Products: R&S®ZVA-Z110, R&S®ZVA24, R&S®ZVA40, R&S®ZVT20, R&S®SMF100A

Millimeter-Wave Measurements Using Converters of the R&S®ZVA Family

Application Note 1EZ55

The converters offered for the R&S®ZVA family extend the vector network analyzers' frequency range to include the millimeter-wave range (EHF band). This Application Note describes the R&S®ZVA-Z110 converters. They cover the W band (75 GHz to 110 GHz). Several measurement examples are included, explaining in detail how to configure a converter-based vector network analyzer system.

ROHDE & SCHWARZ

Subject to change - Michael Hiebel, 09.2007 - 1EZ55_0E

Contents

1. Features

The R&S®ZVA-Z110 converters from Rohde & Schwarz offer the following features:

- The converters feature an integrated attenuator (power adjusting screw) by which the output power of the waveguide test port can be controlled manually.
- Using a suitable waveguide power sensor, you can perform power calibration of the analyzer's reference and measurement receivers. You can then carry out calibrated measurements of wave quantities by means of these receivers. Compared with a direct measurement using a power meter, the measurement performed with the analyzer offers wider dynamic range and higher measurement speed.
- By combining the above two features, you can accurately set the power of the stimulus signal by manual control.
- The converters are shaped so that the screw-connected flange joints are easily accessible.
- The converters come with two exchangeable test port adapters, which makes them compatible with a variety of waveguides.
- The converters can be set up on four or three feet, or using no feet at all, depending on requirements. Using three feet greatly facilitates alignment of the test port flange.
- The converters are of compact design, which facilitates their use in wafer probers and with other applications where space is at a premium.
- The converters are cooled passively, i.e. without using a fan. This is of advantage in particle-sensitive environments; plus, it ensures silent operation.
- The converters come with a storage box to protect them during periods of non-use.
- A special converter control software option available for the R&S®ZVA and R&S®ZVT20 allows the fast and easy configuration of typical measurement tasks. After you have selected the converter type and the cabling scheme, the unit performs all other settings automatically, including all frequency conversion ratios as well as the selection of the test port type (e.g. WR10) and the calibration kit.
- The converters can be operated below their specified minimum frequency, i.e. their operating range can be extended into the next lower band. In other words, R&S®ZVA-Z110 converters can also perform measurements outside the W band operating on frequencies of 60 GHz or higher. In this case, compliance with specified data cannot be fully ensured; this applies in particular when the waveguide is operated in the vicinity of its cutoff frequency.
- The converters come with a universal input AC adaptor including four different AC plugs for nearly all conventional mains sockets.
- The concept of the converters and the related network analyzer also features multiport measurements involving more than two converters (for more details see reference [5]).

2. Key Specifications

Key specifications of the R&S®ZVA-Z110 converters[1]:

Frequency range	75 GHz to 110 GHz
Test port output power	+2 dBm with +7 dBm at *RF IN*
Accuracy of output power	< 4 dB (with 0 dB power attenuation)
Manual power attenuation	0 dB to 25 dB
Dynamic range	95 dB (typ. 110 dB)
Input power at *RF IN*, *LO IN*	+5 dBm to +10 dBm (ideally +7 dBm)
Plug-in power supply	100 V to 240 V, 47 Hz to 63 Hz

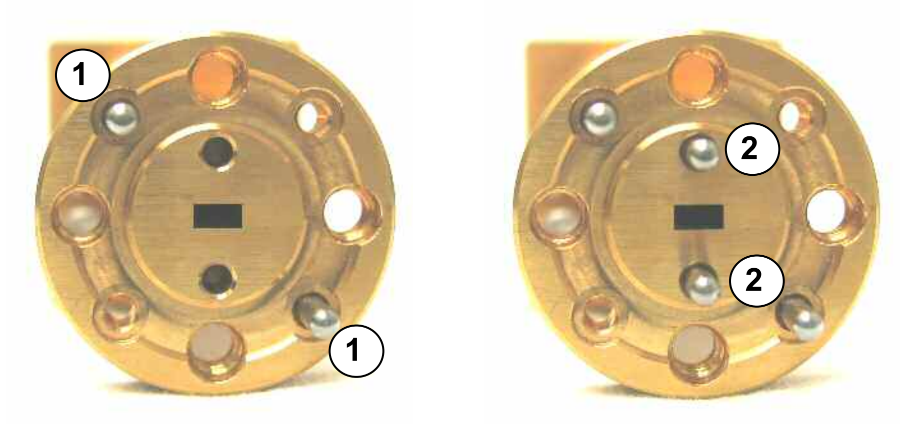

Fig. 2.1: UG-387 precision anti-cocking flange without and with indexing pins

For waveguides above 50 GHz, the UG-387 flange is most commonly used. The converters are compatible with this flange. In accordance with the MIL specification, the UG-387 flange is to be used with alignment pins (Fig. 2.1 ①) with a diameter of 1.565 mm (0.0615 in) [2]. This diameter is supported by numerous manufacturers (e.g. Aerowave, Inc., Custom Microwave, Inc., M/A-COM/Tyco Electronics Ltd., and Flann Microwave Ltd.). Alignment pins with other diameters are also commonly used; an important manufacturer is Agilent Technologies, Inc., offering pins with a diameter of 1.605 mm (0.0630 in). To ensure compatibility also with this variant of the UG-387 flange, the converters come with two different variants of test port adapter (Fig. 2.2). One of the adapters is designed for use with 1.565 mm alignment pins. It makes highly accurate contact even without using indexing pins in addition (Fig. 2.1 ②). The second adapter is designed for use with alignment pins of both 1.565 mm and 1.605 mm in diameter. To achieve contacting as accurate as possible, it is advisable to use indexing pins in addition. Indexing pins are available for both test port adapters (precision flanges). The test port adapters have an outer rim that is designed to prevent cocking of the flanges relative to each other (anti-cocking flanges). It is also possible to connect DUTs with standard flanges (i.e. flanges not featuring the anti-cocking or precision characteristics mentioned above) to the test port adapters.

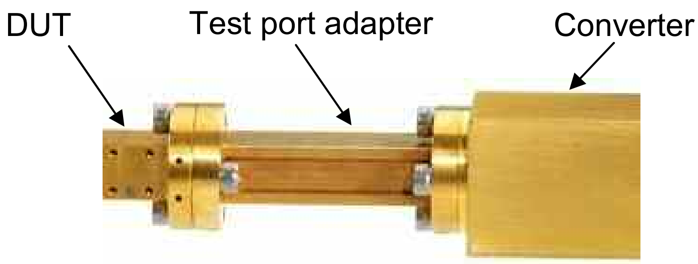

Fig. 2.2: Recommended configuration for connecting a DUT to a converter

[1] For binding data sheet specifications refer to the latest version of reference [1].

