ROHDE&SCHWARZ

Test and Measurement
Division

Manual

Harmonic Mixer for FSEM, FSEK, ESIB26, ESIB40, FSIQ26

FS-Z60 (40 GHz to 60 GHz)

1089.0799.02

FS-Z75 (50 GHz to 75 GHz)

1089.0847.02

FS-Z90 (60 GHz to 90 GHz)

1089.0899.02

FS-Z110 (75 GHz to 110 GHz)

1089.0947.02

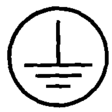
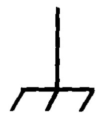
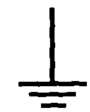
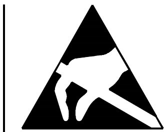
Printed in the Federal
Republic of Germany

Safety Instructions

This unit has been designed and tested in accordance with the EC Certificate of Conformity and has left the manufacturer's plant in a condition fully complying with safety standards.

To maintain this condition and to ensure safe operation, the user must observe all instructions and warnings given in this operating manual.

Safety-related symbols used on equipment and documentation from R&S:

							
Observe operating instructions	Weight indication for units >18 kg	PE terminal	Ground terminal	Danger! Shock hazard	Warning! Hot surfaces	Ground	Attention! Electrostatic sensitive devices require special care

1. The unit may be used only in the operating conditions and positions specified by the manufacturer. Unless otherwise agreed, the following applies to R&S products:

   IP degree of protection 2X, pollution severity 2 overvoltage category 2, only for indoor use, altitude max. 2000 m.

   The unit may be operated only from supply networks fused with max. 16 A.

   Unless specified otherwise in the data sheet, a tolerance of ±10% shall apply to the nominal voltage and of ±5% to the nominal frequency.

2. For measurements in circuits with voltages V_{rms} > 30 V, suitable measures should be taken to avoid any hazards.

   (using, for example, appropriate measuring equipment, fusing, current limiting, electrical separation, insulation).

3. If the unit is to be permanently wired, the PE terminal of the unit must first be connected to the PE conductor on site before any other connections are made. Installation and cabling of the unit to be performed only by qualified technical personnel.

4. For permanently installed units without built-in fuses, circuit breakers or similar protective devices, the supply circuit must be fused such as to provide suitable protection for the users and equipment.

5. Prior to switching on the unit, it must be ensured that the nominal voltage set on the unit matches the nominal voltage of the AC supply network.

   If a different voltage is to be set, the power fuse of the unit may have to be changed accordingly.

6. Units of protection class I with disconnectible AC supply cable and appliance connector may be operated only from a power socket with earthing contact and with the PE conductor connected.

7. It is not permissible to interrupt the PE conductor intentionally, neither in the incoming cable nor on the unit itself as this may cause the unit to become electrically hazardous.

   Any extension lines or multiple socket outlets used must be checked for compliance with relevant safety standards at regular intervals.

8. If the unit has no power switch for disconnection from the AC supply, the plug of the connecting cable is regarded as the disconnecting device. In such cases it must be ensured that the power plug is easily reachable and accessible at all times (length of connecting cable approx. 2 m). Functional or electronic switches are not suitable for providing disconnection from the AC supply.

   If units without power switches are integrated in racks or systems, a disconnecting device must be provided at system level.

9. Applicable local or national safety regulations and rules for the prevention of accidents must be observed in all work performed.

   Prior to performing any work on the unit or opening the unit, the latter must be disconnected from the supply network.

   Any adjustments, replacements of parts, maintenance or repair may be carried out only by authorized R&S technical personnel.

continued overleaf

Only original parts may be used for replacing parts relevant to safety (eg power switches, power transformers, fuses). A safety test must be performed after each replacement of parts relevant to safety.

(visual inspection, PE conductor test, insulation-resistance, leakage-current measurement, functional test).

10. Ensure that the connections with information technology equipment comply with IEC950 / EN60950.
11. Lithium batteries must not be exposed to high temperatures or fire.

    Keep batteries away from children.

    If the battery is replaced improperly, there is danger of explosion. Only replace the battery by R&S type (see spare part list).

    Lithium batteries are suitable for environmentally-friendly disposal or specialized recycling. Dispose them into appropriate containers, only.

    Do not short-circuit the battery.
12. Equipment returned or sent in for repair must be packed in the original packing or in packing with electrostatic and mechanical protection.
13. Electrostatics via the connectors may damage the equipment. For the safe handling and operation of the equipment, appropriate measures against electrostatics should be implemented.
14. The outside of the instrument is suitably cleaned using a soft, lint-free dustcloth. Never use solvents such as thinners, acetone and similar things, as they may damage the front panel labeling or plastic parts.
15. Any additional safety instructions given in this manual are also to be observed.

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1 Introduction

General Remarks

The harmonics mixers of the 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 beyond repair.

- 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 admissible power at the RF input and the LO input (see data sheet) should not be exceeded.
- Electrostatic discharges are to be avoided 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 :

- FSEM 21/31 or FSEK 21/31 or
  FSEM 20/30 or FSEK 20/30 with option FSE-B21
- Firmware version 1.67 or higher

Uses

Harmonics Mixers FS-Z60, FS-Z75, FS-Z90 and FS-Z110 are used for the frequency range extension of spectrum analyzers.
They allow measurements in the frequency ranges 40 GHz to 60 GHz (FS-Z60), 50 GHz to 75 GHz (FS-Z75) and 60 GHz to 90 GHz (FS-Z90) or 75 GHz to 110 GHz (FS-Z110). Thanks 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 FS-Zxx series have been developed for use with the spectrum analyzers of the FSE family. Thus, the conversion loss data supplied only apply to the conditions specified for FSE (see Table 1-1).

Table 1-1: Parameters for operating FS-Zxx waveguide mixers with FSE

	FS-Z60	**FS-Z75**	**FS-Z90**	**FS-Z110**
LO frequency range	10.19 GHz to 15.19 GHz	8.46 GHz to 12.62 GHz	10.12 GHz to 15.12 GHz	9.47 to 13.84 GHz
LO level	15.5 dBm ± 3 dB	15.5 dBm ± 3 dB	15.5 dBm ± 3 dB	15.5 dBm ± 3 dB
Harmonics	4	6	6	8
Intermediate frequency	741.4 MHz	741.4 MHz	741.4 MHz	741.4 MHz

Description

The mixers are of the 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 spectrum analyzer. Thanks to the two-diode concept no additional biasing is required. In addition, the mixers are less sensitive to electrostatic charges.
The basic design of the mixer is shown in Fig. 1-1.

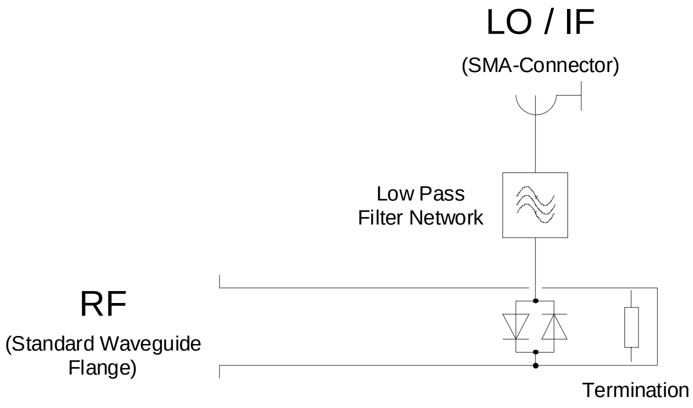

Fig. 1-1: Design of FS-Zxx harmonics mixers

The signal to be measured is fed to the input (RF) of the mixer (Standard waveguide flange).
The signal of the first local oscillator (LO) of the spectrum analyzer is taken to the mixer via the LO/IF SMA connector (see Table 1-1 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 in Fig. 1-2.

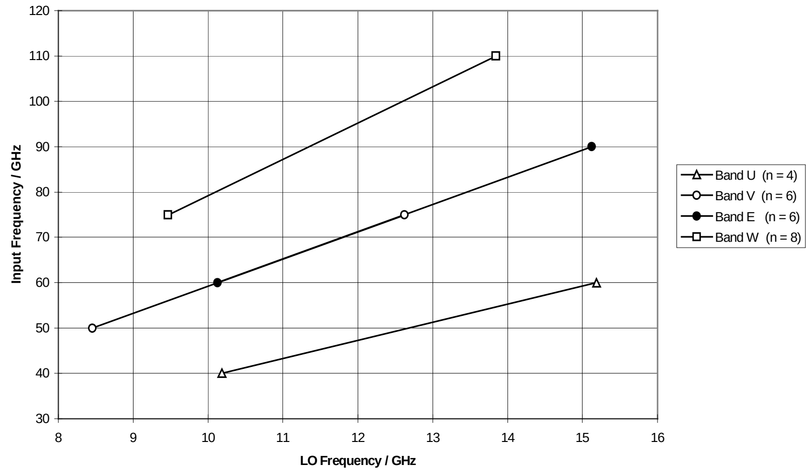

Fig. 1-2: Dependence of LO frequency on the frequency of the input signal to be converted (f_{IF} = 741.4 MHz)

The signal converted to the intermediate frequency is tapped via the LO/IF connector and taken to the spectrum analyzer. Since the LO signal and IF signal are fed and tapped via the same coaxial cable, it is necessary to separate the two signals by means of a diplexer. Such a diplexer is integrated in the spectrum analyzers of the FSE family.

The mixer has no preselection. Image products and other unwanted mixer products are displayed on the spectrum analyzer in addition to the wanted mixer products. Functions are integrated in FSE to identify the input signals (see operating manual of FSE or FSE-B21).

The conversion loss of the harmonics mixer should be taken into account so that the input signal to be measured can be displayed with the correct level at the spectrum analyzer. This conversion loss depends on the 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 the form of a separate document. In addition, a table with correction data is affixed to the mixer for a smaller number of frequency points.

