Using the FREQUENCY CONVERSION Mode of Vector Network Analyzer ZVR

Application Note 1EZ47_0E

Subject to change

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Products:

ZVRL, ZVRE, ZVR, ZVC, ZVCE

with Option ZVR-B4

ROHDE&SCHWARZ

1 Abstract

The option ZVR-B4 (Frequency Converting Measurements) allows measurements on frequency converting DUT´s like mixers or amplifiers. The ZVR´s ARBITRARY mode gives highest degree of freedom in configuring the source and receiver frequency ranges: The frequency sweep range of the ZVR´s generator as well as the frequency sweep ranges of up to two external signal generators and the receiver frequency sweep range of the ZVR may all be defined independently.

This ability guarantees measurements of all kind of mixer and intermodulation products, e.g. conversion loss of up and down converters or sampling mixers or harmonic and intermodulation products of active devices. Together with the option ZVR-B6 (Reference Channel Ports), group delay measurements on frequency converting devices are also possible. Of course, measurements of reflection and isolation can be performed on mixers in the fundamental (non-converting) mode.

2 The ARBITRARY SYSTEM FREQUENCIES Mode

The flexibility of the ZVR-B4 feature is based on two independent internal frequency synthesizers: The signal source of the ZVR is independent of the local oscillators and thus of the receiver unit of the ZVR. Additionally up to two external signal generators can be used for the second or a third signal with arbitrary frequency range. They may be controlled manually (if one constant frequency is sufficient) or by the ZVR via IEC bus. For highest measurement speed, a control mode using the TTL signals BLANK and TRIGGER from the rear panel jacks is implemented.

The heart of the ZVR-B4 option is the table ARBITRARY SYSTEM FREQUENCIES. In this table, the frequency ranges for the sources and the receiver can be defined. This frequency ranges are not directly entered, but are derived from a basic frequency range, the so-called "fundamental frequency". To derive all frequencies f_i from the fundamental frequency F_f, just the basic correlations between the frequencies of interest must be known. In practice, the variables NUM, DEN and OFFSET of the linear equation

$$f_i = \frac{NUM}{DEN} \times F_f + OFFSET$$

must be defined.

3 Principles of Frequency Converting Measurements

The purpose of a mixer application is to convert a signal, in general sweeping over a finite frequency range, into another frequency range. For down-conversion, a high RF (radio frequency) signal and the LO (local oscillator) signal are fed into the mixer. In the ideal case, the mixer will produce the sum and the difference, usually called $IF^{\pm}$ (intermediate frequency). The frequency ranges result in:

$f_{IF\pm} = |f_{RF} \pm f_{LO}|$. The difference gives the down-converted signal. Depending on the LO signal, the frequency range of a mixing product IF is shifted by a constant offset with respect to the RF, or it is constant, if the LO frequency is sweeping with constant offset with respect to the RF.

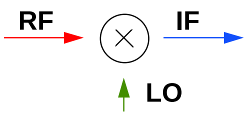


Fig. 1: Principle functionality of a mixer for down-conversion. The RF signal to be converted to a lower frequency range and the LO signal are fed into the mixer. The desired mixing product is usually called IF.

For up-conversion, the (with respect to the RF low) IF and the LO are fed into the mixer. The sum of RF and LO gives the up-converted signal.

If the signal fed into the mixer is to high and compression occurs, harmonic products arise. Furthermore, since a real mixer does not behave like an ideal product modulator, also high order mixing products exist. Besides sum and difference frequencies, also the input signal, the LO and additional mixing products with different magnitudes are present at the output. In general, the frequencies of the mixing products may be described by: $f_{IF}=n*f_{RF} \pm m*f_{LO}$; n, m = 0, ±1, ±2, ± 3, ±4 ....

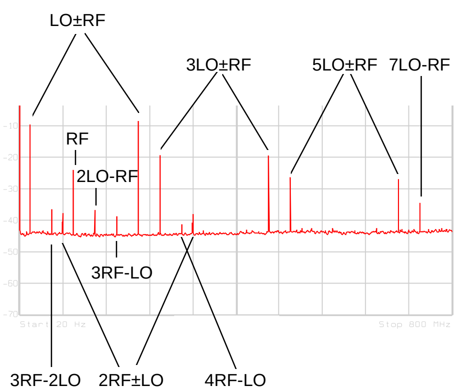


Fig. 2: Typical output frequencies on a mixer measurement.

3.1 Test Setups

Three test setups with typical mixing or intermodulation products are described below (the examples in chapter 5 of this application note refer to this setups):

3.1.1 Test Setup 1: Mixer Measurement

The ZVR´s source signal and the signal of an external signal generator are fed to the mixer. Control of the external signal generator is performed by the ZVR via IEC SYSTEM BUS II connector at the rear panel of the ZVR. In addition, a BNC cable is required, to establish a common reference frequency for the generator and the ZVR. It must be connected to the REF OUT plug of the ZVR and the REF in/out of the external generator (or vice versa).

In the standard IEC control mode, each single frequency value is sent to the signal generator. To accelerate a sweep, a high speed mode may be activated. In this case, the frequency values are loaded into the signal generator on starting a measurement. During the sweeps, just TTL pulses cause the signal generator to step from one frequency point to the next one. If this high speed mode is used, two more BNC cables are required for the BLANK and TRIGGER signals (the MARKER signal is not used). Some R&S generators are equipped with a combined connector instead of the three BNC sockets (table page 7).

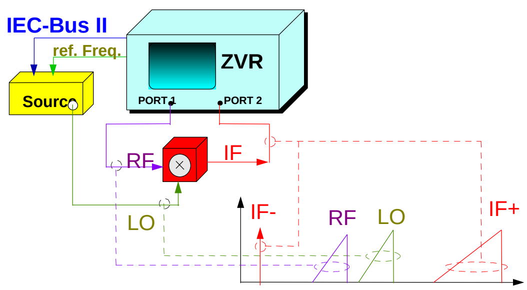


Fig. 3: Test setup for a mixer measurement, consisting of a ZVR, a second signal source (external signal generator), a mixer and IEC bus, control and RF cables.

Mostly of interest are the mixing products $IF^{\pm} = |RF \pm LO|$. In addition, higher order products described by the relation n*LO ± m*RF (n, m = ±2, ± 3, ±4 ...), that stem from the non-linear behaviour of the mixer might be investigated.