3. General Requirements and Operating Principle

The figure below is a transparent CAD representation of an R&S®ZVA-Z110 converter. It has the following main function blocks:

① Source multiplier, which produces the generator signal by way of multiplication

② Waveguide attenuator with power adjusting screw

③ Two harmonics mixers for converting the measurement and the reference channel to a fixed IF

④ Directional coupler to separate incident and reflected wave

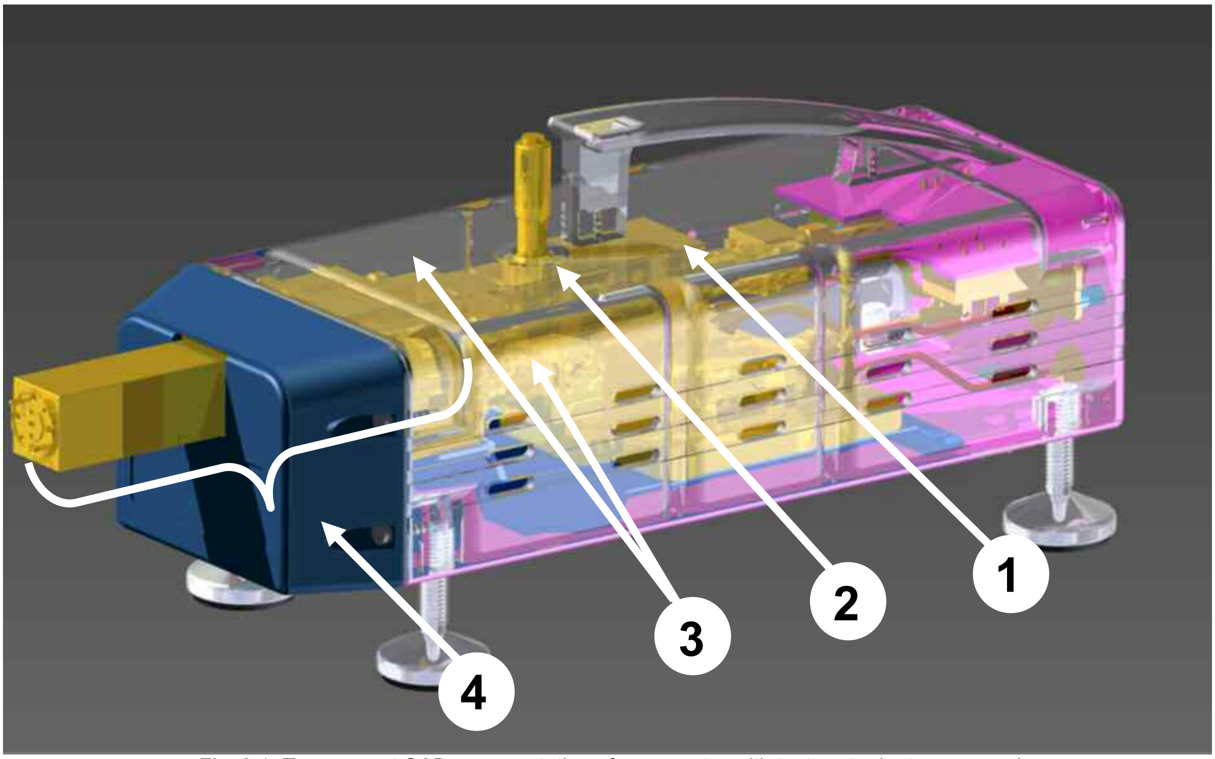

Fig. 3.1: Transparent CAD representation of a converter with test port adapter removed

For the purpose of this Application Note, it is assumed that an R&S®ZVA or R&S®ZVT network analyzer with a suitable upper frequency limit of at least 20 GHz (e.g. R&S®ZVA24, R&S®ZVA40, or R&S®ZVT20) is used. Two standard configurations will be discussed:

- Configuration of the converters without external generators
- Configuration of the converters with an external LO generator

For both configurations, the use of the following network analyzer options is assumed:

- R&S®ZVA-B16 or R&S®ZVT-B16 direct generator/receiver access
- R&S®ZVA-K8 converter control software

Further options may be required to control the external LO generator or a power meter, depending on the test setup.

4. Measurement Examples

When configuring a millimeter-wave test setup, some basic rules have to be observed. For more detailed information, refer to section 5.1 of the attachment. This Application Note discusses one-port and two-port measurements by means of the R&S®ZVA-Z110 converters. Another Application Note [5] deals with multiport measurements (i.e. measurements with three or more waveguide test ports).

Overview of measurement examples:
Following is a brief description of the measurement examples included in this Application Note so that the reader can easily choose the appropriate example:

Measurement example, section 4.1:

- Typical two-port DUT using WR-10 waveguide technology
- Compact test setup containing an R&S®ZVA four-port network analyzer and two R&S®ZVA-Z110 converters
- Typical sequence of steps required for measuring a passive DUT
- Typical measurement quantities of a filter

Measurement example, section 4.2:

- Reflection measurement on a one-port DUT using WR-10 waveguide technology
- In difference to section 4.1, only one converter is required, because only a one-port measurement is performed
- Use of a four-port network analyzer. Alternatively a two-port network analyzer with an external signal generator can be used (see measurement example in section 4.3).
- The example includes additional equipment such as the R&S®FSU and the R&S®FS-Z110. Normally, the DUT takes the place of this equipment.
- Setting of the output power of the waveguide test port (power adjusting screw)
- Calibration by means of a *Sliding Match*

Measurement example, section 4.3:

- Measurement of an active component using WR-10 waveguides
- Alternative test setup to that described in section 4.1
- Use of an R&S®ZVA two-port network analyzer, an external signal generator, and two converters
- Configuration and control of external signal generator by means of network analyzer

What test setup should preferably be used?
Whether you use a test setup with or without an external signal generator will in many cases depend on your existing pool of test equipment. Apart from this, the advantages offered by a test setup without an external signal generator should be taken into account, i.e.:

- Faster sweep rates
- Easier configuration
- Highly compact test setup

4.1 S-Parameter Measurements on a Filter

Measurement task:

A 90 GHz bandpass filter is to be tested. Transmission S_{21} and reflection S_{11} are to be determined. For S_{21}, the cutoff frequencies and the group delay are to be measured.

