Product: Vector Network Analyzer R&S®ZVA

Performing Mixer Measurements with the Vector Network Analyzer ZVA + ZVA-K4 Frequency Conversion option

Application Note

This document describes the typical measurements performed on mixers and how they can be implemented on the ZVA Vector Network Analyzer with the ZVA-K4 Frequency Conversion option. The document describes the concept and setups required to perform Conversion Loss, Isolation, Intermodulation and Reflection measurements.

ROHDE & SCHWARZ

Contents

1. Introduction

This document is designed to be a guide to help point the user in the right direction for configuring the ZVA and ZVT Vector Network Analyzers to make relevant measurements on mixers.

Please note that the measurements in this document will refer to the ZVA only, but is valid for the ZVT as well.

For further information please refer to the internal help of the ZVA [HELP] or alternatively you can access the help online at the Rohde & Schwarz website,

http://www.rohde-schwarz.com/webhelp/zva/start.htm

In this document:

- Hardkeys are shown as   [MODE]
                                                                          [PRESET] [HELP]
  Softkeys are shown as   [Start]
  Windows buttons and tabs are shown as   *Set Power…*
  Windows dialog box names are shown as   Set Powers

The examples and setups shown in this application note are valid for firmware version 2.50 and higher. The examples are not tested on earlier versions, but should be working for these as well.

2. Conversion Loss Measurements

Conversion Loss (or Gain) is a measure of the power change when the Mixer is converting the RF frequency to the IF frequency. It is defined as the ratio between the P_{out} (IF) level and the P_{in} (RF) level and is expressed in dB.

$$\text{Conversion Loss / Gain} = 10 \log \frac{P_{out}\ (IF)}{P_{in}\ (RF)}$$

RF → [mixer] → IF

LO
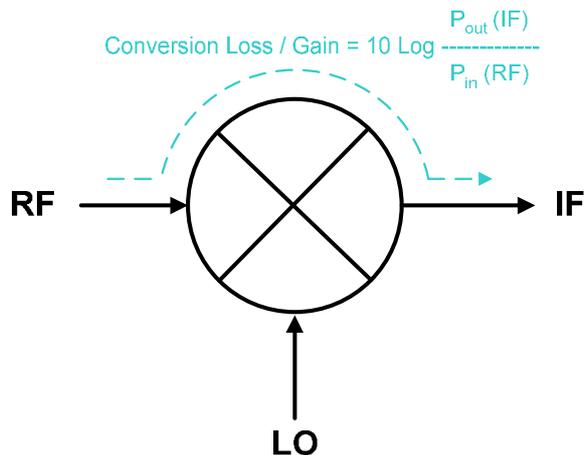
Conversion measurements can be performed as a function of both frequency and amplitude.

Typical Conversion measurements on a mixer include:

- Conversion Loss / Gain over frequency range of interest.
- Mixer dynamic range / compression of the RF input signal.
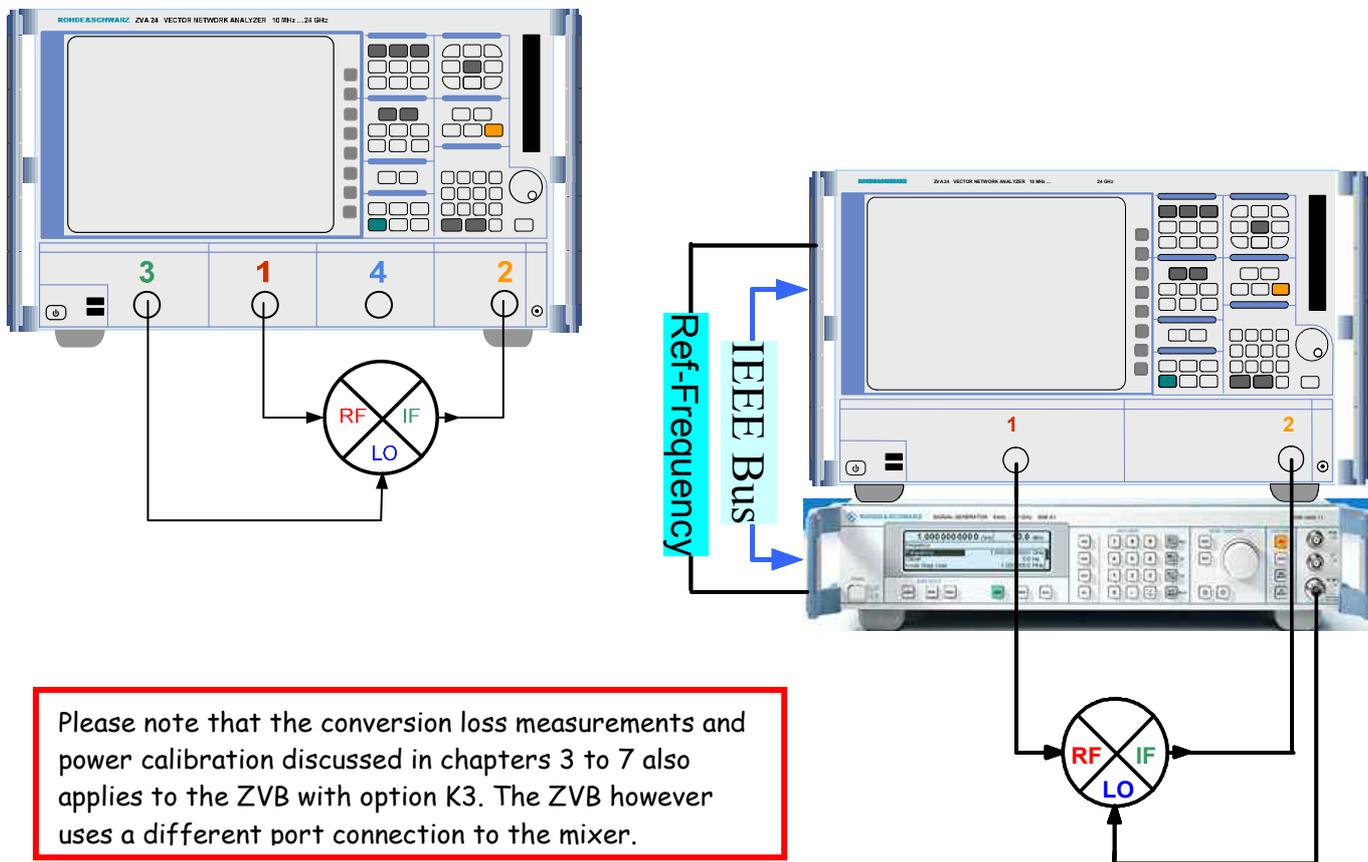- Conversion Loss / Gain as a function of LO power level.

3. Conversion Loss Measurement Setup

To characterize the conversion loss / gain as a function of either frequency or amplitude, the mixer should be connected to port 1, 2 and 3 of a 4-port ZVA with option ZVA-K4, as indicated below (left). The 4-port ZVA has two internal generators allowing the simultaneous feed of both the RF and LO signals.

If a 4-port ZVA is not available, then a 2-port ZVA and an external RF Signal Generator can be used, as indicated below (right).

The Signal Generator will be controlled by the ZVA using a USB-GPIB interface (option ZVAB-B44). Signal Generators like the SMF/SMA/SMB etc. can be controlled with the LAN interface as well. The reference frequencies of the ZVA and the Signal Generator must be locked to each other. Both the ZVA and the Signal Generator can be the master.

The RF Signal Generator will then provide the Local Oscillator signal for the mixer.

Please note that the conversion loss measurements and power calibration discussed in chapters 3 to 7 also applies to the ZVB with option K3. The ZVB however uses a different port connection to the mixer.

To configure an external Signal Generator, press [SYSTEM CONFIG], then [System Config] softkey. Select the *External Generators* tab to configure the Signal Generator.