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

The operations required to read this file on FSE 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").

A high-quality low-loss coaxial cable should be used to feed the LO signal (frequency range 7.5 GHz to 15.2 GHz) or tap the IF signal so as to obtain a low conversion loss for the mixer. The coaxial cable supplied with FSE or option FSE-B21 (SMA connectors on both sides) should always be used.

2 Preparation for Use

First connect the harmonics 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 of the external mixer to the LO OUT / IF IN output of FSE. Use the coaxial cable supplied with the FSEM/K 21/31 or option FSE-B21 (SMA connectors at both ends).

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

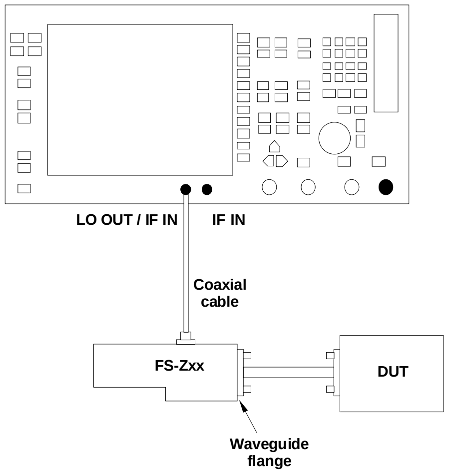

Fig. 2-1: Connecting the harmonics mixer to FSE

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.
  (not relevant if used with FSE)
- Use the coaxial cable supplied with FSEM/K 21/31 or option FSE-B21 to feed the LO signal (see section "Conversion Loss Data"). If another cable is used, ensure that it has a low loss and that the connection is as short as possible. When the insertion loss increases, the LO level of the mixer decreases and, as a result, the conversion loss of the mixer increases.
- 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 on FSE during the measurement:

[**<TASTE>**]	Press a key on the front panel, eg [**FREQUENCY SPAN**]
[<SOFTKEY>]	Press a softkey, eg [MARKER -> PEAK]
[<nn Einheit>]	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 SPAN** : **15 kHz**]

Necessary Steps prior to First Use

Note: *If a file with (old) calibration data stored on the hard disk of FSE should be replaced by a new file, proceed as described in section "Replacing Existing Data Files".*

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

Proceed as follows:

- Insert the disk supplied in the drive of FSE
- [**SYSTEM PRESET**]
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : BAND]
  Select the desired band for which new correction data is to be copied (with cursor keys/rollkey and ENTER):

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

- [**INPUT** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE : LOAD TABLE]
  Start copy with ENTER

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

- [**INPUT** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE]
  Select the desired file with cursor keys/rollkey and ENTER.
  The file is marked with √ in the selection list. After leaving menu *CONV LOSS TABLE* and *SELECT BAND* by actuating the key [⇑] (MENU UP) twice, the correction data of this file is used for level correction.

Example:

The correction data file is to be copied to the hard disk of FSE for mixer FS-Z75. Proceed as follows:

- Insert the disk supplied in the drive of FSE
- [**SYSTEM PRESET**]
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : BAND]
  Select the V band with cursor keys/rollkey and ENTER:
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE : LOAD TABLE]
  Start copy with ENTER
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE].
  Select FS-Z75 with cursor keys/rollkeyand ENTER
- Return to menu *EXTERNAL MIXER* by actuating key *MENU UP* twice
  [⇑]
  [⇑]

Replacing Existing Data Files

To ensure that the new correction data is used after copying, clear the existing file with the same name from the hard disk of FSE. Proceed as follows:

- Insert the disk supplied in the drive of FSE
- [**SYSTEM PRESET**]
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : BAND]
  Select the desired band for which new correction data is to be copied (with cursor keys/rollkey and ENTER):

Mixer	**Waveguide band**
FS-Z60	U
FS-Z75	V
FS-Z90	E
FS-Z110	W

- [**INPUT** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE : LOAD TABLE]
  Start copy with ENTER

- [**INPUT** : EXTERNAL MIXER : SELECT BAND : AVG CONV LOSS : **ENTER**]
  Deactivate the frequency-dependent level correction for the selected band

- [**INPUT** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE]
  Select the file which is to be replaced by a new one (with cursor keys/rollkey and ENTER):

Waveguide band	File name
U	FS-Z60
V	FS-Z75
E	FS-Z90
W	FS-Z110

- [**INPUT** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE : DELETE TABLE]
  Clear the selected file after confirmation with OK
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE : LOAD TABLE]
  Copy the new file from the disk to the hard disk of FSE. Start copy with ENTER

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

- [⇑]
  Return to menu *CONV LOSS TABLE*
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE]
  Select the desired file with cursor keys/rollkey and ENTER
  The file is marked with √ in the selection list. After leaving menu *CONV LOSS TABLE* and *SELECT BAND* by actuating key [⇑] (MENU UP) twice, the correction data of this file is used for level correction.

Example:
New correction data is to be copied to the hard disk of FSE for mixer FS-Z75. Proceed as follows:

- Insert the disk supplied in the drive of FSE
- [**SYSTEM PRESET**]
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : BAND]
  Select the V band with cursor keys/rollkey and ENTER:
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : AVG CONV LOSS : **ENTER**]
  Deactivate the frequency-dependent level correction for the selected band
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE]
  Select file FS-Z75 to be replaced using cursor keys/rollkey and ENTER
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE : DELETE TABLE]
  Clear the selected file
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE : LOAD TABLE]
  Start copy with ENTER
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE].
  Select FS-Z75 with cursor keys/rollkey and ENTER
- Return to menu *EXTERNAL MIXER* by actuating the key *MENU UP* twice
  [⇑]
  [⇑]

User's Guide

Once the conversion loss data file supplied with the mixer has been copied on the hard disk of FSE 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 on FSE.

	FS-Z60	**FS-Z75**	**FS-Z90**	**FS-Z110**
Band	U	V	E	W
Frequency range / GHz	40 - 60	50 - 75	60 - 90	75 - 110
Order of	4	6	6	8
harmonics	even	even	even	even
Ports	2	2	2	2
Bias / mA	0	0	0	0

The allocation of the conversion loss data file to a defined band is maintained after switching off the unit or resetting wit 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 REF LEVEL OFFSET).

Example:

The insertion loss a_0 of the cable used for tapping the IF signal is 0.8 dB at 741.4 MHz (corresponds to the IF). Using

➢ [**LEVEL REF** : REF LEVEL OFFSET : **0.8 dB**]

this insertion loss is taken into account.

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 spectrum analyzer and the harmonics mixer. Measurement errors due to a too low signal/noise ratio are not taken into account in the following.

Errors from the Spectrum Analyzer

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

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

The errors are specified in the data sheet of the spectrum analyzer.

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:

$$M_U = 100 \cdot [(1 \pm r_g \cdot r_l)^2 - 1] \qquad \text{(Equation 3-1)}$$

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:

$$M_U \approx \pm 200 \cdot r_g \cdot r_l \ . \qquad \text{(Equation 3-2)}$$

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

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

with r reflection coefficient
s VSWR

The mismatch of the mixer IF output and spectrum analyzer 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 of the FSE 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 spectrum analyzer:	- Absolute error - IF amplifier error - Linearity error - Error on swtiching 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 spectrum analyzer:	- Linearity error
Conditions:	- Constant bandwidths and reference level setting
	- Measurements at a signal frequency[1]
	- 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 Anaylzers’).

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:

$$\sigma^2 = \frac{a^2}{3} \qquad \text{(Equation 3-4)}$$

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

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

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

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%

$$\sigma^2 = \left(\frac{a_{RSS}}{1{,}96}\right)^2 \qquad \text{(Equation 3-6)}$$

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

[1] 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.

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

$$\sigma^2 = \frac{\left(20 \cdot \lg\left(1 - r_g \cdot r_l\right)\right)^2}{2} \qquad \text{(Equation 3-7)}$$

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

$$r = \frac{s-1}{s+1} \qquad \text{(Equation 3-8)}$$

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

$$\sigma_{tot} = \sqrt{\sigma_1^2 + \sigma_2^2 + \ldots + \sigma_n^2} \ . \qquad \text{(Equation 3-9)}$$

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 at the spectrum analyzer is 100 kHz, the signal level is approx. 20 dB below the reference level. The bandwidth error of the spectrum analyzer should be assumed to be 10%.
The data sheets for the mixer and the spectrum analyzer 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 σ_{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 FSE + 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 the yellow fiels 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 FS-Z60, FS-Z75, FS-Z90 and 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 FS-Zxx series. Defective mixers require rapair 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 5-1 Measuring Equipment and Accessories

Item	Type of equipment	Specifications recommended	Equipment recommended	R&S Order No.	Page
1	Spectrum analyzer	LO frequency range 7.5 GHz to 15.2 GHz LO level 15.5 dBm ± 3 dB IF input 741.4 MHz IF level for full scale deflection > -20 dBm Internal diplexer	FSEM 20 + B21[1)] or FSEM 21 or FSEM 30 + B21[1)] or FSEM 31 or FSEK 20 + B21[1)] or FSEK 21 or FSEK 30 + B21[1)] or FSEK 31 or FSIQ 26 + B21[1)] or ESIB 26 + B21[1)] or ESIB 40 + B21[1)] [1)] Option FSE-B21	1080.1505.20 1080.1505.21 1079.8500.30 1079.8500.31 1088.1491.20 1088.1491.21 1088.3494.30 1088.3494.31 1119.6001.26 1088.7490.26 1088.7490.40 1084.7243.02	18 22
2	Signal generator	Frequency range up to 1 GHz	SMT02	1039.2000.02	18
3	Signal source	Output level > 0 dBm Output VSWR < 2.0 : 1 Frequency range: FS-Z60: 40 GHz to 60 GHz FS-Z75: 50 GHz to 75 GHz FS-Z90: 60 GHz to 90 GHz FS-Z110: 75 GHz to 110 GHz Waveguide flange FS-Z60: UG-383/U-M FS-Z75: UG-385/U FS-Z90: UG-387/U FS-Z110: UG-387/U-M	FS-Z60: Anritsu 68085B FS-Z75: Anritsu 68085B + Anritsu 54000-5WR15 FS-Z90: Anritsu 68085B + Anritsu 54000-5WR15 Anritsu 54000-5WR10 FS-Z110: Anritsu 68085B + Anritsu 54000-5WR10		18
4	Power meter		NRVD	0857.8008.02	18
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	18
6	Power meter	Capability for waveguide sensors FS-Z60: 40 GHz to 60 GHz FS-Z75: 50 GHz to 75 GHz FS-Z90: 60 GHz to 90 GHz FS-Z110: 75 GHz to 110 GHz	Anritsu ML4803A		18

