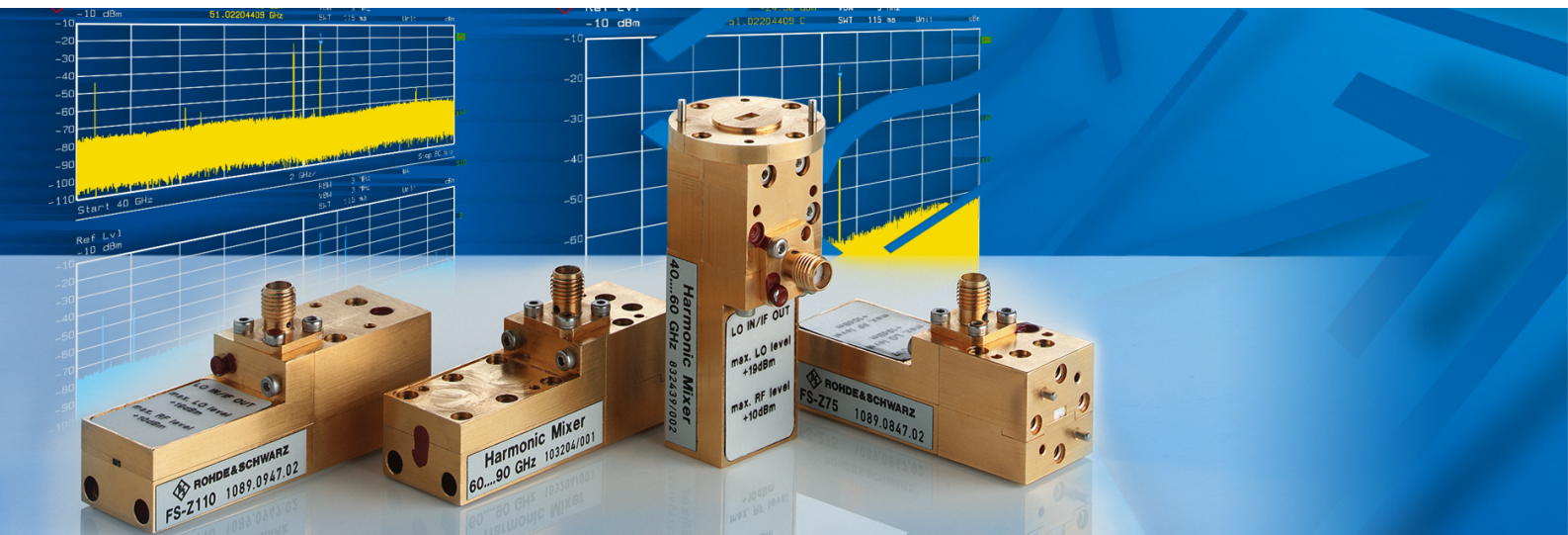


Operating Manual



Harmonic Mixer

R&S® FS-Z60

(40 GHz to 60 GHz)

1089.0799.02

R&S® FS-Z90

(60 GHz to 90 GHz)

1089.0899.02

R&S® FS-Z75

(50 GHz to 75 GHz)

1089.0847.02

R&S® FS-Z110

(75 GHz to 110 GHz)

1089.0947.04

Printed in Germany



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1 Introduction

General Remarks

The harmonics mixers of the R&S FS-Zxx series are highly sensitive measuring accessories. Therefore, the following points should be observed during operation although the equipment is of a sturdy design. Improper handling can cause the mixer to become faulty or damaged.

- Heavy shocks can cause the diodes in the mixer to be destroyed. Shock-proof packaging should therefore be used for storing or dispatching the mixer.
- The maximum power at the RF input and the LO input (see data sheet) must not be exceeded.
- Avoid electrostatic discharges near the connectors.
- When the mixer is not used, the LO/IF connector (SMA) should be covered with the cap supplied with the unit.
- The function of the diodes should not be checked by means of an ohmmeter. This would lead to their destruction.
- Do not loosen the screws of the mixer. Repair of the mixer can only be done at the manufacturer's servicing department.
- Avoid scratching the contact surface of the waveguide flange.

The following conditions are necessary to operate the mixers :

The mixers can be operated with the following instruments from Rohde& Schwarz:

Instrument type	Necessary Firmware-Version
R&S FSP40	For R&S FSU: 2.10 or higher with Windows NT 3.10 or higher with Windows XP For R&S FSP: 2.11 or higher with Windows NT 3.11 or higher with Windows XP
R&S FSU26	
R&S FSU43	
R&S FSU46	
R&S FSU50	
R&S FSU67	
R&S FSQ26	
R&S FSQ40	
R&S FSUP26	
R&S FSUP50	

Application

The harmonic mixers R&S FS-Z60, R&S FS-Z75, R&S FS-Z90 and R&S FS-Z110 are used for the frequency range extension of spectrum analyzers, and signal analyzers (called "instrument" in the following manual).

They allow measurements in the frequency ranges 40 GHz to 60 GHz (R&S FS-Z60), 50 GHz to 75 GHz (R&S FS-Z75), 60 GHz to 90 GHz (R&S FS-Z90) or 75 GHz to 110 GHz (R&S FS-Z110). Due to the two-diode concept, these mixers require no biasing for operation so that measurements with higher level accuracy and reproducibility can be performed.

The mixers of the R&S FS-Zxx series have been developed for use with the spectrum analyzers of the R&S FSP and R&S FSU family¹. Thus, the conversion loss data supplied apply only to the conditions specified for the R&S FSP and R&S FSU families¹ (see Table 1 for R&S FSP and Table 2 for R&S FSU).

Table 1 Parameters for operating R&S FS-Zxx waveguide mixers with R&S FSP

	R&S FS-Z60	R&S FS-Z75	R&S FS-Z90	R&S FS-Z110
LO frequency range	9.90 GHz to 12.97 GHz	8.27 GHz to 12.43 GHz	7.45 GHz to 11.20 GHz	8 th harmonic: 9.32 GHz to 13.07 GHz 10 th harmonic: 10.46 GHz to 10.96 GHz
LO level	15.5 dBm ± 3 dB	15.5 dBm ± 3 dB	15.5 dBm ± 3 dB	15.0 dBm ± 2 dB
Harmonics	4 and 6	6	8	8 75 to 105 GHz 10 105 to 110 GHz
Intermediate frequency	404.4 MHz	404.4 MHz	404.4 MHz	404.4 MHz

Table 2 Parameters for operating R&S FS-Zxx waveguide mixers with R&S FSU

	R&S FS-Z60	R&S FS-Z75	R&S FS-Z90	R&S FS-Z110
LO frequency range	9.90 GHz to 14.90 GHz	8.27 GHz to 12.43 GHz	9.93 GHz to 14.93 GHz	9.32 GHz to 13.70 GHz
LO level	15.5 dBm ± 3 dB	15.5 dBm ± 3 dB	15.5 dBm ± 3 dB	15.0 dBm ± 2 dB
Harmonics	4	6	6	8
Intermediate frequency	404.4 MHz	404.4 MHz	404.4 MHz	404.4 MHz

¹ Note: R&S FSQ and R&S FSUP belong to the R&S FSU instrument family. So all details given for R&S FSU instruments in this operating manual also apply for R&S FSQ and R&S FSUP instruments.

Description

The mixers R&S FS-Z60, R&S FS-Z75, R&S FS-Z90 are of two-port type, which means that only one coaxial cable is required for feeding the LO signal and tapping the IF signal. The two signals are separated by means of a diplexer in the instrument. The mixer R&S FS-Z110 is of three port type which means that it has separate connectors for the LO input and the IF output signal. Thanks to the two-diode concept no additional biasing is required. In addition, the mixers are less sensitive to electrostatic charges.

