization and a DUT with a vertical polarization, or vice versa.
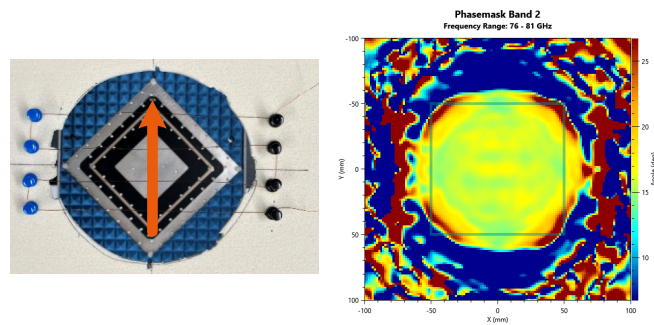
Figure 6-2: Image of a cross-polarized DUT without unwanted effects (invisible heating wires)

The R&S QAR50 must have the same polarization as the mounted radar.

6.2 DUT position

The position of the DUT relative to the clusters is determined by a coordinate system, whose origin is the center of cluster 1.
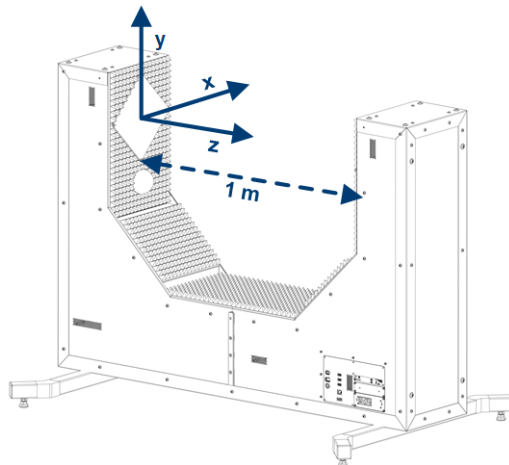
Figure 6-3: Location of the DUT relative to the clusters

Rules for an ideal position of the DUT:

- On the x- and y-axis, the center of the DUT corresponds to the origin of the axes (x and y = 0).
- On the z-axis, the DUT must be halfway between the clusters. The distance between the clusters is 1 m.
- Align the surface area of the DUT parallel to the surface area of the clusters.
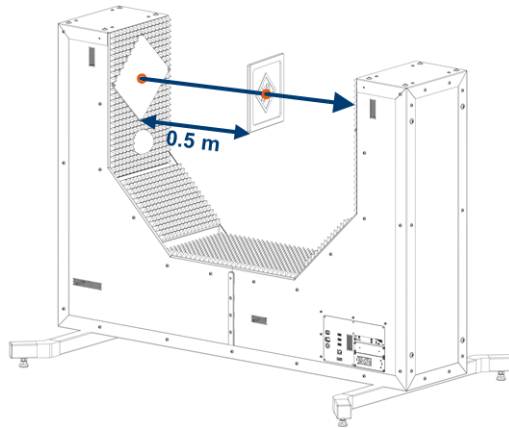
Figure 6-4: Ideal position of a DUT

If you position the DUT differently, there can be negative effects on the results.
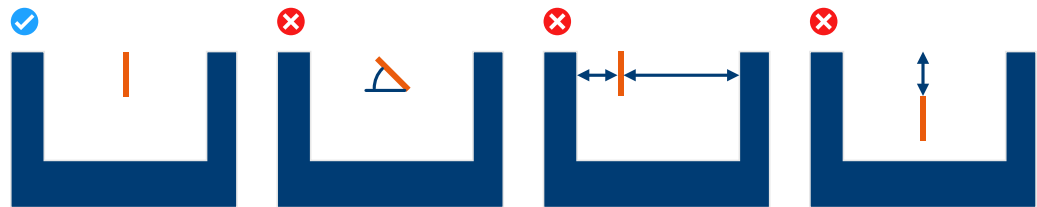
Figure 6-5: Possible wrong positions of a DUT

1 = Properly aligned DUT
2 = Tilted DUT
3 = DUT with a wrong distance to the clusters
4 = DUT not centered to the clusters

6.3 DUT position for different instrument positions

You can set up the R&S QAR50 in two positions: lying and upright (for details, see Chapter 4.3, "Installing the R&S QAR50", on page 17). The position of the R&S QAR50 determines the recommended DUT position.

Of course, you can position the DUT any way you want, regardless of the R&S QAR50 position. However, doing so can result in a millimeter wave image with an unintuitive orientation.

- For the lying position, we recommend positioning the DUT facing up. Using that position, the millimeter wave image also shows the DUT facing up.
- For the upright position, we recommend positioning the DUT facing towards the R&S QAR50. Using that position, the millimeter wave image shows the DUT facing up.

Make sure to select the correct instrument position from the device properties.

Example

Assume that you want to evaluate a millimeter wave image of this Rohde & Schwarz logo. The resulting image shows the logo the right way around.

Regardless of the position of the R&S QAR50, always align the center of the logo with the center of the clusters. The plate with the logo is thin, so the distance from each cluster is about 0.5 m. Thicker DUTs can require a different distance to the clusters - whatever the case, make sure that the distance from both clusters is the same.
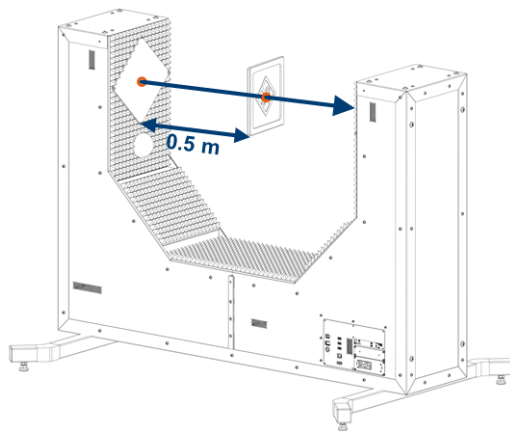
Figure 6-6: Example: General DUT position relative to the clusters

With this DUT position, the R&S QAR50 creates an image that shows the complete logo. To get an image that is also displayed the right way around in the result display, position the DUT as follows.

- For the lying position, position the logo like this:
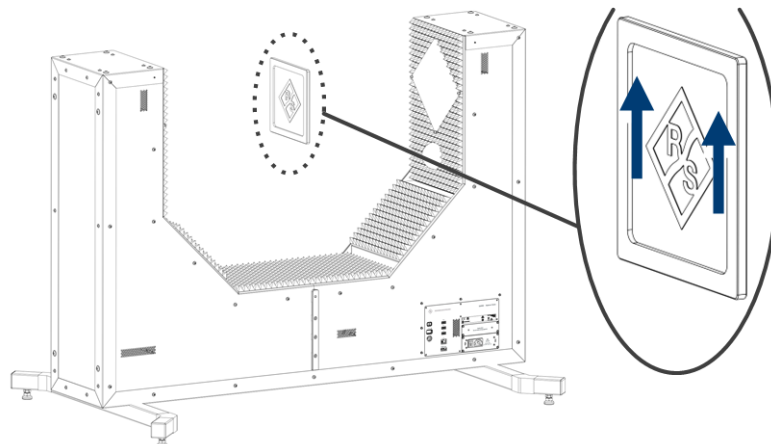
Figure 6-7: Example: DUT position for a lying R&S QAR50

- For the upright position, position the logo like this:
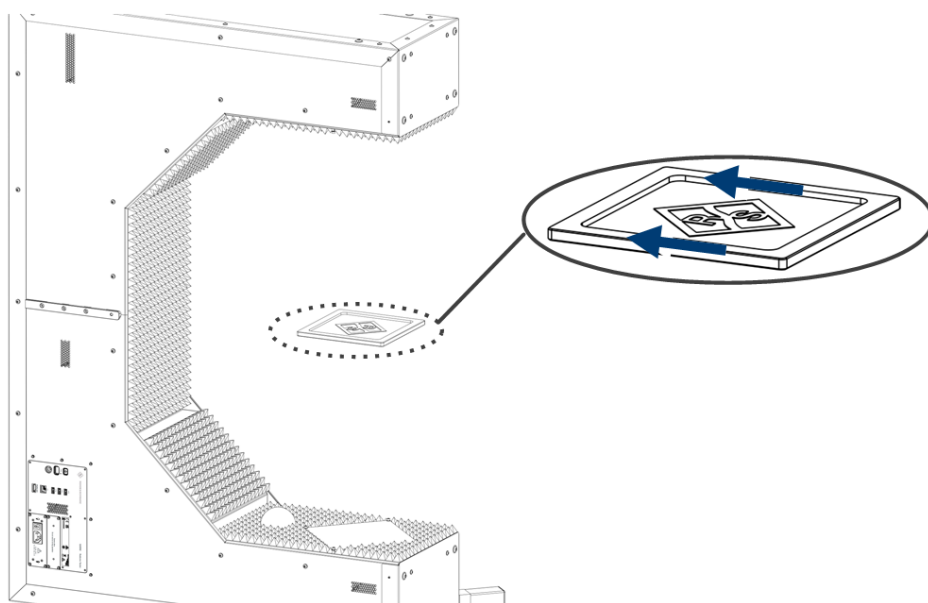
Figure 6-8: Example: DUT position for an upright R&S QAR50

Both DUT positions result in a millimeter wave image with the correct orientation.
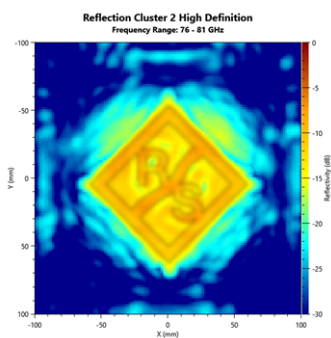
Figure 6-9: Example: Millimeter wave image of the logo

6.4 Effects of tilted DUTs

The angle of the DUT relative to the clusters (tilt) has an impact on the measurement results.

- For phase measurements, the impact is small.
- For transmission loss measurement, the impact is also small.
- For reflection measurements, the impact is big.

Phase and transmission measurements

The effect of tilted DUTs on phase and transmission measurements is the longer path that the signal has to travel through the DUT. A longer signal path results in higher attenuation and phase shift.

For most automotive radome materials, this effect is neglectable.

Let us take a flat piece of polycarbonate plastic that is 3 mm thick as an example. The transmission loss and phase shift that different tilts cause is listed in tables Table 6-1 and Table 6-2.

Table 6-1: Transmission loss depending on the tilt angle

Tilt [deg]	0	5	8	12
Transmission loss [dB]	1.42	1.45	1.50	1.56

Table 6-2: Phase shift depending on the tilt angle

Tilt [deg]	0	5	8	12
Calculated phase shift [deg]*	168.1	167.6	167.0	165.6
Measured phase shift [deg]	168.6	168.1	167.1	165.2

*You can calculate the phase shift with the following equation:

$$\Delta\phi_{DUT} = \frac{2\pi}{\lambda_0} d \left(\sqrt{\epsilon_r - sin^2\alpha} - 1 \right)$$

$\Delta\varphi_{DUT}$ = phase shift
λ_0 = wavelength in vacuum
d = thickness of the DUT
ϵ_r = relative permittivity
α = angle of incidence

Reflection measurements

Due to the influence of the material characteristics (permittivity), the thickness of the DUT affects the measured reflection and transmission loss value even when the sample is not tilted.

Refer to the application card available on the R&S QAR50 product homepage for additional information. A useful tool to calculate these effects is the Rohde & Schwarz permittivity calculator also available on the internet.

For reflection measurements, the impact of a tilted DUT is rather big. Therefore, positioning the DUT parallel to the cluster is crucial. In fact, the impact can be so big that you can see its effects even with an untrained eye.

This effect is caused by the reflection characteristics of the tested material: The incident angle of the wave equals the exit angle and as such, with a higher tilting angle, the instrument no longer receives the main lobe of the reflection.

Because of the large antenna size of the R&S QAR50, the imaging capabilities suppress the effects of tilting up to a tilt angle of approximately 5°. But with higher tilt angles, the effects can become big. This effect occurs because the main lobe of the reflection moves outside of the evaluation area.

- If the DUT is parallel to the cluster, the measurement point with the maximum reflection is in the middle of the DUT (dark gray spots in Figure 6-10). Moving to the edges of the DUT, the reflection gets lower (light gray spots). A parallel DUT therefore makes sure that the signal is reflected back to the cluster.

- For a tilted DUT, it is no longer sure that all signals are reflected back to the cluster. You can see this in Figure 6-10: The maximum reflection point moves to the right and some signals are reflected back into open space. The cluster does no longer receive those signals.
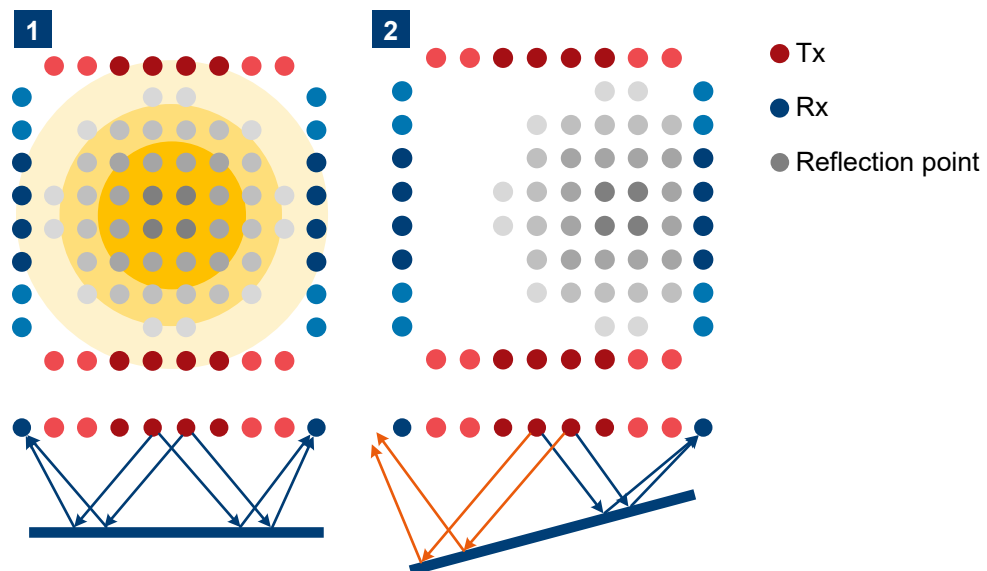
Figure 6-10: Effects of a tilted DUT on the reflection measurement

1 = DUT is parallel to the cluster: max. reflection in the middle of the DUT
2 = DUT is tilted: max. reflection moves no longer in the middle of the DUT

You can even see those effects in the microwave image.
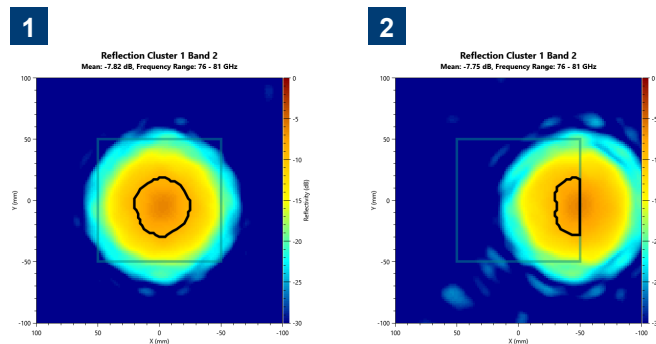
Figure 6-11: Image comparison of an aligned and a misaligned DUT

1 = DUT is parallel to the cluster
2 = DUT is tilted

On a properly aligned, flat DUT, the reflectivity response is perfectly centered. If you tilt the DUT, the reflection maximum and the 3 dB area around it (depicted by the black line) shifts, depending on the tilt angle.

You can, however, use the microwave image as a guide to verify that the DUT is properly aligned.

1. Position the DUT.

2. Measure the reflection of the DUT.

3. Check the result.

4. If the result is not what you expect, realign the DUT and repeat the previous steps. This method works most intuitively on flat and even samples, but you can also use it for structured or curved samples.

Example of the effects of a tilted DUT

A tilted DUT yields inaccurate and distorted measurement results as demonstrated in the following example.

If you look at a single line in the microwave image shown in Figure 6-11, the reflection intensity is approximately bell-shaped with the highest reflection in the center of the image.

1. Normalize the measurement to get a reference measurement (0 dB reflection). For the normalization measurement, make sure that the evaluation window is large enough to fully include the 3 dB line.

2. Measure the reflection of the DUT positioned parallel to the measurement cluster. For a correctly positioned DUT that lies parallel to the measurement cluster, the measured reflection for a single horizontal line in the reflection image would look like the curve in Figure 6-12. This example uses a flat DUT with a mean reflection of -7 dB.