If you want to use a Signal Generator not supported by the ZVA driver library, then contact your Rohde & Schwarz sales representative for information about adding new Signal Generator drivers to your ZVA.

In the following examples, we will examine a passive mixer in the RF frequency range 1.3 to 1.6 GHz with a fixed IF frequency of 70 MHz.

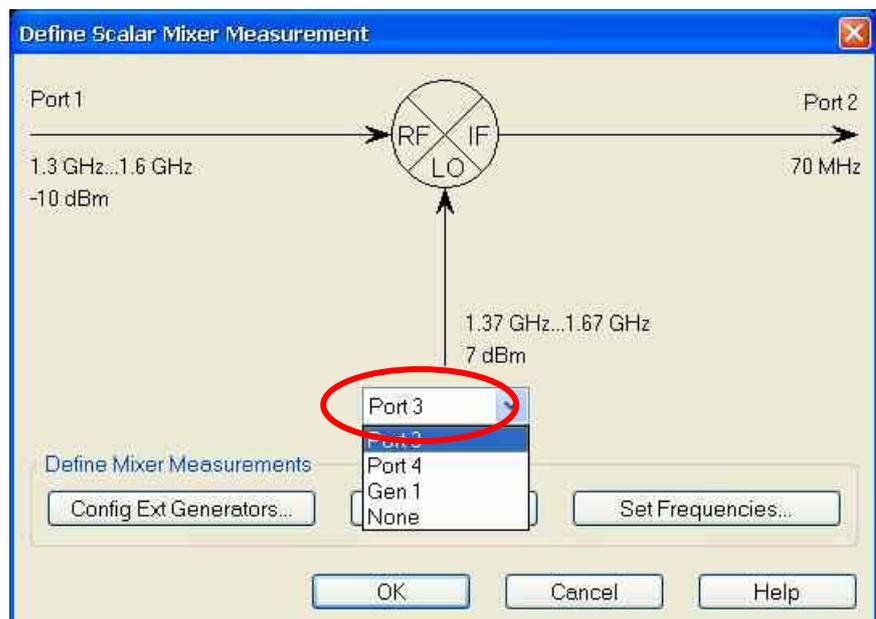First we will configure the ZVA for measuring the RF to IF Conversion Loss.

RF to IF Conversion Loss (or Gain) can be defined as:

$$\text{Conversion Loss (dB)} = 10 \log \frac{P_{out}\ (f_{IF})}{P_{in}\ (f_{RF})}$$

4. RF to IF Conversion Loss Measurement

Press [PRESET]

To start the configuration, press [MODE], then [Scalar Mixer Meas →] and [Define Scalar Mixer Meas] softkeys. The following menu will appear.

On the ZVA, port 1 and 2 are already defined to be used for the mixer RF and IF ports. First step is selecting the source for the LO signal. This can be either port 3, port 4 or an External Generator. On a 4-port ZVA, we select port 3.

Next we can select *Set Powers…* and *Set Frequencies…* to configure the actual measurement.

In the Set Frequencies menu, we select:
RF Frequency = Swept
IF Frequency = Fixed
LO Frequency = Auto

We must also select the type of Conversion required. In this case we have selected IF = LO – RF (LSB), which will give us a LO frequency above the RF frequency.

Then we configure the Start and Stop frequencies. This can also be done using the [START] and [STOP] keys before entering the Mixer configuration menu.

Finally we define the fixed IF frequency. In the Fixed Frequency: IF field, enter 70 MHz
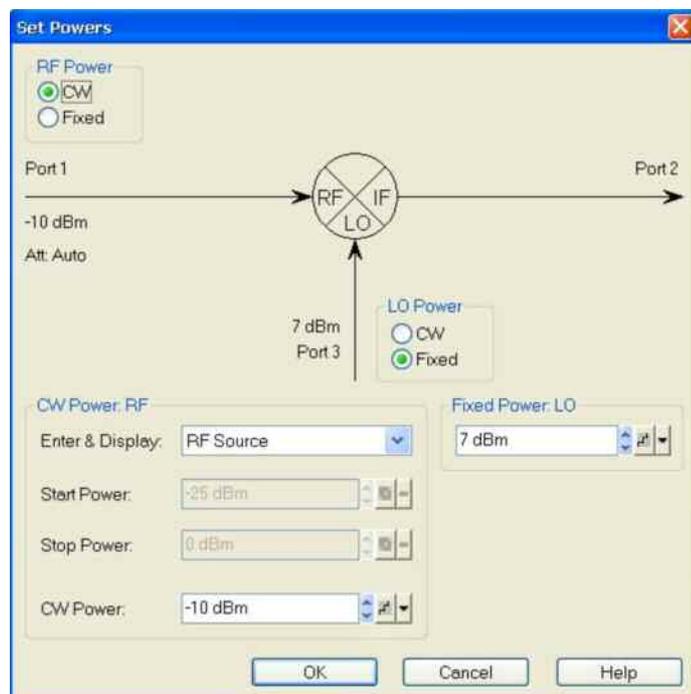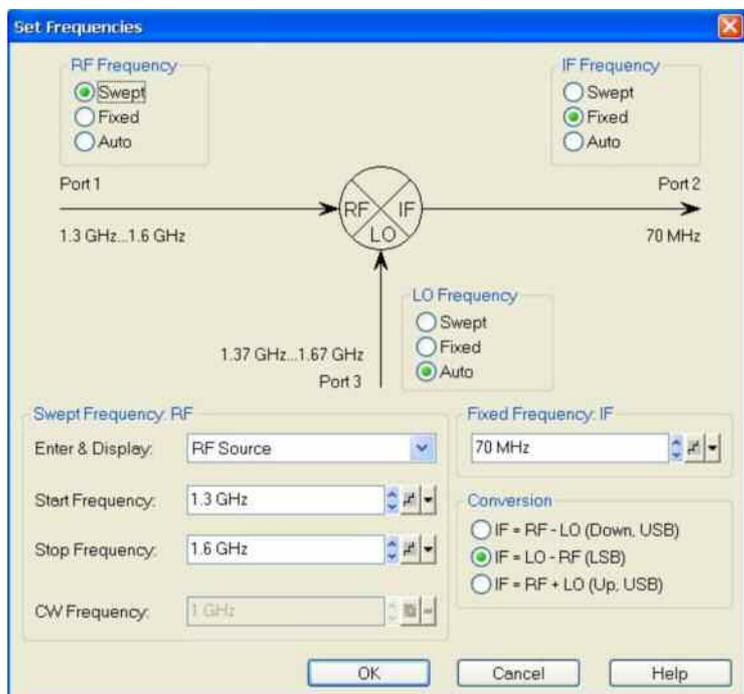
In the Set Powers menu, we enter the appropriate power levels for the RF signal and the LO signal.

The CW Power level should be selected so that the Mixer is not driven into compression, in this case we use -10 dBm.

The Fixed Power:LO level must be sufficiently high to properly bias the mixer diodes, here we use +7 dBm.