3.1.2 Test Setup 2: Amplifier Measurements

An amplifier, fed with a signal at frequency f_0 and driven into compression, will produce harmonic products ($2*f_0$, $3*f_0$, etc). The ZVR makes it very easy to measure this kind of mixing products, as two softkeys (SECOND HARMONIC or THIRD HARMONIC) cause the receiver to measure the double/triple frequency of the generator.

Furthermore, the behaviour of an amplifier fed with a two tone signal (representing a signal in an adjacent channel), is of interest. Such a two tone signal is generated by superposing the ZVR source signal and an external generator signal using a combiner.

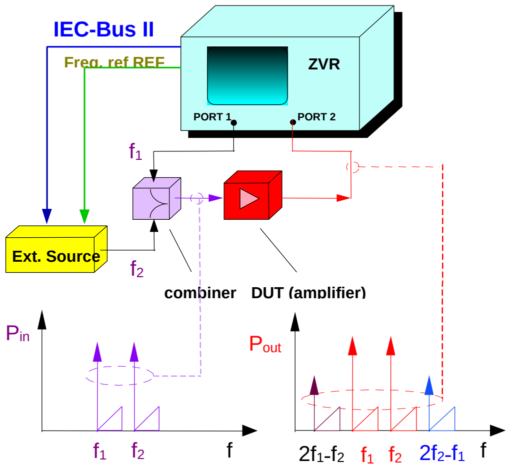


Fig. 4: Test setup for an amplifier measurement: To measure the intermodulation, a two tone signal is produced using a combiner.

Feeding this two tones to an amplifier causes so-called intermodulation products. The third order products, described as $2*f_2$-f_1 (upper IP3) and $2*f_1$-f_2 (lower IP3) are of special interest, as these two frequencies are quite close to the main tones and may hardly be suppressed by a band pass filter (Fig. 5).

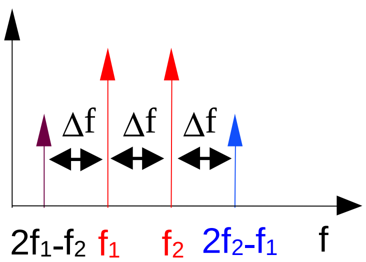


Fig. 5: Relationship between two carriers f_1 and f_2 and their intermodulation products $2*f_2$-f_1 (upper IP3) and $2*f_1$-f_2 (lower IP3). The distance between all adjacent frequencies is constant and equal to $\Delta f = f_2 - f_1$.

3.1.3 Test setup 3: Intermodulation of a Mixer

Feeding e. g. an up-converter with a two tone signal $f_{1,2}$ as RF input results in an intermodulation of the mixing products $F_1 = f_1 + LO$ and $F_2 = f_2 + LO$.

So, the upper IP3 results in

$2*(f_2+LO)-(f_1+LO) = LO+2*f_2-f_1$,

and the lower IP3 is

$2*(f_1+LO)-(f_2+LO) = LO+2*f_1-f_2$.

This kind of measurement becomes important if intermodulation compression is of special interest.

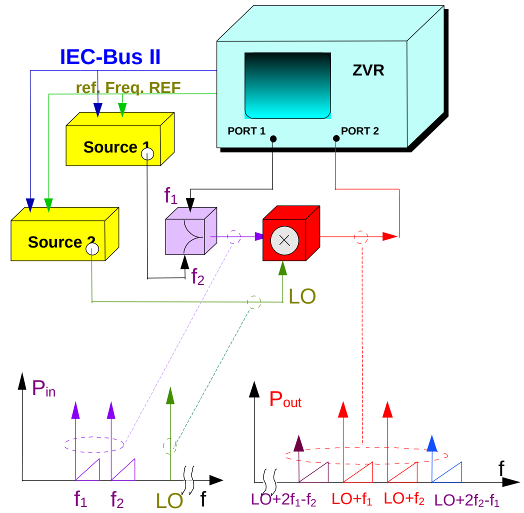


Fig. 6: Test setup for an intermodulation measurement of a mixer: To provide a two tone signal and a LO signal, a second external signal generator is used.

4 Menus of the FREQUENCY CONVERSION Mode

The softkey menu for the ZVR-B4 option is selected by

SYSTEM - MODE : FREQUENCY CONVERS.

FUNDAMENTAL

This key switches off a frequency converting measurement.

SECOND HARMONIC

This key causes the ZVR receiver to measure at the double frequency of the ZVR source at any frequency point of a sweep. On the x-axis, the receiver frequency is indicated. This mode enables the measurement of the second harmonic product (e.g. of an amplifier driven into compression).

THIRD HARMONIC

This key causes the ZVR receiver to measure at the triple frequency of the ZVR source at any frequency point of a sweep. On the x-axis, the receiver frequency is indicated. This mode enables the measurement of the third harmonic product (e.g. of an amplifier driven into compression).

MIXER MEAS

This softkey activates a mixer measurement defined in the DEF MIXER MEAS menu.

DEF MIXER MEAS

This menu allows specific mixer measurements with one fixed frequency (LO, RF or IF).

ARBITRARY

This softkey activates a frequency converting measurement defined in the DEF ARBITRARY menu.

DEF ARBITRARY

This menu opens the tables ARBITRARY SYSTEM FREQUENCIES and EXT SOURCES CONFIG, used to set the parameters for a frequency converting measurement.

4.1 The DEF ARBITRARY Menu & Table

This menu consists of the two softkeys

ARBITRARY SYST FREQ

to edit the table ARBITRARY SYSTEM FREQUENCIES and the softkey

EDIT SRC CONFIG

to edit the table for configuring the control of one or two external signal generators by the ZVR via IEC bus.

The configuration of a frequency converting measurement in the ARBITRARY mode is defined by editing the table ARBITRARY SYSTEM FREQUENCIES. The table is edited by pressing:

SYSTEM- MODE : FREQUENCY CONVERS :DEF ARBITRARY

Once having configured a measurement, the arbitrary mode is activated by

SYSTEM- MODE : FREQUENCY CONVERS : ARBITRARY

The arbitrary mode may be switched off via

SYSTEM- MODE : FREQUENCY CONVERS : FUNDAMENTAL

ARBITRARY SYSTEM FREQUENCIES

FUNDAMENTAL FREQUENCY: 9 kHz ... 4 GHz

FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		-10 dBm	(	1	/	1	)xF		=	9kHz..4GHz
EXT SRC1										
EXT SRC2										
RECEIVE			(	1	/	1	)xF		=	9kHz..4GHz

Table 1: The default setting of the ARBITRARY SYSTEM FREQUENCIES table for a ZVR. To configure a frequency converting measurement, it allows to define the frequency ranges for up to three signal sources and the ZVR receiver.