All measurement points that deviate no more than 3 dB from the maximum reflection are within the evaluation window. The results for the reflection measurements are correct (-7 dB).
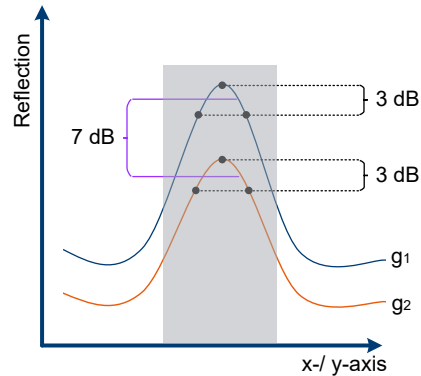
Figure 6-12: Reflection measurement with a correctly positioned DUT

f_1 = Normalization measurement
f_2 = DUT measurement

See Figure 6-11 for an example microwave image with a correctly positioned DUT (left side).

3. Tilt the DUT just slightly and measure the reflection again.
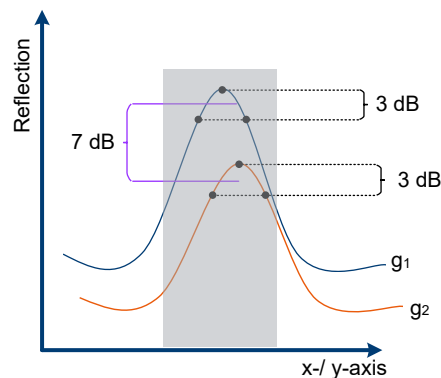
Figure 6-13: Reflection measurement with a slightly tilted DUT

f_1 = Normalization measurement
f_2 = DUT measurement

You can already see that the results are off, compared to the normalization measurement. But all measurement points that deviate no more than 3 dB from the maximum reflection are still within the evaluation window. Measurement results are therefore still correct.
See Figure 6-11 for an example microwave image with a tilted positioned DUT (right side).

4. Tilt the DUT some more and measure the reflection.
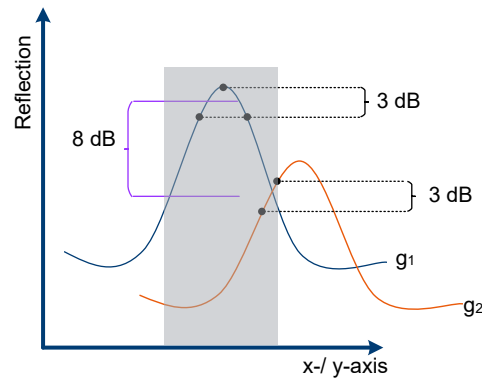
Figure 6-14: Reflection measurement with a tilted DUT

f_1 = Normalization measurement

f_2 = DUT measurement

Results are even more off compared to the previous measurement and the measurement result is wrong (-8 dB). The wrong result occurs because the peak reflection is no longer within the evaluation area. The mean reflection is calculated with a different set of measurements points somewhere below the peak. Accordingly, the mean reflection decreases compared to the real mean reflection of the DUT.

6.5 Effects of curved DUTs

Basically, you can position curved DUTs the same way as flat samples: Make sure that they are located halfway between the clusters, that the area of interest is aligned to the center of the clusters and that the surface is parallel to the cluster surface.

However, the curvature can have an influence on the measurements.

- For phase measurements, curvature has no significant effect for common radomes.
- For transmission loss measurements, curvature adds an additional signal path which is usually neglectable for common radomes.

For reflection measurements based on the image processing technique with a R&S QAR50 and its multiple antenna array, you can see this effect in the results. These effects are, however, much smaller when you compare them to measurements with setups with a single antenna. The reason is the smaller antenna aperture in single antenna setups and that it is impossible to receive signals that are reflected away from the antenna aperture.

Table 6-3 shows the simulated result of an exemplary DUT with varying radius. For a 0.6 m radius, for example, you can see a significant difference between the measurements with and without image processing.

- For measurements with a single antenna, the reflection differs approximately 6.45 dB from a similar, uncurved DUT.
- For measurements with a R&S QAR50, the difference is only 1.15 dB.

Table 6-3: Simulation data of a single point measurement and microwave imaging system

Radius of DUT in m	Reflection power in dB, referenced to metal plate reflection	
	Single point measurement	**Microwave imaging measure-ment**
0	0	0
0.2	-12.63	-3.48
0.4	-8.43	-1.74
0.6	-6.45	-1.15
0.8	-5.2	-0.74
1.0	-4.38	-0.47
40 (equals infinity)	-0.14	-0.01

6.6 Effects of environmental conditions

Environmental conditions have an effect on phase measurements.

- Temperature changes between measurements
- Vibrations during the measurement
- Mechanical movement between measurement

Using the R&S QAR50 minimizes those effects compared to other measurement methods, because you can test a rather large area (100 mm x 100 mm) in a single measurement.

Relative phase is no problem, because the R&S QAR50 measures the whole DUT in a single measurement without having to move from one measurement point to the next. Therefore, you can measure them accurately. Absolute phase shifts, however, are more tricky. At 76.5 GHz, a 1° phase change is equivalent to ~10.8 µm of free space path difference.

For absolute phase measurements, we have the following recommendations.

- Normalize the measurement with the actual measurement position to avoid mechanical movements between normalization and later measurements.
- Normalize at regular intervals to consider temperature changes.
- If you need several measurements to test a single DUT, despite the large measurement area of 100 mm x 100 mm, be careful when you move parts of the measurement setup between measurements. Moving parts of the setup can lead to deviating measurement results.

Example: Effects of temperature change on a block of aluminum

A massive block of aluminum with a length of 50 cm changes its length by about 12 μm when the room temperature changes by 1 kelvin. Such a change is caused by the expansion of the aluminum with its temperature coefficient of around 24e-6 1/k. At 76.5 GHz, this minor temperature change already relates to a phase change of about 1°.

Example: Effects of the DUT itself or other components on a block of aluminum

Not only the temperature can change the shape of a massive block of aluminum, but also its own weight, or the weight of the mounted components: A block of 500 mm x 50 mm x 50 mm aluminum bends by >25 μm (equivalent to 2.3° of electrical phase change) if its tip is weighted with an additional 1 kg.

Therefore, a movement of the measurement device between measurement points is directly affected by mechanical deformations and accelerations caused by gravity. Fortunately, the R&S QAR50 covers already an area by 100 mm x 100 mm and requires very little movement in production and development.

7 User interface

The graphical user interface (GUI) contains several elements.
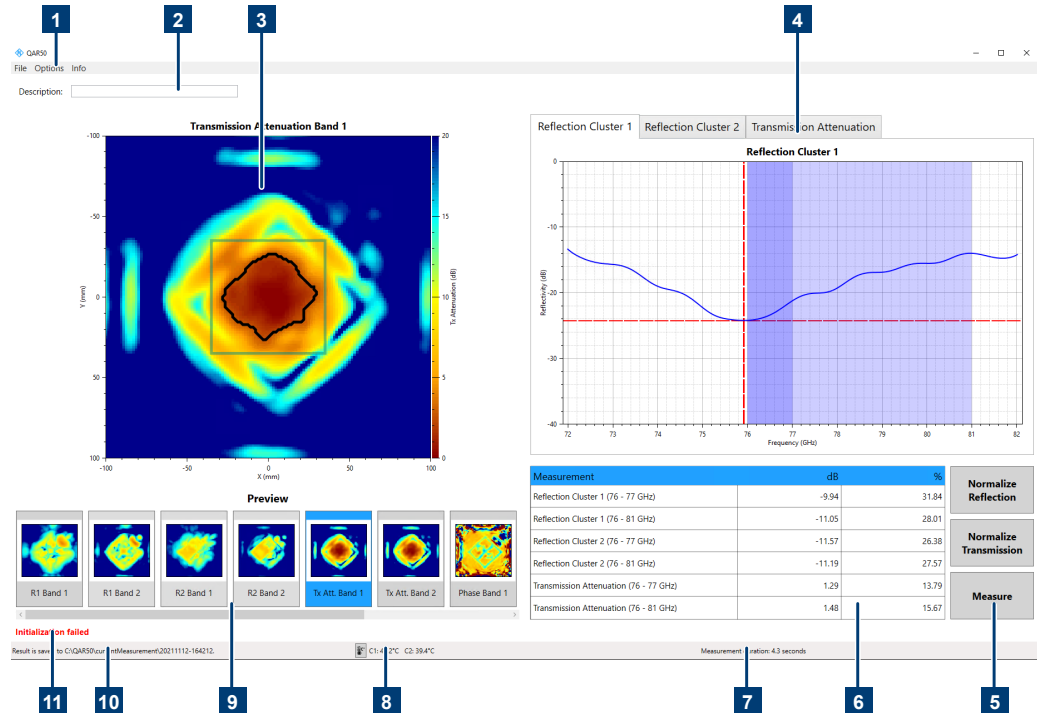
Figure 7-1: Overview of the user interface

1 = Menu bar
2 = Measurement description
3 = Millimeter wave image
4 = Result diagram
5 = Measurement control
6 = Numerical results
7 = Measurement duration
8 = Cluster temperature
9 = Measurement preview
10 = Location of measurement result data
11 = System messages

Menu bar

Contains various functions to configure the R&S QAR50 and the measurement.

For more information, see Chapter 9, "Configuration", on page 65 and Chapter 8, "Measurements and result displays", on page 48.

Measurement description

Contains a short description of the measurement scenario. This description is text you can define as you like and is stored together with the measurement results.

Millimeter wave image

Shows the image of the DUT.

For more information, see Chapter 8, "Measurements and result displays", on page 48.

Result diagram

Available with the optional frequency response application.

Shows the measured DUT characteristics in a diagram.

For more information, see Chapter 8, "Measurements and result displays", on page 48.

Measurement control

Contains functions to control the measurement sequence.

For more information, see Chapter 8, "Measurements and result displays", on page 48.

Numerical results

Shows the measured DUT characteristics in a numerical result table.

For more information, see Chapter 8, "Measurements and result displays", on page 48.

Measurement information

Shows the information about the measurement, for example the time it took to finish.

Cluster temperature

Shows the temperature of the clusters.

Measurement preview

Shows a preview image of the measurements that you have performed for the DUT. If no preview is available, the preview image is an image of the R&S QAR50.

For more information, see Chapter 8, "Measurements and result displays", on page 48.

Location of measurement result data

Shows the directory in which the measurement results have been stored.

For more information, see Chapter 9, "Configuration", on page 65.

System messages

Area that contains system messages, if any occur.

If an error occurs, select "Error" to display the details of all errors in the error queue. You can use this information to fix the error or forward the information to your Rohde & Schwarz service representative.

8 Measurements and result displays

The R&S QAR50 provides several measurements and result displays that you can use to evaluate the quality of a DUT.

Measurements usually consist of two steps, normalization and the actual measurement.

1. Set up the normalization.

2. Perform the normalization.
   For details about measurement normalization, see Chapter 8.1, "Normalization", on page 48.

3. Place the DUT between the clusters.
   Note: For all measurements make sure that the distance between the edges of the DUT and the evaluation area is about 10 mm to 15 mm. For more information, refer to the specifications document.

4. Start the measurement.
   For details about measurement, see Chapter 8.2, "Measurement", on page 50.

5. Evaluate the measurement results using the result displays.
   For details about the result displays, see Chapter 8.3, "Result displays", on page 59.

Queuing measurements

A measurement with the R&S QAR50 basically consists of two steps:

- Recording of the raw data.
- Evaluating the raw data to get the final result.

The sum of these steps adds up to the measurement time of a single measurement.

By default, the evaluation occurs immediately after the recording. If time is an issue for your measurements, you can record and queue the raw data and evaluate it at a later time.

The buffer has a size of up to 50 measurements. When the queue is full, the R&S QAR50 starts to overwrite the oldest datasets (usually dataset no. 1).

Configuring buffered measurements is available via SCPI commands.

8.1 Normalization

Normalization is a separate measurement that provides a baseline to which other measurements are compared.

Always normalize reflection and transmission measurements separately with two separate measurements.

It is not necessary to normalize every measurement. We recommend normalizing the measurement regularly. Refer to the specifications document for more information about recommended normalization intervals.

In addition, the software shows a message if normalization becomes necessary because of temperature changes or other circumstances.

Warm-up time

Before normalizing a measurement, let the R&S QAR50 warm up to its operating temperature.

Multiple normalization datasets

If your test setup consists of a series of measurement for a single DUT with different environmental conditions, you need a different normalization for each measurement in the series. See "Creating a pool of normalization data" on page 66 for details.

Normalizing reflection measurements

Normalizing the reflection measurement requires a clean, smooth and flat metallic plate for a high reflection, for example aluminum. Such a metal plate represents a DUT with 100 % reflectivity. Make sure to use a plate that has a size of at least 300 mm x 300 mm.

If you own the verification kit, you can use the verification plate labeled "E" to normalize the measurement.

1. Place the plate between the clusters at the location where the DUT would be.
   Make sure that the plate is parallel to the clusters. We recommend using the same fixture for the metal plate as for the DUT.

2. Select "Normalize Reflection" to initiate the normalization.
   When the normalization measurement is done, the R&S QAR50 saves the correction data. The R&S QAR50 corrects all subsequent measurements accordingly.
   A valid normalization results in an image with high reflection. The mean reflection should be approximately 0 dB and should not exceed a certain deviation from that value - refer to the specifications document for exact values.

3. Optional: Select "Measure" to verify the normalization (use the same plate as for normalization).
   If the results do not meet the expectations, repeat the normalization.
   If the second normalization still yields unexpected results, verify the test setup.
   For details about verification, see Chapter 12, "System verification", on page 78.

4. Remove the plate used for normalization and continue with measuring actual DUTs.

Normalizing the transmission and phase measurement

For the transmission and phase measurement, normalization is a free space measurement and requires no additional devices. However, make sure that the area between the clusters is free of obstacles. A free space measurement represents a DUT with 0 % attenuation.

1. Select "Normalize Transmission" to initiate the normalization.
    When the normalization measurement is done, the R&S QAR50 saves the correction data. The R&S QAR50 corrects all subsequent measurements accordingly.
    For the transmission measurement, a valid normalization results in a transmission of approximately 0 dB attenuation. The transmission attenuation should not exceed a certain deviation from that value - refer to the specifications document for exact values.
    For the phase measurement, a valid normalization results in an image that shows the same phase throughout the evaluation area of the image. Refer to the specifications document for exact values.

2. Optional: Select "Measure" to verify the normalization.
    If the results do not meet the expectations, repeat the normalization.
    If the second normalization still yields unexpected results, verify the test setup.
    For details about verification, see Chapter 12, "System verification", on page 78.

3. Continue with measuring actual DUTs.

8.2 Measurement

The R&S QAR50 provides several measurements. Each measurement analyzes certain characteristics of the DUT.

The basic process of a measurement is easy with the R&S QAR50.

1. Configure the measurement as required.

2. Normalize the measurement, if necessary.

3. Place the DUT in the center of the R&S QAR50, between the clusters.
    For a detailed description of the test setup, see Chapter 6, "Test setup", on page 34.

4. Select "Measure" in the user interface.
    The R&S QAR50 initiates the measurement.
    The basic principle of all measurements is as follows.

    a) One of the clusters generates a signal.
    b) The cluster transmits the signal in the direction of the DUT.
    c) The signal passes through or gets reflected by the DUT.
    d) Both clusters measure the level characteristics of the reflected or transmitted signal.

    Note: If "Measure" is not available, you have to normalize the measurement.

5. Analyze the measurement results using the result displays.

8.2.1 Introduction

The R&S QAR50 uses all transmit and receive antennas available on the clusters to reconstruct the measurement results.

Microwave image generation

The source of the displayed millimeter wave image is a three-dimensional data set that consists of a few hundred thousand voxels (the image "volume"). The R&S QAR50 characterizes each voxel by measuring the phase change that occurs in the signal while traveling from the transmit antennas to the DUT and back and correcting it by the theoretical expected phase change that occurs without a DUT.

If a reflector exists in the specific voxel, the corrected complex signals add up constructively. When no reflector is present, the signals cancel out each other.