Please note that the ZVA is capable of providing very high power levels, typically >15 dBm directly from the test port. This is more than enough to drive the LO port on almost any type of mixer and overcome the losses caused by additional cabling of filters, matching pads, etc.
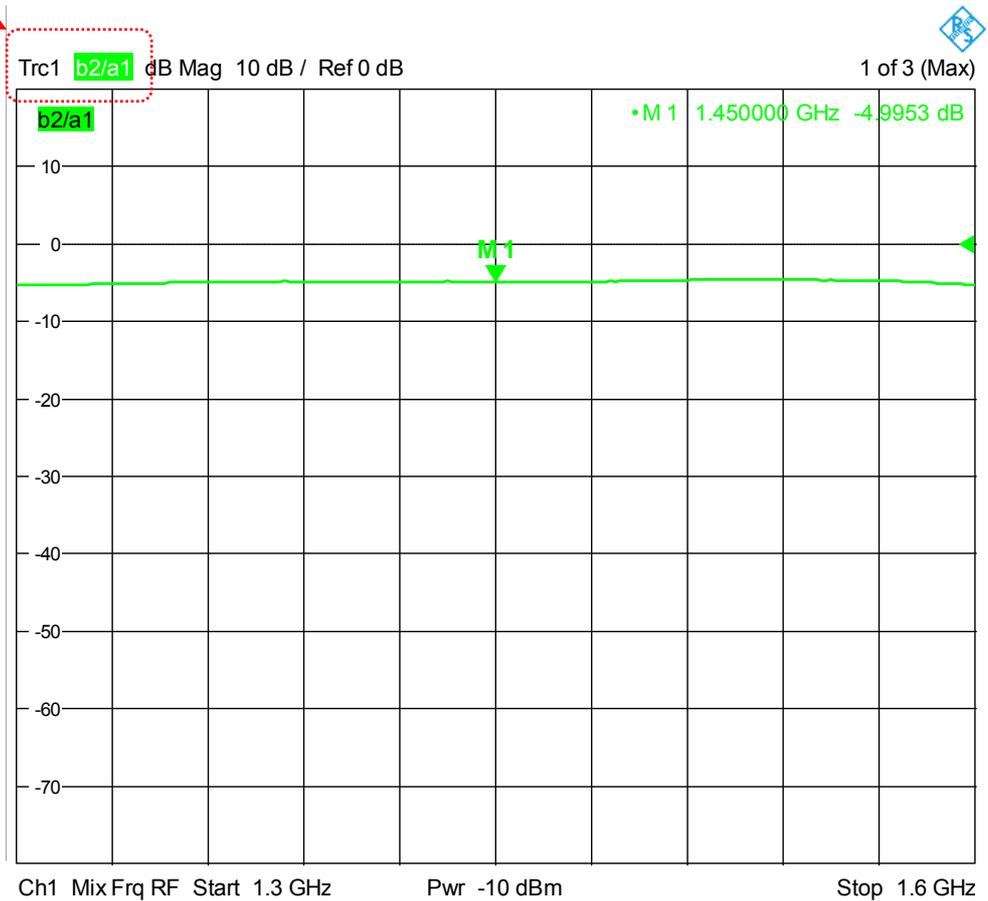
When leaving the Define Scalar Mixer Measurement menu by pressing OK, the ZVA will enable the Mixer measurement configuration.

RF to IF Conversion Loss Measurement

Please note that we do not measure S-parameters here. Instead we measure the **(b2/a1)** wave quantity ratio. This is due to the fact that the two wave quantities are at different frequencies.

(a1) is the RF incident power wave or _reference power_ sweeping from 1.3 to 1.6 GHz. **(b2)** is the transmitted IF power wave or _measured power_ at 70 MHz.

b2/a1:   Conversion Loss

Trc1 b2/a1 dB Mag 10 dB / Ref 0 dB   1 of 3 (Max)

b2/a1   • M 1   1.450000 GHz –4.9953 dB

Ch1 Mix Frq RF Start 1.3 GHz   Pwr -10 dBm   Stop 1.6 GHz

The measurement plot shows a conversion loss value of about 5 dB, which is expected for these kind of passive mixers.

5. RF Input Compression Measurement

In the RF Input Compression measurement, we will setup a RF power sweep at 1.5 GHz and measure the Mixers Conversion Loss as a function of the RF Input power level. This measurement will then enable us to determine the upper limit of the Mixers linear dynamic range.

To start the configuration:

Press [CHAN SELECT], then [Add Channel + Trace + Diag Area] softkey. This will create a second channel in a new diagram area, which is identical to the first channel.

Hint: Double-clicking in the diagram area of a window will expand the window to full screen. Double-clicking again will show all configured windows. This can also be done by pressing [AREA SELECT], then use [Maximize] and [Split All] softkeys.

Press [SWEEP], then [Sweep Type →] and [Power] softkeys. The ZVA is now in *Power Sweep* mode on channel 2.

Press [START CENTER], then [CW Frequency] softkey. Enter 1.5 GHz.

Press [MEAS], then [Ratios →] and [b2/a1 Src Port 1] softkeys.

Press [MODE], then [Scalar Mixer Meas] and [Define Scalar Mixer Meas] softkeys to enter the Scalar Mixer configuration menu. Then press *Set Powers* to enter the Power configuration menu.

Please note that the Set Powers dialog box has changed to reflect that the channel is now setup to do Power Sweep instead of Frequency Sweep.
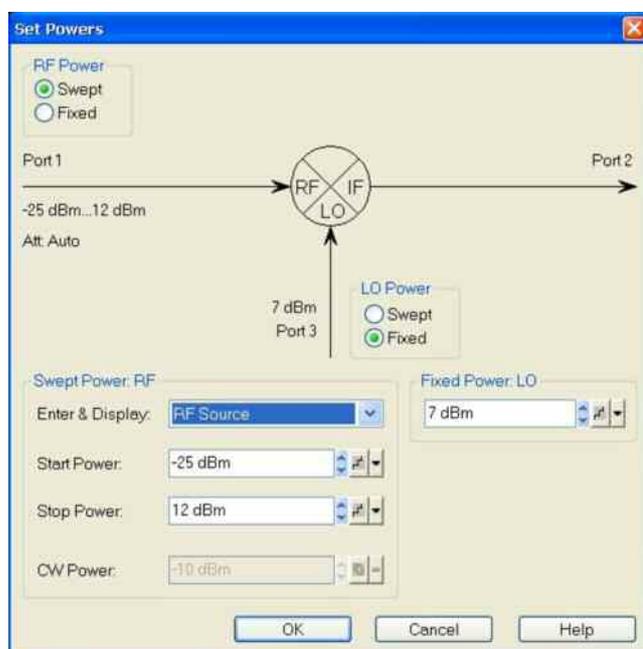
Make sure that the Enter & Display field is set to RF Source, then type in the Start Power = -25 dBm and Stop Power = +12 dBm. Also make sure that the Fixed Power: LO is still +7 dBm.
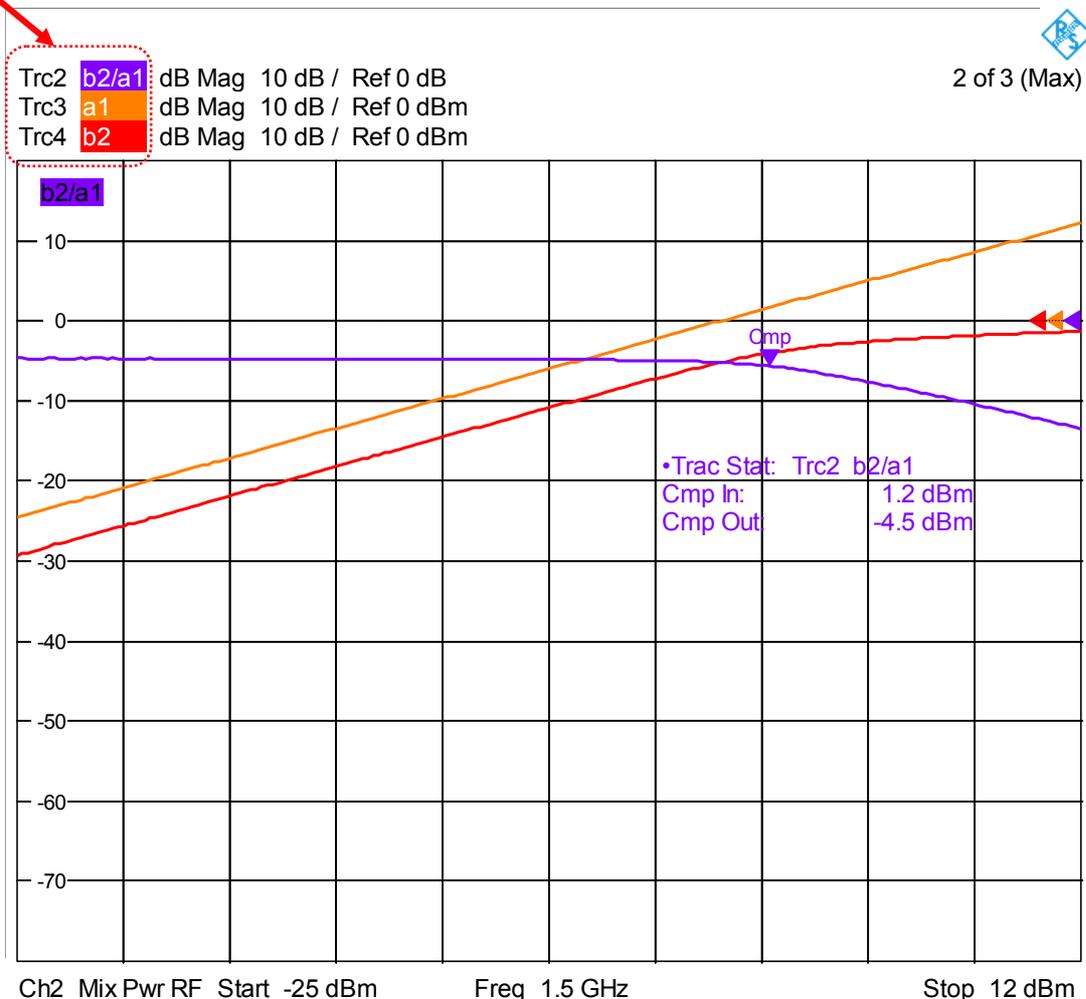
Press OK and OK to exit the Scalar Mixer configuration menu and view the measurement result.