The two design concepts are shown in Fig. 1.

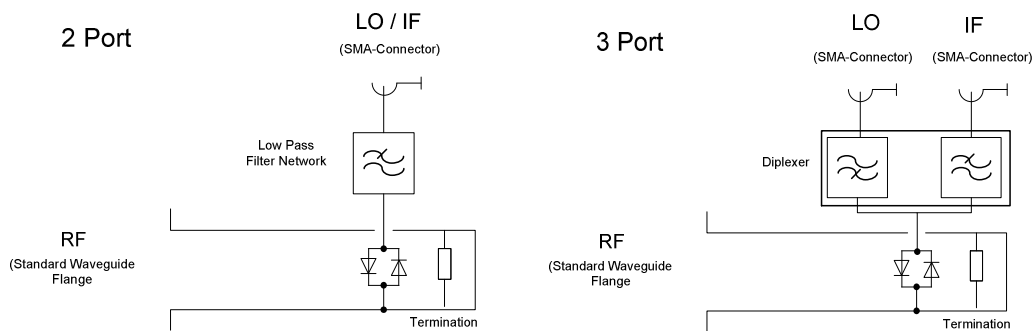


Fig. 1 Design of R&S FS-Zxx harmonics mixers

The signal to be measured is fed into the input (RF) of the mixer (Standard waveguide flange). The signal of the first local oscillator (LO) is applied to the mixer via the LO/IF SMA connector for the 2 port type, and via the LO SMA connector for the 3 port type respectively (see Table 1-1 and Table 1-2 for frequency range and level of the LO signal).

Nonlinearities produce harmonics of the LO signal which are used to convert the input signal to a lower intermediate frequency (IF). The relationship between LO frequency and input signal frequency is shown as approximation in Fig. 2.

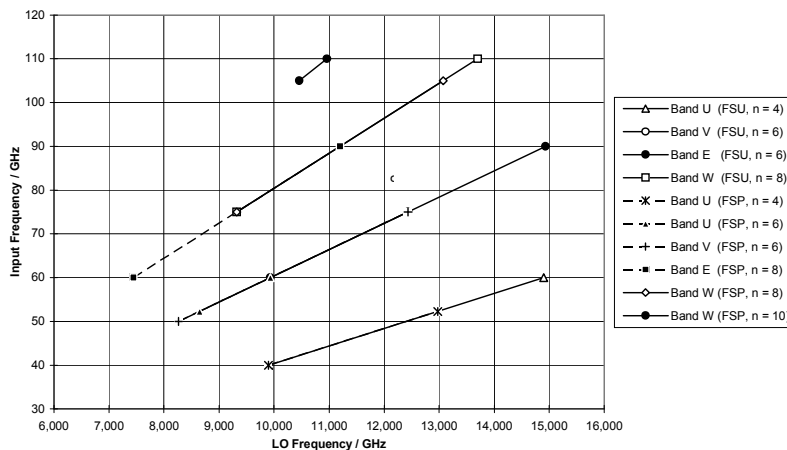


Fig. 2 Dependence of LO frequency on the frequency of the input signal to be converted

The signal converted to the intermediate frequency is tapped via the LO/IF connector on the 2 port mixer type, or the separate IF connector on the 3 port type respectively, and fed into the corresponding connector of the analyzer. Since the LO signal and IF signal are fed and tapped via the same coaxial cable in case of the two port mixers, it is necessary to separate the two signals by means of a diplexer,, which is integrated in the Rohde & Schwarz instruments listed above.

The mixer has no preselection. Image products and other unwanted mixer products are displayed on the instrument in addition to the wanted mixer products. Firmware functions (AUTO ID) are integrated to identify the input signals (see operating manual of the used instrument).

The conversion loss of the harmonic mixers should be taken into account so that the input signal to be measured can be displayed with the correct level at the instrument. The conversion loss depends on frequency and the mixer itself.

Correction data is therefore supplied for each mixer (see section "Conversion Loss Data").

Conversion Loss Data

Conversion loss is measured at 50 frequency points in the factory. The resulting data is supplied in form of a separate document. In addition, a table with correction data for the R&S FSP and the R&S FSU instrument families is affixed to the mixer for a smaller number of frequency points.

Correction data is also supplied in form of a file on a 3.5" floppy disc to facilitate level correction. This file contains conversion loss data of 50 frequency points and all further parameters required for operating the mixer.

The operations required to read this file are explained in section "Necessary Steps prior to First Use".

The conversion loss data only refer to the frequency-dependent conversion loss of the mixer. The attenuation of the cable used to tap the IF should be considered separately (see section "User's Guide").

High-quality low-loss coaxial cables should be used to feed the LO signal (frequency range 7 GHz to 15.5 GHz) or tap the IF signal to obtain a low conversion loss for the mixer. The mixer comes in a package with corresponding coaxial cable(s). It is highly recommended to always use these cables supplied with the mixer.

2 Preparation for Use

First connect the harmonic mixer to the DUT in order not to strain the coaxial cable used to feed the LO signal (see Fig. 2-1).

Then connect the LO/IF SMA connector (2 port type) or the LO SMA connector (3 port type) of the external mixer to the LO OUT / IF IN output of the instrument. In addition for 3 port mixers connect the IF port of the mixer to the IF port of the instrument. Use the coaxial cable(s) supplied with mixer.

Note: To protect the mixer diodes against possible electrostatic discharge of the coaxial cable, first connect the cable to the analyzer.

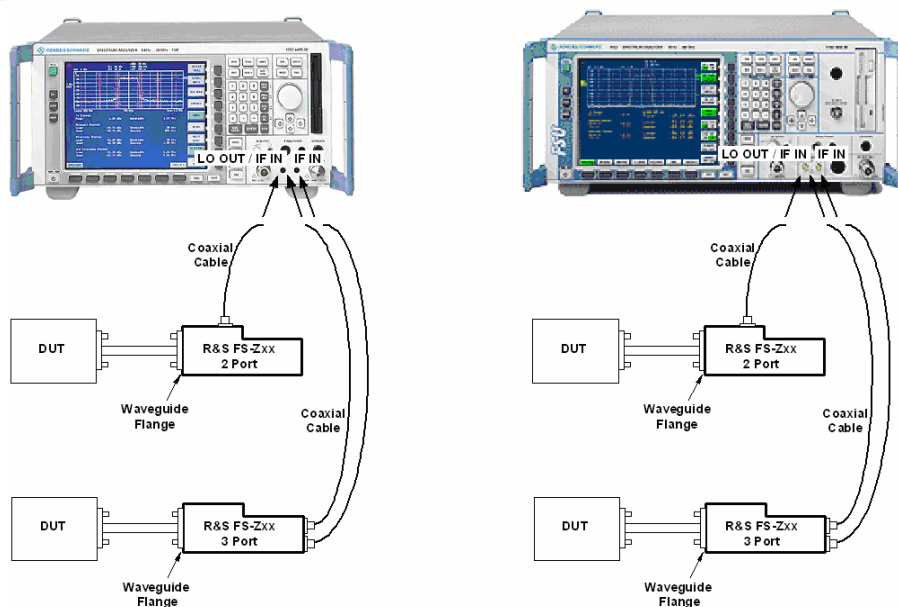


Fig. 3 Connecting the harmonics mixer

Notes concerning operation:

- The level of the input signal at the mixer RF port should not exceed the maximum admissible value (see data sheet). If the order of the level to be measured is not known, first perform a check with a waveguide attenuator and a power meter. The mixer may be connected to the DUT only if the maximum admissible mixer input level is not exceeded.
- The LO level should not exceed the maximum admissible value (see data sheet). A high LO level may cause the mixer to be damaged.
- If cables other than the ones supplied with the mixer are used for IF and LO signals, ensure that they have a low insertion loss and that the connection is as short as possible. If for example the insertion loss increases in the LO path, the LO level of the mixer decreases, resulting in a higher conversion loss and thus a reduced dynamic range.
- Avoid straining the cable used for feeding the LO signal.
- Observe the following points when connecting the mixer to the DUT:
 - There should be no offset between the waveguides
 - The waveguide flanges should be neither soiled nor scratched
 - There should be no air gap between the two waveguide flanges (eg through canting)
- Measurements should be performed only within the specified temperature range (see data sheet).
- When the mixer is not used, the LO/IF connector (SMA) should be covered with the cap provided for the unit.