4.1.1 The parameters of the ARBITRARY SYSTEM FREQUENCIES table

To select a parameter, use the Roll Key or the Key Tabs to step through the fields in the table and press the **x1** hardkey to edit this parameter. Only those fields can be highlighted that allow their contents to be modified.

FUNDAMENTAL FREQUENCY

This frequency range is defined by the hardkeys

STIMULUS- START (STOP) or

STIMULUS- CENTER (SPAN).

From the fundamental frequency range, all other frequency ranges for the sources and the receiver are derived by defining the parameters of a simple linear equation. **The FUNDAMENTAL FREQUENCY will always be displayed on the x-axis !** This makes it possible to get the measurement quantity (e.g. |b2/a1| for the conversion loss) displayed versus the RF, LO or IF frequency values. Having defined once a relationship for the sources and receiver frequency ranges, just the FUNDAMENTAL FREQUENCY range must be changed. All other frequency ranges will be adapted automatically.

FREQ

This column lists all frequencies that can be configured in the ARBITRARY mode:

INT SRC	Source of the ZVR
EXT SCR1	External source #1
EXT SRC2	External source #2
RECEIVE	Receiver of the ZVR

ON

Selecting the ON field for EXT SRC1 or EXT SRC2 and pressing the **x1** hardkey, activates communication with the correspondent IEC bus controlled source. INT SRC and the RECEIVE are always activated.

POWER

This column indicates the output power of the corresponding source.

The power of the ZVR is set by:

SWEEP- SOURCE : POWER

Please take care of the fact, that step attenuation, set by **SWEEP- SOURCE :** STEP ATT a1(2), is not taken into account by the ARBITRARY table (e.g.: -10 dBm source power of the ZVR and 20 dB step attenuation a1 result in an output power of -30 dBm, but -10 dBm are indicated by the arbitrary table).

The power values for the external signal sources are set by:

SWEEP- SOURCE ⇨ EXT SRC 1(2) POWER

This softkey is deactivated as long as no external source is configured in the EXT SOURCES CONFIG table.

NUM		**DEN**	**xF**	**OFFSET**

By these fields, the linear relation

$$f_i = \frac{NUM}{DEN} \times F + OFFSET$$

is defined to derive the desired frequency ranges f_i from the fundamental frequency F.

The integer values in the two columns NUM and DEN are the numerator and the denominator of a fraction to derive a new frequency range from the fundamental frequency range F. The default values are (1/1). Negative values are allowed. Some numerical examples are presented in chapter 5.

Activating the **xF** field causes a multiplication of the fundamental frequency with the defined fraction and enables the sweep mode of the concerned signal source. **xF** may be switched on and off by highlighting the field and pressing the **x1** hardkey. Switching **xF** off results in setting the corresponding frequency to the CW mode.

OFFSET is a constant frequency value. With **xF** switched on, OFFSET is a constant frequency offset. If **xF** is switched off, it defines the constant frequency for a source or the receiver. A negative value, with an absolute value higher than the upper fundamental frequency value, causes also a reverse sweep of the sources or receiver.

RESULT

This column shows the frequency ranges for the sources and the receiver, derived from the fundamental frequency.

Deriving (formal) negative frequency values for the RESULT field causes the concerned source or receiver to sweep in inverse direction.

4.1.2 Configuring an external generator

For the configuration of the external instruments, the table

SYSTEM- MODE : FREQUENCY CONVERS : DEF ARBITRARY : EXT SRC CONFIG

is used. The instrument(s) must be connected to the IEC SYSTEM BUS II connector at the rear panel of the ZVR. Once configured, full control by the ZVR takes place.

EXT SOURCES CONFIG			
SRC	REMOTE	IEC ADDR	TYPE
1	OFF	19	SMIQ02
2	OFF	19	SME03

Table 2: The EXT SOURCES CONFIG table to configure the control of external signal generators by the ZVR.

TYPE

Highlighting a field in the TYPE column and pressing **x1** opens a list of supported signal generators.

IEC ADDR

In this field, the IEC bus address of the external source must be entered. The address can be seen from the generator´s menu.

REMOTE

Activating the REMOTE field, a further table is shown to define the type of communication with the external signal generator. Depending of the type of the instrument, one of the tables below appears:

REMOTE
√OFF
GPIB

REMOTE
√OFF
GPIB
GPIB+TTL

OFF

No communication takes place.

GPIB

The presence of the instrument is checked by a handshake signal. Performing frequency converting measurements, all commands and (frequency) values are sequentially sent to the signal generator.

GPIB + TTL

Available for most newer R&S signal generators, this kind of communication accelerates a measurement by many times. In addition to the IEC bus cable, two BNC cables are required to connect the BLANK and TRIGGER connectors at the rear panel of the ZVR to the corresponding connectors of the signal generator. In some R&S generators, these signals are combined in one connector. Using this mode, a list of frequency values for the configured sweep is sent to the signal generator in the beginning of the measurement. During the measurement, the TTL signals cause the signal generator to step from one frequency point to the next.

4.1.3 List of supported instruments

Instrument	GBIP+TTL Mode	Connector Type of Blank/Marker/Trigger
SME02	X	-
SME03	X	-
SME06	X	-
SMG	-	-
SMGL	-	-
SMGU	-	-
SMH	-	-
SMHU	-	-
SMIQ02	X	X
SMIQ03	X	X
SMP02	-	-
SMP03	-	-
SMP04	-	-
SMP22	-	-
SMT02	-	-
SMT03	-	-
SMT06	-	-
SMY01	-	-
SMY02	-	-
HP8340A	-	-
HP_ESG	-	-

Table 3: List of supported instruments to be used as external sources performing a frequency converting measurement.

In addition to the listed instruments, any instrument may be controlled by the ZVR. An instruction how to establish this is given in the application notes 1EZ46_0D (German) or 1EZ46_0E (English).

5 Examples

The frequency ranges and power levels for all examples described in this chapter refer to the specifications of the amplifiers and mixers used by 1ESP for demonstration purposes.