RF Input Compression Measurement

The measurement plot Trc2 **(b2/a1)** shows a conversion loss value of about 5 dB as long as the Mixer operates in its linear input range. At about 0 dBm, we can see that the Mixer is reaching its compression point and that the conversion loss is increasing.

Additional traces can be added to the channel if you want to examine the **(a1, RF power)** and **(b2, IF power)** wave quantities. See Trc3 and Trc4 in the plot below.

b2/a1:   Conversion Loss
a1:   RF Power in
b2;   IF Power out

Trc2 b2/a1 dB Mag 10 dB / Ref 0 dB
Trc3 a1   dB Mag 10 dB / Ref 0 dBm
Trc4 b2   dB Mag 10 dB / Ref 0 dBm

b2/a1

Cmp

•Trac Stat: Trc2 b2/a1
Cmp In: 1.2 dBm
Cmp Out: -4.5 dBm

Ch2 Mix Pwr RF Start -25 dBm   Freq 1.5 GHz   Stop 12 dBm

By using the ZVA's trace statistics capabilities, it can automatically search for the compression point. Furthermore it will provide information about the absolute input and output power levels at the compression point. To enable this press:

[TRACE FUNCT], then [Trace Statistics →] and [Compression Point] softkeys.

Default compression value is 1 dB, but can be changed by pressing the [Define Compression Value] softkey and enter a different value.

6. Conversion Loss vs. LO Power Measurement

Another important measurement is the Mixer Conversion Loss as a function of the LO Power. Minimum Conversion Loss is obtained when the LO power level can properly bias the Mixer diodes.

To start the configuration:

Make sure that channel 2 from the previous measurement is active.

Please note that when a new channel is created, the settings from the current active channel are copied to the new channel. This avoids configuring the new channel from scratch.

Press [CHAN SELECT], then [Add Channel + Trace + Diag Area] softkey. This will create a third channel in a new diagram area, which is identical to the second channel.

Press [MEAS], then [Ratios →] and [b2/a1 Src Port 1] softkeys.

Press [MODE], then [Scalar Mixer Meas] and [Define Scalar Mixer Meas] softkeys to enter the Scalar Mixer configuration menu. Then press *Set Powers* to enter the Power configuration menu.
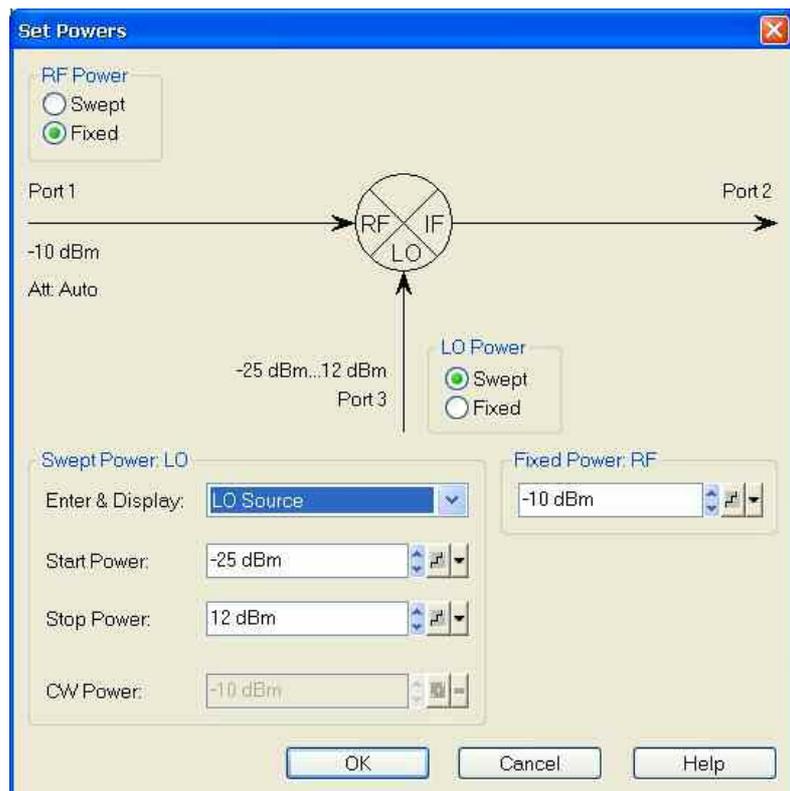

Change the Enter & Display field so that it is set to LO Source. Now we can sweep the LO source power and use a fixed power level for the RF. Then type in Start Power = -25 dBm and Stop Power = +12 dBm.

In the Fixed Power: RF field, enter -10 dBm.

Press OK and OK to exit the Scalar Mixer configuration menu and view the measurement result.

Conversion Loss vs. LO Power Measurement

The measurement plot (Trc5) shows that at low LO power levels, the conversion loss is large. At levels above 0 dBm we can see that the trace is flattened out, indicating that the mixer diodes are properly biased.