3 Operating Instructions

Conventions for settings to be made during the measurement:

- [<TASTE>] Press a key on the front panel, eg [**FREQ**]
- [<SOFTKEY>] Press a softkey, eg [MARKER -> PEAK]
- [<nn Dimension>] Enter a value and terminate by entering the unit, eg [**12 kHz**]
- {<nn>} Enter values indicated in one of the following tables.

- Successive entries are separated by [:], eg [**FREQUENCY : 15 kHz**]

Necessary Steps prior to First Use

Note: *If a file with (old) calibration data stored on the hard disk should be replaced by a new file, proceed as described in section "Replacing Existing Data Files".
If not explicitly explained in the following, described operations are the same for R&S FSP and R&S FSU instruments.*

Prior to the first use of the mixer, the conversion loss data file supplied on a disk have to be imported to hard disk of the used instrument.

Proceed as follows:

- Insert the conversion loss disk supplied in the drive of the instrument
- [**PRESET**]
Defined state of instrument is produced
- [**FREQ : EXTERNAL MIXER : EXT MIXER**]
Mixer option is enabled. Softkey EXT MIXER is switched to ON and all other softkeys (without ACCEPT BIAS) are activated
- [**FREQ : EXTERNAL MIXER : SELECT BAND : band**]
Select the desired band for which new correction data is to be copied (with cursor keys or rollkey and ENTER). Start and Stop frequencies are changed concerning the selected band.

Mixer	Waveguide band
R&S FS-Z60	U
R&S FS-Z75	V
R&S FS-Z90	E
R&S FS-Z110	W

- [**FREQ : EXTERNAL MIXER : CONV LOSS TABLE : LOAD TABLE**]
Start copy pressing **ENTER**.. Conversion loss file on floppy disk is copied to hard disk.

To activate the conversion loss data file copied on hard disk, select the file for the corresponding band in menu *SELECT BAND*.

- [**FREQ** : EXTERNAL MIXER : SELECT BAND : file]
To select the conversion loss file in the SELECT BAND table, go to the row of the desired band with up and down cursor keys. With right cursor key select the CONV LOSS TABLE column and press **ENTER**. In the appearing popup table the copied conversion loss file is listed. Select it with up and down cursor and press **ENTER**. The AVG CONV LOSS/dB table entry is now empty. In the CONV LOSS TABLE column entry the conversion loss file name is listed (see Fig. 4 Fig. 4 below).

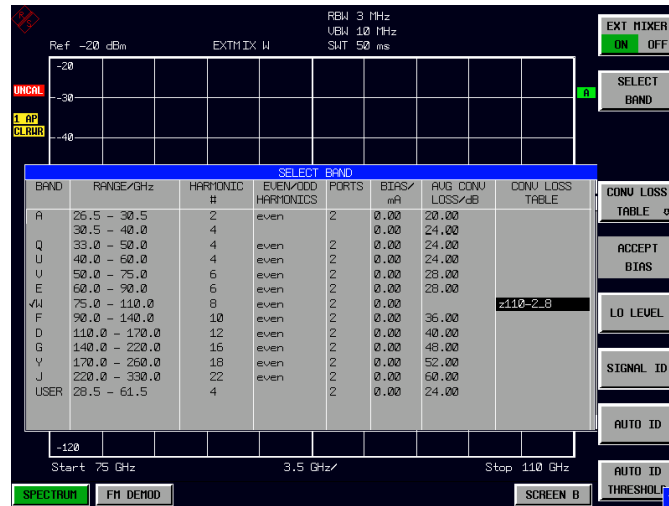


Fig. 4 Activating the conversion loss file

- To leave the SELCET BAND menu press [**↑**] (MENU UP). The correction data of the selected file is now used for level correction.

Example:

The correction data file for mixer R&S FS-Z75 is to be copied to the hard disk, proceed as follows:

- Insert the disk supplied in the instrument drive
- [**PRESET**]
- If external mixer option is not activated (EXT MIXER softkey is switched to OFF) press [**FREQ** : EXTERNAL MIXER : EXT MIXER]
- [**FREQ** : EXTERNAL MIXER : SELECT BAND : band]
Select the V band in the BAND column with cursor keys/rollkey and ENTER.
- [**FREQ** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE : LOAD TABLE]
Start copy with ENTER.
- [**FREQ** : EXTERNAL MIXER : SELECT BAND : file].
Select conversion loss table entry with cursor keys/rollkey in the V-band row and press ENTER.
Select R&S FS-Z75 file with cursor keys and **ENTER**.
- Return to menu *EXTERNAL MIXER* by actuating key *MENU UP* [**↑**].

Replacing Existing Data Files

To ensure that the new correction data of a re-calibrated mixer is used, the existing file with the same name must be deleted from the hard disk. Proceed as follows:

- Insert the disk supplied in the drive
- [**PRESET**]
- If external mixer option is not activated (EXT MIXER softkey is switched to OFF) press [**FREQ** : EXTERNAL MIXER : EXT MIXER]
- [**FREQ** : EXTERNAL MIXER : SELECT BAND : file]
To deactivate the actual used conversion loss file in the SELECT BAND table go to the row of the desired band with up and down cursor keys. With right cursor key select the CONV LOSS TABLE column and press **ENTER**. In the appearing popup table select the entry NONE. Select it with up and down cursor and press **ENTER**. The AVG CONV LOSS/dB table entry is activated. The CONV LOSS TABLE column is empty.
- [**FREQ** : EXTERNAL MIXER : CONV LOSS TABLE : DELETE TABLE]
Start delete pressing **ENTER**. Conversion loss file is deleted from hard disk.
- [**FREQ** : EXTERNAL MIXER : SELECT BAND : band]
Select the desired band for which new correction data is to be copied (with cursor keys or rollkey and ENTER). Start and Stop frequencies are changed concerning the selected band.

Mixer	Waveguide band
R&S FS-Z60	U
R&S FS-Z75	V
R&S FS-Z90	E
R&S FS-Z110	W

- [**FREQ** : EXTERNAL MIXER : CONV LOSS TABLE : LOAD TABLE]
Start copy pressing **ENTER**. Conversion loss file on floppy disk is copied to hard disk.

To activate the conversion loss data file copied on hard disk, select the file for the corresponding band in menu *SELECT BAND*.

- [**FREQ** : EXTERNAL MIXER : SELECT BAND : file]
To select the conversion loss file in the SELECT BAND table go to the row of the desired band with up and down cursor keys. With right cursor key select the CONV LOSS TABLE column and press **ENTER**. In the appearing popup table the copied conversion loss file is listed. Select it with up and down cursor and press **ENTER**. The AVG CONV LOSS/dB table entry is now empty. In the CONV LOSS TABLE column entry the conversion loss file name is listed (see Fig. 3-1 below).
- To leave the SELCET BAND menu press [**↑**] (MENU UP). The new correction data of the selected file is now used for level correction.
- [**FREQ** : EXTERNAL MIXER : SELECT BAND : band]
Select the desired band for which new correction data is to be copied (with cursor keys or rollkey and ENTER)..