For transmission and phase measurements, the principle is the same, only that the cluster on the other side receives the signal. The signal processing calculates the transmission loss or phase shift for each voxel in the volume.
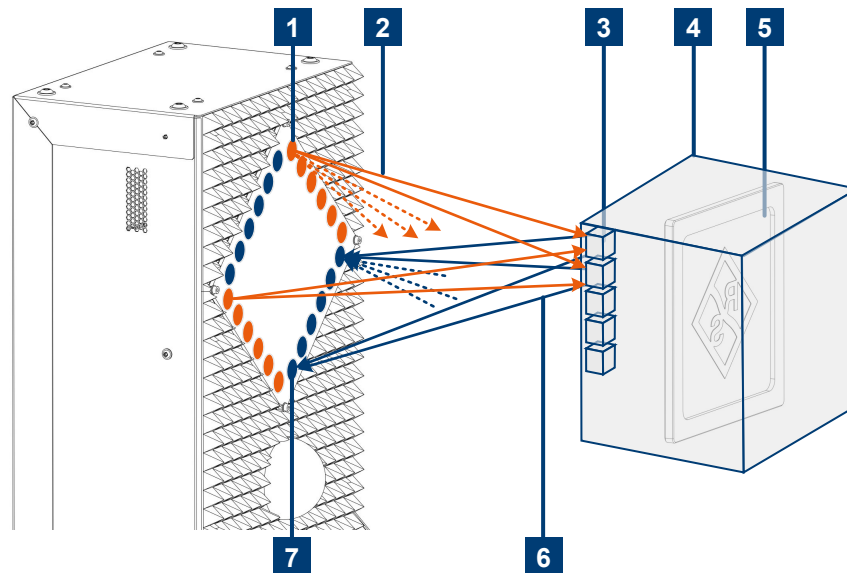
Figure 8-1: Measurement principle for reflection measurement

1 = Transmit antenna on cluster
2 = Transmitted signal
3 = Voxel
4 = Image volume

5 = DUT within borders of image volume
6 = Reflected signal
7 = Receive antenna on cluster

$$R(\vec{r}) = \sum_{k}^{N_\omega} \sum_{p}^{N_T} \sum_{q}^{N_R} s\left(\vec{r}_{T,p}, \vec{r}_{R,q,}, \omega_k\right) h\left(\vec{r}_{T,p}, \vec{r}_{R,q,}, \vec{r}, \omega_k\right)$$

R = reconstructed signal
s = measured signal
h = focusing kernel (correction of signal delay)
r = position vector of the voxel
$r_{T,p}$ = position vector of transmit antenna p
$r_{R,q}$ = position vector of receive antenna q
ω = frequency
ω_k = frequency index

with:

$$h(\vec{r}_T, \vec{r}_R, \vec{r}, \omega) = e^{j\frac{\omega}{c_0}(|\vec{r}_T - \vec{r}| + |\vec{r} - \vec{r}_R|)}$$

To create the final image, this principle is repeated for every combination of transmit and receive antennas. As 3D volumes are hard to evaluate on a 2D screen, the volume can be compressed to an image using a max-hold function through the z-axis of the measurement volume.
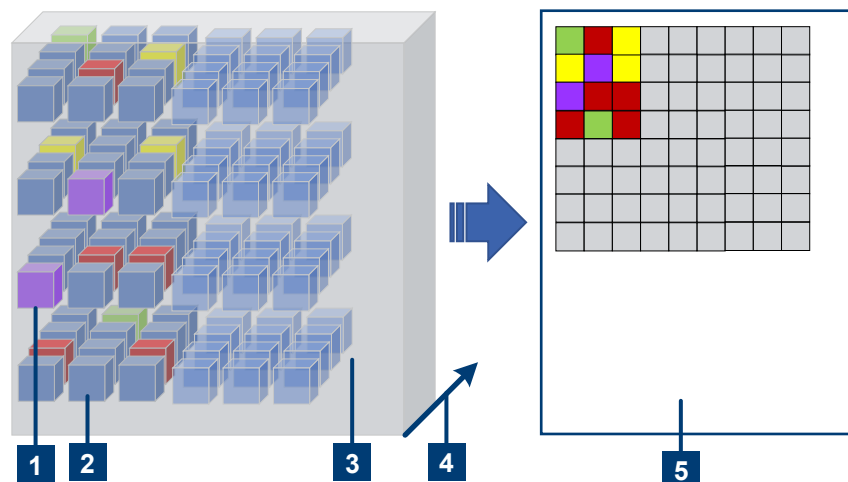
Figure 8-2: 2D image creation

1 = Voxel with the highest reflection on the z-axis of the image volume
2 = Voxel
3 = 3D image volume
4 = Z-axis of the image volume
5 = Resulting 2D image

Linear vs logarithmic results

Depending on the result display, the R&S QAR50 shows the results as linear values in percent, logarithmic values in dB or both.

For reflection measurements, you can convert linear values to logarithmic values with the following equation.

Reflection measurement: result[dB] = 20 * $\log_{10}$(result[%]/100)

Example:

The linear reflection is 80 %.

20 * $\log_{10}$(0.8) = -1.9 dB

To simplify the calculation, the following table helps to convert typical reflection and transmission loss values from the linear to the logarithmic scale.

Reflection [%]	Reflection [dB]
100	0
80	-1.9
60	-4.4
40	-8.0
30	-10.5
20	-14.0
10	-20.0
5	-26.0
1	-40.0

Transmission loss: result[dB] = -20 * $\log_{10}$(100 - result[%]/100)

Instead of transmission loss, you have to use the transmission coefficient for a logarithmic conversion, with the transmission coefficient = 100 % - transmission loss. The following table shows some basic values for the transmission loss measurement.

Example:

The transmission loss is 5 %.

-20 * $\log_{10}$(0.95) = 0.44 dB

Transmission loss [%]	Attenuation [dB]
0	0
1	0.09
5	0.44
10	0.92
20	1.93
30	3.1
40	4.4

Transmission loss [%]	Attenuation [dB]
60	8.0
80	14.0

8.2.2 Reflection measurement

The reflection measurement determines the amount of energy that is being reflected by the DUT over a certain frequency range used by automotive radar sensors. The result (reflectivity) is the ratio of the reflected energy to the energy of the stimulus signal over a certain radar band.

The R&S QAR50 measures the reflection of both sides of the DUT:

● Cluster 1 sends a stimulus signal and receives the reflected energy from the side of the DUT that faces cluster 1.

● Cluster 2 sends a stimulus signal and receives the reflected energy from the side of the DUT that faces cluster 2.
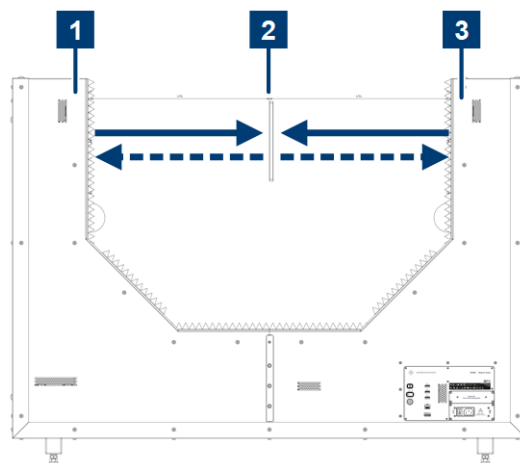
Figure 8-3: Principle of the reflection measurement

1 = Cluster 1
2 = DUT
3 = Cluster 2
straight line = Stimulus signal
dashed line = Reflected energy

The reflected energy does not pass through the DUT and contributes to performance degradation as a result. Reflected signals reduce the performance of the radar and can even interfere with the signals reflected by the intended targets or objects, leading to unwanted effects like a degradation of the received signal. Areas with a high reflection can have various causes, for example defects in materials, undesired interaction between several layers of materials, excessive amount of certain materials, or foreign objects.

The R&S QAR50 achieves spatially resolved reflection measurements of a DUT by linking the information collected by the distributed transmit and receive antennas in a

coherent operation. The resulting millimeter wave image, diagram and numerical results allow for an intuitive evaluation of the DUTs' reflection behavior.

For more information about the result display available for the reflection measurement, see Chapter 8.3, "Result displays", on page 59.

8.2.3 Transmission measurement

The stimulus signal is split in a reflected and a transmitted part. Therefore, it is of interest to measure not only the reflection characteristics of a DUT, but also the transmission properties. The result (transmission attenuation) is the ratio of the energy measured at the receiving cluster to the stimulus signal sent by the transmitting cluster.

For the transmission measurement, both clusters send a signal that passes through the DUT. The passage through the DUT attenuates the signal. The attenuated signal is measured by the opposite cluster. The resulting transmission attenuation is the average of those two measurements.
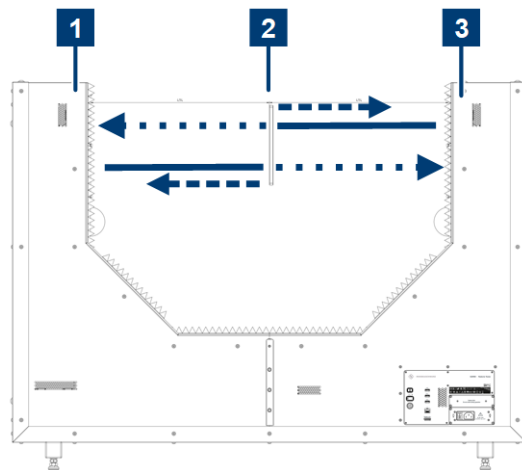
Figure 8-4: Principle of the transmission measurement

```
1            = Cluster 1
2            = DUT
3            = Cluster 2
straight line = Stimulus signal
dotted line  = Attenuated signal
dashed line  = Reflected energy
```

For more information about the result display available for the transmission measurement, see Chapter 8.3, "Result displays", on page 59.

8.2.4 Phase measurement

In addition to reflection and transmission characteristics, the phase characteristics of the DUT are also of interest. When a stimulus signal hits the DUT, the DUT changes the phase characteristics of a signal by a certain amount, depending on its thickness and material.

For the phase characteristics, both clusters send a signal that passes through the DUT. The opposite cluster measures the phase of the received signal. The resulting phase results are the average of those two measurements.

The phase difference is the difference between the phase of the normalization measurement (empty space) and that of the actual measurement.
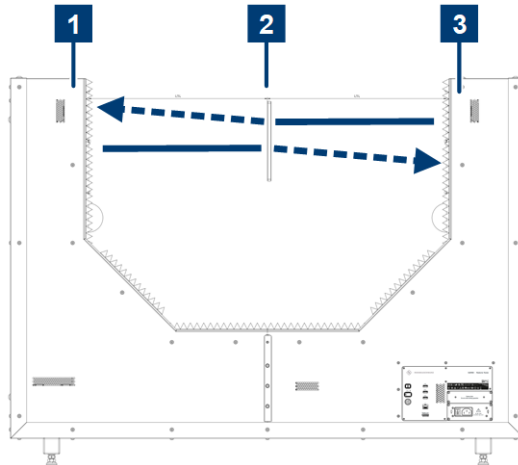
Figure 8-5: Principle of the phase measurement

1 = Cluster 1
2 = DUT
3 = Cluster 2
straight line = Stimulus signal
dashed line = Phase changed signal

For more information about the result display available for the phase measurement, see Chapter 8.3, "Result displays", on page 59.

Image resolution of phase measurements

According to the specifications, the phase measurement has a lateral resolution of 8 mm. This means that the R&S QAR50 can definitely separate objects or areas with a different phase that have a distance of at least 8 mm to each other.

You can test this resolution with the verification plate for phase measurements (verification plate labeled "D").

In an ideal world, you would see a phase shift exactly at the point where the material changes its phase characteristics and the distance between the different phases does not matter. However, because of physical effects, getting these ideal results is not possible, regardless of the measurement method.
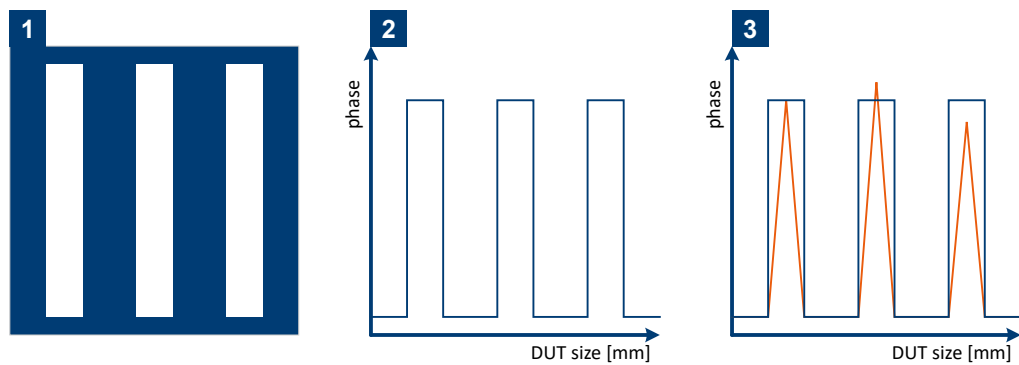
Figure 8-6: Phase measurement in an ideal world vs the real world

1 = Outline of a microwave image of a phase measurement in an ideal world
2 = Ideal phase resolution of a single horizontal line in a mmWave image
3 = Actual phase resolution of a single horizontal line in a mmWave image

The deviation of measurement results compared to the results in an ideal world depends on the size of the area with a different phase and the distance of these areas to each other.

Example 1: Separability

Take, for example, several plastic sheets that cause a phase shift. Each plastic sheet has three vertical cutouts with a different width and a different distance to each other. The distance between the cutouts is the same as the width of the cutouts. Perform a high resolution phase measurement on each of the plastic sheets with the R&S QAR50. In all cases, from 24 mm cutouts to 8 cutouts, you can see the cutouts by the phase shift they cause.

- The 24 mm cutouts with a 24 mm distance to each other are separated more clearly and are more distinguished, with sharper edges and closer to the behavior in the ideal world.
- The 8 mm cutouts are still separated and visible but more sketchy, because they are closer together.
- If you put the cutouts closer together, the phase image would not be able to separate the cutouts.
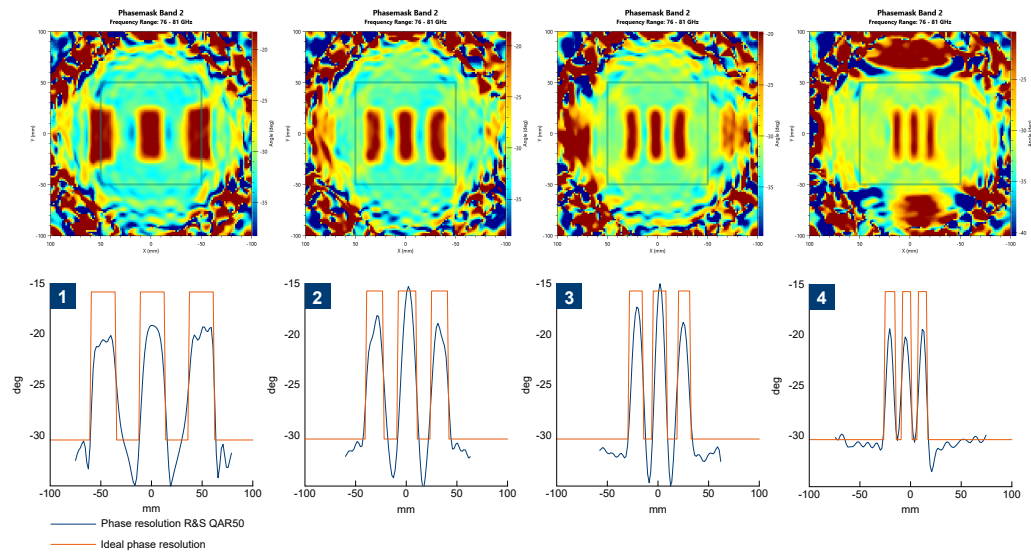
Figure 8-7: Phase resolution for DUTs with different cutout patterns

1 = Phasemask of 24 mm slits
2 = Phasemask of 16 mm slits
3 = Phasemask of 12 mm slits
4 = Phasemask of 8 mm slits

Example 2: Sensitivity

Note that the width of the cutouts is, in effect, not important. If you take an even smaller object, for example a wire with a 0.5 mm diameter, you could still see this wire in the phase image. Only if the wires are very close together, they would not appear as separate entities on the image.

You can still see the influence caused by a wire with 0.5 mm diameter in the recorded phase images.
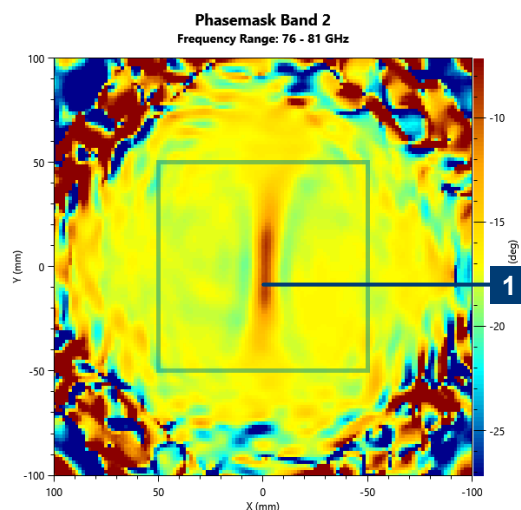
Figure 8-8: Phase result for a 0.5 mm wire inside the measurement area

We can therefore conclude that the phase image of the R&S QAR50 is very sensitive. It can detect even the smallest phase shifts, caused, for example, by a 4 mm wide strip of tape. Such a phase shift is clearly visible in the resulting image.

Refer to the R&S QAR50 video series on the internet for a live demonstration of these two examples.

8.3 Result displays

The R&S QAR50 provides various result displays that you can use to evaluate the results of the measurements.

8.3.1 Millimeter wave image

The millimeter wave image is a graphical representation of the DUT and its characteristics. The image is available for all measurements (reflection, transmission and phase) and both evaluated frequency bands.