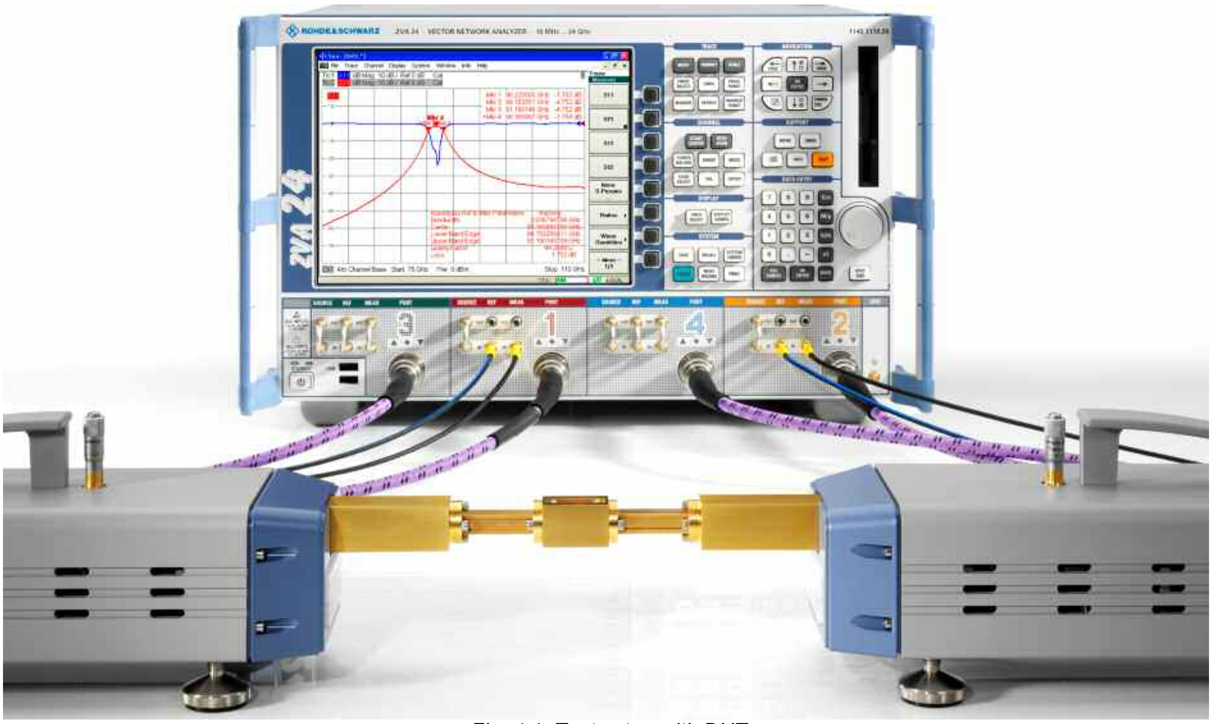

Fig. 4.1: Test setup with DUT

Step 1: Configuring the converters

Select the converter type (ZVA-Z110 in this case) and the cabling scheme (internal RF, internal LO (*RF intern*, *LO intern*) in this case). Activate the setting with *Apply* and terminate the dialog with *Close*.

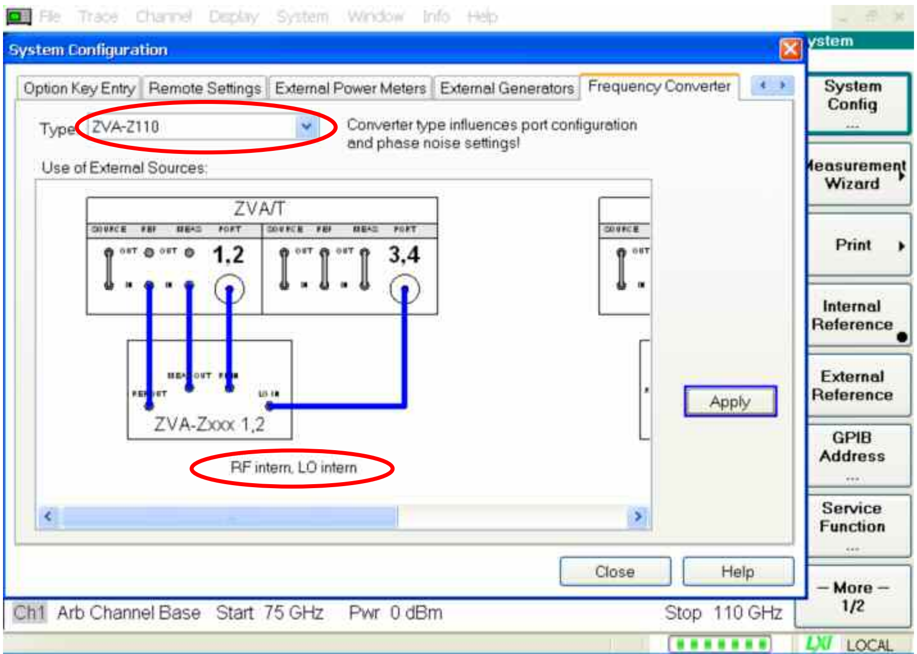

Fig. 4.2: Configuring the converters on the R&S®ZVA

The network analyzer is now configured for operation with the converters. This becomes first obvious by the stimulus axis at the bottom of Fig. 4.2 changing to the range of 75 GHz to 110 GHz. Other settings are influenced as well, for example the test port type (important for calibration). The basic configuration thus created will be restored after a preset. The parameters have to be altered to the needs of the present measurement task as follows:

- Measurement bandwidth: 100 Hz
- Number of test points: 801
- Trc1 trace for parameter S_{21}
- Trc2 trace for parameter S_{11}

Step 2: Connecting the converters
Connect the converters to the network analyzer in accordance with the selected cabling scheme (see also Fig. 4.3). The R&S®ZVA contains two internal source oscillators that deliver the signals necessary for the converters. These oscillators are permanently assigned to ports 1 and 2, and ports 3 and 4, respectively. After step 1 is completed, the network analyzer is set so that the stimulus oscillator 1 provides the RF source signal for the converters and the stimulus oscillator 2 the LO signal for the converters. The REF and MEAS IF signals are feed to the R&S®ZVA via the external receiver inputs of ports 1 and 2. The network analyzer, therefore, treats the waveguide test ports of the converters as ports 1 and 2. Hence, the parameter S_{21} expresses the transmission from converter 1 to converter 2, for example.

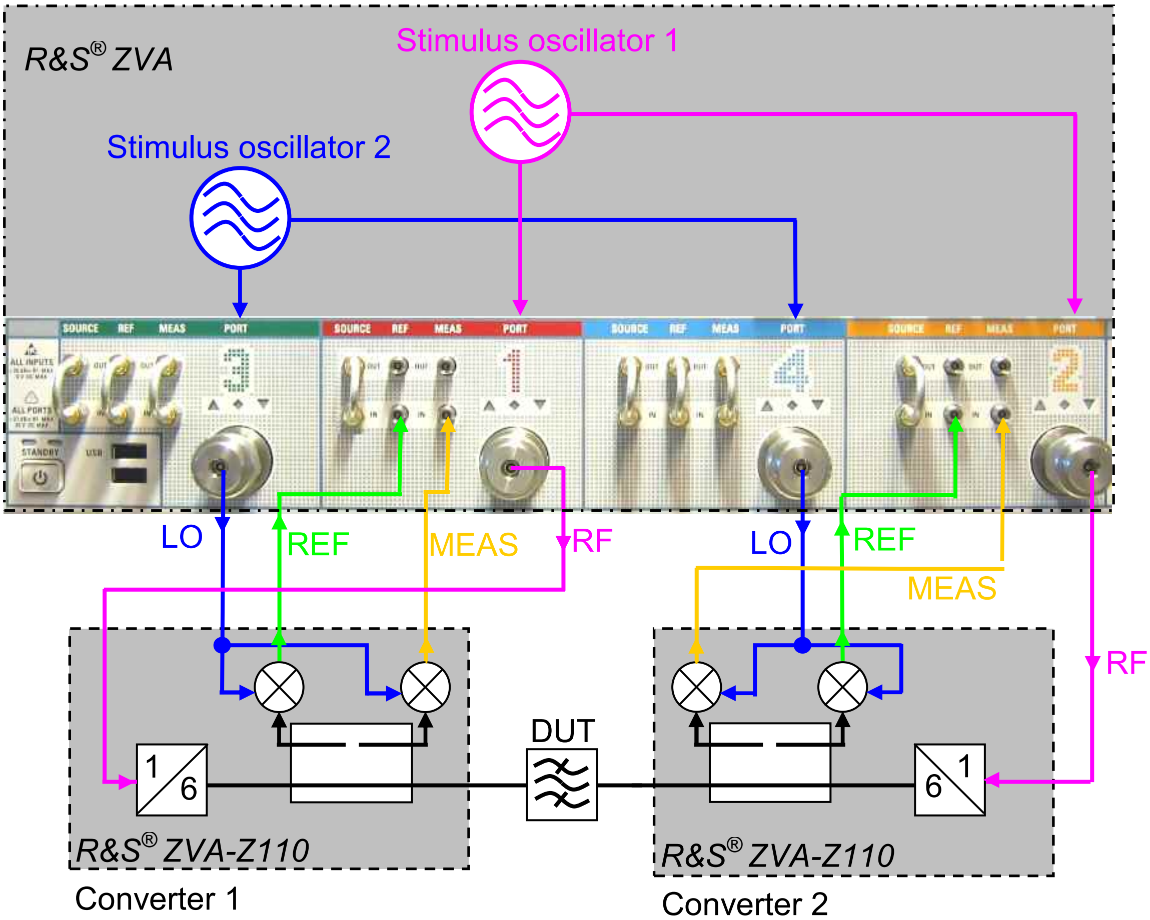

Fig. 4.3: Cabling scheme for two converters and a four-port R&S®ZVA without an external generator

Set the power adjusting screw on the converters for minimum attenuation. Minimum attenuation will be obtained for all settings > 2 mm.