Example:

New correction data is to be copied to the hard disk for mixer R&S FS-Z75. Proceed as follows:

- Insert the disk supplied in the instrument drive
- [**PRESET**]
- If external mixer option is not activated (EXT MIXER softkey is switched to OFF) press [**FREQ** : EXTERNAL MIXER : EXT MIXER]

- [**FREQ** : EXTERNAL MIXER : SELECT BAND : file].
Select conversion loss table entry with cursor keys/rollkey in the V-band row and press ENTER.
Select NONE entry with cursor keys and **ENTER**.
- [**FREQ** : EXTERNAL MIXER : CONV LOSS TABLE : DELETE TABLE]
Start delete pressing **ENTER**.
- [**FREQ** : EXTERNAL MIXER : SELECT BAND : band]
Select the V band in the BAND column with cursor keys/rollkey and ENTER:
- [**FREQ** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE : LOAD TABLE]
Start copy with ENTER
- [**FREQ** : EXTERNAL MIXER : SELECT BAND : file].
Select conversion loss table entry with cursor keys/rollkey in the V-band row and press ENTER.
Select R&S FS-Z75 file with cursor keys and **ENTER**.
- Return to menu *EXTERNAL MIXER* by actuating key *MENU UP* [↑].

User's Guide

Once the conversion loss data file supplied with the mixer has been copied on the hard disk and activated for the corresponding band, no other settings are required after selecting the desired band. The file contains the conversion loss data and all the additional parameters required which are automatically set.

Table 3 Parameters for operating R&S FS-Zxx waveguide mixers with R&S FSP

	R&S FS-Z60	R&S FS-Z75	R&S FS-Z90	R&S FS-Z110
Band	U	V	E	W
Frequency range / GHz	40 - 60	50 - 75	60 - 90	75 - 110
Order of harmonic	4 and 6	6	8	8 75 to 105 GHz 10 105 to 110 GHz
Harmonic even/odd	even	even	even	even
Ports	2	2	2	3
Bias / mA	0	0	0	0

Note: *When using the FS-Z110 in combination with a R&S FSP instrument, the following conditions apply. The local oscillator range of a FSP instrument only covers a RF frequency range of 75 to 110 GHz when using the 8th harmonic. For frequencies above 105 GHz, the 10th harmonic must be used! Therefore the appropriate conversion loss table of the two files supplied on disk must be selected for the corresponding frequency range.*

Table 4 Parameters for operating R&S FS-Zxx waveguide mixers with R&S FSU

	R&S FS-Z60	R&S FS-Z75	R&S FS-Z90	R&S FS-Z110
Band	U	V	E	W
Frequency range / GHz	40 - 60	50 - 75	60 - 90	75 - 110
Order of harmonic	4	6	6	8
Harmonic even/odd	even	even	even	even
Ports	2	2	2	3
Bias / mA	0	0	0	0

Note: *The allocation of the conversion loss data file to a defined band is maintained after switching off the unit or resetting with Preset. After Preset just select the corresponding band.*

Level Correction Hints

The correction data only take into account the conversion loss of the mixer.

The insertion loss of the cable used for tapping the IF signal is to be separately taken into account in the correction of the level.

In contrast to the conversion loss of the mixer, the cable loss in the IF path is independent of the frequency. The cable loss is therefore simply taken into account with a level offset (function [**AMPT** : REF LEVEL OFFSET : value]).

Measurement Accuracy

The measurement of signal levels always involves some uncertainty. Depending on the type of measurement, this uncertainty is due to various sources of errors (see section "Errors from Mismatch"). Basically, these sources of errors originate from the used instrument and the harmonic mixer. Measurement errors due to a too low signal/noise ratio are not taken into account in the following.

Errors from the used instrument

On using the harmonics mixers, the measurement accuracy can be influenced by the following sources of errors due to the instrument.

- Absolute error
- IF amplifier error
- Error on switching the bandwidth
- Bandwidth error

The errors are specified in the data sheet of the instrument.

Errors from the Harmonics Mixer

The following sources of errors from the harmonics mixer can contribute to the overall measurement error:

- Uncertainty
- Deviation of the LO level from the ideal value

As for any measurement, measuring conversion loss of mixers involves some errors which have different causes. These errors are included in the specified uncertainty.

Despite the two-diode concept, there is some dependency between the mixer conversion loss and the LO level. If during measurement another LO level is applied to the mixer than the level for measurement of conversion loss in the factory, the actual conversion loss can deviate from that taken into account by the conversion loss data. The resulting measurement uncertainty, however, is already taken into account in the uncertainty given in the specifications. The values only apply to the LO level range specified.

Errors from Mismatch

An ideal mixer with an input reflection coefficient of 0 would absorb the total input power offered to it irrespective of the output impedance of the signal source.

Mismatch results from the fact that the reflection coefficient of a real mixer is however > 0 . The measurement result thus also depends on the output reflection coefficient of the source which is generally > 0 . The following equation applies to the measurement uncertainty M_U due to mismatch:

$$M_U = 100 \cdot [(1 \pm r_g \cdot r_l)^2 - 1] \quad (\text{Equation 1})$$

with M_U measurement uncertainty in %
 r_g magnitude of the source reflection coefficient
 r_l magnitude of the mixer reflection coefficient.

The following approximation applies:

$$M_U \approx \pm 200 \cdot r_g \cdot r_l \quad (\text{Equation 2})$$

Taking the values of the input or output VSWR of the mixer or DUT, the corresponding reflection coefficients can be calculated as follows:

$$r = \frac{s-1}{s+1} \quad (\text{Equation 3})$$

with r reflection coefficient
 s VSWR

The mismatch of the mixer IF output and the instruments IF input is also a possible source of error. However, the resulting error can be calculated using the above equations. Due to low VSWR at the IF inputs the resulting error can be neglected.

Total Measurement Error

The sources of errors contributing to the total measurement error depend on the type of measurement. The sources of errors are listed below for the most important cases:

Measurement of the absolute level:

Sources of errors of the instrument:

- Absolute error
- IF amplifier error
- Linearity error
- Error on switching the bandwidth
- Bandwidth error (only with channel power and noise measurement)

Sources of errors of the harmonics mixer:

Uncertainty

Error from mismatch:

- Mismatch between DUT output and mixer RF input

Relative level measurement:

- Sources of errors of the instrument: - Linearity error
 Conditions: - Constant bandwidths and reference level setting
 - Measurements at a signal frequency²
 - Constant source output impedance

A maximum error (worst case) can be calculated from these contributions by simply adding them up. The maximum error calculated in this way has confidence level of 100%, ie the actual error from a measurement never exceeds the calculated values.

In practice, however, the maximum error seldom occurs. If the total error is the sum of individual errors the causes of which are independent of another, this is statistically a very rare event that all individual errors occur at the same time with their maximum value and same sign during a measurement.

What is more suitable for the practice is to calculate the total error with a certain confidence level, usually 95% (see Application Note 1EF36_0E 'Level Error Calculation for Spectrum Analyzers').

For systematic errors, ie for all above errors except errors from mismatch, a rectangular distribution is assumed.

The following equation applies to the variance σ^2 of the individual errors:

$$\sigma^2 = \frac{a^2}{3} \tag{Equation 4}$$

with σ^2 the variance and
 a the max. systematic error, in dB .