Item	Type of equipment	Specifications recommended	Equipment recommended	R&S Order No.	Page
7	Power sensor	Frequency range FS-Z60: 40 GHz to 60 GHz FS-Z75: 50 GHz to 75 GHz FS-Z90: 60 GHz to 90 GHz FS-Z110: 75 GHz 110 GHz Waveguide flange FS-Z60: UG-383/U-M FS-Z75: UG-385/U FS-Z90: UG-387/U FS-Z110: UG-383/U-M Input VSWR < 1.5 : 1 Meter noise ≤ -30 dBm Error (RSS) ≤ 4 %	FS-Z60: Anritsu MP715A FS-Z75: Anritsu MP716A FS-Z90: Anritsu MP717A		18
8	Attenuator	Attenuation 10 dB VSWR ≤ 1.15 : 1 Waveguide flange FS-Z60: UG-383/U-M FS-Z75: UG-385/U FS-Z90: UG-387/U FS-Z110: UG-387/U-M	FS-Z60: Millitech FXA-19-R10G0 FS-Z60: Millitech FXA-15-R10G0 FS-Z90: Millitech FXA-12-R10G0		18
9	Tappered waveguide transitions	required only for FS-Z90: WR12 to WR15 WR12 to WR10	Millitech TWT-15-R12R0 TWT-12-R10R0		18

Test Instructions

- Prior the performance check of the harmonic mixer total calibration of the FSE 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 FSE 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	≤ 0.8 %
		meter noise	≤ 20 pW
	- signal source	(table 5-1, item 3)	
		output level	> 0 dBm
		output VSWR	< 2.0 : 1
		frequency range	
		FS-Z60:	40 GHz to 60 GHz
		FS-Z75:	50 GHz to 75 GHz
		FS-Z90:	60 GHz to 90 GHz
		FS-Z110:	75 GHz to 110 GHz
		waveguide flange	
		FS-Z60:	UG-383/U-M
		FS-Z75:	UG-385/U
		FS-Z90:	UG-387/U
		FS-Z110:	UG-387/U-M
	- attenuator	(table 5-1, item 8)	
		attenuator	10 dB
		VSWR	≤ 1,15 : 1
		frequency range	
		FS-Z60:	40 GHz to 60 GHz
		FS-Z75:	50 GHz to 75 GHz
		FS-Z90:	60 GHz to 90 GHz
		FS-Z110:	75 GHz to 110 GHz
		waveguide flange	
		FS-Z60:	UG-383/U-M
		FS-Z75:	UG-385/U
		FS-Z90:	UG-387/U
		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	
	FS-Z60:	40 GHz to 60 GHz
	FS-Z75:	50 GHz to 75 GHz
	FS-Z90:	60 GHz to 90 GHz
	FS-Z110:	75 GHz to 110 GHz
	waveguide flange	
	FS-Z60:	UG-383/U-M
	FS-Z75:	UG-385/U
	FS-Z90:	UG-387/U
	FS-Z110:	UG-387/U-M
- tappered wavguide transitions	(table 5-1, item 9) required only for FS-Z90	
	WR12 to WR15 WR12 to WR10	

Determining the absolute level error
This measurement determines the overall level error due to level error of the FSE 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 741.4 MHz
- level -30 dBm

Measurement:

- determine output power of the signal generator with the power meter. To achive 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 FSE. Use the coaxial cable delivered with FSE or FSE-B21.

FSE settings:

- [**SYSTEM PRESET**]
- [**INPUT** : EXTERNAL MIXER : BAND LOCK ON / OFF]
  activate BAND LOCK OFF mode
- [**INPUT** : EXTERNAL MIXER : AVG CONV LOSS : **0 dB**]
- [**INPUT** : EXTERNAL MIXER : PORTS 2/3]
  select 2 PORT mixer
- [**LEVEL REF** : **-20 dBm**]
- [**FREQUENCY SPAN** : **1 MHz**]
- [**SWEEP COUPLING** : RES BW MANUAL : **10 kHz**]
- set marker to peak
  [**MARKER SEARCH** : PEAK]

Evaluation:

The deviation between the signal levels measured with the power meter and the FSE (level reading of marker 1) reflects the absolute level error of the FSE. It can be calculated as

$$\text{absolute error}_{FSE} = L_{FSE} - L_{\text{power meter}}$$

The determined absolut 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 FS-Z90**:* *Use tappered waveguide transitions (table 5-1, item 9) at the output of the signal source to adapt it to the waveguide flange of the attenuator.*

Signal source settings:

- level 0 dBm
- frequency f_{fresp}

See table 5-2 (item 2) of performance test report for values of f_{fresp}.

Power meter settings:

Determine signal level L_{gen} . To achive 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 FS-Z90*:* *Use tappered 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 FSE with connector 'LO / IF' of the harmonic mixer. Use the coaxial cable delivered with the FSE or FSE-B21.

Signal generator settings:

- frequency f_{fresp}

See table 5-2 (item 3) of performance test report for values of f_{fresp}.

FSE settings:

- [**SYSTEM PRESET**]
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : DEFAULT SETTINGS]
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : BAND]
  selection of band by means of cursor keys and ENTER :

FS-Z60:	band U
FS-Z75:	band V
FS-Z90:	band E
FS-Z110:	band W

- [**INPUT** : EXTERNAL MIXER : SELECT BAND : AVG CONV LOSS : **0 dB**]

- [**INPUT** : EXTERNAL MIXER : SELECT BAND : PORTS 2/3]
  select 2 PORT mixer

- [**FREQUENCY SPAN** : **100 kHz**]
- [**SWEEP COUPLING** : RES BW MANUAL : **10 kHz**]
- [**FREQUENCY CENTER** : {f_{fresp}}]

See table 5-2 (item 3) of performance test report for values of f_{fresp}.

- Set marker to peak
  [**MARKER SEARCH** : PEAK]

The signal level L_{FSE} is displayed by level reading of marker 1.

Evaluation:

The conversion loss can be calculated as follows:

$$a_{conv} = L_{gen} - (L_{FSE} - \text{absolute error})$$

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 5-1, item 1)

Test setup: Connect front panel connector ‘LO OUT / IF IN’ of the FSE with connector ‘LO / IF’ of the harmonic mixer. Use the coaxial cable delivered with the FSE or FSE-B21.

FSE settings:

- [**SYSTEM PRESET**]
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : DEFAULT SETTINGS]
- [**INPUT** : EXTERNAL MIXER : SELECT BAND : BAND]
  selection of band by means of cursor keys and ENTER :

FS-Z60:	band U
FS-Z75:	band V
FS-Z90:	band E
FS-Z110:	band W

- [**INPUT** : EXTERNAL MIXER : SELECT BAND : PORTS 2/3]
  select 2 PORT mixer

- [**FREQUENCY SPAN** : **10 kHz**]
- [**SWEEP COUPLING** : RES BW MANUAL : **1 kHz**]
- [**SWEEP COUPLING** : VIDEO BW MANUAL : **10 Hz**]
- [**TRACE 1** : AVERAGE]
- [**TRACE 1** : SWEEP COUNT : **30 ENTER**]
- [**LEVEL REF** : **-60 dBm**]

- [**FREQUENCY CENTER** : {f_{fresp}}]

See table 5-2 (item 4) of performance test report for values of f_{fresp}.

- [**INPUT** : EXTERNAL MIXER : SELECT BAND : AVG CONV LOSS : {a_{conv}}]

See table 5-2 (item 3) of performance test report for values of a_{conv}.