Fig. 4.4: Power adjusting screw

We recommend that you use a test port adapter (Fig. 2.2) in all measurements you make. This will effectively protect the converter flange against contamination, wear, scratching, or similar impairments.

Step 3: Calibration

To ensure that system errors are eliminated when performing the S-parameter measurements, the test setup is to be calibrated. This is done using the R&S®ZV-WR10 calibration kit. In this example, the TOSM calibration technique is used. Select the R&S®ZV-WR10 calibration kit.[1] The converters are designed such that the flange joints are easily accessible from all sides.

Fig. 4.5: Screwing a waveguide flange to its counterpart, e.g. a DUT

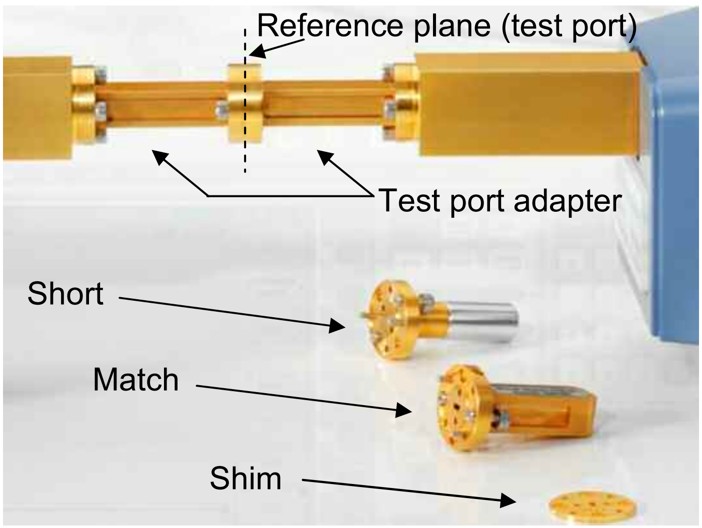

Fig. 4.6: (Direct) Through and other calibration standards

Mount the one-port calibration standards shown in Fig. 4.6 to test ports 1 and 2 one at a time and trigger a calibration measurement every time. The

[1] We recommend that you use the R&S® ZV-WR10 calibration kit. You can also define a waveguide calibration kit of your own. To do this, refer to the interactive help function of the R&S® ZVA.

one-port standards are: a *Short*, an *Offset Short* (made up of a *Short* and a *Shim*[1]), and a *Fixed Match*. When mounting the calibration standards, make sure to evenly tighten the connecting screws on the waveguide flange.[2] The *Through* standard is provided by directly screwing together the two waveguide test ports as shown in Fig. 4.6.

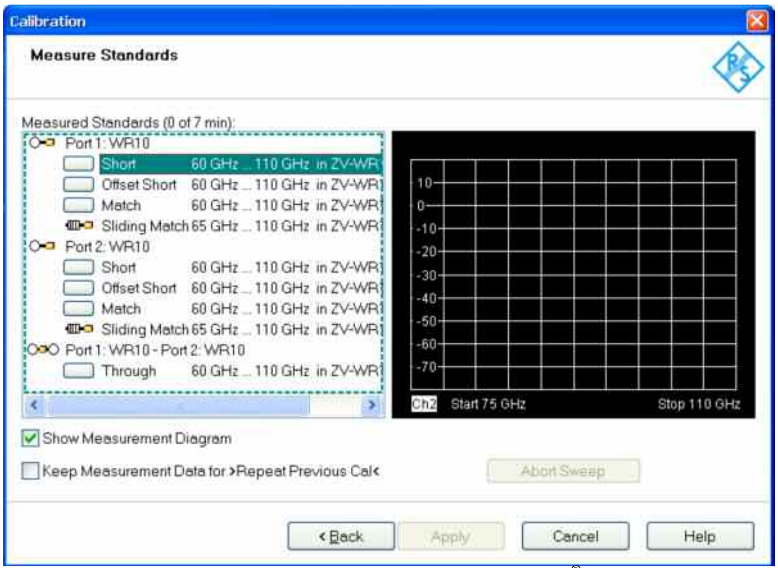

Fig. 4.7: Calibration dialog: TOSM calibration using the R&S®ZV-WR10 calibration kit

A *Sliding Match* is optionally available for the R&S®ZV-WR10 calibration kit. Its use is described in measurement example 4.2.

Step 4: Connecting the DUT

Mount the DUT between the waveguide test ports. The test setup as shown in Fig. 4.1 is now complete. Using the *Bandwidth Marker* function, you can read the filter's 3 dB bandwidth and center frequency directly from the trace.

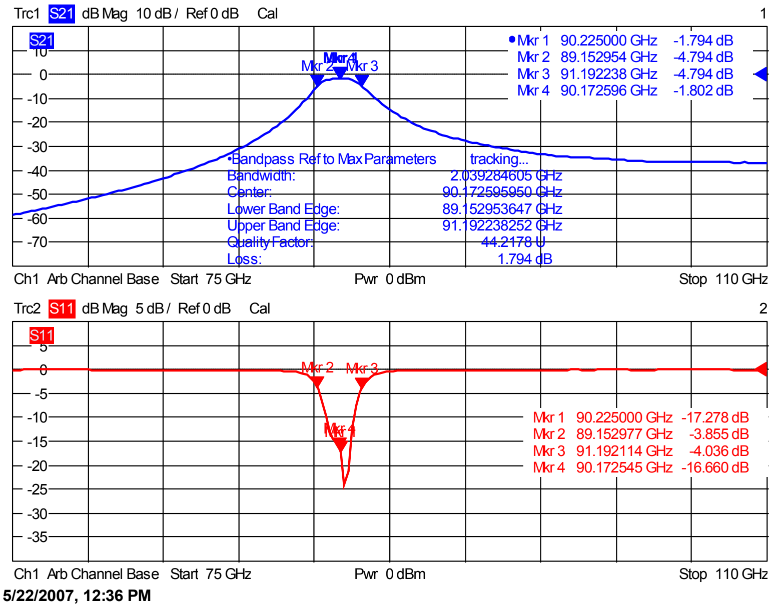

Fig. 4.8: Results of bandpass filter measurement

[1] An *Open* standard cannot be implemented in configurations based on waveguide technology because of the radiation losses occurring at an open end of a waveguide. To obtain an additional reflection standard, a *Short* is used that is appropriately transformed by means of a small waveguide section referred to as a *Shim*.

[2] To further enhance accuracy, you can use the additional indexing pins (see Fig. 2.1 ②) to fix the standards of the R&S®ZV-WR10 calibration kit.