b2/a1: Conversion Loss
a3: LO Power in
b2; IF Power out
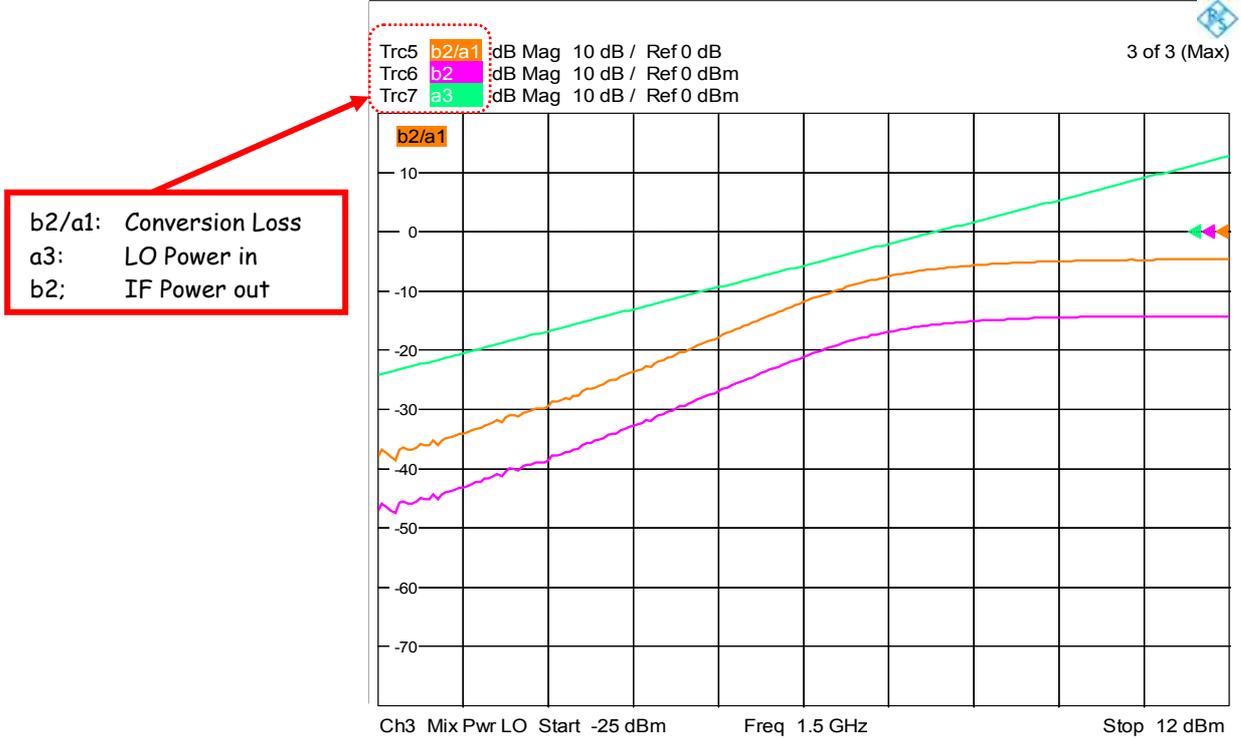
By splitting the windows we have configured so far using [AREA SELECT] and [Split All], we now have the full overview of the configured conversion loss measurements. This is shown in the picture below.
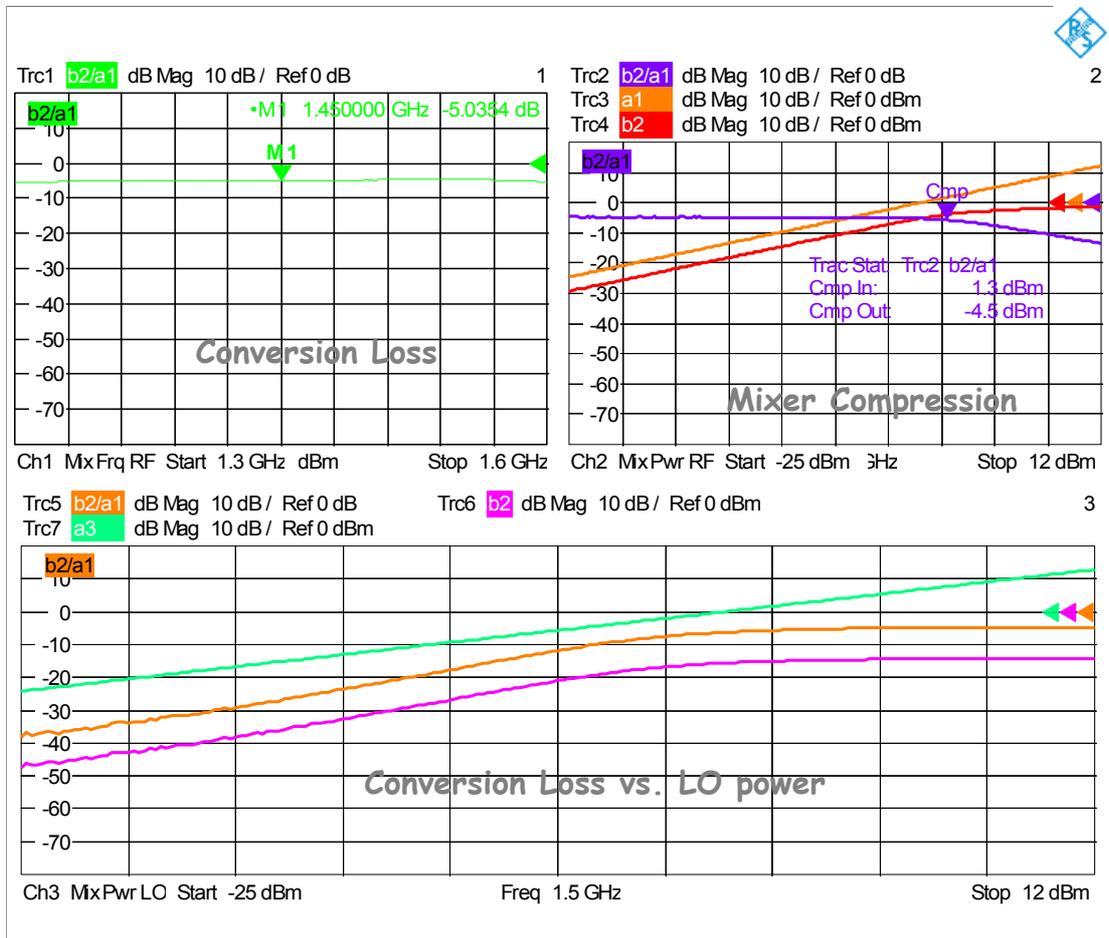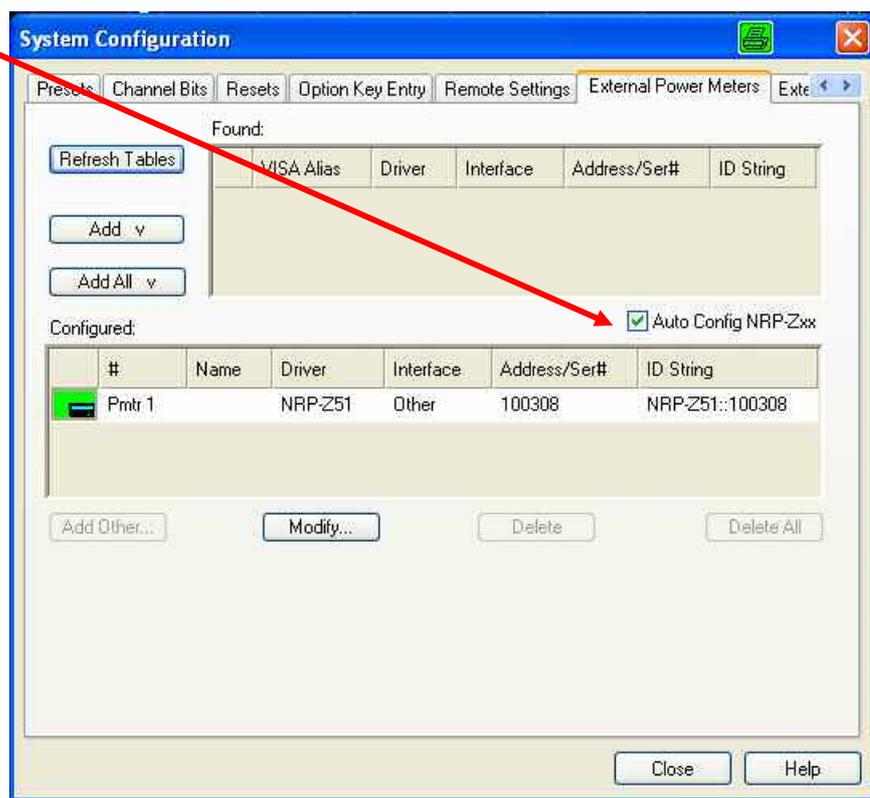
7. Power Calibration

Even though the power level accuracy of the ZVA sources and receivers are quite good, we will in most cases need to perform a power level calibration. Especially when we move into the GHz range, losses in cables and adapters can be significant and influence the accuracy of our measurement. The power calibration routine can even be configured to compensate for a pre-amplifier in the signal path

To perform a power calibration, we need a Power Meter / Sensor connected to the ZVA. The most convenient solution is using a USB Power Sensor from the NRP-Z family such as the NRP-Z11 or NRP-Z51 sensor. Simply connect the Power Sensor to the ZVA front panel USB connector and the sensor will be automatically configured.