You can select the measurement whose image you want to evaluate in more detail from the "Preview" pane below the image.

- "R<x> Band <y>": Shows the results of the reflection measurement of cluster <x> (x = 1 or 2) in the frequency band <y> (<y> = 1 or 2).
- "Tx Att. Band <y>": Shows the results of the transmission measurement in the frequency band <y> (y = 1 or 2).
- "R<x> HD": Shows the high definition version of the reflection measurement of cluster <x> (x = 1 or 2) in the frequency band from 76 GHz to 81 GHz.
  Available with the optional HD reflection image application.
- "Phase Band <y>": Shows the result of the phase measurement (phase difference caused by the DUT) in the frequency band <y> (y = 1 or 2).
  Available with the optional phase measurement application.

Band 1 is the frequency band from 76 GHz to 77 GHz. Band 2 is the frequency band from 76 GHz to 81 GHz.

The currently selected image is highlighted blue in the preview pane.
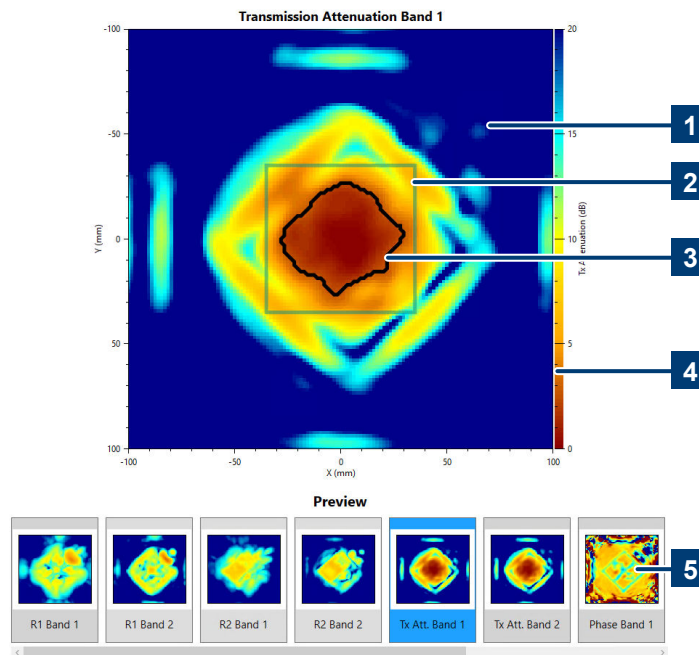
Figure 8-9: Overview of the millimeter wave image result display

1 = Complete image of the DUT
2 = Evaluation area
3 = Area that contains values for mean result calculation
4 = Color map
5 = Preview pane

The resulting image shows the measured levels as different shades of color. The color range depends on the color scheme you have selected.

- For reflection measurements, the image shows the reflectivity in dB. Each color shade corresponds to a certain reflectivity value.

- For transmission measurements, the image shows the transmission attenuation in dB. Each color shade corresponds to a certain attenuation value.

A color map next to the image shows the levels that correspond to each shade of color.

When you click on any pixel in the image, the R&S QAR50 shows details for that pixel, including the result value.
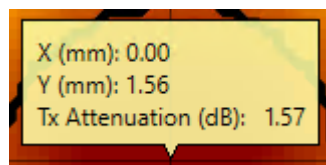
Figure 8-10: Result details

All images show the perspective as seen from cluster 1.

For all measurements, the x- and y-axis show the dimensions of the image in mm (200 mm x 200 mm by default). Note you can change the scale of the x- and y-axis using a mouse. The default value is restored after a new measurement.

Evaluation window

A blue rectangle that is superimposed on the image indicates the part of the image that is evaluated for the numerical results. The size and location of this evaluation window depends on your configuration.

3 dB line

A black line within the blue rectangle surrounding certain areas indicates the measurement points that deviate no more than 3 dB from the maximum reflection value or the minimum attenuation value. There can be several such areas in the image, depending on the characteristics of the DUT. Those areas are the measurement points that actually contribute to the mean reflection and attenuation values as indicated in the numerical result table.

Measuring a homogenous (= flat, highly reflective) DUT usually results in a Gaussian distribution of reflection values (due to the aperture weights of the antenna array). The evaluated values are therefore concentrated to a single area in the image.
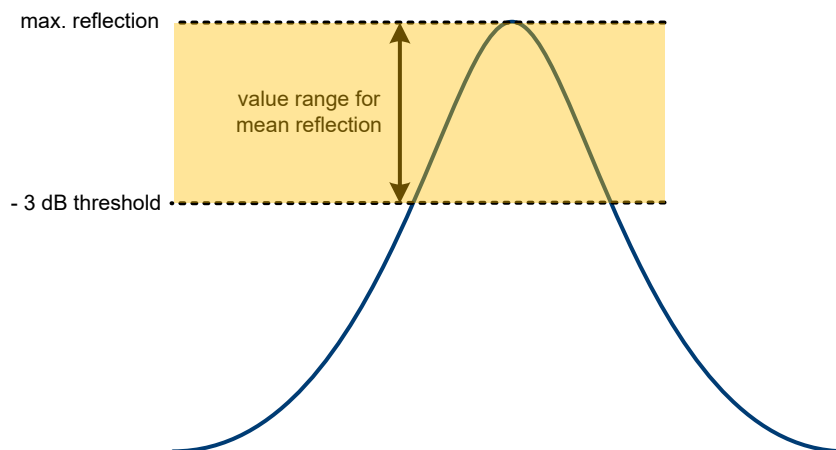
Figure 8-11: Mean reflection on a homogenous DUT

For inhomogeneous DUTs, the distribution can be different, so there maybe several highlighted areas in the image, but the evaluation remains the same.
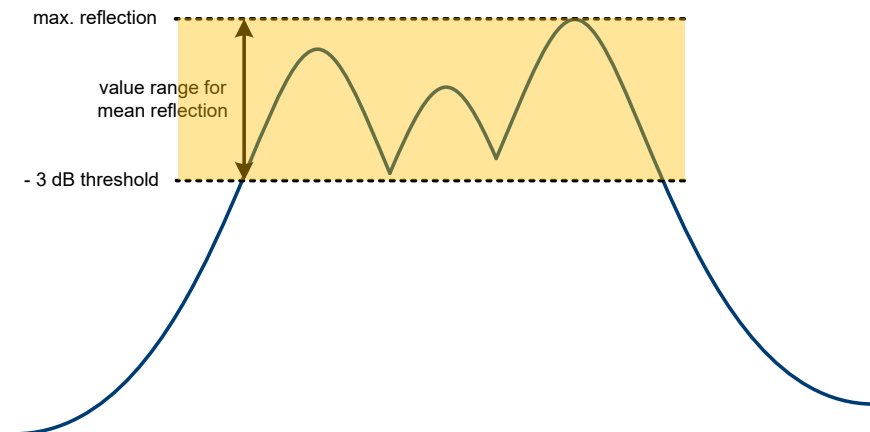
Figure 8-12: Mean reflection on an inhomogeneous DUT

8.3.2　Result diagram

Available with the optional frequency response application.

The result diagram shows the frequency response of the DUT in terms of the level characteristics of the DUT. The results are displayed as a line trace over a certain frequency range. The R&S QAR50 evaluates the frequency range around the typical radar bands.

The result diagram is available for both reflection measurements and transmission measurements.

- For reflection measurements, the R&S QAR50 uses the measurement point with the highest reflection in the millimeter wave image to calculate the frequency response.
- For transmission measurements, the R&S QAR50 uses the measurement point with the lowest transmission loss to calculate the frequency response.

In both cases, the reconstruction point is usually the center of the image for orthogonally placed, homogeneous DUTs.
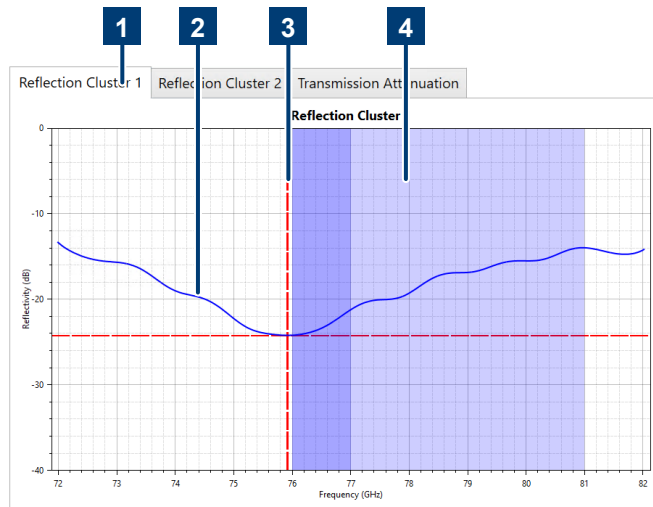
Figure 8-13: Overview of the result diagram

1 = Measurement selection
2 = Trace
3 = Trace minimum indicator (red dotted line)
4 = Radar band indicator (blue area)

For both measurements, the x-axis represents the frequency. The y-axis represents the level characteristics. For both reflection and transmission measurements, the level characteristics are values in dB. Note you can change the scale of the x- and y-axis using a mouse. The default value is restored after a new measurement.

You can also use a mouse to determine the measured values for each pixel of the trace.

The blue areas in the diagram indicate the two radar bands from 76 GHz to 77 GHz (dark blue) and 76 GHz to 81 GHz (light blue).

The red dotted lines indicate the trace minimum.

The minimum and maximum values indicate the degree of frequency matching achieved by the DUT. Ideally, the minimum of the frequency response is located at the operating frequency range of the radar sensor that is to be used in combination with the DUT. Shifted minima indicate issues with the DUT's electrical thickness.

8.3.3 Numerical result table

The numerical result table shows the measurement results as numerical values. The table shows the results in dB (reflection and transmission measurement) and as percentage. For the percentage value, the maximum reflection or transmission corresponds to 100 %.

The interpretation of the percentage value depends on the measurement.

- Reflection measurement: 100 % reflection = complete energy is reflected by the DUT

- Transmission measurement: 100 % transmission attenuation = complete energy is attenuated by the DUT (no energy arrives at the receiving cluster)

Measurement	dB	%
Reflection Cluster 1 (76 - 77 GHz)	-9.94	31.84
Reflection Cluster 1 (76 - 81 GHz)	-11.05	28.01
Reflection Cluster 2 (76 - 77 GHz)	-11.57	26.38
Reflection Cluster 2 (76 - 81 GHz)	-11.19	27.57
Transmission Attenuation (76 - 77 GHz)	1.29	13.79
Transmission Attenuation (76 - 81 GHz)	1.48	15.67

Figure 8-14: Overview of the numerical result table

The numerical results are calculated over all measurement points within the evaluation window that do not deviate more than 3 dB from the maximum reflection or minimum attenuation value. These measurement points are indicated by a black line in the millimeter wave image.

The table contains the following results:

- Mean reflection for clusters 1 and 2, and frequency bands 1 and 2
  The mean reflection indicates the radar transparency of the DUT. The lower the mean reflection, the better the radar transparency of the DUT. A higher mean reflection results in beam refraction, increased transmission loss and standing waves between the DUT and the radar sensor. For optimal radar compatibility, the DUT's mean reflection has to be minimized.
- Mean transmission attenuation for frequency bands 1 and 2.
  The mean transmission attenuation is calculated as follows:
  -20·log10(mean transmission coefficient)
  with mean transmission coefficient = 1 - attenuation
  The mean transmission coefficient is calculated over the respective frequency range.

9 Configuration

Access: "Options"

The R&S QAR50 provides a set of tools to configure the measurement.

9.1 General measurement configuration

Selecting the device properties

The device properties select the characteristics of the test setup.

For details about the different test setups, see Chapter 6, "Test setup", on page 34.

ⓘ   Always make sure that the "Device Properties" are set correctly. Otherwise, measure-
ment results can be invalid.

1. Select "Options" > "Settings".

2. Select the position of the R&S QAR50 from the "Shape Setup" menu.
   - "U" corresponds to the lying position.
   - "C" corresponds to the upright position.

   For details about installing the R&S QAR50 in the different positions, see Chap-
   ter 4.3, "Installing the R&S QAR50", on page 17.

Using the high-quality measurement mode

The high-quality mode averages the raw data of a series of 10 measurements to create
a more accurate image of the DUT. This measurement mode reduces the noise and
therefore increases repeatability while decreasing ripples in the high-resolution images.

Note that using high-quality mode increases the measurement time a little.

1. Select "Options" > "Settings".

2. Select "HQ Mode".

Selecting the frequency band

Automative radar sensors typically use the frequency bands from either 76 GHz to
77 GHz or from 76 GHz to 81 GHz.

By default the R&S QAR50 measures the DUT characteristics in both bands. If you
want to test only one of those bands, select the desired band.

1. Select "Options" > "Settings".

2. Select "Band 1" to measure the DUT in the frequency band from 76 GHz to
   77 GHz.

3. Select "Band 2" to measure the DUT in the frequency band from 76 GHz to 81 GHz.

Selecting the color scheme of the millimeter wave image

You can select one of several color schemes for the millimeter wave image.

1. Select "Options" > "Settings".

2. Select one of the color schemes from the "Colormap" dropdown menu.
   - "Grey": Distribution of level values over gray colors.
   - "Jet": Distribution of level values over the complete color range.
   - "Hot": Distribution of level values between red and yellow colors.
   - "Cool": Distribution of level values between blue and purple colors.

Defining the dynamic range for phase measurements

The results for phase measurements are evaluated over a certain value range that you can adjust.

1. Select "Options" > "Settings".

2. Define the "Relative Phase Range" for phase measurements.
   The value you enter is a deviation from the mean phase that was measured (mean phase ± dynamic range). Only phase values within that range get different shades of colors in the millimeter wave image. Phase values outside that range are treated as the same phase value and have the same color in the image.
   For example, if the mean phase = 20°, a phase range = 30° means that only phase differences between +50° and -10° are resolved by different colors in the millimeter wave image.

Creating a pool of normalization data

By default, the R&S QAR50 uses the data of the normalization for all subsequent measurements. For some test scenarios, testing the DUT can require a series of measurements with a different position in each measurement, for example if the DUT is larger than the evaluation area. Different DUT positions can require a different normalization for the best measurement results, because of different environmental conditions for each measurement.

In such a case, you can create a pool of normalization data and apply a different one to each measurement in the series.

Note that you still have to normalize the measurements on a regular basis.

1. Measure the DUT in its initial position.

   a) Select the normalization data for the first measurement ("Normalization number").

   b) Normalize the measurement (you can skip this step if the measurement is already normalized).
   The R&S QAR50 stores the normalization data under the selected index number.

c) Measure the DUT in the first position.

2. Measure the DUT in its second position.

a) Select the normalization data for the second measurement ("Normalization number").

b) Normalize the measurement (you can skip this step if the measurement is already normalized).
The R&S QAR50 stores the normalization data under the selected index number.

c) Measure the DUT in the second position.

3. Repeat until you have the normalization data for all measurements in the series.

9.2 Evaluation window configuration

The evaluation window is the part of the millimeter wave image that the R&S QAR50 uses to calculate the numerical results.

Defining the size and position of the evaluation window

In the millimeter wave image itself, the evaluation window is indicated by a blue rectangle.

1. Select "Options" > "Settings".

2. Define the "Window Size".
The window is a rectangle whose size is defined by the lengths of its sides in x- and y-direction. The maximum size of the evaluation window is 100 mm x 100 mm. The center of the evaluation window is always in the center of the millimeter wave image.
Always define an evaluation window whose size is smaller than the DUT.
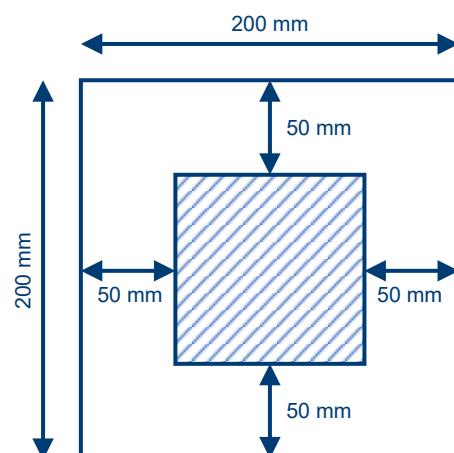
Figure 9-1: Maximum size (shaded area) of the evaluation window

Tips for finding the ideal size of the evaluation window:

● For reflection measurements, select an evaluation window as big as possible.

● For transmission measurements, select an evaluation window as small as possible.

Therefore, you need to find a good tradeoff between transmission loss and reflection evaluation window.

Defining the size and position of the evaluation window for phase measurements

For phase and high-resolution attenuation measurements, there is an alternative to create an evaluation window. Instead of defining a rectangle with a certain size, you can use masks with arbitrary shapes.