Step 5: Measuring the group delay

To perform the measurement based on the 3 dB cutoff frequencies (see marker in the upper trace of Fig. 4.8), this trace is used without any modifications. Instead of S_{11}, the lower trace diagram of Fig. 4.9 shows the parameter S_{21} both in terms of phase, and group delay. The network analyzer determines the group delay by way of calculation. For this, an appropriate aperture must be chosen. The selected aperture has an influence on the calculated group delay curve. A value which is too large results in a loss of details. On the other hand, a value which is too small will overemphasize the influence of noise. The default value of *Aperture Steps = 10* is a good compromise in this case. Use the *Trace Statistics* function to calculate the peak-to-peak value of the group delay trace within the 3 dB bandwidth of the DUT. The peak-to-peak value is a quality criterion commonly used for filters.

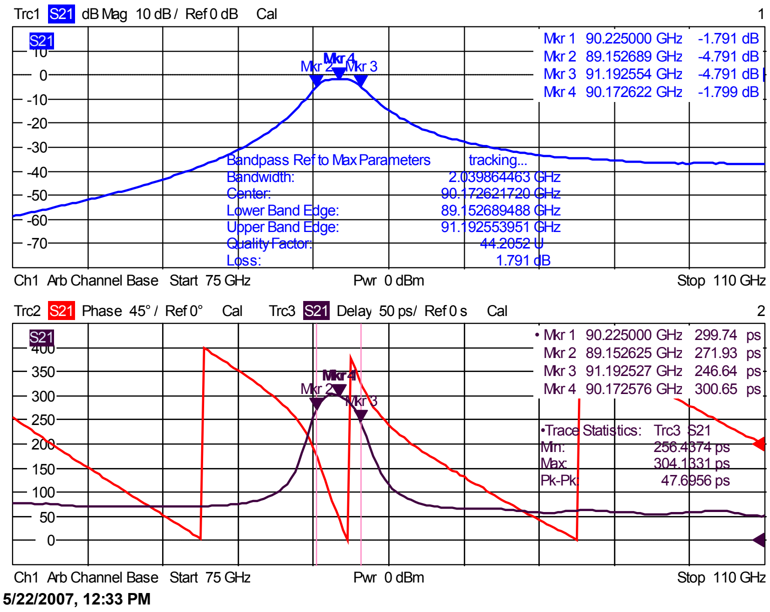

Fig. 4.9: Results of bandpass filter measurement

4.2 Measuring the RF Matching of a Harmonics Mixer

Measurement task:

A harmonics mixer (75 GHz to 110 GHz) is to be tested. Such a mixer is available as an option (R&S®FS-Z110) for the R&S®FSU spectrum analyzer, for example. In the configuration shown in Fig. 4.10, the R&S®FSU delivers the LO signal for the mixer, and records the IF signal returned by the mixer. This configuration and operating mode is a typical application of a harmonics mixer in spectrum analysis. To simulate the operating conditions for the DUT as realistically as possible, an RF power of approx. -15 dBm is to be applied. In this example, only a reflection measurement is performed; a second converter is thus not required.

Step 1: Creating the test setup

- Configure and connect the converter analogously to section 4.1.
- Set further parameters on the R&S®ZVA:
  - Measurement bandwidth 100 Hz
  - Parameter S_{11}
  - dB magnitude (*dB Mag*) format
- Configure the mixer on the spectrum analyzer and connect it to the spectrum analyzer. For details, see operating manual for the R&S®FS-Z110 option.

- Synchronize the R&S®ZVA to the spectrum analyzer by means of the 10 MHz reference signal.

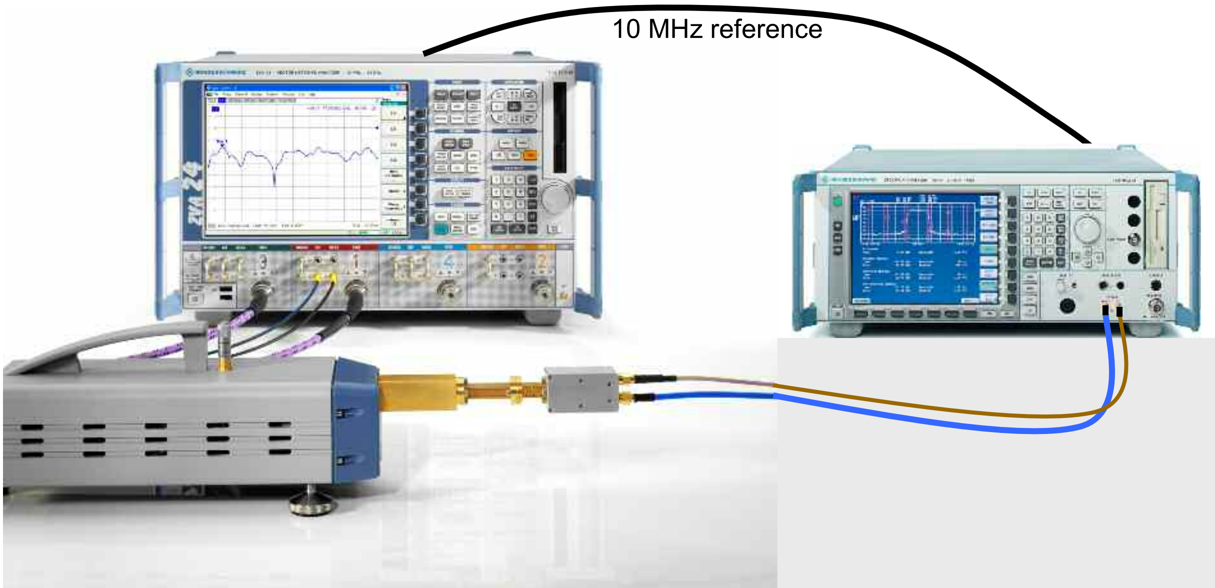

Fig. 4.10: Test setup for measuring the RF matching of the R&S®FS-Z110 mixer

Step 2: Setting the power

By turning the power adjusting screw (Fig. 4.4) in the direction toward 0 mm (clockwise direction), the test port output power will be lowered. For reasons inherent in the device, appreciable attenuation will not be reached until a value smaller than 2 mm is set. Using a dBm scale on the power adjusting screw to indicate the output power is not possible because the output power is dependent on a variety of factors (environmental conditions, cables used, etc). Nevertheless, the test port output power can be set directly by using a suitable waveguide power sensor and a power meter. If the power meter is, a suitable one it can be connected to the R&S®ZVA via the R&S®ZVAB-B44 option (USB-to-IEC/GPIB adapter), and its results can be displayed versus the frequency of the stimulus signal. In this example, this approach was taken to set the test port output power to approx. –15 dBm.

Step 3: Calibrating the sliding match

The RF matching of the mixer is determined by means of a one-port measurement. Calibration is performed using the OSM technique. There is also a variant of the R&S®ZV-WR10 calibration kit that contains a *Sliding Match* in addition to the standards described above. This variant is recommended in particular if you want to perform highly accurate reflection measurements. In this example, the *Sliding Match* is used instead of the *Fixed Match* as a calibration standard. Thus, with the *Fixed Match* not used for calibration, it is available as a verification standard. The *Short* and *Offset Short* standards are used same as in example 4.1, step 3.