Bandwidth errors are usually specified in %. Thus, the following applies:

$$\sigma^2 = \frac{\left(10 \cdot \lg\left(1 + \frac{RBW_{err}}{100}\right)\right)^2}{3} \tag{Equation 5}$$

with σ^2 the variance and
 RBW_{err} the bandwidth error, in % .

If an error (eg uncertainty of conversion loss data of the mixer) is already given with a defined confidence level, ie the indication does not reflect the maximum value, the variance should be first calculated from the specified value.

The following equation applies to indications with a confidence level of 95%

$$\sigma^2 = \left(\frac{a_{RSS}}{1,96}\right)^2 \tag{Equation 6}$$

with σ^2 the variance and
 a_{RSS} the systematic error with a confidence level of 95% in dB.

Errors from mismatch have a U distribution. Thus, the following equation applies to variance σ^2

² If the signal frequency varies just a little between two signals to be measured (up to some MHz), the frequency response can be neglected. What appears is just the linearity error of the spectrum analyzer.

$$\sigma^2 = \frac{\left(20 \cdot \lg(1 - r_g \cdot r_l)\right)^2}{2} \tag{Equation 7}$$

with σ^2 the variance,
 r_g the magnitude of the source reflection coefficient and
 r_l the magnitude of the sink reflection coefficient.

The magnitude of the reflection coefficient can be calculated with the equation

$$r = \frac{s - 1}{s + 1} \tag{Equation 8}$$

with r the reflection coefficient and
 s the VSWR.

Taking the variances σ_i of the different contributions, the combined standard deviation σ_{tot} is calculated using the equation

$$\sigma_{tot} = \sqrt{\sigma_1^2 + \sigma_2^2 + \dots + \sigma_n^2} \tag{Equation 9}$$

The resulting standard deviation has a confidence level of 68%. This value should be multiplied by 1.96 to obtain a confidence level of 95%.

Example:

For the absolute level measurement of an input signal (output VSWR of signal source 1.2:1), the total error is to be determined with a confidence level of 95%. The resolution bandwidth set is 100 kHz, the signal level is approx. 20 dB below the reference level. The bandwidth error should be assumed to be 10 %. The data sheets for the mixer and the instrument contain the relevant specifications.

	Specified error	Variance σ_i^2	Remarks
Spectrum analyzer			
Absolute error (with external mixing)	1.0 dB	0.33	comp. equation 3-4
IF amplifier error	0.2 dB	0.01	comp. equation 3-4
Linearity error	0.3 dB	0.03	comp. equation 3-4
Error on switching the bandwidth	0.2 dB	0.01	comp. equation 3-4
Bandwidth error	10 %	0.07	comp. equation 3-5
Harmonics mixer			
Uncertainty	3,0 dB	2,34	comp. equation 3-6
Mismatch			
VSWR RF input of mixer	3,5		
VSWR signal source output	1,2	0,10	comp. equation 3-7

The combined standard deviation for $\sigma_{tot} = 1.70$ can be calculated from variances σ_i^2 using equation 3-9. The total measurement error of 3.34 dB is obtained with a confidence level of 95% by multiplying the standard deviation by a factor of 1.96.

A MS Excel® 5.0 spreadsheet (file EXTERROR.XLS) is supplied on disk with the mixer to simplify such error calculations.

Error Calculation for FSP/FSU + External Mixer		
Inherent errors	specified error	variance
Spectrum analyzer		
absolute error (IF input for external mixing) [dB]	1,00	0,33
IF gain [dB]	0,20	0,01
log linearity [dB]	0,30	0,03
bandwidth switching error [dB]	0,20	0,01
bandwidth error [%]	10,00	0,07
External mixer		
uncertainty of conversion loss data (95% confidence level) [dB]	3,00	2,34
combined variance		2,80
combined standard uncertainty		1,67
rss error (95% confidence level) [dB]		3,28
Error due to source mismatch		
VSWR of external mixer (RF port)	3,50	
VSWR of DUT	1,20	0,10
combined variance		2,90
combined standard uncertainty		1,70
error including source mismatch (95%) [dB]		3,34

The different errors are to be entered in the yellow fields in the specified unit. The calculated error with a confidence level of 95 % is output in the dark blue fields.
 The error output under 'rss error (95 % confidence level)' takes into account all individual errors including the mismatch in the IF branch.
 Errors due to mismatch between DUT and mixer input are taken into account in the value for 'error including source mismatch (95 %)'.

4 Maintenance and Troubleshooting

Maintenance

Harmonics Mixers R&S FS-Z60, R&S FS-Z75, R&S FS-Z90 and R&S FS-Z110 are maintenance-free. The contact surface of the waveguide flange should be cleaned with alcohol and a soft cloth at regular intervals.

**Caution:**

Do not scratch the contact surface.

To keep measurement errors at a minimum level the mixer should be returned to the manufacturer for recalibration at regular intervals (see specifications for calibration intervals in the data sheet).

Troubleshooting

Troubleshooting as such is not possible in the harmonics mixers of the R&S FS-Zxx series. Defective mixers require repair and new measurement of conversion loss by the manufacturer. Damages generally make themselves felt by increased conversion loss up to complete dropout.

**Caution:**

- *The function of the diodes should not be checked by means of an ohmmeter. The diodes can be destroyed by the battery voltage.*
- *The screws of the mixer and the screws for fastening the SMA connector should not be loosened.*
- *The label with conversion loss data also serves as a seal. Conversion loss data becomes invalid if this seal is broken.*

5 Checking Rated Specifications

Measuring Equipment and Accessories

Table 5 Measuring Equipment and Accessories

Item	Type of equipment	Specifications recommended	Equipment recommended	R&S Order No.	Page
1	Spectrum analyzer	LO frequency range 7 GHz to 15 GHz LO level adjustable 13-17dBm default 15.5 dBm IF input 404.4 MHz IF level for full scale deflection > -20 dBm Internal diplexer	R&S FSP40 + B21 ¹⁾ or R&S FSU26 + B21 or R&S FSU46 + B21 or R&S FSU50 + B21 or R&S FSQ26 + B21 or R&S FSQ40 + B21 or R&S FSUP26 + B21 or R&S FSUP50 + B21 ¹⁾ Option R&S FSP/FSU-B21 R&S Order No. 1155.1758.01 for R&S FSP, 1157.1090.02 for R&S FSU, 1157.1090.02 for R&S FSUP	1164.4391.40 1166.1660.26 1166.1660.46 1166.1660.50 1155.5001.26 1155.5001.40 1166.3505.26 1166.3505.50	23
2	Signal generator	Frequency range up to 1 GHz	SMT02	1039.2000.02	23
3	Signal source	Output level > 0 dBm Output VSWR < 2.0 : 1 Frequency range: R&S FS-Z60: 40 GHz to 60 GHz R&S FS-Z75: 50 GHz to 75 GHz R&S FS-Z90: 60 GHz to 90 GHz R&S FS-Z110: 75 GHz to 110 GHz Waveguide flange R&S FS-Z60: UG-383/U-M R&S FS-Z75: UG-385/U R&S FS-Z90: UG-387/U R&S FS-Z110: UG-387/U-M	R&S FS-Z60: SMR60 R&S FS-Z75: Anritsu MG3690B + Anritsu 63850-15 R&S FS-Z90: Anritsu MG3690B + Anritsu 63850-12 R&S FS-Z110: Anritsu MG3690B + Anritsu 63850-10	1134.9008.60	23
4	Power meter		NRVD	0857.8008.02	23
5	Power sensor	Frequency range up to 1 GHz RSS error referred to indicated power ≤ 0,8% Meter noise ≤ 20 pW	NRV-Z4	0828.3618.02	23
6	Power meter	Capability for waveguide sensors R&S FS-Z60: 40 GHz to 60 GHz R&S FS-Z75: 50 GHz to 75 GHz R&S FS-Z90: 60 GHz to 90 GHz R&S FS-Z110: 75 GHz to 110 GHz	R&S FS-Z60: Anritsu ML4803A + Anritsu MP715A4		23