5.1 Mixing with constant LO

5.1.1 Upconversion: Upper sideband

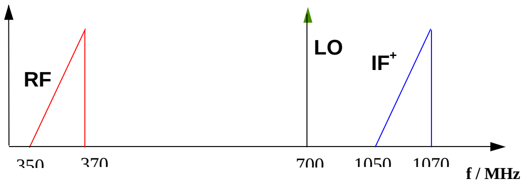
This example requires “Test Setup 1: Mixer Measurement” (page 3).

In this example, the sweeping RF signal is generated by the ZVR. The RF frequency range should be displayed on the x-axis and thus be equal to the fundamental frequency. The fundamental frequency is entered with the keys**: STIMULUS - START** (350 MHz) and **STIMULUS - STOP** (370 MHz) for this example. Without further changing, the RESULT value in first line of the ARBITRARY SYSTEM table results in “350 MHz ... 370 MHz”, the desired value for the ZVR source (INT SRC).

To cause a fixed LO signal (700 MHz) with the external signal generator, the ON field in the EXT SRC1 line must be activated; the **xF** field remains deactivated, as no sweep mode is required. For the OFFSET value, 700 MHz must be entered.

Supposed the upper side band IF^+ = RF+LO is of interest, the frequency range of 1050 MHz to 1070 MHz for the ZVR receiver must be derived from the fundamental frequency. This is done by entering 700 MHz in the OFFSET field of the RECEIVE line (due to the formula on page 2).

The frequency ranges look as outlined below:



The source power of the ZVR should be set to 0 dBm, the external source should be 7 dBm (see page 6 for setting the power). The corresponding configuration table results in:

ARBITRARY SYSTEM FREQUENCIES										
FUNDAMENTAL FREQUENCY: 350 MHz ... 370 MHz										
FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		0 dBm	(	1	/	1	)xF		=	350MHz..370MHz
EXT SRC1	√	7 dBm						700 MHz	=	700MHz
EXT SRC2										
RECEIVE			(	1	/	1	)xF	+700 MHz	=	1.05GHz..1.07GHz

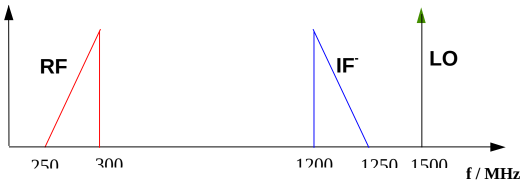
The same measurement of |b2/a1| can also be configured by displaying the corresponding IF frequency on the x-axis, which must be equal to the fundamental frequency, as the fundamental frequency is always displayed on the x-axis. In this case, the frequency for the generator must be derived from the fundamental frequency, which is now 1.050 GHz to 1.070 GHz:

ARBITRARY SYSTEM FREQUENCIES										
FUNDAMENTAL FREQUENCY: 1.05 GHz ... 1.07 GHz										
FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		0 dBm	(	1	/	1	)xF	-700 MHz	=	350MHz..370MHz
EXT SRC1	√	7 dBm						700 MHz	=	700MHz
EXT SRC2										
RECEIVE			(	1	/	1	)xF		=	1.05GHz..1.07GHz

5.1.2 Upconversion: Lower sideband, sweep inversion

This example requires “Test Setup 1: Mixer Measurement” (page 3).

If the situation occurs, that the LO frequency is higher than the RF frequency range, the lower side band, defined by $IF^- = |RF - LO|$, is in inverted position. This means, that with increasing RF frequency, the IF frequency decreases. This situation is shown in the drawing below:



The ARBITRARY SYSTEM FREQUENCIES table below configures this measurement, displaying the RF frequency on the x-axis:

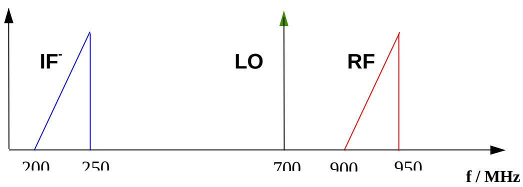
(Swept negative frequencies mean that the sweep direction is inverted)

ARBITRARY SYSTEM FREQUENCIES										
FUNDAMENTAL FREQUENCY: 250 MHz ... 300 MHz										
FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		0 dBm	(	1	/	1	)xF		=	250MHz..300MHz
EXT SRC1	√	7 dBm						1.5 GHz	=	1.5GHz
EXT SRC2										
RECEIVE			(	1	/	1	)xF	-1.5 GHz	=	1.25GHz..1.2GHz

5.1.3 Downconversion

This example requires “Test Setup 1: Mixer Measurement” (page 3).

If a high RF input signal should converted in a lower band, a high LO signal is applied. The desired mixing product is given by $IF^- = |RF - LO|$. The drawing below shows the situation:



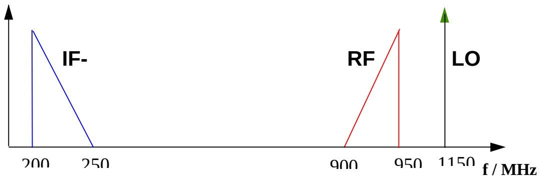
If we want the IF to be displayed, the corresponding configuration table results in:

ARBITRARY SYSTEM FREQUENCIES										
FUNDAMENTAL FREQUENCY: 200 MHz ... 250 MHz										
FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		0 dBm	(	1	/	1	)xF	+700 MHz	=	900MHz..950MHz
EXT SRC1	√	7 dBm						700 MHz	=	700MHz
EXT SRC2										
RECEIVE			(	1	/	1	)xF		=	200MHz..250MHz

5.1.4 Downconversion: Inverse sweep

This example requires “Test Setup 1: Mixer Measurement” (page 3).

A similar same result as in 5.1.3 may be achieved, when the LO frequency is higher than the RF frequency. But in this case, the IF^- = |RF - LO| accepts again inverse direction:



To configure the inverse sweep direction of the receiver in the ARBITRARY table, the fundamental frequency range is converted into the negative range by subtracting the frequency span of 450 MHz. The ZVR will display the fundamental frequency range (200 MHz to 250 MHz) on the x-axis.