Fig. 4.11: Waveguide sliding match of the R&S®ZV-WR10 calibration kit set to 0.35 mm

Waveguide *Sliding Matches* operate on the principle of an absorber moving inside a high-precision waveguide along its longitudinal axis. During calibration, the reflection coefficient of the *Sliding Match* is measured at various positions of the absorber. The accuracy of the *Sliding Match* is not determined primarily by the absorber quality, but by the physical characteristics (precision) of the waveguide that is part of the *Sliding Match*. To be able to calculate a reference value for S_{11} = 0 from the reflection coefficients measured on the *Sliding Match*, six absorber positions are set, and a measurement is performed at each position. It must be ensured that the result of the calculation is unambiguous; for this, the following positions are proposed:[1]

- Scale position 0 mm
- Scale position 0.35 mm
- Scale position 0.8 mm
- Scale position 1.4 mm
- Scale position 2.1 mm
- Scale position 4.2 mm

Terminate the calibration with *Apply*. Next, verify the calibration by using the *Fixed Match* of the calibration kit as a DUT. Compare the measured values of the *Fixed Match* with its specified values. Any deviation of measured values from specified values is indicative of a possible calibration error.

Step 4: Connecting the DUT

Mount the mixer (DUT) to the waveguide test port. The test setup as shown in Fig. 4.10 is now complete. In the trace diagram shown below, the *Max Search* marker function is used to determine the frequency at which the mixer exhibits the greatest mismatch. The associated power value shows that the mixer has a return loss of at least 16 dB. Comparable mixers of other make usually have significantly poorer return loss.

Fig. 4.12: Measuring return loss on the RF port of an R&S®FS-Z110 mixer

[1] Note that the scale positions stated above are only proposed positions. An unambiguous result can also be obtained using other, suitable positions. It is therefore not mandatory to move the absorber exactly to the stated positions. It is important, however, to observe a certain minimum distance between the measurement positions in each case. Furthermore it is necessary to use unequal distances between the positions. The proposed positions are optimal for the 75 GHz to 110 GHz waveguide band. Other bands require other positions.

4.3 Measuring an Amplifier (75 GHz to 100 GHz)

Measurement task:

This measurement task is similar to that described in section 4.1. Alternatively to the test setup described in the following, the measurement can thus also be performed using the test setup described in section 4.1. In the example we are going to discuss now, a test setup with a two-port network analyzer and an external LO generator will be presented. As a generator, the R&S®SMF100A with the R&S®SMF-B31 high output power option and the R&S®SMF-B122 option will be used. **Important:** Do not connect the converters until you have completed step 2.

Step 1: Synchronization and remote control of external generator

Synchronize the R&S®ZVA24 to the 10 MHz reference of the R&S®SMF100A generator. Since the LO frequency for the converters' has to be tracked during the measurement, a remote connection between the generator and the network analyzer is required. In this example, a remote connection is established via the IEC/GPIB bus, using the options R&S®ZVAB-B44 (USB-to-IEC/GPIB adapter) and R&S®SMF-B83 (removable GPIB).[1] After making the connection, you can detect the generator on the network analyzer under *System* | *System Config* | *External Generators* by means of *Refresh Tables*, and add it to the list of configured generators (*Configured:*) by means of *Add v*.

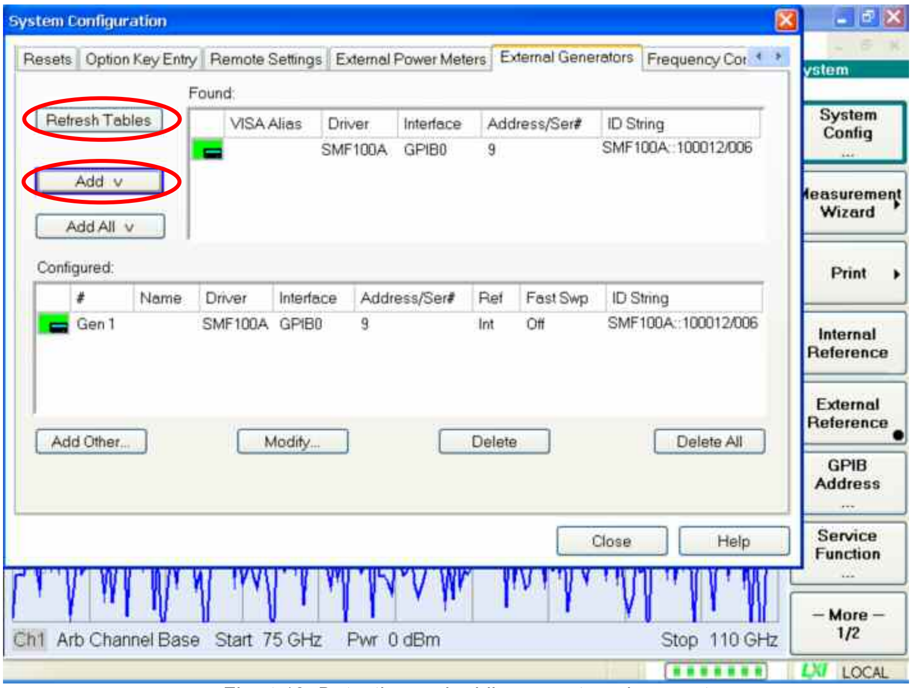

Fig. 4.13: Detecting and adding an external generator

Step 2: Configuring the converters

The converters are configured in the *System Config* dialog using the *Frequency Converter* tab (cf. page 7, Fig. 4.2). Select the converter type (ZVA-Z110 in this case), and then the cabling scheme (internal RF, external LO (*RF intern*, *LO extern*) in this case). Confirm the setting with *Apply*.

[1] Instead of an IEC/GPIB connection, a LAN connection can be used to link up the generator to the network analyzer. The R&S®ZVAB-B44 and R&S®SMF-B83 options will not be needed in this case. Controlling an external generator takes more time than controlling an internal generator of the network analyzer. To accelerate generator tracking during frequency sweeps, the *TRIGGER* and *BLANK* handshake signals of the generator can be applied to the R&S®ZVA USER CONTROL port in addition to an existing remote-control connection. This makes it possible to use the *List* function to perform sweeps. When this function is used, the network analyzer transfers all frequency points to the generator via the remote connection (GPIB or LAN) prior to the start of the sweep. During the frequency sweep (or repeated frequency sweeps), the handshake signals are used exclusively to switch to the next frequency point.

Step 3: Connecting the converters
The generator delivers the LO signal, which is distributed to the two converters via a power splitter. The test ports 1 and 2 of the network analyzer deliver the RF stimulus signal for the converters. The RF stimulus signal is applied to the converters alternately, i.e. to only one converter at a time, depending on the measurement direction. The IF from the converters is tapped via the *REF IN* and *MEAS IN* direct receiver inputs of the analyzer.