Item	Type of equipment	Specifications recommended	Equipment recommended	R&S Order No.	Page
7	Power sensor	Frequency range R&S FS-Z60: 40 GHz to 60 GHz R&S FS-Z75: 50 GHz to 75 GHz R&S FS-Z90: 60 GHz to 90 GHz R&S FS-Z110: 75 GHz 110 GHz Waveguide flange R&S FS-Z60: UG-383/U-M R&S FS-Z75: UG-385/U R&S FS-Z90: UG-387/U R&S FS-Z110: UG-387/U-M Input VSWR < 1.5 : 1 Meter noise ≤ -30 dBm Error (RSS) ≤ 4 %	R&S FS-Z110: Agilent E4419A V8486A R&S FS-Z90: Anritsu ML4803A + Anritsu MP717A4 R&S FS-Z110: Agilent E4419A W8486A		23
8	Attenuator	Attenuation 10 dB VSWR ≤ 1.15 : 1 Waveguide flange R&S FS-Z60: UG-383/U-M R&S FS-Z75: UG-385/U R&S FS-Z90: UG-387/U R&S FS-Z110: UG-387/U-M	R&S FS-Z60: Millitech FXA-19-R10G0 R&S FS-Z60: Millitech FXA-15-R10G0 R&S FS-Z90: Millitech FXA-12-R10G0 R&S FS-Z90: Millitech FXA-10-R10G0		23
9	Waveguide transitions	required only for R&S FS-Z60: V-coaxial male to WR-19 transition	Anritsu 35WR19V		23

Test Instructions

- Prior the performance check of the harmonic mixer total calibration of the R&S FSP/FSU after a warm-up time of at least 30 minutes has to be carried out. Only in this case can the compliance with the guaranteed data be ensured.
- The settings are made from the Preset condition.
- Conventions for setting the R&S FSP/FSU during measurements:
 [<KEY>] Press a key on the front panel, eg [SPAN]
 [<SOFTKEY>] Press a softkey, eg [MARKER -> PEAK]
 [<nn unit>] Enter a value and terminate by entering the unit, eg [12 kHz]
 Successive entries are separated by [:], eg [**SPAN**: 15 kHz]
- Values given in the following sections are not guaranteed. Only the technical specifications of the data sheet are binding.

Checking the Conversion Loss

Test equipment:	- spectrum analyzer	(table 5-1, item 1)	
	- signal generator	(table 5-1, item 2)	
		frequency range	up to 1 GHz
	- power meter	(table 5-1, item 4)	
	- power sensor	(table 5-1, item 5)	
		frequency range	up to 1 GHz
		RSS error referred to indicated power	$\leq 0.8 \%$
		meter noise	$\leq 20 \text{ pW}$
	- signal source	(table 5-1, item 3)	
		output level	$> 0 \text{ dBm}$
		output VSWR	$< 2.0 : 1$
		frequency range	
		R&S FS-Z60:	40 GHz to 60 GHz
		R&S FS-Z75:	50 GHz to 75 GHz
	R&S FS-Z90:	60 GHz to 90 GHz	
	R&S FS-Z110:	75 GHz to 110 GHz	
	waveguide flange		
	R&S FS-Z60:	UG-383/U-M	
	R&S FS-Z75:	UG-385/U	
	R&S FS-Z90:	UG-387/U	
	R&S FS-Z110:	UG-387/U-M	
- attenuator	(table 5-1, item 8)		
	attenuator	10 dB	
	VSWR	$\leq 1,15 : 1$	
	frequency range		
	R&S FS-Z60:	40 GHz to 60 GHz	
	R&S FS-Z75:	50 GHz to 75 GHz	
	R&S FS-Z90:	60 GHz to 90 GHz	
	R&S FS-Z110:	75 GHz to 110 GHz	
	waveguide flange		
	R&S FS-Z60:	UG-383/U-M	
	R&S FS-Z75:	UG-385/U	
	R&S FS-Z90:	UG-387/U	
	R&S FS-Z110:	UG-387/U-M	

- power meter (table 5-1, item 6)
capability for waveguide power sensors
- power sensor (table 5-1, item 7)
 - meter noise ≤ -30 dBm
 - RSS error ≤ 4 %
 - input VSWR < 1.5 : 1
 - frequency range
 - R&S FS-Z60: 40 GHz to 60 GHz
 - R&S FS-Z75: 50 GHz to 75 GHz
 - R&S FS-Z90: 60 GHz to 90 GHz
 - R&S FS-Z110: 75 GHz to 110 GHz
 - waveguide flange
 - R&S FS-Z60: UG-383/U-M
 - R&S FS-Z75: UG-385/U
 - R&S FS-Z90: UG-387/U
 - R&S FS-Z110: UG-387/U-M
- waveguide transition (table 5-1, item 9)
required only for R&S FS-Z60
V-coaxial male to WR19

Determining the absolute level error

This measurement determines the overall level error due to level error of the R&S FSP/FSU and insertion loss of the cable in the IF path.

- Test setup:
- connect power sensor (table 5-1, item 5) to the power meter (table 5-1, item 4) and execute function 'ZERO' when there is no signal applied to the power sensor.
 - connect power sensor directly to RF output of signal generator (table 5-1, item 2).
- Signal generator settings:
- frequency 404.4 MHz
 - level -30 dBm
- Measurement:
- determine output power of the signal generator with the power meter. To achieve higher accuracy it is recommended to compensate the frequency response of the power sensor.
 - connect RF output of the signal generator to front panel connector 'LO OUT / IF IN' of the R&S FSP/FSU. Use the coaxial cable delivered with R&S FSP/FSU, R&S FSP-B21 or R&S FSU-B21.

- R&S FSP/FSU settings:
- [**PRESET**]
 - If external mixer option is not activated (EXT MIXER softkey is switched to OFF) press
[**FREQ** : EXTERNAL MIXER : EXT MIXER]
 - [**FREQ** : EXTERNAL MIXER : SELECT BAND : band]
 - Select band USERS with up and down cursor keys and press ENTER.
 - Select AVG CONV LOSS/dB table entry with cursor keys, press ENTER, write 0dB and press ENTER again.
 - Select PORTS entry with cursor keys, press ENTER, select "2" for 2 port mixers and "3" for 3 port mixers respectively and press ENTER again.
 - Return to menu *EXTERNAL MIXER* by actuating key *MENU UP* [↑].
 - [**AMPT** : -10 dBm]
 - [**SPAN** : 1 MHz]
 - [**BW** : RES BW MANUAL : 10 kHz]
 - set marker to peak
[**MKR->** : PEAK]

Evaluation: The deviation between the signal levels measured with the power meter and the R&S FSP/FSU (level reading of marker 1) reflects the absolute level error of the R&S FSP/FSU. It can be calculated as

$$\text{absolute error}_{\text{FSP/FSU}} = L_{\text{FSP/FSU}} - L_{\text{power meter}}$$

The determined absolute error should be noted in table 5-2 (item 1) of the performance test report.

Determining the output level of the signal source

- Test setup:
- connect power sensor (table 5-1, item 7) to the power meter (table 5-1, item 6) and execute function 'ZERO' when there is no signal applied to the power sensor.
 - connect power sensor via attenuator (table 5-1, item 8) to RF output of signal source (table 5-1, item 3).