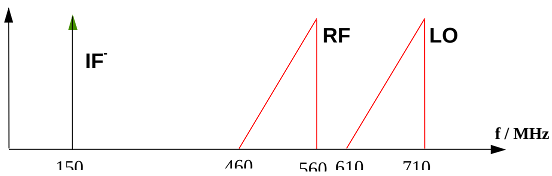
ARBITRARY SYSTEM FREQUENCIES										
FUNDAMENTAL FREQUENCY: 200 MHz ... 250 MHz										
FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		0 dBm	(	1	/	1	)xF	+700 MHz	=	900MHz..950MHz
EXT SRC1	√	7 dBm						1.15 GHz	=	1.15GHz
EXT SRC2										
RECEIVE			(	1	/	1	)xF	-450 MHz	=	250MHz..200MHz

5.2 Mixing to a constant frequency

5.2.1 Downconversion

This example requires “Test Setup 1: Mixer Measurement” (page 3).

Up to now, a signal generator was set to a constant LO frequency. Sweeping both, the RF and the LO signal, allows to mix them to a fixed IF. In this example, the IF^- = |RF-LO| should be constant 150 MHz as may be seen from the schema below:



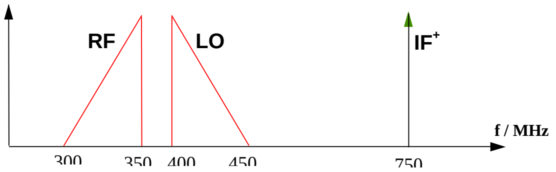
To activate the sweep mode of the external signal generator, the **xF** field for the external source must be switched on. In the RECEIVE line, the **xF** must be deactivated. In this case, the receiver of the ZVR will be set to a constant frequency value of 150 MHz, defined by the OFFSET value.

ARBITRARY SYSTEM FREQUENCIES										
FUNDAMENTAL FREQUENCY: 460 MHz ... 560 MHz										
FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		0 dBm	(	1	/	1	)xF		=	460 MHz..560 MHz
EXT SRC1	√	7 dBm	(	1	/	1	)xF	+150 MHz	=	610 MHz..710 MHz
EXT SRC2										
RECEIVE								150 MHz	=	150 MHz

5.2.2 Upconversion

This example requires “Test Setup 1: Mixer Measurement” (page 3).

Sweeping the LO and the RF frequency range in opposite directions allows to up-convert to a constant IF frequency, if the sum $IF^+ = RF + LO$ is regarded. An example is outlined below:



In this case, the external generator has to sweep in inverse direction. To configure this measurement, from the fundamental frequency (equal to RF), which varies from 300 MHz to 350 MHz, the LO frequency range, varying from 450 MHz to 400 MHz must be derived. A (formal) negative frequency value causes the ZVR source to sweep in inverse direction. In this case, the negative sign is generated by subtracting 750 MHz from the fundamental frequency.

ARBITRARY SYSTEM FREQUENCIES

FUNDAMENTAL FREQUENCY: 300 MHz ... 350 MHz

FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		0 dBm	(	1	/	1	)xF		=	300 MHz..350 MHz
EXT SRC1	√	7 dBm	(	1	/	1	)xF	-750 MHz	=	450 MHz..400 MHz
EXT SRC2										
RECEIVE								750 MHz	=	750 MHz

5.3 Measurements on mixers with internal LO

Some converter modules incorporate an internal LO. In a test setup, no additional signal generator is necessary. If such a measurement object is not available (as it is still in development or not part of the demonstration kit), the measurement setup may be simulated by using a standard mixer without internal LO in combination with an external signal generator (similar to “Test Setup 1: Mixer Measurement”, page 3), but switching off the IEC bus control of the signal generator (in the EXT SOURCES CONFIG table) and setting the constant LO frequency manually. This example - 5.3 - refers to the setup with standard mixer and external source, but this setup makes no difference for the configuration of the ARBITRARY table in comparison to a measurement on a mixer with internal LO.

Make sure that the power of the signal generator is set the right value, e. g. +7 dBm.

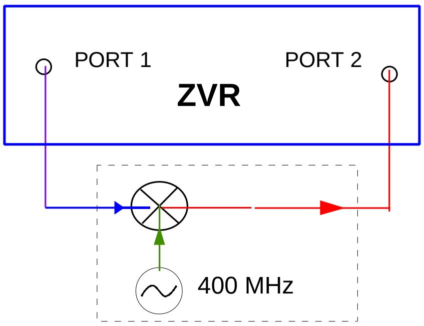
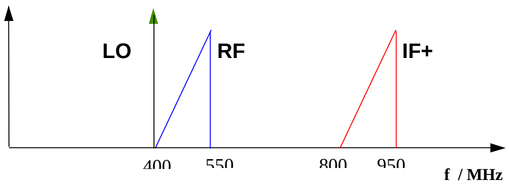


Fig. 7: Block diagram for a measurement on a mixer with internal LO generator, symbolised by the dashed line. LO frequency e. g. 400 MHz. In this example, the internal LO can be simulated using an external signal generator, which is not controlled by the ZVR but manually configured.

Note that this type of measurement is only possible if the residual FM of the internal LO is much smaller than the IF bandwidth of the ZVR.

The frequency ranges for a simple up-conversion measurement may look as drawn below.



To perform this measurement, it is sufficient to sweep just the source and the receiver of the ZVR with a constant offset of 400 MHz.

ARBITRARY SYSTEM FREQUENCIES

FUNDAMENTAL FREQUENCY: 400 MHz ... 550 MHz

FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		0 dBm	(	1	/	1	)xF		=	400 MHz..550 MHz
EXT SRC1										
EXT SRC2										
RECEIVE			(	1	/	1	)xF	+400 MHz	=	800 MHz..950 MHz

If the internal LO frequency of the mixer is not known precisely, it can be determined by performing a measurement of the power of the IF signal (usually by a measurement of input b2) in dependence of the IF frequency. This kind of measurement is possible, if there is a LO penetration to the output of the mixer. On page 13, a typical measurement result is displayed. In this quasi spectrum analyzer mode, the CENTER frequency should be set to the assumed LO frequency and the SPAN to about 50 kHz. The measured peak position gives the LO frequency. The shape of the peak depends on the internal IF bandwidth, as the shape of the digital filter for the IF will be transferred to the displayed b2(f) pattern.