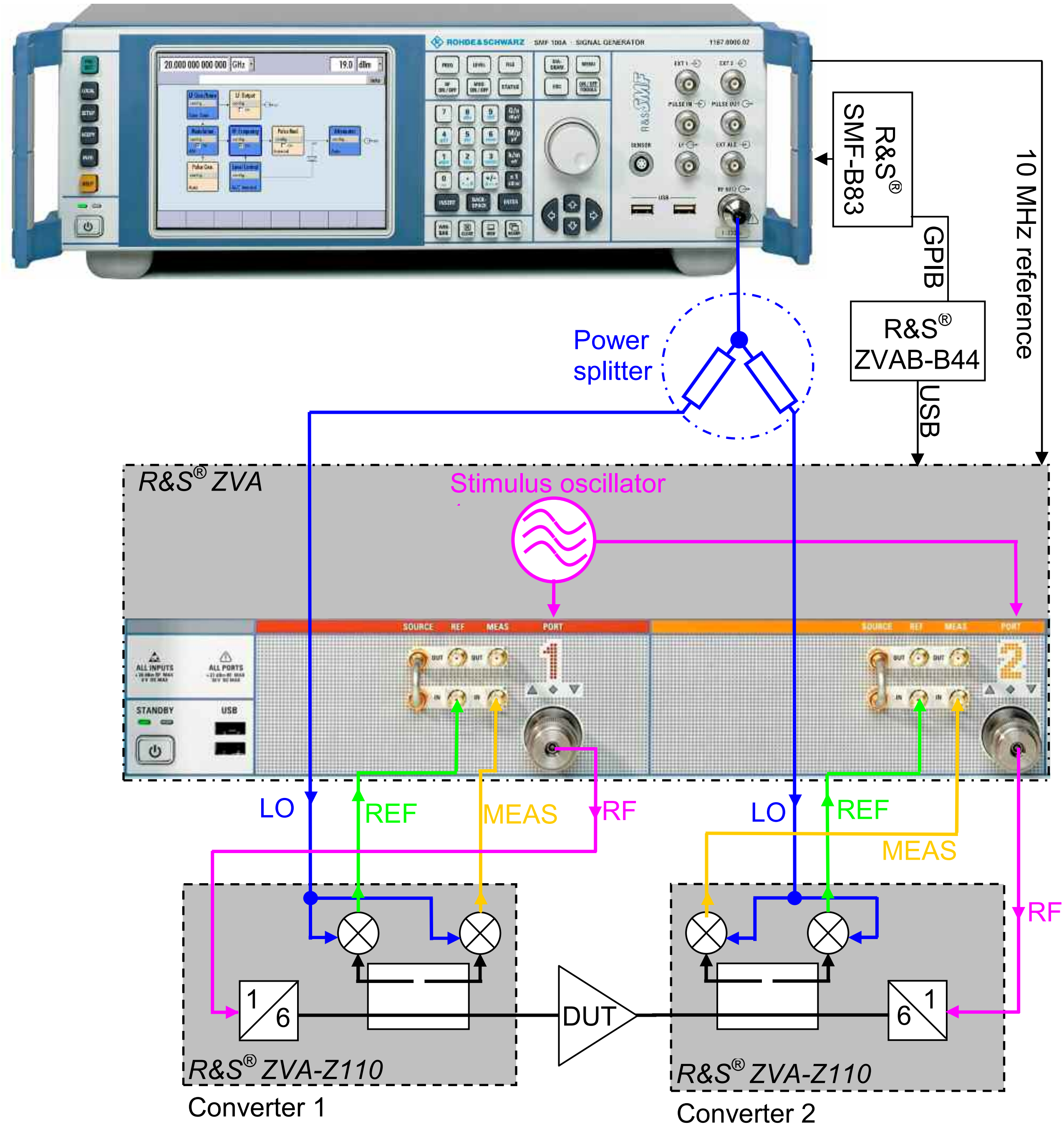

Fig. 4.14: Test setup with an external LO generator

The optimal LO input power for an R&S®ZVA-Z110 converter is 7 dBm. Since test setups including only one converter – and therefore no power splitter – are also possible, the generator output power is automatically set to 7 dBm in step 2. In a two-converter configuration, however, an insertion loss of 6 dB is to be assumed for the power splitter. This means that the generator output power must be increased in the example presented here. The value automatically set in step 2 can be modified under *Mode* | *Port Config* on the R&S®ZVA. For the configuration discussed here, the value is to be increased as follows: 7 dBm + 6 dB = 13 dBm. The recommended measurement bandwidth is 1 kHz or 100 Hz. Traces are to be created (*Add Trc*) for each of the four S-parameters of the two-port test configuration.

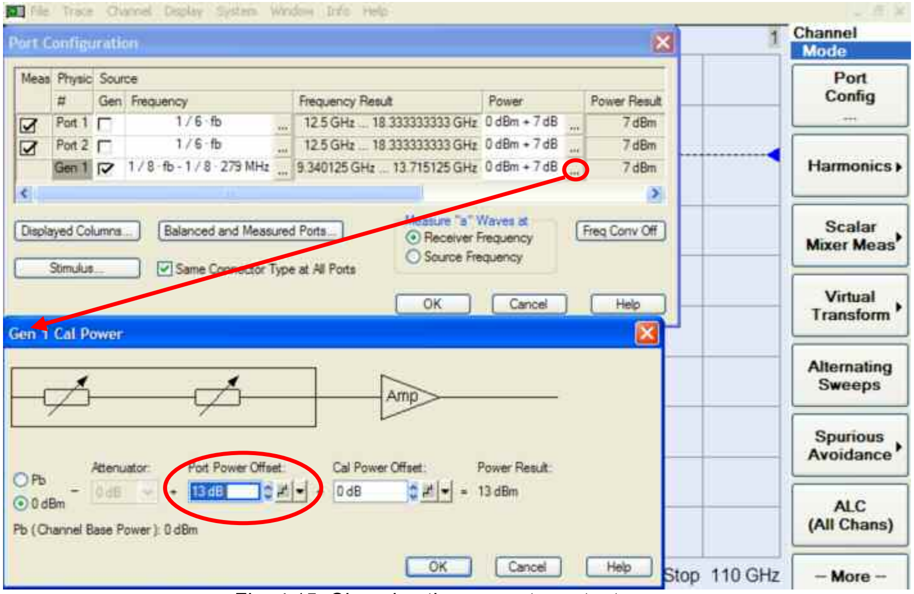

Fig. 4.15: Changing the generator output power

Step 4: Setting the power
A power of approx. +1 dBm is needed for the measurement. This corresponds to the nominal output power of the R&S®ZVA-Z110 converter without any power reduction. The power adjusting screw (see Fig. 4.4) is set to minimum attenuation with all settings higher than 2 mm. An extra power meter is therefore not required for power setting.

Step 5: Calibration
Calibration can be performed, for example, with the TOSM technique (see section 4.1, step 3). In this case, the TOM technique was chosen because it requires only the *Through*, *Offset Short* (made up of a *Short* and a *Shim*), and *Fixed Match* standards to be mounted. Moreover, the TOM technique features an implicit error control.

Step 5: Measurement
Mount the DUT (IAF MDMAW01BM amplifier) between the converters' test ports and apply the supply voltage to the DUT.

Fig. 4.16: Amplifier mounted between two R&S®ZVA-Z110 converters (DUT by courtesy of Fraunhofer Institute for Applied Solid-State Physics, Freiburg/Germany)

The diagram below shows the traces obtained for the four S-parameters of the amplifier.

Fig. 4.17: Measurement results obtained for an IAF MDMAW01BM amplifier

Fig. 4.17 shows that the DUT has a forward transmission coefficient (S_{21}) of approx. 10 dB to 13 dB and a reverse transmission coefficient (S_{12}) of at least 50 dB.

5. Attachment

5.1 General Information

The information given in the following is meant to help you reproduce the discussed measurement examples as accurately as possible and to avoid errors. It is not meant to replace the relevant instrument documentation.