- set marker to peak
  [**MARKER SEARCH** : PEAK]

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

Performance Test Report

Note: *The values given in the datasheet are the guaranteed limits. Due to measurement errors these limits must be extended by the tolerance of the measuring equipment used in this performance test.*

Table 5.3-5-2 Performance test report

Item No.	Characteristic	Test to page	Min. value	Actual value	Max. value	Unit
1	Checking the conversion loss	18				
	absolute error		-	______	-	dB
2	Checking the conversion loss	18				
	output level L_{gen} of signal source					
	f_{fresp}					
	FS-Z60:					
	40 GHz		-	______	-	dBm
	41 GHz		-	______	-	dBm
	42 GHz		-	______	-	dBm
	43 GHz		-	______	-	dBm
	44 GHz		-	______	-	dBm
	45 GHz		-	______	-	dBm
	46 GHz		-	______	-	dBm
	47 GHz		-	______	-	dBm
	48 GHz		-	______	-	dBm
	49 GHz		-	______	-	dBm
	50 GHz		-	______	-	dBm
	51 GHz		-	______	-	dBm
	52 GHz		-	______	-	dBm
	53 GHz		-	______	-	dBm
	54 GHz		-	______	-	dBm
	55 GHz		-	______	-	dBm
	56 GHz		-	______	-	dBm
	57 GHz		-	______	-	dBm
	58 GHz		-	______	-	dBm
	59 GHz		-	______	-	dBm
	60 GHz		-	______	-	dBm

Item No.	Characteristic	Test to page	Min. value	Actual value	Max. value	Unit
2	Checking the conversion loss	18				
	output level L_{gen} of signal source					
	f_{fresp}					
	FS-Z75:					
	50 GHz		-	______	-	dBm
	51 GHz		-	______	-	dBm
	52 GHz		-	______	-	dBm
	53 GHz		-	______	-	dBm
	54 GHz		-	______	-	dBm
	55 GHz		-	______	-	dBm
	56 GHz		-	______	-	dBm
	57 GHz		-	______	-	dBm
	58 GHz		-	______	-	dBm
	59 GHz		-	______	-	dBm
	60 GHz		-	______	-	dBm
	61 GHz		-	______	-	dBm
	62 GHz		-	______	-	dBm
	63 GHz		-	______	-	dBm
	64 GHz		-	______	-	dBm
	65 GHz		-	______	-	dBm
	66 GHz		-	______	-	dBm
	67 GHz		-	______	-	dBm
	68 GHz		-	______	-	dBm
	69 GHz		-	______	-	dBm
	70 GHz		-	______	-	dBm
	71 GHz		-	______	-	dBm
	72 GHz		-	______	-	dBm
	73 GHz		-	______	-	dBm
	74 GHz		-	______	-	dBm
	75 GHz		-	______	-	dBm
	FS-Z90:					
	60 GHz		-	______	-	dBm
	61 GHz		-	______	-	dBm
	62 GHz		-	______	-	dBm
	63 GHz		-	______	-	dBm
	64 GHz		-	______	-	dBm
	65 GHz		-	______	-	dBm
	66 GHz		-	______	-	dBm
	67 GHz		-	______	-	dBm
	68 GHz		-	______	-	dBm
	69 GHz		-	______	-	dBm
	70 GHz		-	______	-	dBm
	71 GHz		-	______	-	dBm
	72 GHz		-	______	-	dBm
	73 GHz		-	______	-	dBm
	74 GHz		-	______	-	dBm
	75 GHz		-	______	-	dBm
	76 GHz		-	______	-	dBm
	77 GHz		-	______	-	dBm
	78 GHz		-	______	-	dBm
	79 GHz		-	______	-	dBm
	80 GHz		-	______	-	dBm
	81 GHz		-	______	-	dBm
	82 GHz		-	______	-	dBm
	83 GHz		-	______	-	dBm
	84 GHz		-	______	-	dBm
	85 GHz		-	______	-	dBm
	86 GHz		-	______	-	dBm
	87 GHz		-	______	-	dBm
	88 GHz		-	______	-	dBm
	89 GHz		-	______	-	dBm
	90 GHz		-	______	-	dBm

Item No.	Characteristic	Test to page	Min. value	Actual value	Max. value	Unit
2	Checking the conversion loss output level of the signal source $L_{power\ meter}$ f_{fresp}	18				
	FS-Z110:					
	75 GHz		-	______	-	dBm
	76 GHz		-	______	-	dBm
	77 GHz		-	______	-	dBm
	78 GHz		-	______	-	dBm
	79 GHz		-	______	-	dBm
	80 GHz		-	______	-	dBm
	81 GHz		-	______	-	dBm
	82 GHz		-	______	-	dBm
	83 GHz		-	______	-	dBm
	84 GHz		-	______	-	dBm
	85 GHz		-	______	-	dBm
	86 GHz		-	______	-	dBm
	87 GHz		-	______	-	dBm
	88 GHz		-	______	-	dBm
	89 GHz		-	______	-	dBm
	90 GHz		-	______	-	dBm
	91 GHz		-	______	-	dBm
	92 GHz		-	______	-	dBm
	93 GHz		-	______	-	dBm
	94 GHz		-	______	-	dBm
	95 GHz		-	______	-	dBm
	96 GHz		-	______	-	dBm
	97 GHz		-	______	-	dBm
	98 GHz		-	______	-	dBm
	99 GHz		-	______	-	dBm
	100 GHz		-	______	-	dBm
	101 GHz		-	______	-	dBm
	102 GHz		-	______	-	dBm
	103 GHz		-	______	-	dBm
	104 GHz		-	______	-	dBm
	105 GHz		-	______	-	dBm
	106 GHz		-	______	-	dBm
	107 GHz		-	______	-	dBm
	108 GHz		-	______	-	dBm
	109 GHz		-	______	-	dBm
	110 GHz		-	______	-	dBm

Item No.	Characteristic	Test to page	Min. value	Actual value	Max. value	Unit
3	Checking the conversion loss	18				
	a_{conv}					
	f_{fresp}					
	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
	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 to page	Min. value	Actual value	Max. value	Unit
3	Checking the conversion loss $\mathbf{a_{conv}}$ f_{fresp} **FS-Z90:**	18				
	60 GHz		-	______	40	dB
	61 GHz		-	______	40	dB
	62 GHz		-	______	40	dB
	63 GHz		-	______	40	dB
	64 GHz		-	______	40	dB
	65 GHz		-	______	40	dB
	66 GHz		-	______	40	dB
	67 GHz		-	______	40	dB
	68 GHz		-	______	40	dB
	69 GHz		-	______	40	dB
	70 GHz		-	______	40	dB
	71 GHz		-	______	40	dB
	72 GHz		-	______	40	dB
	73 GHz		-	______	40	dB
	74 GHz		-	______	40	dB
	75 GHz		-	______	40	dB
	76 GHz		-	______	40	dB
	77 GHz		-	______	40	dB
	78 GHz		-	______	40	dB
	79 GHz		-	______	40	dB
	80 GHz		-	______	40	dB
	81 GHz		-	______	40	dB
	82 GHz		-	______	40	dB
	83 GHz		-	______	40	dB
	84 GHz		-	______	40	dB
	85 GHz		-	______	40	dB
	86 GHz		-	______	40	dB
	87 GHz		-	______	40	dB
	88 GHz		-	______	40	dB
	89 GHz		-	______	40	dB
	90 GHz		-	______	40	dB

Item No.	Characteristic	Test to page	Min. value	Actual value	Max. value	Unit
3	Checking the conversion loss $\mathbf{a}_{\mathbf{conv}}$ f_{fresp}	18				
	FS-Z110:					
	75 GHz		-	______	42	dB
	76 GHz		-	______	42	dB
	77 GHz		-	______	42	dB
	78 GHz		-	______	42	dB
	79 GHz		-	______	42	dB
	80 GHz		-	______	42	dB
	81 GHz		-	______	42	dB
	82 GHz		-	______	42	dB
	83 GHz		-	______	42	dB
	84 GHz		-	______	42	dB
	85 GHz		-	______	42	dB
	86 GHz		-	______	42	dB
	87 GHz		-	______	42	dB
	88 GHz		-	______	42	dB
	89 GHz		-	______	42	dB
	90 GHz		-	______	42	dB
	91 GHz		-	______	42	dB
	92 GHz		-	______	42	dB
	93 GHz		-	______	42	dB
	94 GHz		-	______	42	dB
	95 GHz		-	______	42	dB
	96 GHz		-	______	42	dB
	97 GHz		-	______	42	dB
	98 GHz		-	______	42	dB
	99 GHz		-	______	42	dB
	100 GHz		-	______	42	dB
	101 GHz		-	______	42	dB
	102 GHz		-	______	42	dB
	103 GHz		-	______	42	dB
	104 GHz		-	______	42	dB
	105 GHz		-	______	42	dB
	106 GHz		-	______	42	dB
	107 GHz		-	______	42	dB
	108 GHz		-	______	42	dB
	109 GHz		-	______	42	dB
	110 GHz		-	______	42	dB

Item No.	Characteristic	Test to page	Min. value	Actual value	Max. value	Unit
4	Checking the noise display	22				
	f_{fresp}					
	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
	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 to page	Min. value	Actual value	Max. value	Unit
4	Checking the noise display f_{fresp} **FS-Z90:**	22				
	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 to page	Min. value	Actual value	Max. value	Unit
4	Checking the noise display	22				
	f_{fresp}					
	FS-Z110:					
	75 GHz		-	______	-88	dBm
	76 GHz		-	______	-88	dBm
	77 GHz		-	______	-88	dBm
	78 GHz		-	______	-88	dBm
	79 GHz		-	______	-88	dBm
	80 GHz		-	______	-88	dBm
	81 GHz		-	______	-88	dBm
	82 GHz		-	______	-88	dBm
	83 GHz		-	______	-88	dBm
	84 GHz		-	______	-88	dBm
	85 GHz		-	______	-88	dBm
	86 GHz		-	______	-88	dBm
	87 GHz		-	______	-88	dBm
	88 GHz		-	______	-88	dBm
	89 GHz		-	______	-88	dBm
	90 GHz		-	______	-88-	dBm
	91 GHz		-	______	-88	dBm
	92 GHz		-	______	-88	dBm
	93 GHz		-	______	-88	dBm
	94 GHz		-	______	-88	dBm
	95 GHz		-	______	-88	dBm
	96 GHz		-	______	-88	dBm
	97 GHz		-	______	-88-	dBm
	98 GHz		-	______	-88	dBm
	99 GHz		-	______	-88	dBm
	100 GHz		-	______	-88	dBm
	101 GHz		-	______	-88	dBm
	102 GHz		-	______	-88	dBm
	103 GHz		-	______	-88	dBm
	104 GHz		-	______	-88	dBm
	105 GHz		-	______	-88	dBm
	106 GHz		-	______	-88	dBm
	107 GHz		-	______	-88	dBm
	108 GHz		-	______	-88	dBm
	109 GHz		-	______	-88	dBm
	110 GHz		-	______	-88	dBm

Products FSEM21/31 and FSEK21/31 or FSEM20/30 and FSEK20/30 with FSE-B21

Frequency Range Extension of Spectrum Analyzers with Harmonic Mixers

Application Note

This application note describes the principle of harmonic mixing and the requirements to be met by spectrum analyzers and external mixers.