1. Draw a shape that defines the evaluation window.

2. Save the shape as a monochrome bitmap (`.bmp` file) with a size of exactly 129 x 129 pixels.
   Everything in the bitmap with a value > 0 is evaluated during the measurement.
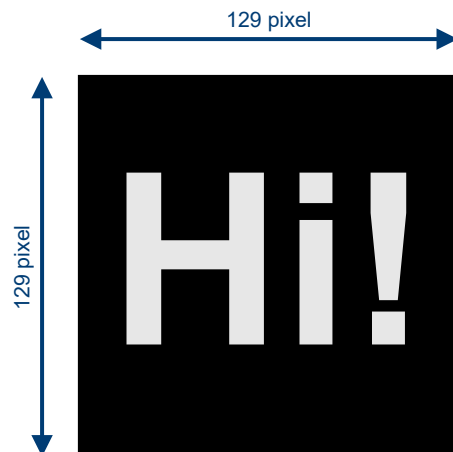
Figure 9-2: Evaluation window for phase measurements: the word "Hi!" is evaluated

3. Select "Options" > "Settings".

4. Select "Phasemask file" to import the bitmap.

5. Select "Use evaluation phasemask file" to activate the evaluation window.
   As long as this feature is active, the R&S QAR50 uses the bitmap to evaluate phase measurements instead of the rectangle.
   Reflection and transmission measurement continue to use the rectangular window.

You can evaluate the following results:

● Mean phase and transmission

● Maximum deviation of any grid cell from the mean values

● Maximum deviation from any neighboring cell
   Only directly adjacent cells are considered (left, right, upper and lower neighbors).

Make sure that the measurement area and especially the evaluation window is homogenous. Keep the evaluation window free of features on the DUT that can distort the image (for example metal elements on the edges of the DUT).

Method 1: Finding the ideal size of the evaluation window (reflection)

One method to determine the ideal size of the evaluation window is to use the reflection measurement as a guide.

If the evaluation window is correct for reflection measurements, you can usually also apply it to transmission measurements or phase measurements. If the windows size for reflection measurements does not work for phase measurements, you can also use another method to find the ideal size for phase measurements.

If you use the reflection image as a guide, your reference point is the black 3 dB line in the reflection image.

In an ideal image, the 3 dB line is completely inside the evaluation window.

1. Measure the reflection of your DUT.

2. Check the resulting reflection image.

   ● If the 3 dB line is well within the borders of the evaluation window, the results should be fine.
   ● If the 3 dB line borders on the evaluation window and follows the evaluation window in a straight line, something is wrong. In that case, increase the size of the evaluation window.
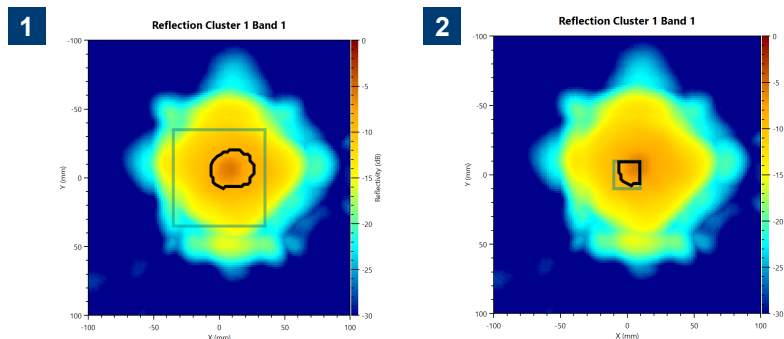
Figure 9-3: Good vs bad size of the evaluation window

1 = Evaluation window size is good
2 = Evaluation window size is too small

An evaluation window that is too small yields inaccurate and distorted measurement results as demonstrated in the following example.

If you look at a single line in the microwave image shown in Figure 9-3, the reflection intensity is approximately bell-shaped with the highest reflection in the center of the image. With a correctly chosen evaluation window, the measured reflection for a single horizontal line in the reflection image looks like the curve in Figure 9-4.
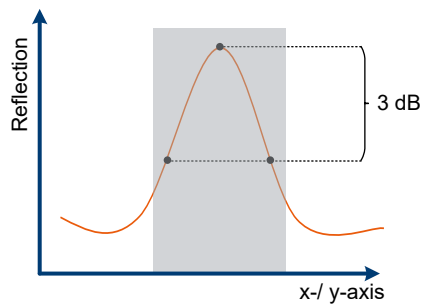
Figure 9-4: Reflection result with an evaluation window that covers the 3 dB area

Now, if you reduce the size of the evaluation window to a size that does not include the 3 dB points, the results get clipped. You can see this effect in Figure 9-5: the results only evaluate measurement points that deviate around 1 dB from the maximum reflection instead of the proper 3 dB.

Note that the displayed mean reflection is still correct, because the R&S QAR50 normalizes the measurement to the new evaluation window size.

For an example about the evaluation window size that also considers a tilt in the DUT, see "Example of the effects of a tilted DUT" on page 41.
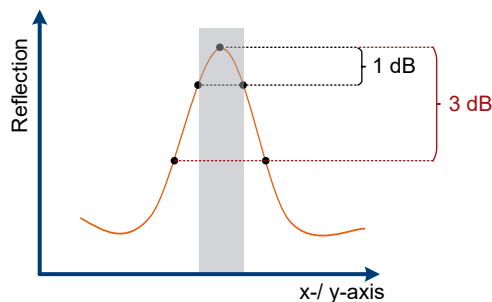
Figure 9-5: Reflection result with an evaluation window that does not cover the 3 dB area: the 3 dB points are outside the evaluation window and the results are clipped

Method 2: Finding the ideal size of the evaluation window (phase)

Although using the reflection measurement is a good guide to determine the size of the evaluation window, it can happen that it does not fit for phase measurements. For phase measurement, there is another approach to find the ideal evaluation window size.

1. Measure the phase of your DUT.

2. Check the resulting phase image.

   ● The image areas not covered by the DUT (empty space / air) have a phase shift of around 0°. If not, normalize the measurement.
   ● The image areas covered by the DUT show a phase shift. The amount depends on the material.

3. Adjust the size of the evaluation window according to the following recommendations.

- The evaluation window does not extend into empty space areas (phase shift of around 0°).
- When you define the size of the evaluation area, consider edge effects.
  Edge effects occur on the boundary between the DUT and the adjacent empty space. These effects can cause distortion and overshootings in the phase results.
  Therefore, keep a safety margin between the edge of the DUT and the evaluation window.
  This safety margin depends on the DUT characteristics, but it is usually around 10 mm to 15 mm.
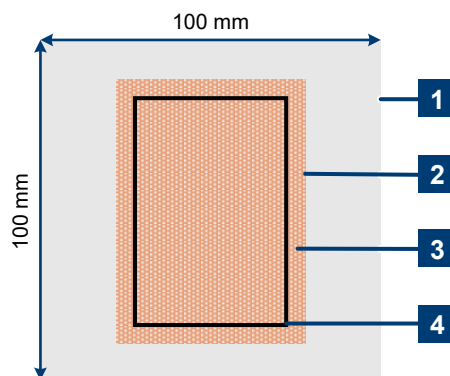
Figure 9-6: Determining the size of the evaluation window

1 = Measurement area
2 = DUT edges
3 = Area of edge effects
4 = Evaluation window

9.3 Grid evaluation

An evaluation grid helps you to find the areas with highly differing phase and transmission (phase mask and HD reflection only) characteristics on your DUT more easily. The principle is to divide the DUT into several small areas (cells), and evaluate the characteristics of each cell separately instead of the complete DUT.

If the image shows that some individual grids fall into areas influenced by edge effects or structure, you can manually remove these grid cells from the exported measurement results.

1. Select "Options" > "Grid Settings".

2. Define the size of the grid cells in mm ("Cell Size").
   The maximum grid size is 100 mm x 100 mm.

3. Define the location of the grid in terms of an offset from the origin of the coordinate system ("Grid Position".
   The center of the coordinate system is the center of the image.

4. Define the size of the grid in terms of the "Number of Cells".
   Grid cells are numbered 1 to x, beginning at the top left cell.
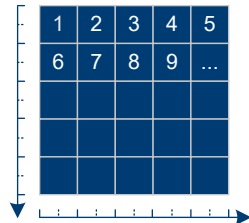
The size of the grid is independent of the size of the evaluation window. However, make sure that the size of the grid is not larger than the maximum size of the evaluation window (100 mm x 100 mm).

5. Enable grid evaluation.
   The millimeter wave image shows the specified grid.

6. Define if and in which format you want to save the grid results.
   ● "Save grid results in mat file": stores the results in the MATLAB file (`results.mat`).
   ● "Save grid results in csv file": stores the results in a separate `csv` file.
   ● "Show grid in images": Stores an image that contains a visualization of the grid.

7. Start a measurement and analyze the results.
   The results contain information on the mean value, the maximum deviation of any grid cell from that mean value, and the maximum deviation from any neighboring cell. For the analysis, only direct neighboring cells (left, right, upper and lower neighbor) are considered.

Note that the `csv` and `mat` contain an additional row and column that indicate the center coordinates of the grid cells.

Figure 9-7: Structure of csv and mat files

A to E = coordinates of the cell center on the x-axis in columns A to E
a to e = coordinates of the cell center on the y-axis in rows a to e
1 to n = measurement results for each cell

Grid evaluation for high-resolution measurements

High-resolution attenuation measurements support the grid evaluation.

The grid acts as an averaging filter. If you define, for example, a grid with 10 mm cell size, the R&S QAR50 calculates the mean value of all pixels within the cell.
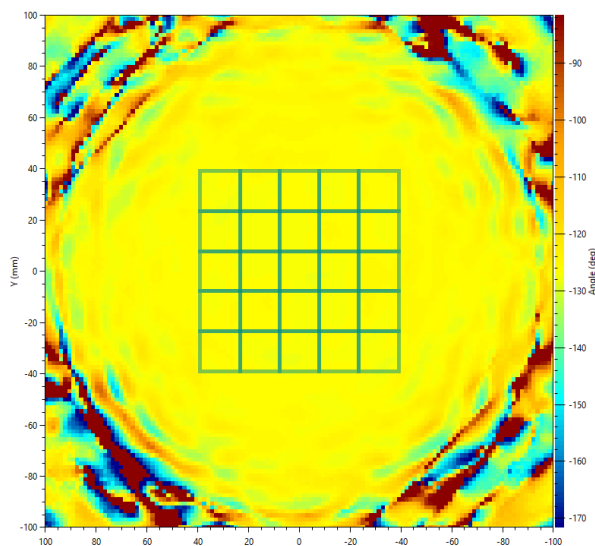
Figure 9-8: Phase measurement with a 5x5 grid and no shift in x- or y-direction

10 Data management

Access: "File" menu

Access: "Options" > "Settings"

You can export the measurement data, for example to store it on an external memory device or copy it to a different computer for further analysis with different software. You can also restore data that you have taken at some point and review it in the application.

1. Select "Options" > "Settings".

2. Define the default directory in which to save the results in the "Save Path" input field.
   For each measurement, the R&S QAR50 creates a subfolder that contains the measurement data. This subfolder's name has a variable name that contains the time stamp of the measurement: `yyyymmdd-hhmmss`.

3. Select "Autosave after every measurement" to use the auto save functionality.
   When you are using the autosave feature, the R&S QAR50 automatically stores the results after each measurement.

   Tip: You can always save the measurement results deliberately using the "File" > "Save" feature.

4. Select the data you want to save from the "Saving Result" dropdown menu.
   - "Statistics": Exports the numerical results from the numerical results table.
   - "Statistics, results and images": Exports all measurement results (numerical results, trace data and 2D imaging data) and the images.
   - "Statistics, results, images and volume": Exports all measurement results, images and the raw 3D imaging data.
     Exporting the raw 3D takes a few seconds to export because of the amount of data that is exported (approx. 10 MB per measurement).
     All exports include information about the measurement configuration.

5. Restore the measurement data using the "File" > "Open" feature.
   Restoring measurement results requires the full measurement result data (`results.mat`). The data package "Statistics + Pictures" only contains the images (`.png)` and statistics (numerical results etc.) and is therefore not sufficient to restore results.

A measurement dataset of results, image and volume contains the following files.
- `<yyyy-mm-dd-hh-mm-ss>_config.json`
  Contains general information about the measurement.
- `<yyyy-mm-dd-hh-mm-ss>_result_statistics.json`
  Contains the numerical measurement results (mean reflection etc.).
- `<yyyy-mm-dd-hh-mm-ss>_<measurement>.png`

Image of the measurements (millimeter wave image and frequency response trace).

- `<yyyy-mm-dd-hh-mm-ss>_results.mat`
  Contains the raw 2D imaging data and the trace data for the result diagram.
- `<yyyy-mm-dd-hh-mm-ss>_volume.mat`
  Contains the raw 3D imaging data.

Re-evaluating measurements

You can re-evaluate previous measurements if you want to analyze different aspects of the DUT.

1. Restore the measurement data you want to re-evaluate ("File" > "Open").

2. Change one or more of the following settings.
   - Frequency band
   - Color scheme
   - Size or position of the evaluation window
   - Evaluation grid characteristics

   The R&S QAR50 automatically updates the results.

   Note: If you select "Measure" after changing a setting, the R&S QAR50 discards the changes and restores the settings that were saved originally.

3. Save the updated measurement results ("File" > "Save").

11 Software management

Updating the measurement software

When software updates become available, we recommend to install them. You can download newer software version from the R&S QAR50 website at: https://www.rohde-schwarz.com/product/qar50.

Software updates require a memory stick or direct internet connection on the R&S QAR50.

1. Download the software update from the internet.

2. Copy the file into the root directory of the memory stick. No other files should be present.

3. Connect the memory stick to one of the USB ports on the R&S QAR50.

4. Log in as an administrator.

5. Open the Windows Explorer and navigate to the memory stick.

6. Run the installer file.
   The software update takes a few minutes.

   When the software update is done, the system restarts.

Installing optional software components

Some software options require separate installations before you can activate and use them. You can find these components on the product page of the R&S®QAR50 at: https://www.rohde-schwarz.com/product/qar50.

1. Copy the file into the root directory of a memory stick. No other files should be present.

2. Connect the memory stick to one of the USB ports on the R&S®QAR50.

3. Log in as an administrator.

4. Open the Windows Explorer and navigate to the memory stick.

5. Run the installer file.
   The installation can take a few minutes.

6. Activate the software license.

Activating software licenses

Before you can use optional software components on your R&S QAR50, you have to activate the corresponding license. You can activate and manage licenses with the R&S License Server Manager. The R&S License Server Manager is already installed on your R&S QAR50.

1. Select the R&S License Server Manager icon (🖼) from the system tray in the task-bar ("Open Manager").

2. The user interface of the R&S License Server Manager opens in a browser.

3. Select the "Licenses" tab to manage licenses.

4. Select "Activate" to add a new license.
    The license key is part of the delivery of the option you bought.

    For a detailed description of the features of the R&S License Manager, refer to its integrated help (available via the "?" icon) or the documentation available on Gloris.

12 System verification

The R&S QAR50 provides a verification procedure to validate the quality of the measurements. Verification consists of a series of measurements with standardized DUTs which are located in the center the R&S QAR50.

Verification requires the verification kit (R&S QAR50-Z44, order no. 1343.0082.02). All verification objects are delivered with a quality approved surface finish. Any surface features are either intentional or are considered to be uncritical for the intended purpose.

The verification kit includes the following parts;
- Frame for verification plates
- 2 x plastic verification plates with different thickness
- 1 x glass-ceramic verification plate
- 1 x metal verification plate
- 1 x transparent plastic verification plate for phase measurement verification

The verification plates each have a sticker with some numbers on it. These values indicate the limits that must not be violated during the verification. Each sticker contains four values:
- a_{77}: one-way mean attenuation in the frequency range from 76 GHz to 77 GHz.
- a_{81}: one-way mean attenuation in the frequency range from 76 GHz to 81 GHz.
- r_{77}: mean reflection in the frequency range from 76 GHz to 77 GHz.
- r_{81}: mean reflection in the frequency range from 76 GHz to 81 GHz.

The process of the verification is independent of the position of the R&S QAR50 (lying or upright). It works the same in both cases, only the orientation of the verification kit is either vertical (in lying position) or horizontal (in upright position).

If verification fails, validate the verification setup. If verification fails several times in a row, despite a valid setup, contact Rohde & Schwarz customer support to calibrate the R&S QAR50 and check the hardware.

Warm-up time

Before verifiying the system, let the R&S QAR50 warm up to its operating temperature.

Installing the frame for the verification objects

The verification objects come with a frame that holds the objects.

The R&S QAR50 has mounting rails on each side of the main body that can hold the frame.