- Waveguide flanges are high-precision mechanical components that may be damaged by improper handling, for example by cocking of the flanges relative to each other. Make sure, therefore, to set up the test equipment on an even and stable surface. Flanges must be properly aligned relative to each other before they are mounted.
- Do not operate the converters above their maximum permissible input power otherwise they may be damaged. Therefore, prior to making the RF and LO connections to the converters, make sure that their maximum specified input power is not exceeded. Prior to connecting the converters, you should always select the correct converter type and cabling scheme in the *Frequency Converter* configuration dialog (see Fig. 4.2), and activate the setting with *Apply*.
- The converters operate on the principle of frequency multiplication. Along with the frequencies of the RF and the LO signal, any phase errors of these signals will be multiplied, too. Phase errors may result, for example, from the use of unsuitable cables for the RF and LO connections. By contrast, the IF signals, which have a frequency of approx. 300 MHz, can be considered uncritical in this respect.
- Another avoidable cause of phase errors is the improper mounting of coaxial connectors. A suitable torque wrench should therefore be used for mounting the connectors.
- Temperature fluctuations inevitably lead to phase drift due to the longitudinal expansion of the coaxial cables (RF, LO) and waveguide

components. High temperature stability is therefore a vital prerequisite for performing high-accuracy millimeter-wave measurements.

5.2 Waveguide Frequency Bands

The following table, which is taken from reference [4], lists typical rectangular waveguide cross sections. For each band, the table states the operating frequency range commonly used, the cutoff frequency (i.e. the frequency from which wave propagation is possible in a waveguide), and the internal dimensions. For cross sections smaller than WR-3, no binding designation has yet been defined; this also applies to the Y, J, and H letter codes.

Operating frequency in GHz	Waveguide band	Cutoff frequency in GHz	Designation EIA (US)	Designation RCSR (UK)	Internal dimensions in mm (in inches)
50 – 75	V	39.8616	WR-15	WG 24	3.7592 × 1.8796 (0.148 × 0.074)
60 - 90	E	48.3567	WR-12	WG 25	3.0988 × 1.5494 (0.122 × 0.061)
75 – 110	W	58.9951	WR-10	WG 27	2.5400 × 1.2700 (0.100 × 0.050)
90 – 140	F	73.7439	WR-8	WG 28	2.0320 × 1.0160 (0.080 × 0.040)
110 – 170	D	90.7617	WR-7	WG 29	1.6510 × 0.8255 (0.065 × 0.0325)
140 – 220	G	115.6767	WR-5	WG 30	1.2954 × 0.6477 (0.051 × 0.0255)
170 – 260	(Y)	137.1980	WR-4	WG 31	1.0922 × 0.5461 (0.043 × 0.0215)
220 – 325	J(H)	173.5151	WR-3	WG 32	0.8636 × 0.4318 (0.034 × 0.017)
325 – 500	Y	268.1596	WR-2.2	-/-	0.5588 × 0.2794 (0.0220 × 0.0110)
500 – 750		393.3008	WR-1.5	-/-	0.3810 × 0.1910 (0.0150 × 0.0075)
750 – 1000		589.9512	WR-1	-/-	0.2540 × 0.1270 (0.0100 × 0.0050)

Table 5.1: Rectangular waveguide cross sections based on EIA and RCSR

6. References

[1] "R&S® ZVA-Z110 Converter WR10 Specifications", Rev. 01.00, Rohde & Schwarz GmbH & Co. KG, June 2007

[2] Kerr, A. R., Wollack, E., and Horner, N.: "ALMA Memo No. 278: Waveguide Flanges for ALMA Instrumentation"; ALMA/National Radio Astronomy Observatory, Nov. 1999

[3] "Quick Start Guide: R&S®ZVA-Z110 Converter WR10", Rev. 1.0, Rohde & Schwarz GmbH & Co. KG, June 2007

[4] Hiebel, Michael: "Fundamentals of Vector Network Analysis", Rohde & Schwarz GmbH & Co. KG, 2nd Edition, 2007, ISBN 978-3-939837-06-0

[5] Hiebel, Michael: "Application Note 1EZ56: Multiport Millimeter-Wave Measurements Using Converters of the R&S®ZVA Family", Rohde & Schwarz GmbH & Co. KG, 2007

7. Ordering Information

Measurement example, section 4.1

2	Converters WR10	R&S®ZVA-Z110	75 GHz to 110 GHz	1307.7000.02
4	Test Port Cables, 965 mm, 3.5 mm (f)/3.5 mm (m)	R&S®ZV-Z193	0 Hz to 26.5 GHz	1306.4520.36
1	Waveguide Calibration Kit WR10	R&S®ZV-WR10	without Sliding Match	1307.7100.10
1	Vector Network Analyzer, 24 GHz, 4 ports	R&S®ZVA24	10 MHz to 24 GHz	1145.1110.26
1	Direct Generator/Receiver Access (option)	R&S®ZVA24-B16		1164.0209.26
1	Converter Control Software (option)	R&S®ZVA-K8		1307.7022.02

Measurement example, section 4.2

1	Converters WR10	R&S®ZVA-Z110	75 GHz to 110 GHz	1307.7000.02
2	Test Port Cables, 965 mm, 3.5 mm (f)/3.5 mm (m)	R&S®ZV-Z193	0 Hz to 26.5 GHz	1306.4520.36
1	Waveguide Calibration Kit WR10	R&S®ZV-WR10	with Sliding Match	1307.7100.11
1	Vector Network Analyzer, 24 GHz, 4 ports	R&S®ZVA24	10 MHz to 24 GHz	1145.1110.26
1	Direct Generator/Receiver Access (option)	R&S®ZVA24-B16		1164.0209.26
1	Converter Control Software (option)	R&S®ZVA-K8		1307.7022.02

For the DUT: R&S®FS-Z110 external mixer and R&S®FSU3 spectrum analyzer with R&S®FSU-B21 option

Measurement example, section 4.3

2	Converters WR10	R&S®ZVA-Z110	75 GHz to 110 GHz	1307.7000.02
4	Test Port Cables, 965 mm, 3.5 mm (f)/3.5 mm (m)	R&S®ZV-Z193	0 Hz to 26.5 GHz	1306.4520.36
1	Waveguide Calibration Kit WR10	R&S®ZV-WR10	without Sliding Match	1307.7100.10
1	Vector Network Analyzer, 24 GHz, 2 ports	R&S®ZVA24	10 MHz to 24 GHz	1145.1110.24
1	Direct Generator/Receiver Access (option)	R&S®ZVA24-B16		1164.0209.24
1	Converter Control software (option)	R&S®ZVA-K8		1307.7022.02
1	USB-to-IEC/*GPIB* Adapter (option)	R&S®ZVAB-B44		1302.5544.02
1	Microwave Signal Generator	R&S®SMF100A		1167.0000.02
1	Frequency Range 1 GHz to 22 GHz (option)	R&S®SMF-B122	1 GHz to 22 GHz	1167.7004.02
1	High Output Power 1 GHz to 22 GHz (option)	R&S®SMF-B31	1 GHz to 22 GHz	1167.7404.02
1	Removable GPIB (option)	R&S®SMF-B83		1167.6408.02

Additional equipment required:

Power splitter, SMA/3.5 mm (e.g. Weinschel/Aeroflex model 1579, or Weinschel/Aeroflex model 1534, or a similar product)

For all ordering information please note:

Cables with ruggedized connectors (e.g. R&S®ZV93, 1301.7595) cannot be used for connecting the R&S®ZVA to the R&S®ZVA-Z110 converters because of the large dimensions of these connectors.

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