ROHDE & SCHWARZ

Subject to change – Christoph Rauscher 11.98 – Application Note 1EF43_0E

Contents

1 Introduction

The growing number of applications using wireless signal transmission, eg radiocommunication or collision avoidance systems, calls for an ever increasing number of frequencies. Since frequency requirements can no longer be met by the lower frequency bands alone, frequencies in the millimeter range are used to a growing extent. So this frequency range is not only employed by military users but opened up also for civil applications. So far, the frequencies up to 110 GHz have been of main interest. However, with demands made on harmonic suppression getting higher and EMC directives becoming more stringent (eg FCC CFR47 Part 15), this frequency limit is shifted to 200 GHz.

The frequency range above 40 to 50 GHz is covered by spectrum analyzers usually by means of external mixers because the fundamental mixing commonly employed in the lower frequency range is too complex and expensive or required components such as preselectors are not available.

This application note describes the principle of harmonic mixing and the criteria to be taken into account.

2 Fundamentals

Waveguides

Wired signal transmission in the millimeter range is preferably realized by means of waveguides because they offer low attenuation and high reproducibility. Unlike coaxial cables, the frequency range in which waveguides can be used is limited also towards lower frequencies (highpass filter characteristics). Wave propagation in the waveguide is not possible below a certain cutoff frequency where attenuation of the waveguide is very high. Beyond a certain upper frequency limit, several wave propagation modes are possible so that the behaviour of the waveguide is no longer unambiguous. In the unambiguous range of a rectangular waveguide, only H_{10} waves are capable of propagation. The following formula applies to the lower cutoff frequency $f_{c,1}$, from which such waves are capable of propagation:

$$f_{c,1} = \frac{c}{2 \cdot a \cdot \sqrt{\varepsilon_r}} \qquad \text{(Equation 2-1)}$$

where
- $f_{c,1}$ Lower cutoff frequency (in Hz)
- c Velocity of light (in m/s)
- a Length of larger dimension of waveguide (in m)
- ε_r Dielectric constant of medium in waveguide (= 1 for air)

From a limit frequency of $f_{c,2}$, the H_{01} wave can propagate in addition to the H_{10} wave. $f_{c,2}$ is therefore the upper limit frequency of the unambiguous range. The following applies:

$$f_{c,2} = \frac{c}{2 \cdot b \cdot \sqrt{\varepsilon_r}} \qquad \text{(Equation 2-2)}$$

where
- $f_{c,2}$ Upper limit frequency (in Hz)
- b Length of smaller dimension of waveguide (in m)

Usually, a ratio of $a/b = 2$ of the edge lengths is selected, so that $f_{c,2} = 2 \cdot f_{c,1}$.

Because of the high wave attenuation near the lower cutoff frequency $f_{c,1}$, and to allow for mechanical tolerances, the following transmission range is usually selected in practice [1]:

$$1.25 \cdot f_{c,1} \le f \le 1.9 \cdot f_{c,1} \qquad \text{(Equation 2-3)}$$

The dimensions of rectangular and circular waveguides are defined by international standards such as 153-IEC for various frequency ranges. These frequency ranges are also referred to as waveguide bands. They are designated using different capital letters depending on the standard. Table 2-1 provides an overview of the different waveguide bands together with the designations of the associated waveguides and flanges.

For rectangular waveguides, which are mostly used in measurements, harmonic mixers with matching flanges are available. For connecting harmonic mixers to circular waveguides, transitions are to be used whose attenuation has to be taken into account in the evaluation of results.

Table 2-1 Waveguide bands and associated waveguides

Band	Frequency	Designations				Internal dimensions of waveguide		Designations of frequently used flanges		
	in GHz	MIL-W-85	EIA	153-IEC	RCSC (British)	in mm	in inches	MIL-F-3922	UG-XXX /U equivalent (reference)	Remarks
Ka	26.5 - 40.0	3-006	WR-28	R320	WG-22	7.11 x 3.56	0.280 x 0.140	54-003 68-002 67B-005	UG-599 /U - UG-381 /U	Rectangular Rectangular Round
Q	33.0 - 50.0	3-010	WR-22	R400	WG-23	5.69 x 2.84	0.224 x 0.112	67B-006	UG-383 /U	Round
U	40.0 - 60.0	3-014	WR-19	R500	WG-24	4.78 x 2.388	0.188 x 0.094	67B-007	UG-383 /U-M	Round
V	50.0 - 75.0	3-017	WR-15	R620	WG-25	3.759 x 1.879	0.148 x 0.074	67B-008	UG-385 /U	Round
E	60.0 - 90.0	3-020	WR-12	R740	WG-26	3.099 x 1.549	0.122 x 0.061	67B-009	UG-387 /U	Round
W	75.0 - 110.0	3-023	WR-10	R900	WG-27	2.540 x 1.270	0.100 x 0.050	67B-010	UG-383 /U-M	Round
F	90.0 - 140.0	3-026	WR-08	R1200	WG-28	2.032 x 1.016	0.080 x 0.040	67B-M08 / 74-001	UG-383 /U-M	Round, pin contact
D	110.0 - 170.0	3-029	WR-06	R1400	WG-29	1.651 x 0.826	0.065 x 0.0325	67B-M06 / 74-002	UG-383 /U-M	Round, pin contact
G	140.0 - 220.0	3-032	WR-05	R1800	WG-30	1.295 x 0.635	0.051 x 0.0255	67B-M05 / 74-003	UG-383 /U-M	Round, pin contact
Y	170.0 - 260.0		WR-04	R2200	WG-31	1.092 x 0.5461	0.043 x 0.0215	67B-M04 / 74-004	UG-383 /U-M	Round, pin contact
J	220.0 - 325.0		WR-03	R2600	WG-32	0.8636 x 0.4318	0.034 x 0.017	67B-M03 / 74-005	UG-383 /U-M	Round, pin contact

Harmonic Mixing

In harmonic mixers, a harmonic of the local oscillator (LO) is used for signal conversion to a lower intermediate frequency (IF). The advantage of this method is that the frequency range of the local oscillator may be much lower than with fundamental mixing, where the LO frequency must be of the same order (with low IF) or much higher (with high IF) than the input signal (RF). Microwave spectrum analyzers use harmonic mixing also in the fundamental frequency range, FSEK for example from 26.5 GHz. To ensure image- and spurious-free spectrum display in the fundamental frequency range, a tracking preselection is provided at the RF input of the spectrum analyzer. In this way, signals are displayed at the desired frequency only. Image-frequency signals, which the mixer is not capable of distinguishing from signals at the desired frequency, are suppressed by the preselector. Preselection is not commonly used with external harmonic mixers because of the high frequencies involved. Preselection would be very costly in this case and hardly possible to realize at extremely high frequencies.

Fig. 2-1 shows the test setup for measurements using an external harmonic mixer. The mixer is fed a high-level LO signal. The harmonics generated in the mixer because of its nonlinearity are used for conversion.

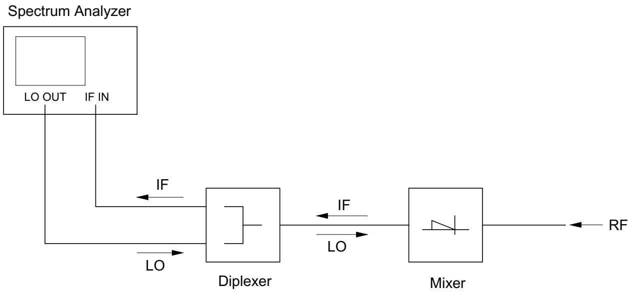

Fig. 2-1: Test setup for measurements using an external two-port mixer

The signal converted to the IF is coupled out of the line which is also used for feeding the LO signal. Because of the great frequency spacing between the LO and the IF signal, the two signals can be separated by means of a simple diplexer. The diplexer may be realized as part of the mixer or the spectrum analyzer, or as a separate component. Mixers with an integrated diplexer are also referred to as three-port mixers, mixers without diplexers as two-port mixers. To enable the use of both types of mixer, FSEM and FSEK offer a separate IF input as well as an integrated diplexer.

The LO path of harmonic mixers often contains a lowpass filter for the suppression of harmonics of the incoming LO signal. This is to prevent LO harmonics to be superimposed on the mixer-generated harmonics. Depending on the phase of the harmonics, this may cause blanking, which leads to higher conversion loss or produces notches in the frequency response characteristic. When selecting an external mixer, therefore, care should be taken that the limit frequency of the integrated lowpass filter is higher than the maximum LO frequency of the spectrum analyzer.

The RF signal applied to the input of the external mixer together with its harmonics is mixed with all harmonics of the LO signal. The mixer products that fall within the IF of the spectrum analyzer are displayed. They must fulfil the following criterion:

$$| m \cdot f_{LO} \pm n \cdot f_{RF} | = f_{IF}$$ (Equation 2-4)

where m, n 1, 2, ...

f_{LO} Frequency of LO signal (in Hz)

f_{RF} Frequency of input signal (in Hz)

f_{IF} Intermediate frequency (in Hz)

The local oscillator of FSEM and FSEK is tunable between 7.5 and 15.2 GHz. The intermediate frequency is 741.4 MHz. For an input signal with a frequency of 39 GHz, the criterion according to equation 2-4 is fulfilled for the LO frequencies listed in Table 2-2.