For R&S FS-Z60: Use waveguide transition V to WR19 (table 5-1, item 8) it to the waveguide flange of the attenuator.

- Signal source settings:
- level 0 dBm
 - frequency f_{fresp}

See Table 6 (item 2) of performance test report for values of f_{fresp} .

Power meter settings: Determine signal level L_{gen} . To achieve higher accuracy it is recommended to compensate the frequency response of the power sensor.

Determining the conversion loss of the mixer

- Test setup:
- connect harmonic mixer via attenuator (table 5-1, item 8) to signal source (table 5-1, item 3).
 - For R&S FS-Z60: Use tapered waveguide transitions (table 5-1, item 9) at the output of the signal source to adapt it to the waveguide flange of the attenuator.*
 - Connect front panel connector 'LO OUT / IF IN' of the R&S FSP/FSU with connector 'LO / IF' of the harmonic mixer in case of a 2 port mixer. In case of a 3 port mixer connect front panel connector 'LO OUT / IF IN' of the R&S FSP/FSU with connector 'LO' of the harmonic mixer and the 'IF IN' of the R&S FSP/FSU with connector 'IF'. Use the coaxial cables delivered with the mixer.

Signal generator settings: - frequency f_{fresp}
See Table 6 (item 3) of performance test report for values of f_{fresp} .

- R&S FSP/FSU settings:
- [**PRESET**]
 - If external mixer option is not activated (EXT MIXER softkey is switched to OFF) press
[**FREQ** : EXTERNAL MIXER : EXT MIXER]
 - [**FREQ** CENTER : { f_{fresp} }]
 - See Table 6 (item 3) of performance test report for values of f_{fresp} .
 - [**FREQ** : EXTERNAL MIXER : SELECT BAND : band]
 - Select desired band (R&S FS-Z60 band U, R&S FS-Z75 band V, R&S FS-Z90 band E, R&S FS-Z110 band W) with up and down cursor keys and press ENTER.
 - Select AVG CONV LOSS/dB table entry in the selected band with cursor keys, press ENTER, write 0dB and press ENTER again.
 - Select PORTS entry with cursor keys, press ENTER, select "2" for 2 port mixers and "3" for 3 port mixers respectively and press ENTER again.
 - Return to menu *EXTERNAL MIXER* by actuating key *MENU UP* [\uparrow].
 - [**SPAN** : 100 kHz]
 - [**BW** : RES BW MANUAL : 10 kHz]
 - Set marker to peak
[**MKR->** : PEAK]

The signal level $L_{\text{FSP/FSU}}$ is displayed by level reading of marker 1.

Evaluation: The conversion loss can be calculated as follows:

$$a_{\text{conv}} = L_{\text{gen}} - (L_{\text{FSP/FSU}} - \text{absolute error})$$

Compare the measured values with the limits given in table 5-2 (item 3) of performance test report.

Checking the Noise Display

Test equipment:	- Spectrum analyzer (Table 5, item 1)
Test setup:	Connect front panel connector 'LO OUT / IF IN' of the R&S FSP/FSU with connector 'LO / IF' of the harmonic mixer. Use the coaxial cable delivered with the R&S FSP-B21 or R&S FSU-B21.
R&S FSP/FSU settings:	<p>- [PRESET]</p> <p>- If external mixer option is not activated (EXT MIXER softkey is switched to OFF) press [FREQ : EXTERNAL MIXER : EXT MIXER]</p> <p>- [FREQ CENTER : {f_{fresp}}]</p> <p>See Table 6 (item 3) of performance test report for values of f_{fresp}.</p> <p>- [FREQ : EXTERNAL MIXER : SELECT BAND : band]</p> <ul style="list-style-type: none"> • Select desired band (R&S FS-Z60 band U, R&S FS-Z75 band V, R&S FS-Z90 band E, R&S FS-Z110 band W) with up and down cursor keys and press ENTER. • Select AVG CONV LOSS/dB table entry in the selected band with cursor keys, press ENTER, write {a_{conv}} and press ENTER again. See Table 6 (item 3) of performance test report for value of a_{conv} at {f_{fresp}}. • Select PORTS entry with cursor keys, press ENTER, select "2" for 2 port mixers and "3" for 3 port mixers respectively and press ENTER again. • Return to menu <i>EXTERNAL MIXER</i> by actuating key <i>MENU UP</i> [\uparrow]. <p>- [SPAN : 10 kHz]</p> <p>- [BW : RES BW MANUAL : 1 kHz]</p> <p>- [BW : VIDEO BW MANUAL : 10 Hz]</p> <p>- [TRACE : AVERAGE]</p> <p>- [TRACE : SWEEP COUNT : 30 ENTER]</p> <p>- [AMPT : -35 dBm]</p> <p>- [SWEEP : SINGLE SWEEP]</p> <p>- set marker to peak</p> <p>[MKR-> : PEAK]</p>
Evaluation:	The noise level is displayed by the level reading of marker 1. Compare the measured values with the limits given in table 5-2 (item 4) of performance test report

Item No.	Characteristic	Test described on page	Min. value	Actual value	Max. value	Unit
2	Checking the conversion loss output level L_{gen} of signal source f_{resp} R&S FS-Z75: 50 GHz 51 GHz 52 GHz 53 GHz 54 GHz 55 GHz 56 GHz 57 GHz 58 GHz 59 GHz 60 GHz 61 GHz 62 GHz 63 GHz 64 GHz 65 GHz 66 GHz 67 GHz 68 GHz 69 GHz 70 GHz 71 GHz 72 GHz 73 GHz 74 GHz 75 GHz R&S FS-Z90: 60 GHz 61 GHz 62 GHz 63 GHz 64 GHz 65 GHz 66 GHz 67 GHz 68 GHz 69 GHz 70 GHz 71 GHz 72 GHz 73 GHz 74 GHz 75 GHz 76 GHz 77 GHz 78 GHz 79 GHz 80 GHz 81 GHz 82 GHz 83 GHz 84 GHz 85 GHz 86 GHz 87 GHz 88 GHz 89 GHz 90 GHz	23	-	_____	-	dBm

Item No.	Characteristic	Test described on page	Min. value	Actual value	Max. value	Unit
3	Checking the conversion loss	23				
	a_{conv}					
	f_{fresp}					
	R&S FS-Z60:					
	40 GHz		-	_____	25	dB
	41 GHz		-	_____	25	dB
	42 GHz		-	_____	25	dB
	43 GHz		-	_____	25	dB
	44 GHz		-	_____	25	dB
	45 GHz		-	_____	25	dB
	46 GHz		-	_____	25	dB
	47 GHz		-	_____	25	dB
	48 GHz		-	_____	25	dB
	49 GHz		-	_____	25	dB
	50 GHz		-	_____	25	dB
	51 GHz		-	_____	25	dB
	52 GHz		-	_____	25	dB
	53 GHz		-	_____	25	dB
	54 GHz		-	_____	25	dB
	55 GHz		-	_____	25	dB
	56 GHz		-	_____	25	dB
	57 GHz		-	_____	25	dB
	58 GHz		-	_____	25	dB
	59 GHz		-	_____	25	dB
	60 GHz		-	_____	25	dB
	R&S FS-Z75:					
	50 GHz		-	_____	34	dB
	51 GHz		-	_____	34	dB
	52 GHz		-	_____	34	dB
	53 GHz		-	_____	34	dB
	54 GHz		-	_____	34	dB
	55 GHz		-	_____	34	dB
	56 GHz		-	_____	34	dB
	57 GHz		-	_____	34	dB
	58 GHz		-	_____	34	dB
	59 GHz		-	_____	34	dB
	60 GHz		-	_____	34	dB
	61 GHz		-	_____	34	dB
	62 GHz		-	_____	34	dB
	63 GHz		-	_____	34	dB
	64 GHz		-	_____	34	dB
	65 GHz		-	_____	34	dB
	66 GHz		-	_____	34	dB
	67 GHz		-	_____	34	dB
	68 GHz		-	_____	34	dB
	69 GHz		-	_____	34	dB
	70 GHz		-	_____	34	dB
	71 GHz		-	_____	34	dB
	72 GHz		-	_____	34	dB
	73 GHz		-	_____	34	dB
	74 GHz		-	_____	34	dB
	75 GHz		-	_____	34	dB