In case a normal Power Meter is used, press [SYSTEM CONFIG], then [System Config] softkey and select the *External Power Meters* tab to configure the meter.

Please note that in case of using a normal Power Meter, you need the ZVAB-B44 option and the VISA I/O libraries installed on the ZVA. Even if a LAN connection is used, you still need the VISA I/O libraries.

Please note that with this hook active, just one NRP is detected and controlled.

Click *Refresh Tables* to scan USB and GPIB interfaces for attached Power Meters / Sensors. Select Power Meter to use in the *Found:* section and click *Add v* to move it to the *Configured:* section.

Before starting the Calibration process, we need to consider the measurement uncertainty contribution from the mismatch between the ZVA ports and the mixer ports. On passive mixers we can expect typical Return Loss values in the range from 10 to 20 dB. On the ZVA we have an uncorrected test port Return Loss in the range from 10 to 16 dB, depending on frequency and ZVA model.

Using the standard mismatch error formula:

$$E_M = 20\log_{10}\left(\frac{1}{1 \pm \rho S \rho L}\right) dB$$

We can see that a 12 dB Return Loss value for both ZVA and Mixer will give us a mismatch uncertainty value of ~ +/-0.55 dB.

To reduce the mismatch uncertainty contribution in the mixer conversion loss measurements, we can add fixed attenuators (often called matching pads) between the ZVA and the mixer. This will improve the ZVA source match and therefore reduce uncertainties. It is mainly on the RF and LO ports we have the matching problems.

Improving the ZVA Return Loss with a matching pad to 30 dB, will reduce the mismatch uncertainty value to ~ +/-0.07 dB.
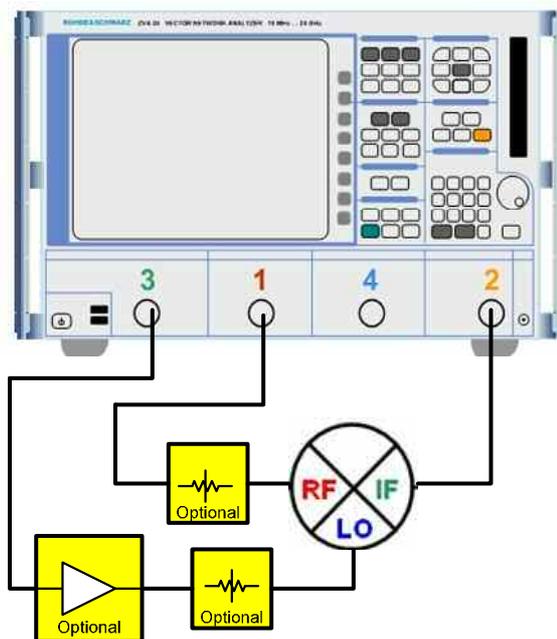
The problem with matching pads is sometimes that we don't have sufficient power to drive the mixer. This is especially true for the LO signal, which typically needs to be in the range from +7 to +15 dBm, depending on the mixer type. Therefore extra amplification is sometimes required when using matching pads.

Please remember that the ZVA can deliver typically >15 dBm at the test port, which often eliminate the need for an amplifier.

The optimal values for the matching pads are >=10 dB on order to provide good isolation. We will however need to compromise due to the maximum power available from the ZVA (~ +15 dBm).

In the following Power Calibration example we will use a 6 dB pad on the RF port and a 3 dB pad on the LO port. No amplifier is used.

To start the power calibration process, do the following:

Select (Trc1) in channel 1. In this channel we are doing a frequency sweep.

Press [MODE], then [Scalar Mixer Meas] and [Scalar Mixer Meas Power Cal…] softkeys. This will open the Scalar Mixer Measurement Power Calibration window:
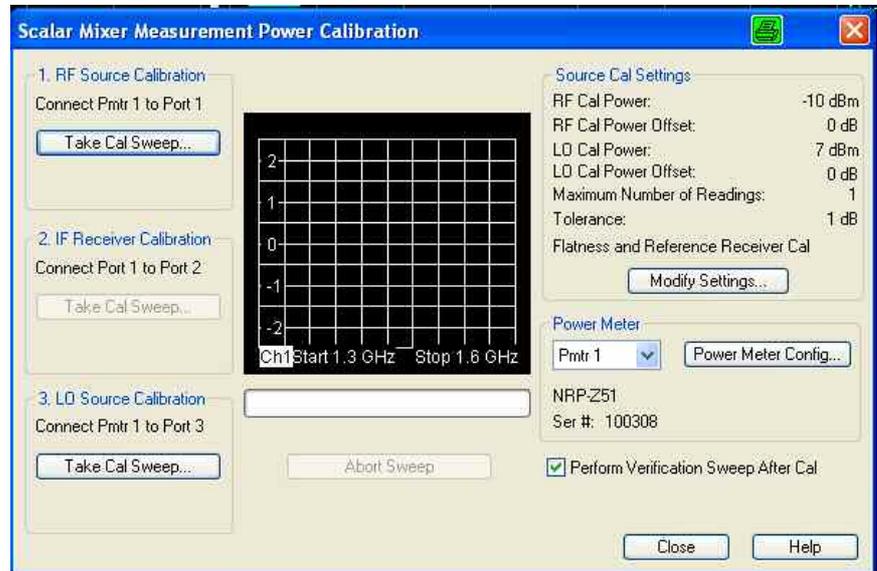
In the Source Cal Settings section we can see the values for the RF and LO power levels for the active channel. Below that are two fields, this is the Maximum Number of Readings (1) and Tolerance (1 dB) values. Those settings determine the target accuracy for the power calibration and the maximum number of iterations to obtain the specified accuracy. To change these settings, press the Modify Settings… button.

Press *Modify Cal Power* to add Cal Power Offset values in case external pads and/or amplifiers are used.