The variable m corresponds to the order of the harmonic of the LO signal by which the input signal is converted to the IF. The criterion is fulfilled twice for each harmonic. The input signal is represented as the upper sideband (normal position) and also as the lower sideband (inverted position) of the local oscillator signal. Components with $n \neq 1$ are harmonics of the input signal that are generated, for example, in the mixer. It can be seen that these harmonics are converted to the desired IF only by LO harmonics of a comparatively high order m. If the level of the input signal is well below the 1 dB compression point of the mixer, such components have a markedly lower level since the harmonics of the input signal are sufficiently attenuated with respect to the fundamental and in addition the conversion loss of the mixer increases with increasing order m. Therefore, only responses with $n \leq 4$ are listed in Table 2-2. While components with higher m and n exist, they can be neglected because of their low level.

Table 2-2: LO frequencies for which the criterion according to equation 2-4 is fulfilled (f_{IF} = 741.4 MHz, $n \leq 4$, $m \leq 12$)

m	n	f_{LO} / GHz	m	n	f_{LO} / GHz	m	n	f_{LO} / GHz
3	1	12.7529	8	2	9.6573	10	3	11.6259
3	1	13.2471	8	2	9.8427	10	3	11.7741
4	1	9.5647	8	3	14.5323	11	3	10.5690
4	1	9.9354	8	3	14.7177	11	3	10.7038
5	1	7.6517	9	2	8.5843	11	4	14.1144
5	1	7.9483	9	2	8.7490	11	4	14.2492
6	2	12.8764	9	3	12.9176	12	3	9.6882
6	2	13.1236	9	3	13.0824	12	3	9.8118
7	2	11.0369	10	2	7.7259	...	...	
7	2	11.2488	10	2	7.8741			

Spectrum analyzers however display the received spectrum not versus the LO frequency but versus the input frequency. For this, the user has to enter on the spectrum analyzer the order m' of the harmonic by which the input signal is to be converted. For the representation of signals in the lower sideband at the correct frequency f_{RF}', the following equation applies (derived from equation 2-4):

$$f_{RF}' = m' \cdot f_{LO} - f_{IF}$$ (Equation 2-5)

where m' Harmonic set by user

f_{RF}' Frequency at which a spectral component is displayed on the analyzer (in Hz)

The LO frequency f_{LO}, which is required for conversion of a signal in the lower sideband, is obtained from equation 2-4 as follows:

$$f_{LO} = \frac{f_{IF} + n \cdot f_{RF}}{m}. \quad \text{(Equation 2-6)}$$

By substituting equation 2-6 in equation 2-5, the following is obtained for f_{RF}':

$$f_{RF}' = m' \cdot \frac{f_{IF} + n \cdot f_{RF}}{m} - f_{IF} \quad \text{(Equation 2-7)}$$

The following applies to components converted as the lower sideband by means of a harmonic of the order $m = m'$:

$$f_{RF}' = n \cdot f_{RF}, \quad \text{(Equation 2-8)}$$

Such components are therefore represented at the correct frequency. For image frequency response, the following corresponding equations apply:

$$f_{LO} = \frac{n \cdot f_{RF} - f_{IF}}{m} \quad \text{(Equation 2-9)}$$

and

$$f_{RF}' = m' \cdot \frac{n \cdot f_{RF} - f_{IF}}{m} - f_{IF}. \quad \text{(Equation 2-10)}$$

The following is then obtained for $m = m'$:

$$f_{RF}' = n \cdot f_{RF} - 2 \cdot f_{IF} \quad \text{(Equation 2-11)}$$

If $m = 3$ is selected, the spectrum displayed on the analyzer contains components at the frequencies listed in Table 2-3 (see also Fig. 2-2 on next page). Components lying within the corresponding waveguide band (Ka band in this case) are highlighted grey.

Table 2-3: Displayed components for $m' = 3$ (lower sideband, f_{IF} = 741.4 MHz); sinewave input signal with f_{RF} = 39 GHz

m	*n*	f_{LO} / GHz	f_{RF}' / GHz	*m*	*n*	f_{LO} / GHz	f_{RF}' / GHz	*m*	*n*	f_{LO} / GHz	f_{RF}' / GHz
3	1	12.7529	37.5172	8	2	9.6573	28.2306	10	3	11.6259	34.1362
3	1	13.2471	39.0000	8	2	9.8427	28.7866	10	3	11.7741	34.5810
4	1	9.5647	27.9526	8	3	14.5323	42.8556	11	3	10.5690	30.9655
4	1	9.9354	29.0647	8	3	14.7177	43.4116	11	3	10.7038	31.3699
5	1	7.6517	22.2138	9	2	8.5843	25.0115	11	4	14.1144	41.6019
5	1	7.9483	23.1034	9	2	8.7490	25.5057	11	4	14.2492	42.0063
6	2	12.8764	37.8879	9	3	12.9176	38.0115	12	3	9.6882	28.3233
6	2	13.1236	38.6293	9	3	13.0824	38.5057	12	3	9.8118	28.6940
7	2	11.0369	32.3694	10	2	7.7259	22.4362	...	...		
7	2	11.2488	33.0049	10	2	7.8741	22.8810				

The input signal converted by means of the 3rd harmonic of the LO signal is displayed at the correct frequency f_{RF}' = 39 GHz. The image signal is displayed below this signal at a spacing of $2 \cdot f_{IF}$ = 1.4828 GHz (cf. Equation 2-11).

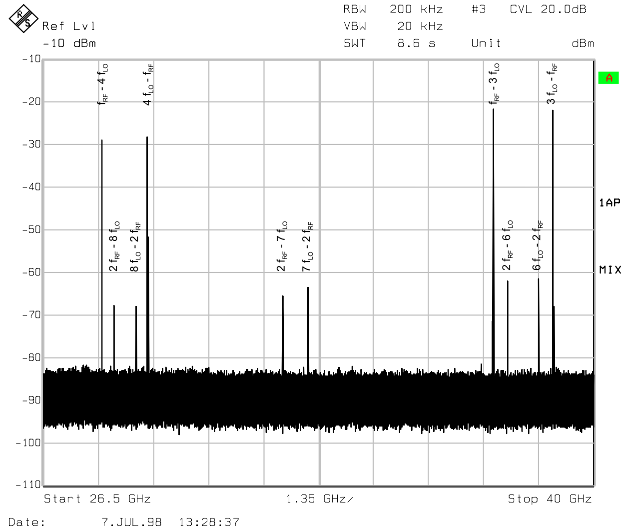

Fig. 2-2: Spectrum of 39 GHz CW signal recorded with harmonic mixer

The above example illustrates that even a simple sinewave signal produces a large number of responses. If the input signal itself contains several spectral components, intermodulation products may be generated in the mixer in addition to harmonics, such products too being converted to the IF. If the input signal consists of two sinewave carriers, the following applies:

$$\left| m \cdot f_{LO} \pm \left| n \cdot f_{RF,1} \pm k \cdot f_{RF,2} \right| \right| = f_{IF} \qquad \text{(Equation 2-12)}$$

where	k, n	0, 1, 2, ...
	m	1, 2, ...
	f_{LO}	Frequency of LO signal (in Hz)
	$f_{RF,1}$, $f_{RF,2}$	Frequencies of input signals (in Hz)
	f_{IF}	Intermediate frequency (in Hz)

The number of components increases considerably. It is advisable, therefore, to make use of the highpass filter characteristic of waveguides to suppress unwanted input signals.

Signal Identification

In the previous example, the type of input signal was known, and so it was easy to distinguish the true (or wanted) displayed signal from unwanted mixer products obtained as a result of image frequency response and mixing by other harmonics.

Frequently, the spectrum to be measured is not known however so that criteria have to be found to distinguish unwanted mixer products from spectral components that are true components of the input signal. From equation 2-10 it can be seen that for each mixture product there exist image frequencies which appear at a spacing of $f_{IF} \cdot (m'/m+1)$ below the mixture product. For $m = m'$, the spacing is exactly $2 \cdot f_{IF}$ (equation 2-11). The same applies to harmonics of the input signal, ie to $n \neq 1$. However, since the frequency ranges of the standardized waveguide bands are considerably smaller than one octave, such mixer products will not become apparent even if the full band is displayed.

Based on this criterion, the following algorithm can be realized: Apart from the actual test sweep, in which the lower sideband is defined as “wanted”, a reference sweep is performed. For the reference sweep, the frequency of the LO signal is tuned such that the user-selected harmonic of the LO signal (order *m´*) is shifted downwards by $2 \cdot f_{IF}$ relative to the test sweep (see Fig. 2-3).