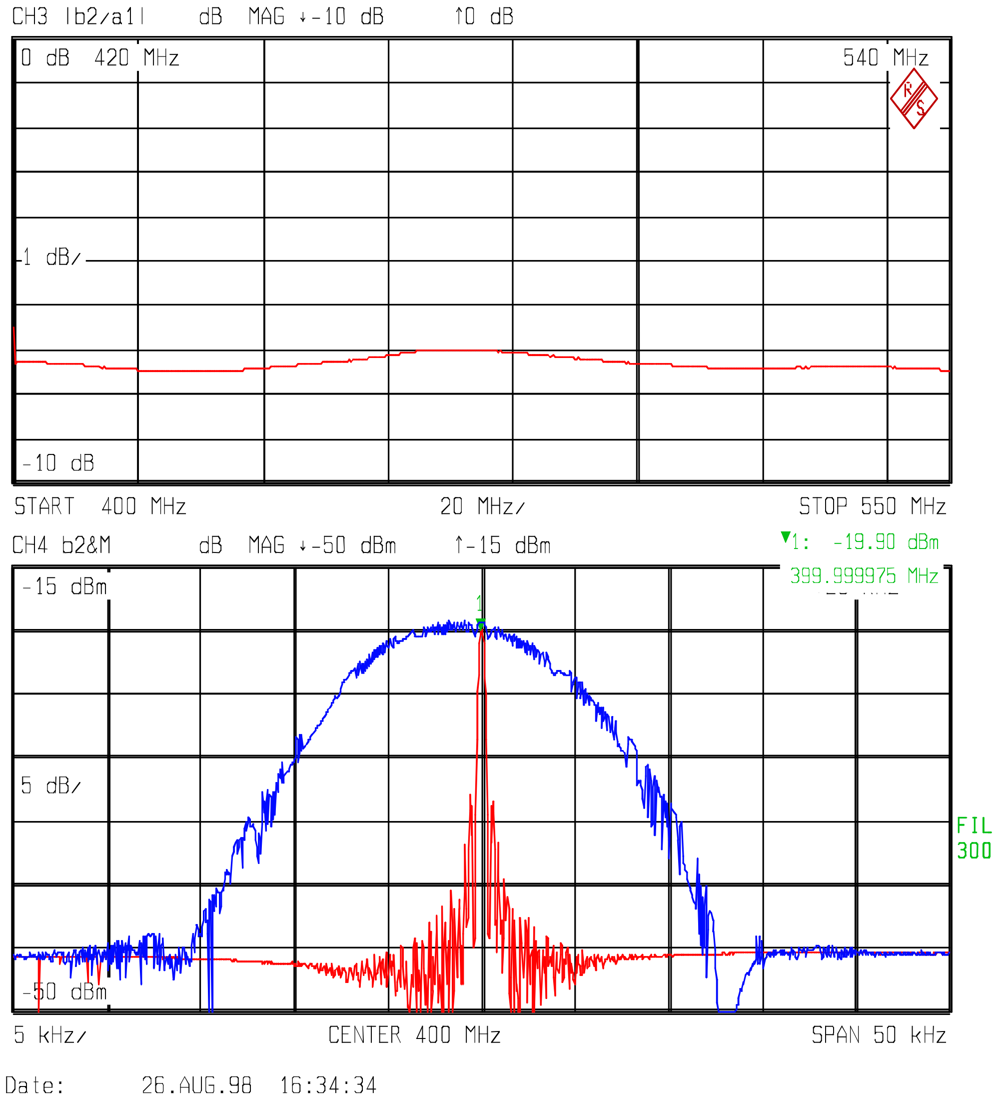


Fig. 8:

Upper display:

Conversion gain |b2/a1| of the measurement described in chapter 5.3.

Lower display:

Measurement of b2, to get the exact value of an internal LO frequency (LO penetration). This type of measurement is realised in this example with a mixer without internal LO, but in combination with an external signal generator. A sweep was configured with center frequency 400 MHz and span 50 kHz. The cursor at the maximum gives 399.999975 MHz for the LO (signal generator). Two different internal bandwidths are used: 100 Hz (small peak, red) and 10 kHz (wide peak, blue), to show the influence of the IF bandwidth in the ZVR.

5.4 Measurement of intermodulation products of an amplifier

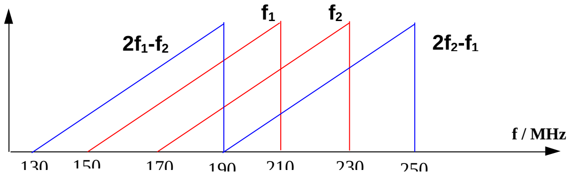
This example - 5.4 - refers to “Test Setup 2: Amplifier Measurements” (page 4).

The measurement parameter should be set to **RESPONSE - MEAS :** INPUT : b2, as the conversion gain is no more a meaningful measurement parameter measuring the output power of an amplifier. When active devices with nonlinear behaviour are stimulated with a multitone signal, they will produce mixing products of the signals. Fed with two frequencies f_1 and f_2, the resulting frequency spectrum is given by $|n*f_1 \pm m*f_2|$, n,m=0, ±1, ±2, ...

The third order intermodulation products (IP3) $2*f_1-f_2$ and $2*f_2-f_1$ are of special interest (page 4).

For f_1=150 MHz to 210 MHz and f_2=170 MHz to 230 MHz, the resulting frequency ranges are:

2 f_1-f_2=130 MHz to 190 MHz and 2 f_2-f_1=190 MHz to 250 MHz, as shown in the drawing below:



The frequency range of the lower signal f_1 should be displayed on the x axis and thus be equal to the fundamental frequency F:

$F=f_1$=150 MHz to 210 MHz

Then f_2 is given by an offset of 20 MHz to f_1: $f_2 = f_1$ + 20 MHz

The receiver frequency ranges are derived from the fundamental frequency F by:

Lower IP3: $2*f_1-f_2 = 2* f_1-(f_1+20$ MHz) = f_1-20 MHz = f-20 MHz

Upper IP3: $2*f_2-f_1 = 2*(f_1+20$ MHz)-f_1 = f_1+40 MHz = f+40 MHz

ARBITRARY configuration table for $2*f_1-f_2$ (lower IP3):

ARBITRARY SYSTEM FREQUENCIES										
FUNDAMENTAL FREQUENCY: 150 MHz ... 210 MHz										
FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		0 dBm	(	1	/	1	)xF		=	150 MHz..210 MHz
EXT SRC1	√	7 dBm	(	1	/	1	)xF	+20 MHz	=	170 MHz..230 MHz
EXT SRC2										
RECEIVE			(	1	/	1	)xF	-20 MHz	=	130 MHz..190 MHz

ARBITRARY configuration table for $2*f_2-f_1$ (upper IP3):

ARBITRARY SYSTEM FREQUENCIES										
FUNDAMENTAL FREQUENCY: 150 MHz ... 210 MHz										
FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		0 dBm	(	1	/	1	)xF		=	150 MHz..210 MHz
EXT SRC1	√	7 dBm	(	1	/	1	)xF	+20 MHz	=	170 MHz..230 MHz
EXT SRC2										
RECEIVE			(	1	/	1	)xF	+40 MHz	=	190 MHz..250 MHz

5.5 Measurement of intermodulation products of a mixer (Upconverter)

This example refers to “Test Setup 3: Intermodulation of a Mixer” (page 4).