Controls max number of iterations the ZVA should use for reaching the specified Tolerance value.
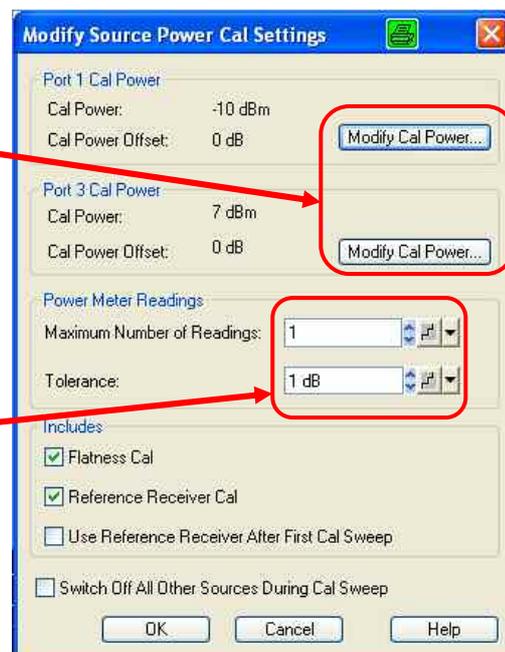
A good compromise between speed and accuracy in the power calibration could be setting Maximum Number of Readings = 3 and Tolerance = 0.3 dB.
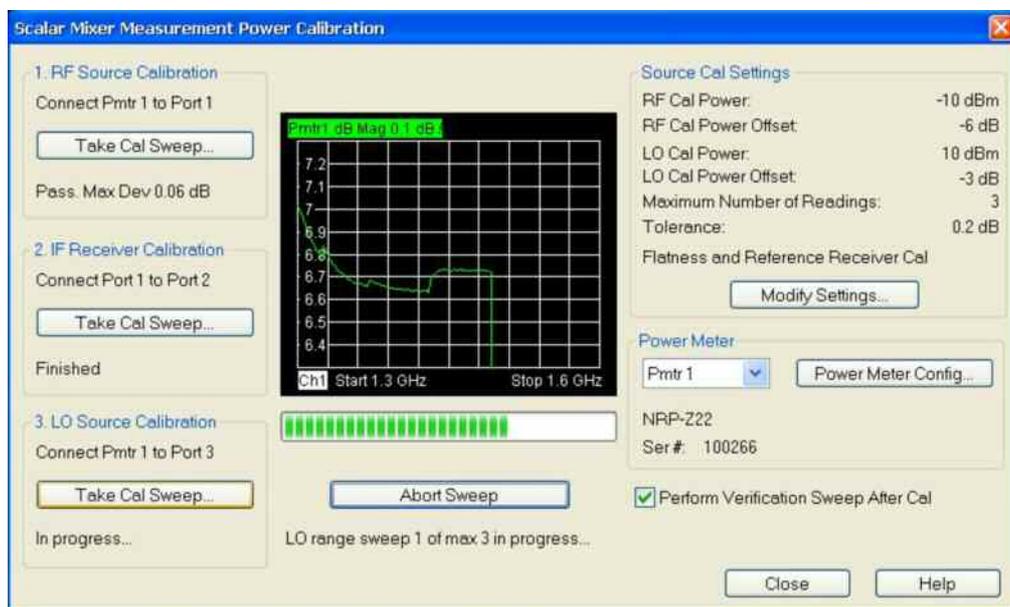
Power Calibration

In case of using matching pads and/or external amplifiers in the setup, press the Modify Cal Power button to add the proper offset. The example below shows the compensation for a 6 dB matching pad at the ZVA port 1 (mixer's RF port). Please note the channel base power (Pb) initially must be set 6 dB higher to compensate for the matching pad.
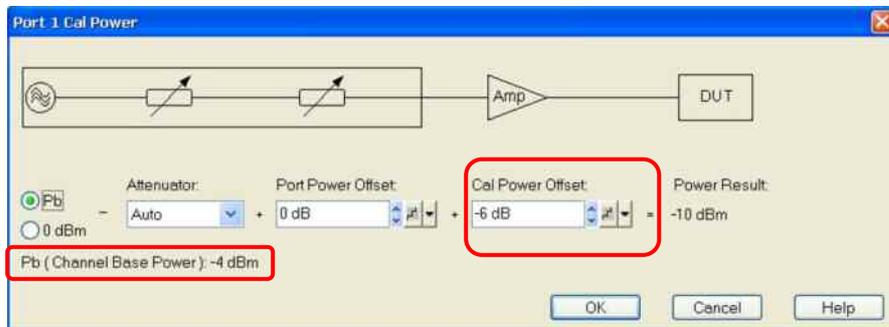
With the desired Source Cal Settings in place, the calibration process is started by following the 3 steps in the left side of the Power Calibration window. 3 steps are required to calibrate the 3 active ports on the ZVA. They are:

1.   RF Source Calibration
2.   IF Receiver Calibration
3.   LO Source Calibration

The calibration process can be monitored in the graphical plot and on the progress bar below.

When step 3 is completed, press Close to close the Power Calibration window. The power calibration of channel 1 is now completed.

Since the frequency and power settings of channel 2 and 3 are different from channel 1, separate power calibrations on these channels must be performed as well. The procedure is identical to the channel 1 calibration.
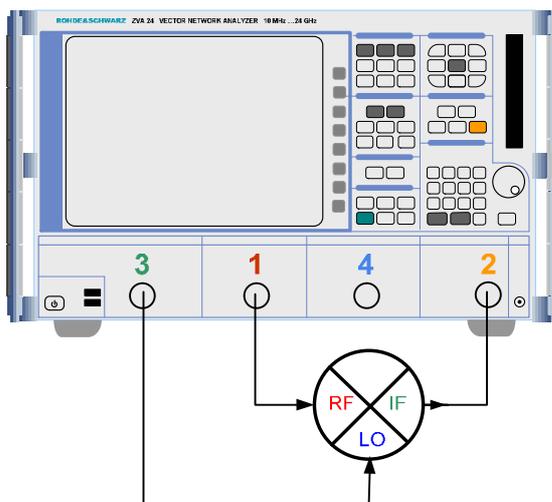
8. Isolation Measurements

The Isolation is a measure of signal leakage or feed-through from one mixer port to another port. Good isolation corresponds to low leakage. Unbalance of the internal transformers or lead inductance is the main cause of port-to-port leakage. The amount of feed-through from the LO to the RF port is specified by the LO-RF isolation. In an analogous way, the LO-IF isolation defines the level at which the LO signal appears at the IF port.
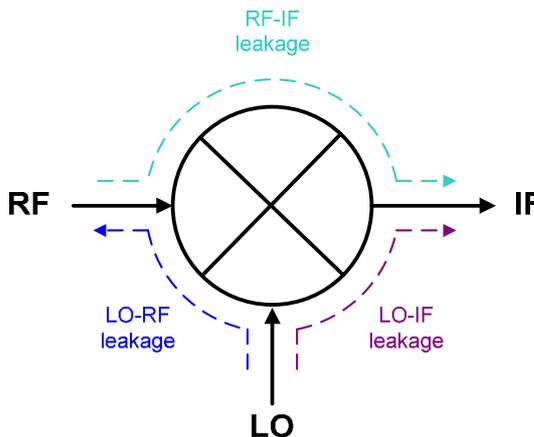
Isolation is measured in dB and is a frequency-dependent quantity. High isolation is preferable, since signal leakage will create spurious signal components in the output spectrum.

9. Isolation Measurement Setup

The isolation measurement setup is identical to the conversion loss setup, here shown for a 4-port ZVA only:

For measurement setup with a 2-port ZVA, please refer to section 3 for details.

10. Arbitrary Port Configuration

The configuration of isolation measurements is different from the conversion loss setup. For these measurements, we cannot use the mixer configuration wizard, we need to manually configure the ZVA source and receiver settings using the [MODE], then [Port Config] keys to get to the Port Configuration menu.
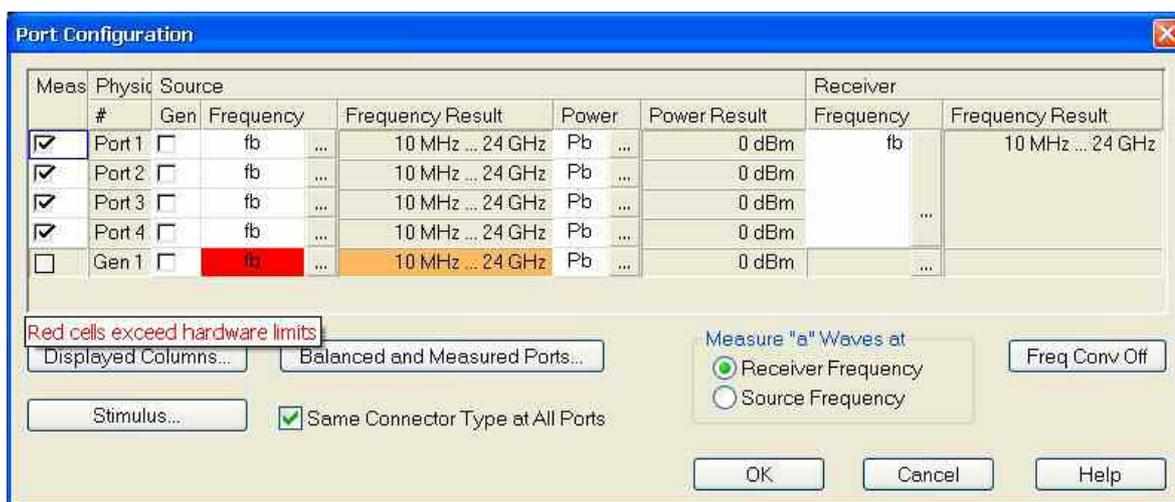
The Port Configuration menu uses two terms named (fb) and (Pb):

(fb) is the base frequency entered using [START CENTER] and [STOP SPAN] keys and (Pb) is the base power entered using the [PWR BW AVG] key.