1. Slide the frame onto the mounting rails of the R&S QAR50.
   You can only install the frame one way with the screws on the frame pointing to the side that contains cluster "1" as indicated in Figure 12-1.
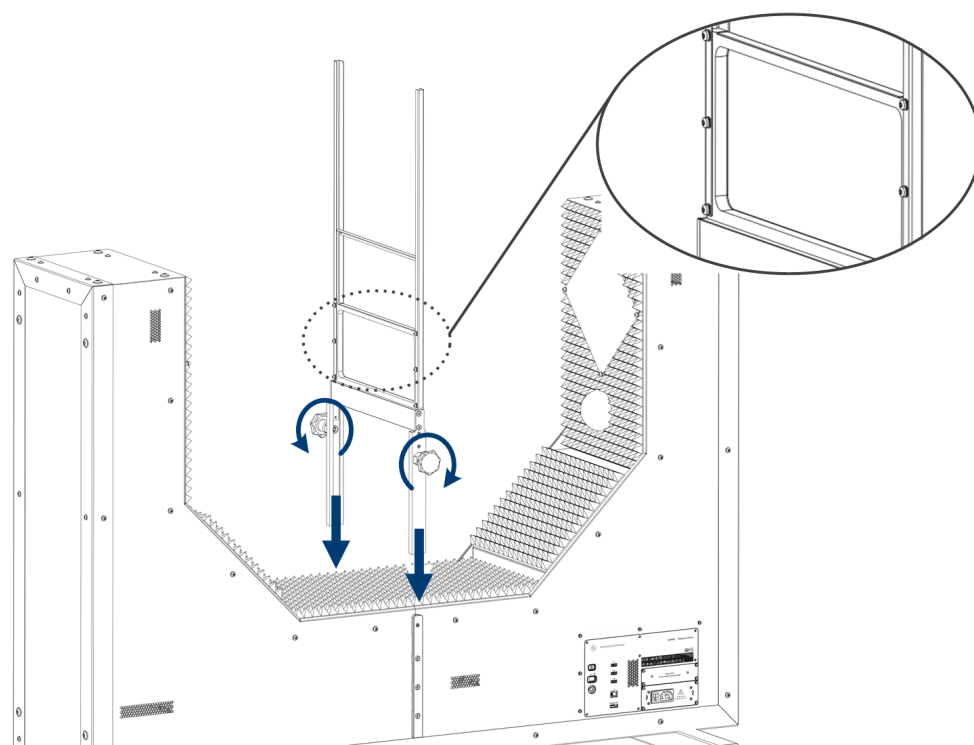
Figure 12-1: Installing the verification plate frame

2. Secure the frame by tightening the screws on each side of the frame.

Verifying reflection and transmission measurements

The verification process consists of four consecutive measurements with the verification objects (square plates).

The verification objects are labeled A to E.

1. **NOTICE!** Handling the verification objects.
   ● Wear the gloves that are part of the delivery when you handle the verification plates.
   ● Store the verification plates in the bag they were delivered in.
   ● Keep the verification plates clean and without fingerprints.
   ● Do not scratch the verification plates.
   ● Clean the plates with a lint-free duster or a damp rag. Do not use chemicals.

   Normalize the reflection measurement.

a) Put the metal plate labeled "E" into the frame.
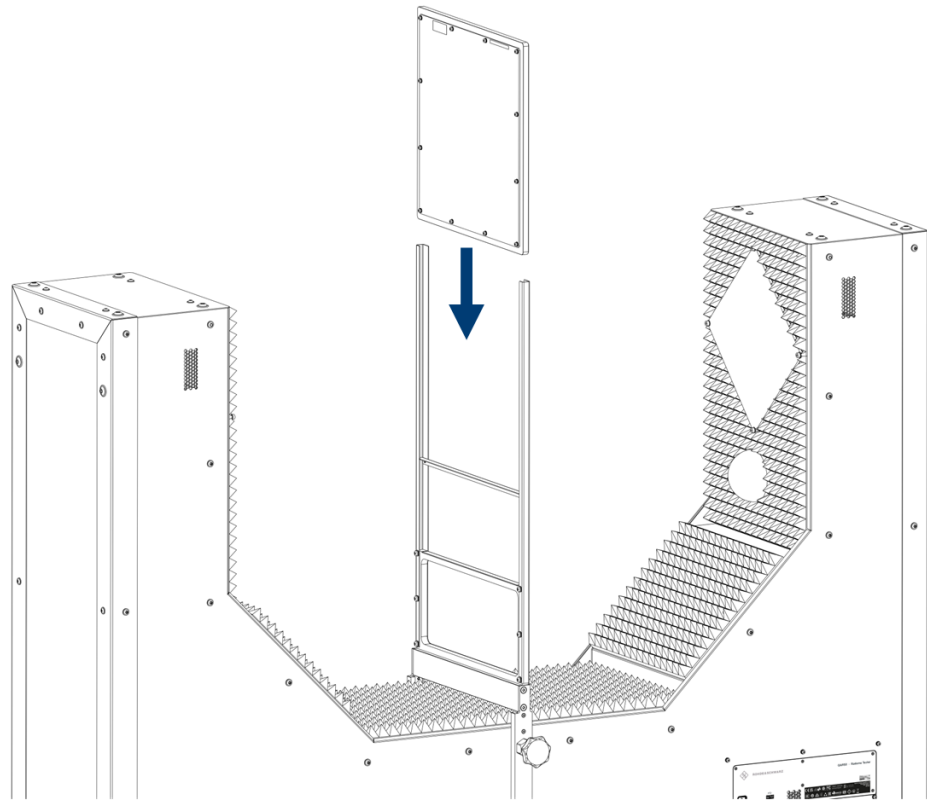
Figure 12-2: Mounting verification plates

b) Select "Normalize Reflection" to initiate a measurement.
c) Wait until the results are displayed.
d) Remove the metal plate from the frame.

The mean reflection should be around 0 dB.

2. Normalize the transmission measurement.

a) Select "Normalize Transmission" to initiate a free-space measurement.

The resulting transmission attenuation should be at approximately 0 dB.

3. Verify the reflection and transmission measurement.

a) Put the glass-ceramic plate labeled "A" into the frame.
b) Initiate a measurement.
c) Remove the plastic plate from the frame.
d) Do the same for the other two plastic plates labeled "B" (plastic) and "C" (plastic).

After each measurement, check the mean transmission loss against the limits a_{77} and a_{81} specified on the stickers attached to the verification plates. The sticker shows the attenuation characteristics of the plate and the deviation the result may have.

After each measurement, check the mean reflection against the limits r_{77} and r_{81} specified on the stickers attached to the verification plates. The sticker shows the reflection characteristics of the plate and the deviation the result may have.

Verifying phase measurements

The process to verify phase measurements depends on the verification plate you are using.

1. For verification plates with a serial number < 101350, proceed as follows.

   a) Put the transparent plastic plate labeled "D" into the frame.
      Make sure that the plate has the correct orientation.
   b) Initiate a measurement.
      After the measurement, check the phase results in the millimeter wave image.
      Phase steps should be clearly visible in the image.

2. For verification plates with a serial number ≥ 101350, proceed as follows.

   a) Select "Options" > "Resolution Verification".
      The R&S QAR50 starts a wizard that guides you through the verification.
   b) Put the transparent plastic plate labeled "D" into the frame.
      Make sure that the plate has the correct orientation.

3. Initiate a measurement for each of the two phase evaluation masks mentioned in the wizard.
   These phase evaluation masks are part of the delivery.
   After the measurements, the R&S QAR50 calculates the phase difference of the two measurements. Compare the results to the values specified on the stickers attached to the verification plate. The sticker shows the phase deviation of the plate and the deviation the result may have.

13 Remote control

You can remote control the R&S QAR50 using SCPI commands.

In addition to the remote control basic in this manual, refer to the following document available on the R&S QAR50 website provides a general introduction to remote control using SCPI commands.

https://www.rohde-schwarz.com/manual/remote-control-via-scpi-manuals-gb1_78701-1090624.html

Note that this document can describe features (especially remote control interfaces and protocols) that the R&S QAR50 does not support.

13.1 Remote control interface and protocol

For the R&S QAR50, the remote control interface is the LAN interface. The LAN interface consists of a connector, a network interface card and protocols.

The network card can be operated with the following interfaces:
- 10 Mbit/s Ethernet IEEE 802.3
- 100 Mbit/s Ethernet IEEE 802.3u
- 1Gbit/s Ethernet IEEE 802.3ab

For remote control via a network, the PC and the instrument must be connected via the LAN interface to a common network with TCP/IP network protocol. They are connected using a commercial RJ45 cable (shielded or unshielded twisted pair category 5). The TCP/IP network protocol and the associated network services are preconfigured on the instrument. Software for instrument control and the VISA program library must be installed on the PC (controller).

IP address

Only the IP address or a valid DNS host name is required to set up the connection. The host address is part of the "VISA resource string" used by the programs to identify and control the instrument.

The VISA resource string has the form:

```
TCPIP::host address[::LAN device name][::INSTR]
```

where:
- **TCPIP** designates the network protocol used
- **host address** is the IP address or host name of the device
  `inst0` selects the VXI-11 protocol

- **LAN device name** defines the protocol and the instance number of a sub-instrument;
- **INSTR** indicates the instrument resource class (optional)

Example:

- Instrument has the IP address *192.1.2.3*; the valid resource string using VXI-11 protocol is:
  `TCPIP::192.1.2.3::INSTR`

Identifying instruments in a network

If several instruments are connected to the network, each instrument has its own IP address and associated resource string. The controller identifies these instruments by the resource string.

VISA library

A VISA installation is a prerequisite for remote control using the LAN interface.

VISA is a standardized software interface library providing input and output functions to communicate with instruments. High level programming platforms use VISA as an intermediate abstraction layer.

The I/O channel (LAN or TCP/IP) is selected at initialization time by one of the following:

- The channel–specific address string ("VISA resource string")
- An appropriately defined VISA alias (short name).

For more information about VISA, refer to the VISA user documentation.

VXI-11 protocol

The VXI-11 standard is based on the open network computing remote procedure call (ONC RPC) protocol which in turn relies on TCP/IP at the network/transport layer. The TCP/IP network protocol and the associated network services are preconfigured.

TCP/IP ensures connection-oriented communication, where the order of the exchanged messages is adhered to and interrupted links are identified. With this protocol, messages cannot be lost.

SCPI compatibility

SCPI commands (standard commands for programmable instruments) are used for remote control. The SCPI standard is based on standard IEEE 488.2 and aims at the standardization of instrument-specific commands, error handling and the status registers. The tutorial "Automatic Measurement Control - A tutorial on SCPI and IEEE 488.2" from John M. Pieper (R&S order number 0002.3536.00) offers detailed information on concepts and definitions of SCPI. The instrument supports the SCPI version 1999.

Commands that are not taken from the SCPI standard follow the SCPI syntax rules.

Communication ports

You have to open several ports in the firewall to be able to communicate via SCPI. By default, these ports are already open on the R&S QAR50. If you want to close these ports, you can run a script that closes these ports.

- To close the ports, run the
  script `.\firewall\firewall-disableaccess.bat`.
  Closing the ports disables remote control functionality.
- To reopen the ports, run the script `.\firewall\firewall-setting.bat`.

13.2 Remote control commands

You only need to configure the measurement once. After this initial configuration, the R&S QAR50 applies this configuration to all future measurements. Therefore, you only have to change the settings if you need a different measurement configuration, for example a different evaluation window size for future measurements.

13.2.1 General commands

&GTL

Closes a remote session and returns to local mode.

Example:	//Initiate remote session
	`&GTR`
	//Send commands
	`MEAS:START`
	`MEAS:SAVE 'A great measurement'`
	//Close the remote session
	`&GTL`
Usage:	Event

&GTR

Initiates a remote session.

Always send this command before sending a sequence of commands.

During a remote session, the user interface is unavailable. To access the user interface again, you have to return to local mode via the user interface or end the remote session with `&GTL`.

Example:	//Initiate remote session
	`&GTR`
	//Send commands
	`MEAS:START`
	`MEAS:SAVE 'A great measurement'`
Usage:	Event

SYSTem:ERRor

Queries the most recent error queue entry for SCPI errors and deletes it. SCPI errors have a negative number.

To query device errors, use `SYSTem:STATus:ERRor[:NEXT]?`.

Possible SCPI errors are defined in the SCPI standard.

For a list of possible errors, see Chapter 15, "Troubleshooting error messages", on page 104.

Return values:
<ErrorCode>

<ErrorMessage>

Usage:	Event

SYSTem:STATus:ERRor[:NEXT]?

Queries the most recent error queue entry for device errors and deletes it. Device errors have a positive sign.

To query SCPI errors, use `SYSTem:ERRor`.

For a list of possible device errors, see Chapter 15, "Troubleshooting error messages", on page 104.

Return values:
<ErrorCode>

<ErrorMessage>

Usage:	Query only

SYSTem:EXIT

Shuts down the system.

Shutting down the system automatically closes the SCPI connection.

Example:	//Shut down the system
	`SYST:EXIT`

Usage:	Event

SYSTem:REBoot

Reboots the system.

Rebooting the system automatically closes the SCPI session. If you want to continue remote controlling the system after the reboot, you have to re-establish the SCPI session after the reboot with `&GTR`.

Example:	//Reboot system
	`SYST:REB`

Usage:	Event

SYSTem:STATus:CODE?

Queries the current system status.

Return values:

<StatusCode>

0

System ready for operation.

1

System is initializing.

2

System has an initialization error.
You can query the details about the error with `SYSTem:STATus:ERRor[:NEXT]?`.

Example:	See Chapter 13.3, "Remote control examples", on page 94.

Usage:	Query only

13.2.2 Measurement configuration

MEASurement:EVALuation:MASK:ENABle <State>

Turns phase evaluation masks on and off.

Setting parameters:

<State>

0

Phase mask = off

1

Phase mask = on

*RST: 0

Example: //Deactivate a phase mask

MEAS:EVAL:MASK:ENAB 0

MEASurement:EVALuation:MASK:LOAD <FileName>

Loads an evaluation mask for phase measurements and also activates the phase mask.

Setting parameters:

<FileName> String containing the path (.bmp file) to the bitmap you want to load.

Example: //Load a bitmap file

MEAS:EVAL:MASK:LOAD 'c:\hi.bmp'

Usage: Setting only

MEASurement:EVALuation:WINDow <XSize>, <YSize>

Defines the size of the evaluation window.

Setting parameters:

<XSize> Length of the horizontal side of the evaluation window in mm.

Range: 10 to 100

<YSize> Length of the vertical side of the evaluation window in mm.

Range: 10 to 100

Example: See Chapter 13.3, "Remote control examples", on page 94.

Usage: Setting only

MEASurement:GRID:CONFig <CellSizeX>, <CellSizeY>, <GridPositionX>,
<GridPositionY>, <CellsX>, <CellsY>,<StoreMat>,<StoreCsv>

Defines the size and location of an evaluation grid.

Setting parameters:

<CellSizeX> Size of a grid cell in x-direction.

*RST: 0
Default unit: mm

<CellSizeY> Size of a grid cell in y-direction.

*RST: 0
Default unit: mm

<GridPositionX>	Location of the grid on the x-axis relative to origin of the evaluation window.
	*RST: 0
	Default unit: mm
<GridPositionY>	Location of the grid on the y-axis relative to origin of the evaluation window.
	*RST: 0
	Default unit: mm
<CellsX>	Number of cells on the x-axis.
	*RST: 0
<CellsY>	Number of cells on the y-axis.
	*RST: 0
<StoreMat>	1 | 0
	Turns result export in a .mat file on and off.
	*RST: 0
<StoreCsv>	1 | 0
	Turns result export in a .csv file on and off.
	*RST: 0
Example:	See `MEASurement:GRID:RESult?` on page 88
Usage:	Setting only

MEASurement:GRID:ENABle <State>

Turns the measurement using an evaluation grid on and off.

Setting parameters:

<State>	1 | 0
	*RST: 0
Example:	See `MEASurement:GRID:RESult?` on page 88

MEASurement:GRID:RESult?

Queries the results of the grid measurement.
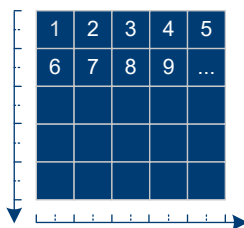
Note that the results for the transmission attenuation are linear values. You can calculate the logarithmic values in dB with: 20*log10(attenuation_linear).

Return values:

<Results>   String that contains the location of the grid cells and the measurement results for each grid cell.
                                  For each cell, the command returns the average transmission and phase results for both frequency bands. The number of results depends on the number of cells in the grid.

Example: //Define a grid with 25 cells (five on the x-axis and five on the y-axis)
                                  `MEAS:GRID:CONF 5,5,0,0,5,5,0,1`
                                  `MEAS:GRID:ENAB 1`
                                  `MEAS:START`
                                  `MEAS:GRID:RES?`
                                  would return the results in a .txt file
                                  `#<number_of_characters in the file>`
                                  `"GridCoordinatesX":`
                                  `  location of the cell borders in x-direction in mm`
                                  `"GridCoordinatesY":`
                                  `  location of the cell borders in y-direction in mm`
                                  `"GridCoordinatesXMean":`
                                  `  location of the center of each cell in x-direction in mm`
                                  `"GridCoordinatesYMean":`
                                  `  location of the center of each cell in y-direction in mm`
                                  `"Transmission":`
                                  `  "Attenuation":`
                                  `    "PhasemaskBand1":`
                                  `     results for each cell from top left to bottom right`
                                  `     devided by grid rows`
                                  `    "PhasemaskBand2":`
                                  `    "HighResBand1":`
                                  `    "HighResBand2":`

Usage: Query only

MEASurement:HQMode:ENABle <State>

Turns high quality mode on and off.