In this case, the measurement parameter must be set to **RESPONSE - MEAS :** RATIO : |b2/a1|, as the conversion loss is measured. Two frequencies f_1 and f_2 are fed to the mixer using a combiner. Beside other products, this results in two new frequency ranges F_1=LO+f_1 and F_2=LO+f_2, acting as carriers and causing further mixing products. We will focus again on the IP3 products, which are described now as:

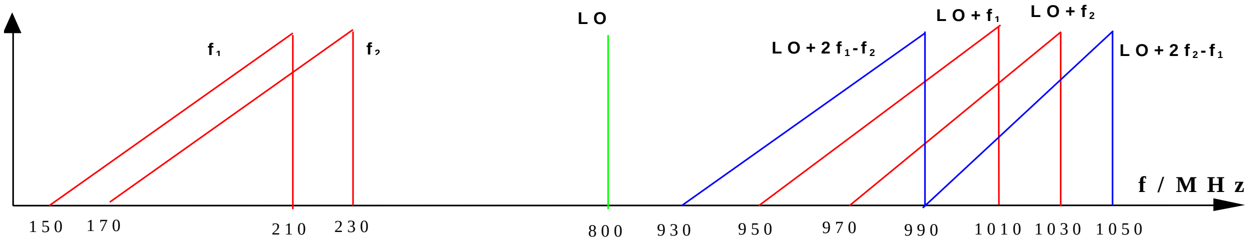
Lower IP3: $2*F_1-F_2 = 2*(LO+f_1)-(LO+f_2) = LO+2*f_1 - f_2$

Upper IP3: $2*F_2-F_1 = 2*(LO+f_2)-(LO+f_1) = LO+2*f_2 -f_1$

With f_1 =150 MHz to 210 MHz,

f_2 =170 MHz to 230 MHz and

LO = 800 MHz, the resulting frequency ranges are:



- The lower carrier frequency f_1 should be displayed on the x axis and thus be equal to the fundamental frequency F: F = f_1 = 150 MHz to 210 MHz (ZVR source)
- The second carrier f_2 is given by an offset of 20 MHz to the F: f_2 = F + 20 MHz (external source #1)
- The LO is set to the constant value of 800 MHz (external source #2).
- The receiver frequency for the lower IP3 is given by:
  $LO+2f_1 - f_2$ = LO+2F-(F+20 MHz) = F+780 MHz
  The receiver frequency for the upper lower IP3 is given by:
  $LO+2f_2 -f_1$ = LO+2(F+20 MHz)-F = F+840 MHz

ARBITRARY configuration table for the lower IP3:

ARBITRARY SYSTEM FREQUENCIES										
FUNDAMENTAL FREQUENCY: 150 MHz ... 210 MHz										
FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		0 dBm	(	1	/	1	)xF		=	150MHz..210MHz
EXT SRC1	√	0 dBm	(	1	/	1	)xF	+20 MHz	=	170MHz..230MHz
EXT SRC2	√	0 dBm						800 MHz	=	800MHz
RECEIVE			(	1	/	1	)xF	+780 MHz	=	930MHz..990MHz

ARBITRARY configuration table for the upper IP3:

ARBITRARY SYSTEM FREQUENCIES										
FUNDAMENTAL FREQUENCY: 150 MHz ... 210 MHz										
FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		0 dBm	(	1	/	1	)xF		=	150MHz..210MHz
EXT SRC1	√	0 dBm	(	1	/	1	)xF	+20 MHz	=	170MHz..230MHz
EXT SRC2	√	0 dBm						800 MHz	=	800MHz
RECEIVE			(	1	/	1	)xF	+840 MHz	=	990MHz..1.05GHz

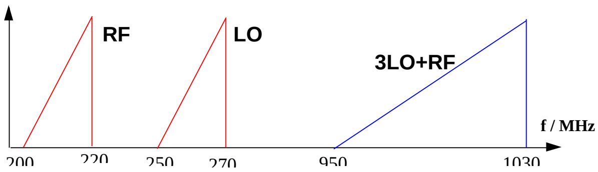
5.6 Measurement of spurious products of a mixer

For this example “Test Setup 1: Mixer Measurement” (page 3), is required.

In the general case, a mixer will produce high order mixing products in addition to the desired products. As an example, a measurement of the spurious product 3*LO+RF should be configured, displaying the conversion loss |b2/a1| versus the frequency range of the mixing product. For the LO and RF frequencies is assumed LO = RF + 50 MHz:

RF = 200 MHz to 220 MHz

LO = 250 MHz to 270 MHz



The parameters for the ARBITRARY table can be derived as described below. The frequency range of the mixing product should be displayed on the x-axis and so be equal to the fundamental frequency F:

REC (Receiver frequency range): F = 3*LO+RF= 950 MHz to 1030 MHz

INT SRC (ZVR source frequency range): F = 3*LO+RF=3*(RF+50MHz)+RF = 4*RF+150 MHz

⇒ RF = F/4 - 37.5 MHz

EXT SCR1 (external source frequency range): LO = RF + 50 MHz = F/4 + 12.5 MHz

Using this values, the ARBITRARY configuration table looks like:

ARBITRARY SYSTEM FREQUENCIES

FUNDAMENTAL FREQUENCY: 950 MHz ... 1.03 GHz

FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		0 dBm	(	1	/	4	)xF	-37.5 MHz	=	200 MHz..220 MHz
EXT SRC1	√	7 dBm	(	1	/	4	)xF	+12.5 MHz	=	250 MHz..270 MHz
EXT SRC2										
RECEIVE			(	1	/	1	)xF		=	950 MHz..1.03GHz

The same measurement, but displaying |b2/a1| versus the input frequency range RF, will be configured with:

ARBITRARY SYSTEM FREQUENCIES

FUNDAMENTAL FREQUENCY: 200 MHz ... 220 MHz

FREQ	ON	POWER		NUM		DEN	xF	OFFSET		RESULT
INT SRC		0 dBm	(	1	/	1	)xF		=	200 MHz..220 MHz
EXT SRC1	√	7 dBm	(	1	/	1	)xF	+50 MHz	=	250 MHz..270 MHz
EXT SRC2										
RECEIVE			(	4	/	1	)xF	+150 MHz	=	950 MHz..1.03GHz

Whereby the RECEIVE frequency range is given by:

3*LO+RF = 3*(RF+50 MHz)+RF = 4*F+150 MHz

6 Further Application Notes

[1] O. Ostwald: 3-Port Measurements with Vector Network Analyzer ZVR, Appl. Note 1EZ26_1E.