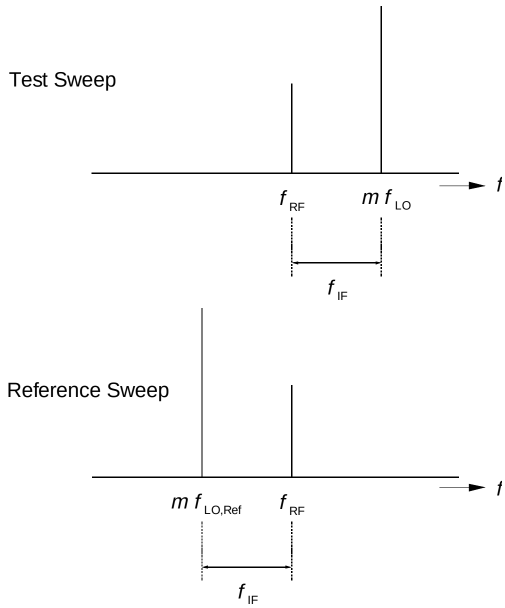

Fig. 2-3: Signal identification by means of reference sweep

For this reference sweep, the upper sideband is the wanted sideband. Equation 2-5 is therefore modified to take the following form:

$$f_{RF,Ref}' = m' \cdot f_{LO,Ref} + f_{IF} \,. \qquad \text{(Equation 2-13)}$$

where $f_{RF,Ref}´$ Frequency, at which a spectral component is displayed in reference sweep (in Hz)

$f_{LO,Ref}$ LO frequency in reference sweep (in Hz)

Equation 2-6 is modified accordingly to:

$$f_{LO,Ref} = \frac{n \cdot f_{RF} - f_{IF}}{m} \,. \qquad \text{(Equation 2-14)}$$

By substituting equation 2-14 in equation 2-13, the following results:

$$f_{RF,Ref}' = m' \cdot \frac{n \cdot f_{RF} - f_{IF}}{m} + f_{IF} \,. \qquad \text{(Equation 2-15)}$$

The following applies to image frequency responses:

$$f_{LO,Ref} = \frac{n \cdot f_{RF} + f_{IF}}{m} \qquad \text{(Equation 2-16)}$$

and therefore:

$$f_{RF,Ref}' = m' \cdot \frac{n \cdot f_{RF} + f_{IF}}{m} + f_{ZF} \,. \qquad \text{(Equation 2-17)}$$

By selecting *m´ = m* in equation 2-17, it will be seen that, unlike the test sweep, image frequency responses are displayed at a spacing of $2 \cdot f_{IF}$ above the actual input signal (cf. equation 2-8). This allows image frequency responses and other unwanted mixer products to be identified (see Fig. 2-4).

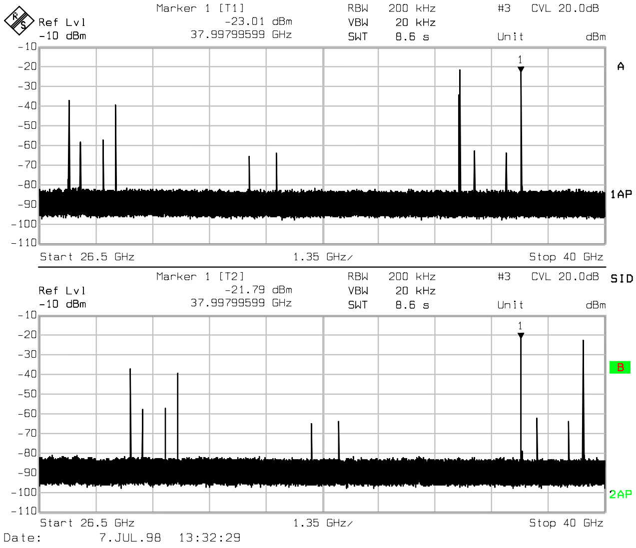

Fig. 2-4: Test sweep (top) and reference sweep (bottom)
Input signal with f_{RF} = 38 GHz

A true signal should be displayed at the same frequency in the test sweep and the reference sweep, ie $f_{RF}' = f_{RF,Ref}'$. If m' is the same for both sweeps, the following is obtained for the LO frequency $f_{LO,Ref}$ to be set for the reference sweep:

$$f_{LO,Ref} = f_{LO} - \frac{2 \cdot f_{IF}}{m'} . \qquad \text{(Equation 2-18)}$$

Apart from this method of signal identification by variation of the LO frequency, it is possible to vary the level of the input signal to identify displayed components.

By varying the level of the input signal by ΔL / dB, the level of displayed true components will vary to the same extent. The levels of intermodulation products and harmonics generated in the mixer, on the other hand, will vary according to their order n, ie a variation of the input level by 1 dB will cause a level variation of n dB. This is subject to the condition that such intermodulation products and harmonics are generated exclusively in the mixer. Care must be taken, therefore, that the input signal is free from such products. Moreover, it must be ensured that the IF input of the spectrum analyzer is not overloaded.

Since the input level can be varied only by the user, this method, unlike signal identification by varying the LO frequency, is not suitable for being implemented in a spectrum analyzer.

Characteristics of Mixers

Harmonic mixers are divided into single-diode and double-diode mixers. Most commercially available mixers are single-diode mixers, because these are easier to realize. Single-diode mixers basically operate with both even and odd harmonics of the LO signal.

The disadvantage of this concept is that it requires biasing. To this end, the mixer is fed with a DC voltage via the LO line. The DC voltage is to be adjusted frequency-dependent for minimum conversion loss of the mixer, which complicates automatic measurements at different frequencies.

Double-diode mixers are more complex but require no biasing; they are therefore also referred to as zero-bias mixers. To attain minimum conversion loss, such mixers should normally be operated with even harmonics.

Moreover, the following characteristics should be taken into account in selecting the mixer:

- required as well as maximum permissible LO power,
- permissible LO frequency range,
- conversion loss,
- frequency response of conversion loss across small frequency spans,
- order of harmonic for which the specified conversion loss is valid,
- sensitivity of conversion loss to changes of LO level,
- permissible intermediate frequency.

In addition to the optimum LO level, at which minimum conversion loss is obtained, the maximum LO power is normally specified at which the mixer can be used without any damage being caused. Because of the lowpass filter contained in the LO path of the mixer (see section “Harmonic mixing”), the usable LO frequency range must be taken into account. If the mixer incorporates a diplexer, it must further be ensured that the IF frequency of the spectrum analyzer is within the bandwidth of the IF port of the mixer.

To ensure a small level error, not only the conversion loss should be as small as possible for high sensitivity, but a continuous frequency response is equally important. Narrowband notches or steps of the frequency response can only with difficulty be taken into account in the level correction of the spectrum analyzer.

The specified conversion loss applies only to a specific order of the harmonic. If a different harmonic is selected on the spectrum analyzer, level correction by means of the values supplied for the frequency-dependent conversion loss will lead to erroneous results. To obtain reproducible results, dependence of conversion loss on the LO level should be as small as possible.

Spectrum Analyzer Requirements and their Realization in FSE

Order of LO Harmonic

To obtain low conversion loss of the external mixer, the order of the harmonic used for converting the input signal should be as low as possible. For this, the frequency range of the local oscillator must be as high as possible. Spectrum Analyzers FSEM and FSEK fully meet this requirement with an LO frequency range of 7.5 to 15.2 GHz.

A wide LO frequency range and thus a low order *m´* is of advantage also in phase noise measurements of microwave signals.

Multiplication of the signal causes an increase of the phase noise by the multiplication factor. For a harmonic of the order *m´*, SSB phase noise is obtained as follows [2]:

$$L_{PNm'}(f_{off}) = L_{LO}(f_{off}) + 20 \lg (m')\text{dB} \qquad \text{(Equation 2-19)}$$

where $L_{PNm'}(f_{off})$ SSB phase noise of harmonic of the order *m´* at a carrier offset f_{off} (in dBc(Hz))

$L_{LO}(f_{off})$ SSB phase noise of LO signal at a carrier offset f_{off} (in dBc(Hz))

Fig. 2-5 shows the typical SSB phase noise of the local oscillator of FSE.

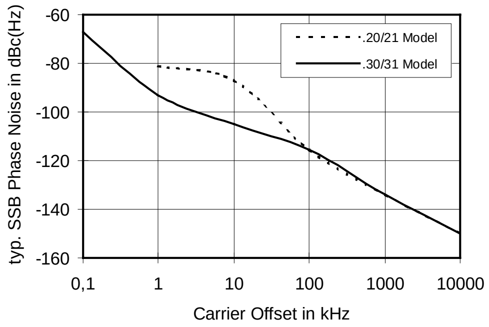

Fig. 2-5: Typical SSB phase noise of local oscillator of FSEM / FSEK

The overall noise figure of the system, which consists of a spectrum analyzer and external mixer, is composed as follows: noise figure at IF input of spectrum analyzer, plus conversion loss of mixer, plus feedthrough of LO SSB noise to the intermediate frequency. Sensitivity is usually specified as **D**isplayed **A**verage **N**oise **L**evel (L_{DAN}) for a specific IF bandwidth. The following applies:

$$L_{DAN} = -174\ \text{dBm(Hz)} + a_{CVL} + NF_{SA} + (10 \cdot \lg \frac{B_{IF}}{\text{Hz}})\text{dB} - 2{,}5\ \text{dB} \qquad \text{(Equation 2-20)}$$

where L_{DAN} Displayed average noise level (in dBm)

a_{CVL} Conversion loss of external mixer (in dB)

NF_{SA} Noise figure of analyzer at IF input (in dB)

B_{IF} Noise bandwidth of IF filter (in Hz)

The value of –174 dBm corresponds to the noise power over 1 Hz bandwidth of a 50 Ω resistance at an ambient temperature of 290 K. The correction value of 2.5 dB is necessary because of averaging of logarithmic level values.

FSEM and FSEK have a noise figure of typically 7.5 dB at their IF inputs.

The effects of broadband noise of the local oscillator are not taken into account in equation 2-20. Such effects may lead to further reduction of sensitivity. If the IF input is open and the two-port mixer is selected, the noise displayed on FSEM and FSEK is about 3 dB higher than with a three-port mixer.

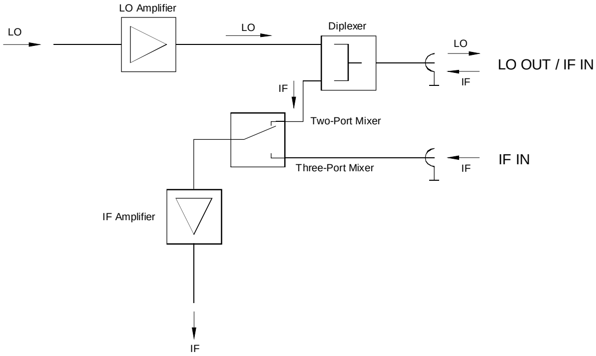

Fig. 2-6: LO amplifier and diplexer in FSE

If the signal path for a two-port mixer is selected, broadband noise at the output of the LO amplifier is applied directly to the IF path in the diplexer and leads to a higher displayed noise as described above (see Fig. 2-6).