Setting parameters:

<State>   **0**
                                  High quality mode = off

                                  1
                                  High quality mode = on

                                  *RST: 0

Example: //Turn on high quality mode
                                  `MEAS:HQM:ENAB 1`

13.2.3 Normalization

MEASurement:NORMalize:REFLection:REQuired?

Queries if the reflection measurement has been normalized.

Return values:

<State>	1	0
	If the result is 1, normalize the measurement with MEASurement:NORMalize:REFLection:STARt.
	If the result is 0, the measurement is already normlized. You can proceed with the actual measurement.

Example: See Chapter 13.3, "Remote control examples", on page 94.

Usage: Query only

MEASurement:NORMalize:REFLection:STARt

Initiates a normalization of the reflection measurement.

Example: See Chapter 13.3, "Remote control examples", on page 94.

Usage: Event

MEASurement:NORMalize:SWITch <IndexValue>

Selects normalization data for the next measurement if you have a pool of normalization data.

Parameters:

<IndexValue>	<numeric value> (integer only)
	Range: 0 (corresponds to "Default" in the UI) to 100
	*RST: 0

Return values:

<IndexValue>	<numeric value> (integer only)
	Range: 0 to 100

Example: See "Programming example for handling a pool of normalization data" on page 96.

MEASurement:NORMalize:TRANsmission:REQuired?

Queries if the transmission measurement has been normalized.

Return values:

<State>	1 | 0
	If the result is 1, normalize the measurement with MEASurement:NORMalize:TRANsmission:STARt.
	If the result is 0, the measurement is already normlized. You can proceed with the actual measurement.
Example:	See Chapter 13.3, "Remote control examples", on page 94.
Usage:	Query only

MEASurement:NORMalize:TRANsmission:STARt

Initiates a normalization of the transmission measurement.

Example:	See Chapter 13.3, "Remote control examples", on page 94.
Usage:	Event

13.2.4 Buffered measurements

For details about buffered measurements, see "Queuing measurements" on page 48.

MEASurement:BUFFer:ACQuisition?

Initiates a measurement and adds the measurement data to a queue for later evaluation.

The return value indicates the queue number for that measurement.

Return values:

<IndexValue>	<numeric value> (integer only)
	Range: 1 to 50
Example:	See "Programming example for buffered measurements" on page 96.
Usage:	Query only

MEASurement:BUFFer:CALCulation <Index>

Initiates the evaluation of measurement data in the queue.

Setting parameters:

<IndexValue>	<numeric value> (integer only)
	Range: 1 to 50
Example:	See "Programming example for buffered measurements" on page 96.

Usage:	Setting only

MEASurement:BUFFer:RESet

Clears the measurement data currently in the buffer waiting for evaluation.

Example:	See "Programming example for buffered measurements" on page 96.
Usage:	Event

13.2.5 Measurement control

MEASurement:LOAD <Directory>

Restores previously recorded measurement data.

The restored data depends on what was saved (`MEASurement:RESult:SAVE:WHAT`).

Setting parameters:

<Directory>	String containing the path to the directory that contains the dataset.

Example:	//Restore measurement data
	`MEAS:LOAD 'c:`
	`\qar50\measurements\20211111-111111_measurement0001'`

Usage:	Setting only

MEASurement:RESult?

Queries the numerical measurement results.

Return values:

<Result>	Byte array containing the result value in `.json` format. The array has the following structure: `#<headervalue1><headervalue2><data>` • `#`: hash sign • `<headervalue1>`: length of the length information (number of digits) • `<headervalue2>`: length information of the binary data (number of bytes)

- `<data>`: binary data with the indicated number of bytes
Example for the header: `#3376`, binary data has a length of 376 bytes. The number of digits of the length information is 3.
For an example of the structure of the `.json` file, see "Structure of the .json file containing results" on page 97.

Example:	See Chapter 13.3, "Remote control examples", on page 94.
Usage:	Query only

MEASurement:RESult:DIRectory <Directory>

Defines the base directory in which measurement are stored.

The results themselves are stored in a subfolder of this directory. The subfolder has a fix naming logic.

Parameters:

<Directory>	String containing the path to the directory.
Example:	See Chapter 13.3, "Remote control examples", on page 94.

MEASurement:RESult:SAVE:AUTO <State>

Turns automatic saving of the results of each measurement on and off.

Parameters:

<State>	1 | 0
	*RST: 1
Example:	See Chapter 13.3, "Remote control examples", on page 94.

MEASurement:RESult:SAVE:WHAT <Data>

Selects the data that is stored in a dataset.

Parameters:

<Data>	**0**
	Saves numerical results.
	1
	Saves all results and images.
	2
	Saves all results, images and 3D data.
	*RST: 1
Example:	See Chapter 13.3, "Remote control examples", on page 94.

MEASurement:SAVE? [<Description>]

Saves the results of the last measurement and returns the location of the results.

We recommend turning off automatic result saving if you use this command (MEASurement:RESult:SAVE:AUTO). If you use this command in addition to the automatic saving of results, the R&S QAR50 saves the results a second time.

Query parameters:

<Description>	Optional parameter. String that contains the description (or name) of a specific measurement.

Return values:

<Directory>	String that contains the path to the directory in which the results are stored.

Example:	See Chapter 13.3, "Remote control examples", on page 94.
Usage:	Query only

MEASurement:STARt

Initiates a measurement (reflection, transmission and phase measurement).

Example:	See Chapter 13.3, "Remote control examples", on page 94.
Usage:	Event

13.3 Remote control examples

The following examples show a typical sequence of remote commands to perform a measurement with the R&S QAR50.

Programming example for a measurement

```
//Initiate SCPI session
&GTR
//Query system status
SYST:STAT:CODE?
//If result = 0, system is ready for operation
//Define size of evaluation window
MEAS:EVAL:WIND 50,50
//Define settings for automatic result storage
MEAS:RES:SAVE:AUTO 1
MEAS:RES:SAVE:WHAT 1
MEAS:RES:DIR 'c:\qar50\mymeasurements\'
//Run measurement
MEAS:NORM:REFL:REQ?
//If result = 1, normalize reflection measurement
MEAS:NORM:REFL:STAR
MEAS:NORM:TRAN:REQ?
//If result = 1, normalize transmission measurement
MEAS:NORM:TRAN:STAR
MEAS:STAR
```

```
MEAS:RES?
//returns, e.g.:
#41372{
 "reflection" : {
  "S11" : {
        "mean_Band1dB" : -35.18,
        "mean_Band1Percent" : 1.74,
        "mean_Band2dB" : -36.36,
        "mean_Band2Percent" : 1.54,
        "FResponseMinimumdB" : -58.00,
        "FResponseMinimumPercent" : 0.12,
        "FResponseMinimumFrequencyValue" : 81039370078.47,
     }
  }
}
//etc.


//Query location of the measurement results
MEAS:SAVE? 'test'
//Restore the results
MEAS:LOAD 'c:\qar50\mymeasurements\20211111-111111_test'
//End SCPI session
&GTL
```

Programming example to verify phase measurements

Requires a verification plate "D" with serial number ≥ 101350.

```
//Initiate SCPI session
&GTR
//Load first evaluation mask
MEAS:EVAL:MASK:LOAD 'C:\Program Files (x86)\Rohde-Schwarz\QAR50\config\
evaluationMask_70_30_0_20.bmp'
// Start first measurement
MEAS:STAR
//Query and store measurement results of the first measurement
MEAS:RES?
//Load second evaluation mask
MEAS:EVAL:MASK:LOAD 'C:\Program Files (x86)\Rohde-Schwarz\QAR50\config\
evaluationMask_70_30_0_-20.bmp'
//Start second measurement
MEAS:STAR
//Query and store measurement results of the second measurement
MEAS:RES?
```

After the two measurements, substract the mean phase results of the first measurement from the second measurement and compare the absolute value of the results with the values printed on the plates.

Programming example for handling a pool of normalization data

```
//Select a slot for normalization data
MEAS:NORM:SWIT? 1
//return value confirms the dataset number
1
//Check if the selected dataset contains valid normalization data
MEAS:NORM:REFL:REQ?
//return value if no normalization data was found:
1
//Normalize the measurement
MEAS:NORM:REFL:STAR
//Confirm that normalization was successful
MEAS:NORM:REFL:REQ?
//return value if normalization is available:
0
//Start a measurement with selected normalization data
MEAS:STAR
//Select the normalization dataset for the next measurement
MEAS:NORM:SWIT? 5
//return value:
5
...
```

Programming example for buffered measurements

```
//Record raw data of measurement no. 1
MEAS:BUFF:ACQ?
//return value indicates the queue number:
1
//Record raw data of measurement no. 2
MEAS:BUFF:ACQ?
//return value:
2

//Evaluate data in buffer 1:
MEAS:BUFF:CALC 1
MEAS:RES?
MEAS:SAVE "result_001"

//Record raw data of measurement no. 3
MEAS:BUFF:ACQ?
//return value:
3

//Evaluate data in buffer 2:
MEAS:BUFF:CALC 2
MEAS:RES?
MEAS:SAVE "result_002"

//Record raw data of measurement no. 4
```

```
MEAS:BUFF:ACQ?
//return value:
4
...
//Clear the queue
MEAS:BUFF:RES
```

Structure of the .json file containing results

```
{
 "Reflection": {
  "S11": {
   "MeanBand1dB": -10.91,
   "MeanBand1Percent": 28.48,
   "MeanBand2dB": -9.74,
   "MeanBand2Percent": 32.57,
   "FResponseMinimumdB": -9.6,
   "FResponseMinimumPercent": 33.1,
   "FResponseMinimumFrequencyValue": 79385826771.34,
   "FResponseMaximumdB": -8.89,
   "FResponseMaximumPercent": 35.93,
   "FResponseMaximumFrequencyValue": 80999999999.73
   },
  "S22": {
   "MeanBand1dB": -11.88,
   "MeanBand1Percent": 25.47,
   "MeanBand2dB": -10.45,
   "MeanBand2Percent": 30.01,
   "FResponseMinimumdB": -15.53,
   "FResponseMinimumPercent": 16.72,
   "FResponseMinimumFrequencyValue": 72259842519.19,
   "FResponseMaximumdB": -10.53,
   "FResponseMaximumPercent": 29.77,
   "FResponseMaximumFrequencyValue": 80999999999.73
   }
  },
 "Transmission": {
  "Attenuation": {
  "MeanBand1dB": 0.65,
  "MeanBand1Percent": 7.23,
  "MeanBand2dB": 0.8,
  "MeanBand2Percent": 8.76,
  "MeanPhaseBand1Degree": -162.19,
  "MeanPhaseBand1Radian": -2.8307,
  "MeanPhaseBand2Degree": -165.62,
  "MeanPhaseBand2Radian": -2.8906,
  "StdDevPhaseBand1Degree": 5.86,
  "StdDevPhaseBand1Radian": 0.1022,
  "StdDevPhaseBand2Degree": 5.65,
  "StdDevPhaseBand2Radian": 0.0986,
```

```
        "MaxDevPhaseBand1Degree": 13.33,
        "MaxDevPhaseBand1Radian": 0.2326,
        "MaxDevPhaseBand2Degree": 11.55,
        "MaxDevPhaseBand2Radian": 0.2016,
        "FResponseMinimumdB": 0.4,
        "FResponseMinimumPercent": 4.45,
        "FResponseMinimumFrequencyValue": 75251968503.52,
        "FResponseMaximumdB": 0.79,
        "FResponseMaximumPercent": 8.72,
        "FResponseMaximumFrequencyValue": 80685039369.8,
        "MeanHighResBand1dB": 0.95,
        "MeanHighResBand2dB": 1.06,
        "StdDevHighResBand1dB": 0.38,
        "StdDevHighResBand2dB": 0.33,
        "MaxDevHighResBand1dB": 0.85,
        "MaxDevHighResBand2dB": 0.78
        }
      },
      "GridResults": {
       "Transmission": {
        "Attenuation": {
         "PhasemaskBand1": {
          "MeanDegree": -149.26,
          "MaxDeviationToMeanDegree": 0.0,
          "MaxDeviationToNeighborDegree": 0.0
          },
         "PhasemaskBand2": {
          "MeanDegree": -154.26,
          "MaxDeviationToMeanDegree": 0.0,
          "MaxDeviationToNeighborDegree": 0.0
          },
         "HighResAttenuationBand1": {
          "MeandB": 0.42,
          "MaxDeviationToMeandB": 0.0,
          "MaxDeviationToNeighbordB": 0.0
          },
         "HighResAttenuationBand2": {
          "MeandB": 0.6,
          "MaxDeviationToMeandB": 0.0,
          "MaxDeviationToNeighbordB": 0.0
          }
         }
        }
       }
      }
```

14 Real-time imaging

Real-time imaging is an optional application that allows you to display live images of a test object. You can use these images to check the test object for faults in your own post processing tools. The application runs continuous measurements that result in a continuous image stream of the characteristics of the test object, like a video stream. The image stream is based on the WebSocket protocol. The frame rate depends on the configuration of the test setup - with a standard configuration frame rate is about 30 fps.

With the R&S QAR50-K80, you can measure the reflection and phase characteristics of the test object.

The real-time imaging application uses a different software environment than the base unit. This software is REST API based on the OpenAPI standard, but you can also use a basic user interface that comes with the application.

Using the radome measurement software of the base unit and the software of the real-time imaging application at the same time is not possible.

Accessing the real-time imaging application

The easiest way to access the real-time imaging application directly is a local connection with a web browser. You can use this method to get familiar with the application and view the API documentation.

1. Start the real-time imaging software using the shortcut on the desktop.

2. Open a web browser on the R&S QAR50.

3. Enter the IP address of the local host (`127.0.0.1:8000`).
   The web browser displays the functions provided by the real-time imaging application, including the documentation of the API. You can get all API functions and the type it is from this documentation.

   This page also has a few quick links to access the most important functions.
   - "Get live image": Shows a non moving image of the current measurement (frame).
   - "Get live video": Shows a video stream of the measurement, including the number of measurements (frames) that have been streamed in this session.

When you open the video stream in the browser, you can access a few selected functions in the browser.

- Result type selection
- Distance from object to cluster
- Dynamic range
- Color map

Working with the real-time imaging application

Frequency
Defines the frequency range of the measurement.

We recommend using the frequency ranges the R&S QAR50 is calibrated for.

- 72 GHz to 82 GHz (256 frequency points)
- 76 GHz to 81 GHz (128 frequency points)

Using other frequency range requires a recalibration of the setup. If you need to use different frequency ranges, contact your Rohde & Schwarz representative.

Remote command:
```
/initialize?f_start=<start_freq.>&f_stop=<stop_freq.>
&num_frequencies=<freq._point>
```

Volume definition
Defines the image volume which corresponds to the amount of data that is processed during image reconstruction and on the size of the image.

A small volume has the advantage that image processing gets faster. However, smaller image contain less information. A rule thumb is to define a volume that is as small as possible, but large enough to be able to see the complete DUT.

Note that the volume definition has no effect on the raw data. The raw data of the measurements is always captured completely.

Define the volume size with the following variables:
- `nx` / `ny` / `nz`: Number of voxels in x-, y- and z-direction
- `dx` / `dy` / `dz`: Spacing in x-, y- and z-direction in meter

Remote command:
```
/volume-definition
```

Live image
Queries an image of the current measurement.

The live image is available in different formats: `.png`, `.jpg`, `.bmp` and `.tiff`

The API returns the raw image data in binary format that you can use for further evaluations.

- For `.png`, `.jpg`, `.bmp`, the command returns the first slice of the volume.
- For `.tiff`, the command returns the entire complex-valued 3D volume in a multi-page `.tiff` file. Each slice consists of two pages representing the real and imaginary part of the corresponding slice.

Remote command:
```
/live-image.png
/live-image.jpg
/live-image.bmp
/live-image.tiff
```

Live video
Starts the user interface that shows the live stream of the recorded image.

To access the live stream from the client, open a WebSocket with the command `/ws`.

The API starts sending continuous messages to the connected client. The client must differentiate between one of two different message types:

- json: The json string contains the metadata of the live stream (frame rate, frame count etc.). You can get the detailed contents from the REST API documentation.
- bytes: The byte stream contains the raw image data in binary .jpg format that you can use for further image evaluation.
  When you disconnect the client from the WebSocket, the live stream stops.

Remote command:
`/live-video`

Result type
Selects the displayed result type of the measurement.