[2] H.-G. Krekels: Automatic Calibration of Vector Network Analyzer ZVR, Appl. Note 1EZ30_1E.

[3] O. Ostwald: 4-Port Measurements with Vector Network Analyzer ZVR, Appl. Note 1EZ25_1E.

[4] T. Bednorz: Measurement Uncertainties for Vector Network Analysis, Appl. Note 1EZ29_1E.

[5] P. Kraus: Measurements on Frequency-Converting DUTs using Vector Network Analyzer ZVR, Appl. Note 1EZ32_1E.

[6] J. Ganzert: Accessing Measurement Data and Controlling the Vector Network Analyzer via DDE, Appl. Note 1EZ33_1E.

[7] J. Ganzert: File Transfer between Analyzers FSE or ZVR and PC using MS-DOS Interlink, Appl. Note 1EZ34_1E.

[8] O. Ostwald: Group and Phase Delay Measurements with Vector Network Analyzer ZVR, Appl. Note 1EZ35_1E.

[9] O. Ostwald: Multiport Measurements using Vector Network Analyzer, Appl. Note 1EZ37_1E.

[10] O. Ostwald: Frequently Asked Questions about Vector Network Analyzer ZVR, Appl. Note 1EZ38_3E.

[11] A. Gleißner: Internal Data Transfer between Windows 3.1 / Excel and Vector Network Analyzer ZVR, Appl. Note 1EZ39_1E.

[12] A. Gleißner: Power Calibration of Vector Network Analyzer ZVR, Appl. Note 1EZ41_2E

[13] O. Ostwald: Pulsed Measurements on GSM Amplifier SMD ICs with Vector Analyzer ZVR, Appl. Note 1EZ42_1E.

[14] O. Ostwald: Time Domain Measurements using Vector Network Analyzer ZVR, Appl. Note 1EZ44_0E.

[15] J. Simon: Virtual Embedding Networks for ZVR and ZVC Network Analyzers, Appl. Note 1EZ45_0E.

[16] J. Ganzert: Controlling External Generators and Power Meters with Vector Network Analyzer ZVR, Appl. Note 1EZ46_0E.

7 Ordering Information

Order designation	Type	Frequency range	Order No.
Vector Network Analyzers (test sets included) *			
3-channel, unidirectional, 50 Ω, passive	ZVRL	9 kHz to 4 GHz	1043.0009.41
3-channel, bidirectional, 50 Ω, passive	ZVRE	9 kHz to 4 GHz	1043.0009.51
3-channel, bidirectional, 50 Ω, active	ZVRE	300 kHz to 4 GHz	1043.0009.52
4-channel, bidirectional, 50 Ω, passive	ZVR	9 kHz to 4 GHz	1043.0009.61
4-channel, bidirectional, 50 Ω, active	ZVR	300 kHz to 4 GHz	1043.0009.62
3-channel, bidirectional, 50 Ω, active	ZVCE	20 kHz to 8 GHz	1106.9020.50
4-channel, bidirectional, 50 Ω, active	ZVC	20 kHz to 8 GHz	1106.9020.60
Alternative Test Sets *			
75 W SWR Bridge for ZVRL (instead of 50 W) [1]			
75 Ω, passive	ZVR-A71	9 kHz to 4 GHz	1043.7690.18
75 W SWR Bridge Pairs for ZVRE and ZVR (instead of 50 W) [1]			
75 Ω, passive	ZVR-A75	9 kHz to 4 GHz	1043.7755.28
75 Ω, active	ZVR-A76	300 kHz to 4 GHz	1043.7755.29
Options			
AutoKal	ZVR-B1	0 to 8 GHz	1044.0625.02
Time Domain	ZVR-B2	same as analyzer	1044.1009.02
Mixer Measurements [2]	ZVR-B4	same as analyzer	1044.1215.02
Reference Channel Ports	ZVR-B6	same as analyzer	1044.1415.02
Power Calibration [3]	ZVR-B7	same as analyzer	1044.1544.02
3-Port Adapter	ZVR-B8	0 to 4 GHz	1086.0000.02
Virtual Embedding Networks [4]	ZVR-K9	same as analyzer	1106.8830.02
4-Port Adapter (2xSPDT)	ZVR-B14	0 to 4 GHz	1106.7510.02
4-Port Adapter (SP3T)	ZVR-B14	0 to 4 GHz	1106.7510.03
Controller (German) [5]	ZVR-B15	-	1044.0290.02
Controller (English) [5]	ZVR-B15	-	1044.0290.03
Ethernet BNC for ZVR-B15	FSE-B16	-	1073.5973.02
Ethernet AUI for ZVR-B15	FSE-B16	-	1073.5973.03
IEC/IEEE-Bus Interface for ZVR-B15	FSE-B17	-	1066.4017.02
Generator Step Attenuator PORT 1	ZVR-B21	same as analyzer	1044.0025.11
Generator Step Attenuator PORT 2 [6]	ZVR-B22	same as analyzer	1044.0025.21
Receiver Step Attenuator PORT 1	ZVR-B23	same as analyzer	1044.0025.12
Receiver Step Attenuator PORT 2	ZVR-B24	same as analyzer	1044.0025.22
External Measurements, 50 Ω [7]	ZVR-B25	10 Hz to 4 GHz (ZVR/E/L) 20 kHz to 8 GHz (ZVC/E)	1044.0460.02

[1] To be ordered together with the analyzer.
[2] Harmonics measurements included.
[3] Power meter and sensor required.
[4] Only for ZVR or ZVC with ZVR-B15.
[5] DOS, Windows 3.11, keyboard and mouse included.
[6] For ZVR or ZVC only.
[7] Step attenuators required.

*** Note:**
Active test sets, in contrast to passive test sets, comprise internal bias networks, eg to supply DUTs.