Item No.	Characteristic	Test described on page	Min. value	Actual value	Max. value	Unit
4	Checking the noise display	27				
	f_{resp}					
	R&S FS-Z60:					
	40 GHz		-	_____	-107	dBm
	41 GHz		-	_____	-107	dBm
	42 GHz		-	_____	-107	dBm
	43 GHz		-	_____	-107	dBm
	44 GHz		-	_____	-107	dBm
	45 GHz		-	_____	-107	dBm
	46 GHz		-	_____	-107	dBm
	47 GHz		-	_____	-107	dBm
	48 GHz		-	_____	-107	dBm
	49 GHz		-	_____	-107	dBm
	50 GHz		-	_____	-107	dBm
	51 GHz		-	_____	-107	dBm
	52 GHz		-	_____	-107	dBm
	53 GHz		-	_____	-107	dBm
	54 GHz		-	_____	-107	dBm
	55 GHz		-	_____	-107	dBm
	56 GHz		-	_____	-107	dBm
	57 GHz		-	_____	-107	dBm
	58 GHz		-	_____	-107	dBm
	59 GHz		-	_____	-107	dBm
	60 GHz		-	_____	-107	dBm
	R&S FS-Z75:					
	50 GHz		-	_____	-97	dBm
	51 GHz		-	_____	-97	dBm
	52 GHz		-	_____	-97	dBm
	53 GHz		-	_____	-97	dBm
	54 GHz		-	_____	-97	dBm
	55 GHz		-	_____	-97	dBm
	56 GHz		-	_____	-97	dBm
	57 GHz		-	_____	-97	dBm
	58 GHz		-	_____	-97	dBm
	59 GHz		-	_____	-97	dBm
	60 GHz		-	_____	-97	dBm
	61 GHz		-	_____	-97	dBm
	62 GHz		-	_____	-97	dBm
	63 GHz		-	_____	-97	dBm
	64 GHz		-	_____	-97	dBm
	65 GHz		-	_____	-97	dBm
	66 GHz		-	_____	-97	dBm
	67 GHz		-	_____	-97	dBm
	68 GHz		-	_____	-97	dBm
	69 GHz		-	_____	-97	dBm
	70 GHz		-	_____	-97	dBm
	71 GHz		-	_____	-97	dBm
	72 GHz		-	_____	-97	dBm
	73 GHz		-	_____	-97	dBm
	74 GHz		-	_____	-97	dBm
	75 GHz		-	_____	-97	dBm

Item No.	Characteristic	Test described on page	Min. value	Actual value	Max. value	Unit
4	Checking the noise display f _{resp} R&S FS-Z90:	27				
	60 GHz		-	_____	-90	dBm
	61 GHz		-	_____	-90	dBm
	62 GHz		-	_____	-90	dBm
	63 GHz		-	_____	-90	dBm
	64 GHz		-	_____	-90	dBm
	65 GHz		-	_____	-90	dBm
	66 GHz		-	_____	-90	dBm
	67 GHz		-	_____	-90	dBm
	68 GHz		-	_____	-90	dBm
	69 GHz		-	_____	-90	dBm
	70 GHz		-	_____	-90	dBm
	71 GHz		-	_____	-90	dBm
	72 GHz		-	_____	-90	dBm
	73 GHz		-	_____	-90	dBm
	74 GHz		-	_____	-90	dBm
	75 GHz		-	_____	-90	dBm
	76 GHz		-	_____	-90	dBm
	77 GHz		-	_____	-90	dBm
	78 GHz		-	_____	-90	dBm
	79 GHz		-	_____	-90	dBm
	80 GHz		-	_____	-90	dBm
	81 GHz		-	_____	-90	dBm
	82 GHz		-	_____	-90	dBm
	83 GHz		-	_____	-90	dBm
	84 GHz		-	_____	-90	dBm
	85 GHz		-	_____	-90	dBm
	86 GHz		-	_____	-90	dBm
	87 GHz		-	_____	-90	dBm
	88 GHz		-	_____	-90	dBm
	89 GHz		-	_____	-90	dBm
	90 GHz		-	_____	-90	dBm

Item No.	Characteristic	Test described on page	Min. value	Actual value	Max. value	Unit
4	Checking the noise display f _{resp} R&S FS-Z110:	27				
	75,00 GHz ⁵		-	_____	-88	dBm
	75,81 GHz		-	_____	-88	dBm
	76,52 GHz		-	_____	-88	dBm
	77,23 GHz		-	_____	-88	dBm
	77,94 GHz		-	_____	-88	dBm
	78,65 GHz		-	_____	-88	dBm
	79,36 GHz		-	_____	-88	dBm
	80,07 GHz		-	_____	-88	dBm
	80,78 GHz		-	_____	-88	dBm
	81,49 GHz		-	_____	-88	dBm
	82,20 GHz		-	_____	-88	dBm
	82,91 GHz		-	_____	-88	dBm
	83,62 GHz		-	_____	-88	dBm
	84,33 GHz		-	_____	-88	dBm
	85,04 GHz		-	_____	-88	dBm
	85,75 GHz		-	_____	-88	dBm
	86,46 GHz		-	_____	-88	dBm
	87,17 GHz		-	_____	-88	dBm
	87,88 GHz		-	_____	-88	dBm
	88,59 GHz		-	_____	-88	dBm
	89,30 GHz		-	_____	-88	dBm
	90,01 GHz		-	_____	-88	dBm
	90,72 GHz		-	_____	-88	dBm
	91,43 GHz		-	_____	-88	dBm
	92,14 GHz		-	_____	-88	dBm
	92,85 GHz		-	_____	-88	dBm
	93,56 GHz		-	_____	-88	dBm
	94,27 GHz		-	_____	-88	dBm
	94,98 GHz		-	_____	-88	dBm
	95,69 GHz		-	_____	-88	dBm
	96,40 GHz		-	_____	-88	dBm
	97,11 GHz		-	_____	-88	dBm
	97,82 GHz		-	_____	-88	dBm
	98,53 GHz		-	_____	-88	dBm
	99,24 GHz		-	_____	-88	dBm
	100,00 GHz		-	_____	-88	dBm
	100,66 GHz		-	_____	-88	dBm
	101,37 GHz		-	_____	-88	dBm
	102,08 GHz		-	_____	-88	dBm
	102,79 GHz		-	_____	-88	dBm
	103,50 GHz		-	_____	-88	dBm
	104,21 GHz		-	_____	-88	dBm
	105,00 GHz ⁶		-	_____	-88	dBm
	105,63 GHz		-	_____	-88	dBm
	106,34 GHz		-	_____	-88	dBm
	107,05 GHz		-	_____	-88	dBm
	107,76 GHz		-	_____	-88	dBm
	108,47 GHz		-	_____	-88	dBm
	109,18 GHz		-	_____	-88	dBm
	110,00 GHz		-	_____	-88	dBm

⁵ Note: Use 8th harmonic from 75 to 105 GHz

⁶ Note: Use 10th harmonic from 105 to 110 GHz