Magnitude	Shows the amplitude characteristics of the reflection measurement of the test object.
Phase	Shows the phase characteristics of the reflection measurement of the test object.

Remote command:
Turn on phase results: `/phase-visualization?show_phase=true`
Turn off phase results: `/phase-visualization?show_phase=false`

Origin of the image
Defines the position of the evaluation window and distance of the test object to the cluster. Note that all values are in "m" (meters). By default, the size of the evaluation window is 256 mm x 256 mm.

The positioning parameters also contain a query parameter `pipe_id` (pipeline ID) which has an effect on image reconstruction. By default, the real-time imaging application uses one pipeline. We recommend not changing this value.

x-position	Defines the position of the evaluation window in horizontal direction. The point of origin is the lower left edge of the image. Therefore, entering a positive value moves the reconstruction volume to the right.
y-position	Defines the position of the evaluation window in vertical direction. The point of origin is the lower left edge of the image. Therefore, entering a positive value moves the reconstruction volume downwards.
z-position	Defines the distance between test object and cluster.

Remote command:
`/origin?xpos=<hor.pos.>&ypos=<vert.pos.>&zpos=<distance>`

Color map for the image
Selects the color map for the image. The color map defines the type of colors used in the image.

Note that the phase results do not support all color maps.

Remote command:
`colormap/viridis`
`colormap/ocean`

```
colormap/turbo
colormap/black & white
```
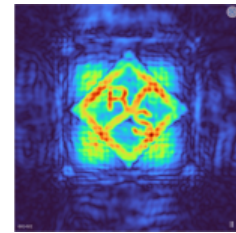
Dynamic range

Defines the range of amplitude levels that the image displays.

The dynamic range allows you to improve the contrast of the image by removing certain level ranges from the image. The effect is that you can highlight certain details in the image and thus get a more balanced image.
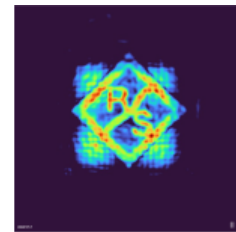
Example:

The displayed level range is 100 dB.

However, levels of interest occur only in a small level range. Most parts of the color range represent noise or ripples that you do not want to see.

When you reduce the dynamic range, the contrast between interesting and non-interesting parts of the image increases - non-interesting parts become black areas in the image.

You can define a different dynamic range for magnitude and phase measurements.

Remote command:

Dynamic range magnitude:

`/dynamic-range/magnitude?rel_offset_min=<level>&rel_offset_max=<level>`

Dynamic range phase:

`/dynamic-range/phase?val_min=<level>&val_max=<level>`

Normalization

Turns automatic normalization of the measured amplitudes on and off.

Available for magnitude measurements only.

True	The R&S QAR50 automatically normalizes the measured amplitudes to the maximum amplitude within the reconstructed image to get the best result for each image.
False	The R&S QAR50 does not normalize the measured amplitude after each measurement. Not normalizing the measurement can lead to images in which the magnitude is clipped.

Remote command:

Normalization on: `/magnitude-normalization?normalize-magnitude=true`

Normalization off: `/magnitude-normalization?normalize-magnitude=false`

Get settings

Queries the current measurement settings.

Remote command:

`/settings`

15 Troubleshooting error messages

If there are any errors, you can view the details by selecting "Errors" in the user interface. If you cannot solve the error, contact your Rohde & Schwarz service representative and send them the error log. You can export the error log with "File" > "Dump all log files". In addition to the error log, the log file also contains other useful information that allows service to solve the issues.

The following errors (hardware and software) can occur during the operation of the R&S QAR50. Try to resolve the error with the suggested solutions.

Table 15-1: Possible errors for the R&S QAR50

Error code	Description	Solution
Err_1	Error: Error while getting the firmware.	Try restarting the device.
Err_2	Error: Updating all FPGA files failed.	Read next entry in errorqueue.
Err_3	Error: Failed to initialize the firmware.	Try restarting the device.
Err_4	Error: Failed to initialize the device.	Read next entry in errorqueue.
Err_5	Error: Warming up the hardware failed.	Read next entry in errorqueue.
Err_6	Error: Interrupting the hardware warmup failed.	Read next entry in errorqueue.
Err_7	Error: Could not switch to reconstruction using GPU.	Try restarting the device.
Err_8	Error: Could not switch to reconstruction using CPU.	Try restarting the device.
Err_9	Error: Could not load user config	Reinstall the software.
Err_10	Error: Could not load device config	Reinstall the software.
Err_11	Error: Could not save user config	Make sure there is sufficient storage space.
Err_12	Error: Could not save device config	Make sure there is sufficient storage space.
Err_13	Error: Could not get the Matlab status.	Try restarting the device.
Err_14	Error: Could not get the device status.	Try restarting the device.
Err_15	Error: Could not get the temperature result.	Try restarting the device.
Err_16	Error: Could not create the folder	Make sure there is sufficient storage space.
Err_17	Error: Could not set the save level	Use a supported savelevel.
Err_18	Error: Could not load result. The results.mat file does not exist	Save your results in a higher savelevel.
Err_19	Error: Could not load result data	Incompatible result.
Err_20	Error: Could not load result	Make sure the path contains a valid result.
Err_21	Error: Could not save result	Make sure there is sufficient storage space.
Err_22	Error: Error during the normalization.	Repeat the normalization measurement.
Err_23	Error: Normalization is required before performing a measurement.	Perform a normalization measurement.
Err_24	Error: The device is not ready for a measurement now.	Read next entry in errorqueue.

Error code	Description	Solution
Err_25	Error: Measurement failed.	Read next entry in errorqueue.
Err_26	Error: The device is busy at the moment.	Please try sending the command again.
Err_27	Error: Evaluation window parameters are out of range.	Use compatible evaluation window settings.
Err_28	Error: Dumping the log files failed.	Try restarting the device.
Err_29	Error: Calibration failed.	Rename the last backup Calibraion folder to 'CalibrationData' and try restarting the device.
Err_30	Error: Loading evaluation phase mask file failed.	Check the log files for detail.
Err_31	Error: Resolution verification failed.	Check the log files for detail.
Err_100	Error: Error file is missing, or corrupt.	Reinstall the software.
Err_101	Error: Driver instance not available.	Read next entry in errorqueue.
Err_102	Error: Could not open reconstruction interface instance.	Read next entry in errorqueue.
Err_103	Error: Could not open Matlab interface.	Read next entry in errorqueue.
Err_104	Error: Initialization failed.	Read next entry in errorqueue.
Err_105	Error: Device initialization missing.	Read next entry in errorqueue.
Err_106	Error: Hardware Driver was not released. Check .\logs\HW_driver*.txt for more details.	See HW_driver.txt for more details.
Err_107	Error: Settings invalid, please adjust settings.	Reset settings to default values.
Err_108	Error: Switching to CPU reconstruction failed.	Try restarting the device.
Err_109	Error: Switching to GPU reconstruction failed.	Try restarting the device.
Err_110	Error: Calibration data missing.	Calibrate the device or restore calibration data.
Err_111	Error: Cannot get data from Hardware Driver. Check .\logs\HW_driver*.txt for more details.	See HW_driver.txt for more details.
Err_112	Error: GPU reconstruction and transfer to Matlab failed.	Read next entry in errorqueue.
Err_113	Error: GPU based result calculation in Matlab failed.	Read next entry in errorqueue.
Err_114	Error: CPU based result calculation in Matlab failed.	Read next entry in errorqueue.
Err_115	Error: CPU reconstruction not available w/o Matlab.	Read next entry in errorqueue.
Err_116	Error: Transferring data to Matlab.	Read next entry in errorqueue.
Err_117	Error: Matlab initialization failed.	Reinstall the software.
Err_118	Error: Matlab getting or reading results failed.	Try restarting the device.
Err_119	Error: Matlab save result failed.	Read next entry in errorqueue.
Err_120	Error: Unable to read json file.	Reinstall the software.
Err_121	Error: No config.json file found.	Reinstall the software.
Err_122	Error: Failed to calibrate the system.	Read Matlab logfile for more details.
Err_123	Error: FPGA files missing.	Reinstall the software.

Error code	Description	Solution
Err_124	Error: Wrong format queried. Please query result correctly.	Reinstall the software.
Err_125	Error: GPU reconstruction volume missing. Please run GPU reconstruction first.	Reinstall the software.
Err_126	Error: Evaluation mask size invalid.	Reset settings to default values.
Err_127	Error: Failed to open file.	Check data integrity of file.
Err_128	Error: Invalid setting in config.json.	Reset settings to default values.
Err_129	Error: Reconstruction json file must contain a reconstruction indicator and a cluster combination.	Reinstall the software.
Err_130	Error: Cannot access file .\config\FanControllerParameters.json.	Reinstall the software.
Err_131	Error: Object in FanControllerParameters.json holds inadequate number of elements.	Reinstall the software.
Err_132	Error: Fast Warmup procedure did not reach the goal temperature given in config.json.	Adjust temperature fields synthesizerTemp (environment + 10 K) and clusterTemp (environment + 5 K) in config.json.
Err_133	Error: Fast Warmup procedure did not reach the goal temperature given in normalization files.	Normalize transmission and reflection and restart software.
Err_150	Error: Hardware initialization failed. Check .\logs\HW_driver*.txt for more details.	See HW_driver.txt for more details.
Err_151	Error: FPGA version needs to be updated.	Reinstall the software and restart the device.
Err_152	Error: Mainboard fan FAN1: Synthesizer defective.	Replace defective fan.
Err_153	Error: Mainboard fan FAN2: Power Supply defective.	Replace defective fan.
Err_154	Error: Mainboard fan FAN3: FPGA defective.	Replace defective fan.
Err_155		
Err_156	Error: Mainboard fan FAN5: CEX defective.	Replace defective fan.
Err_157	Error: Cluster 1 fan defective.	Replace defective fan.
Err_158	Error: Cluster 2 fan defective.	Replace defective fan.
Err_159	Error: Raw Data Test failed. Please check output folder for more details.	Check Matlab logfile for more details.
Err_160	Error: Getting part temperatures failed.	Read next entry in errorqueue.
Err_161	Error: Failed to read fan speeds. Check .\logs\HW_driver*.txt for more details.	See HW_driver.txt for more details.
Err_162	Error: Failed to set fan speeds. Check .\logs\HW_driver*.txt for more details.	See HW_driver.txt for more details.
Err_163	Error: Temperature control settings exceed maximum ratings.	Reset settings to default values.
Err_164	Error: Failed to read mainboard FPGA temperature.	Restart device, or replace defective component.
Err_165	Error: Failed to read digital cluster FPGA temperature.	Restart device, or replace defective component.

Error code	Description	Solution
Err_166	Error: Failed to read synthesizer temperature.	Restart device, or replace defective component.
Err_167	Error: Failed to read Tx Tera chip temperature.	Restart device, or replace defective component.
Err_168	Error: Failed to read Rx Tera chip temperature.	Restart device, or replace defective component.
Err_180	Error: No appropriate GPU found.	Check "Display adapters" availability in "Device Manager". Replace graphics card, if necessary.
Err_181	Error: Installed GPU has too less memory.	Check "Display adapters" in "Device Manager". Replace graphics card, if the installed has < 8 GB memory.
Err_200	Error: Error list file is missing.	Reinstall the software.
Err_201	Error: CAL_CONF file does not exist.	Reinstall the software.
Err_202	Error: Save path folder can not be created.	Change save path to a valid path and make sure there is sufficient storage space.
Err_203	Error: Result directory can not be created.	Change save path to a valid path and make sure there is sufficient storage space.
Err_204	Error: Normalization folder is missing.	Normalize the device.
Err_205	Error: Reflection normalization file is missing.	Normalize the device.
Err_206	Error: Loading reflection normalization data failed. Using default normalization data.	Normalize the device.
Err_207	Error: Transmission normalization file is missing.	Normalize the device.
Err_208	Error: Loading transmission normalization data failed. Using default normalization data.	Normalize the device.
Err_209	Error: Result directory does not exist.	Use a valid result directory when loading results.
Err_210	Error: Result volume file does not exist.	Try loading the result without the volume file.
Err_211	Error: Loading savefile failed. File might be corrupted.	Try to repair the corrupted file.
Err_212	Error: File could not be saved.	Change save path to a valid path and make sure there is sufficient storage space.
Err_213	Error: Configuration file config.json is missing.	Reinstall the software.
Err_214	Error: Configuration file config.json is corrupted.	Reinstall the software.
Err_215	Error: Tolerance file is corrupted.	Try to repair the corrupted file.
Err_216	Error: Tolerance file is missing.	Specify a valid tolerance file.
Err_217	Error: Could not save normalization data.	Make sure there is sufficient storage space.
Err_218	Error: Loading calibration data failed.	Calibrate the device or restore calibration data.
Err_219	Error: Calibration data missing.	Calibrate the device or restore calibration data.
Err_220	Error: Failed to save calibration data.	Make sure there is sufficient storage space.
Err_221	Error: Evaluation mask file is corrupted.	Try to repair the corrupted file.
Err_222	Error: Evaluation mask file is missing.	Specify a valid evaluation mask.
Err_223	Error: Evaluation mask file is incompatible.	Specify a valid evaluation mask.

Error code	Description	Solution
Err_224	Error: Loading of calGeometryError.mat failed.	Reinstall the software.
Err_225	Error: Reflection normalization failed. Not a valid reference plate position.	Make sure the metal plate for the normalization is parallel to the antenna cluster surfaces, or disable the position check.
Err_226	Error: Transmission normalization failed. Main transmission is not centered.	Make sure the space between the clusters is empty, or disable the position check.
Err_227	Error: RawDataTest of synthesizer ref. channel failed.	Call your service representative.
Err_228	Error: RawDataTest of LO/RF swap failed.	Make sure that the LO and RF cabels are correct connected.
Err_229	Error: RawDataTest of badChannels failed.	Call your service representative.
Err_230	Error: RawDataTest of SNR and signal power failed.	Call your service representative.
Err_231	Error: RawDataTest of cluster swap failed.	Make sure that cluster modules are connected to the correct cascade.

16 Maintenance, storage and disposal

The product does not require regular maintenance. It only requires occasional cleaning. It is however advisable to check the nominal data from time to time.

16.1 Cleaning

The R&S QAR50 and its accessories are sensitive devices. Clean the R&S QAR50 in an appropriate manner to prevent the components from getting damaged.

Cleaning the R&S QAR50

1. Clean the measurement electronics (cluster and calibration sphere) only if necessary (visible dirt particles). If cleaning these parts becomes necessary, do so carefully with a dry, lint-free duster.
   Do not use liquids to clean the measurement electronics. Using liquids can lead to inaccurate measurements.

2. Clean the frame and rear side of the R&S QAR50 with a lint-free duster. For stubborn dirt, you can also wipe the frame and rear side with a damp rag.

3. We recommend not to clean the absorbers, because they can break easily. If the absorbers become too dirty, contact Rohde & Schwarz service to replace them with new ones.

Cleaning the verification kit

► Clean the verification kit with a soft, lint-free dust cloth. If necessary, you can dampen the cloth.
   Do not use chemical cleaning agents or solvents like alcohol or cellulose lacquer thinners.

16.2 Storage

Protect the product against dust. Ensure that the environmental conditions, e.g. temperature range and climatic load, meet the values specified in the specifications document.

16.3 Disposal

Rohde & Schwarz is committed to making careful, ecologically sound use of natural resources and minimizing the environmental footprint of our products. Help us by disposing of waste in a way that causes minimum environmental impact.

Disposing of electrical and electronic equipment

A product that is labeled as follows cannot be disposed of in normal household waste after it has come to the end of its life. Even disposal via the municipal collection points for waste electrical and electronic equipment is not permitted.

Figure 16-1: Labeling in line with EU directive WEEE

Rohde & Schwarz has developed a disposal concept for the eco-friendly disposal or recycling of waste material. As a manufacturer, Rohde & Schwarz completely fulfills its obligation to take back and dispose of electrical and electronic waste. Contact your local service representative to dispose of the product.

17 Contacting customer support

Technical support – where and when you need it

For quick, expert help with any Rohde & Schwarz product, contact our customer support center. A team of highly qualified engineers provides support and works with you to find a solution to your query on any aspect of the operation, programming or applications of Rohde & Schwarz products.

Contact information

Contact our customer support center at www.rohde-schwarz.com/support, or follow this QR code:

Figure 17-1: QR code to the Rohde & Schwarz support page

18 Transporting

Lifting and carrying

See:

*   "Lifting, carrying and installing the product" on page 8

Packing

Use the original packaging material. It consists of antistatic wrap for electrostatic protection and packing material designed for the product.

If you do not have the original packaging, use similar materials that provide the same level of protection. You can also contact your local Rohde & Schwarz service center for advice.

Securing

When moving the product in a vehicle or using transporting equipment, make sure that the product is properly secured. Only use items intended for securing objects.

Transport altitude

The maximum transport altitude without pressure compensation is 4500 m above sea level.

List of commands