Intermediate Frequency

The higher the IF frequency of the spectrum analyzer, the greater the spacing at which image frequency response is displayed on the frequency axis (cf. equation 2-11). Mixer products generated by conversion of the fundamental of the input signal (n = 1 in equation 2-4) by means of harmonics of the LO signal have a level clearly above that of other mixer products and are therefore easy to identify.

For a single modulated or unmodulated input signal displayed on the frequency axis, an image-free range of $2 \cdot f_{IF}$ is obtained around this signal in which no signal identification is necessary. Because of the high IF of 741.4 MHz, the image-free range for FSEM and FSEK is 1.4828 GHz. This is sufficient for many applications, doing away with the need for signal identification.

Local Oscillator Level

The level of the LO signal must be sufficiently high to ensure proper functioning of the mixer, taking into account the loss due to the cable for feeding the LO signal to the mixer. The frequency response of the LO level should be as flat as possible.

If a two-port mixer is used, it is of advantage if a diplexer is integrated in the spectrum analyzer. This does away with the need for an external diplexer, and thus no extra insertion loss needs to be taken into account in level measurements.

FSEM and FSEK both feature an internal diplexer as well as an additional IF signal input (“IF IN“ connector, see Fig. 2-6). This allows the use of either two-port or three-port mixers without the need for any external components.

Signal Identification Methods

Apart from hardware requirements, signal identification methods play an important role for the efficient use of harmonic mixers. In FSEM and FSEK, the method described in section “Signal Identification“ is implemented. The test and the reference sweep can be compared “manually” by the user and also automatically. Unwanted mixer products are blanked in the displayed spectrum. This enables fast, continuous signal identification.

Measurement Hints

To obtain accurate and reproducible results, the following points should be observed:

- A low-loss cable with a flat frequency response should be used for feeding the LO signal to the mixer. The conversion loss of the mixer is normally specified for a defined LO level. It is therefore important to maintain this level at the LO port of the mixer in order to achieve the desired accuracy.
- In level correction on the spectrum analyzer, the insertion loss of the cable used for tapping the IF signal is to be taken into account.
- If an external diplexer is used for connecting a two-port mixer, the insertion loss of the IF path of the diplexer is to be taken into account in level correction on the spectrum analyzer.

Harmonic mixers frequently have a low return loss (typ. VSWR > 2.5:1). If in addition the DUT has poor output matching, the actual conversion loss may markedly deviate from specified values. It is therefore expedient to insert an attenuator or isolator between the mixer and the DUT in order to increase measurement accuracy. However, the insertion loss caused by such a component will reduce the sensitivity of the spectrum analyzer and mixer setup. This insertion loss has also to be taken into account in level correction on the spectrum analyzer.

3 Operation of External Mixers on FSE

The operation of external mixers on FSE will be explained by means of the following example.

A sinewave signal with f = 14.5 GHz is applied to the input of a multiplier. The spectrum at the output of the multiplier is to be measured in the range 52 to 60 GHz by means of FSE and a two-port mixer for the V band. The mixer used is a double-diode mixer. Its frequency-dependent conversion loss is stored in a file on the FSE hard disk (file name: “EXTMIX_V“).

First, the mixer is connected to the waveguide output of the signal source. The LO/IF port is connected to the “LO OUT / IF IN“ connector of FSE using a low-loss coaxial cable.

External mixing is activated by:

- [**INPUT :** EXTERNAL MIXER] (1)

Then the BAND LOCK ON MODE is activated:

- [**INPUT** : EXTERNAL MIXER : BAND LOCK ON / OFF]. (2)

With

- [**INPUT** : EXTERNAL MIXER : SELECT BAND] (3)

the table with the parameters for the individual waveguide bands is called up. From this table the desired band, in this case band V, is selected.

- [**INPUT** : EXTERNAL MIXER : SELECT BAND : BAND] (4)
  Selection of band by means of cursor keys and ENTER

After selecting the band, the frequency-dependent conversion loss is to be activated. To this end, the file containing the conversion loss of the mixer used is selected.

- [**INPUT** : EXTERNAL MIXER : SELECT BAND : CONV LOSS TABLE] (5)
  Selection of file “EXTMIX_V“ with cursor keys and ENTER

The file contains all the required parameters, so that no further settings are necessary. The selected file remains stored for the selected band. If the same mixer is selected in later measurements, only steps 1 to 4 have to be executed.

After leaving the selection table with the key ⇑ (menu up), a span is set automatically by which the complete V band is covered, ie 50 to 75 GHz. The frequency range to be investigated is set with

- [**FREQUENCY START : 52 GHz**]

and

- [**FREQUENCY STOP : 60 GHz**]

To ensure reliable signal identification by means of the AUTO ID function, the video bandwidth is reduced as follows:

- [**SWEEP COUPLING** : VIDEO BW MANUAL : **1 MHz**]

The spectrum shown in Fig. 3-1 is obtained.

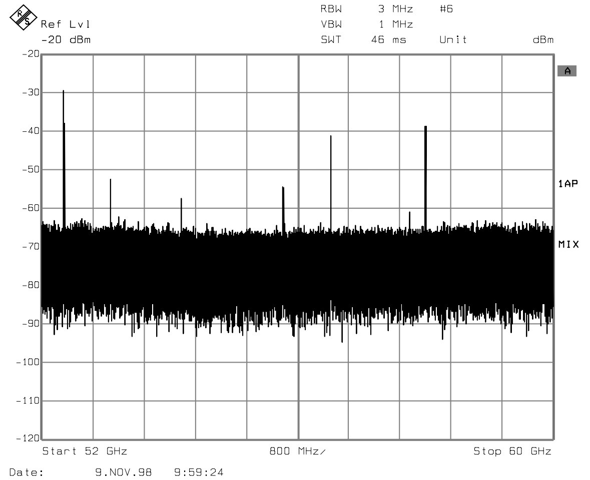

Fig. 3-1: Output spectrum of multiplier, measured by means of external mixer

To identify the true input signal, the AUTO ID function is activated:

➢ [**INPUT** : EXTERNAL MIXER : SIGNAL ID : AUTO ID]

AUTO ID operates on the principle described in section 2.3. In addition to the test sweep, a reference sweep is performed in which the LO frequency is shifted downwards in accordance with equation 2-18. The spectra measured in the two sweeps are compared with each other automatically and the result is displayed. Unwanted mixer products are blanked in the displayed trace. The display shown in Fig. 3-2 is obtained.

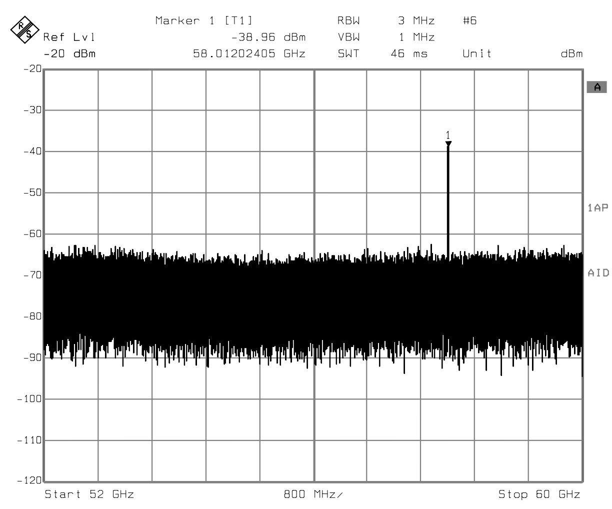

Fig. 3-2: Output spectrum of multiplier, measured by means of external mixer and AUTO ID function

Since the LO frequency is shifted downwards in the reference sweep, the mixer conversion loss may turn out to be different for the test and the reference sweep. The reasons for this are the LO output power of the spectrum analyzer varying with the frequency and the non-ideal characteristics of the mixer. A certain tolerance should therefore be allowed in the comparison of the signal levels of the test sweep and the reference sweep. The user can set this tolerance with:

➢ [**INPUT** : EXTERNAL MIXER : SIGNAL ID : AUTO ID THRESHOLD : {value} **dB**]

The tolerance must be at least as large as the difference between the conversion losses obtained for the test sweep and the reference sweep. If this is not observed, the true input signal might be displayed with an incorrect level. In the above example, a tolerance of 5 dB was selected.

Mixer conversion loss is already taken into account in the display. Only the insertion loss a_0 @ 741.4 MHz of the cable used for tapping the IF signal is to be taken into account in determining the signal level. The actual level of the input signal is higher by a_0.

4 References

[1] Janssen, W.: Hohlleiter und Streifenleiter.
Dr. Alfred Hüthig Verlag Heidelberg, 1977

[2] Engelson, M.: Sideband noise measurement using the spectrum analyzer. Application note 26W-7047, Tektronix

5 Ordering Information

Spectrum Analyzer

FSEM 20	(9 kHz to 26.5 GHz)	1080.1505.20
FSEM 21	(9 kHz to 26.5 GHz, with output for external mixer)	1080.1505.21
FSEM 30	(20 Hz to 26.5 GHz)	1079.8500.30
FSEM 31	(20 Hz to 26.5 GHz, with output for external mixer)	1079.8500.31
FSEK 20	(9 kHz to 40 GHz)	1088.1491.20
FSEK 21	(9 kHz to 40 GHz, with output for external mixer)	1088.1491.21
FSEK 30	(20 Hz to 40 GHz)	1088.3494.30
FSEK 31	(20 Hz to 40 GHz, with output for external mixer)	1088.3494.31

Required Accessories for FSEM / FSEK Models 20 / 30:

FSE-B21	(Output for external mixer)	1084.7243.02

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