In the above example, an external generator (Gen1) is configured, but not used. So the error message shown can be ignored.

11. RF to IF Isolation Measurement

To start the RF to IF isolation measurement configuration, do the following:

Press [PRESET]

Press [START CENTER] and enter a start frequency of *1.3 GHz*

Press [STOP SPAN] and enter a stop frequency of *1.6 GHz*

Press [PWR BW AVG] and enter a power level of *-10 dBm*

Now the (fb) and (Pb) terms are set and we can start the actual configuration of the test ports.

For this test we will again be using an IF frequency of 70 MHz and a LO signal which is higher than the RF signal (IF = LO – RF).

Press [MODE], then [Port Config] keys to get to the Port Configuration menu.

To configure the LO frequency and power, click on the (fb) and (Pb) fields in the Port 3 row to open the Port 3 Source Frequency and Port 3 Cal Power configuration windows. They allow you to configure the frequency and power using (fb) and (Pb) as a base for the configuration, or simply by typing in any desired value.
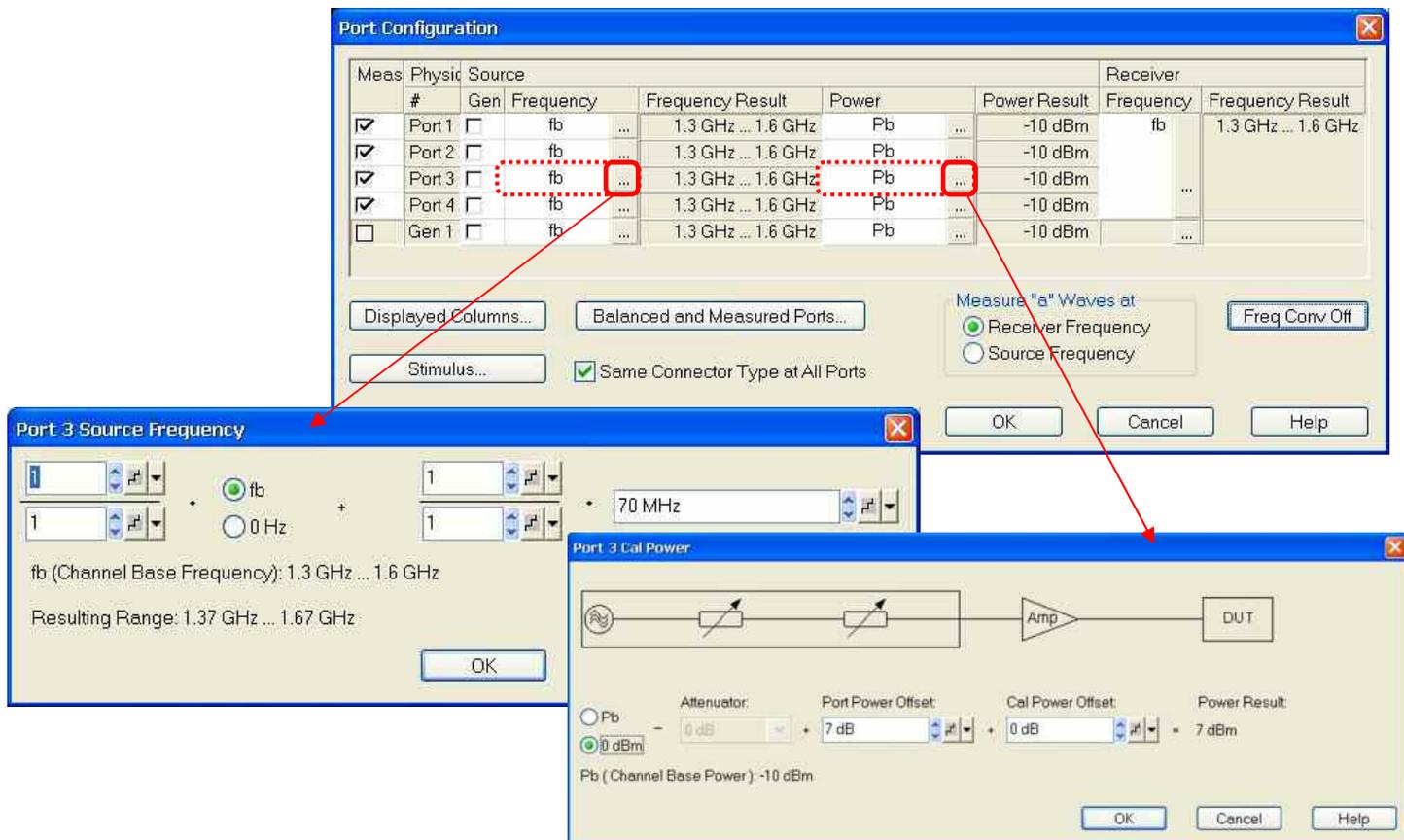
The LO frequency should be offset from the base freq (fb) by 70 MHz, so we just add the 70 MHz in the configuration. For the LO power, we want a fixed level of +7 dBm, which is configured as shown above.

Below is the completed RF to IF Isolation Configuration. Remember to enable the generators for Port 1 and 3. Click *OK* to exit.
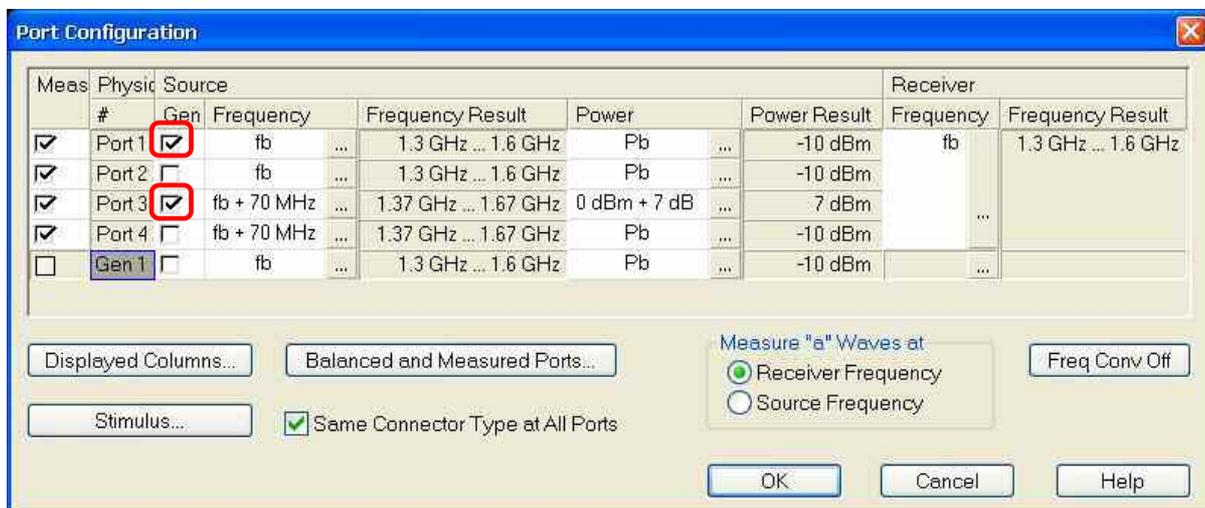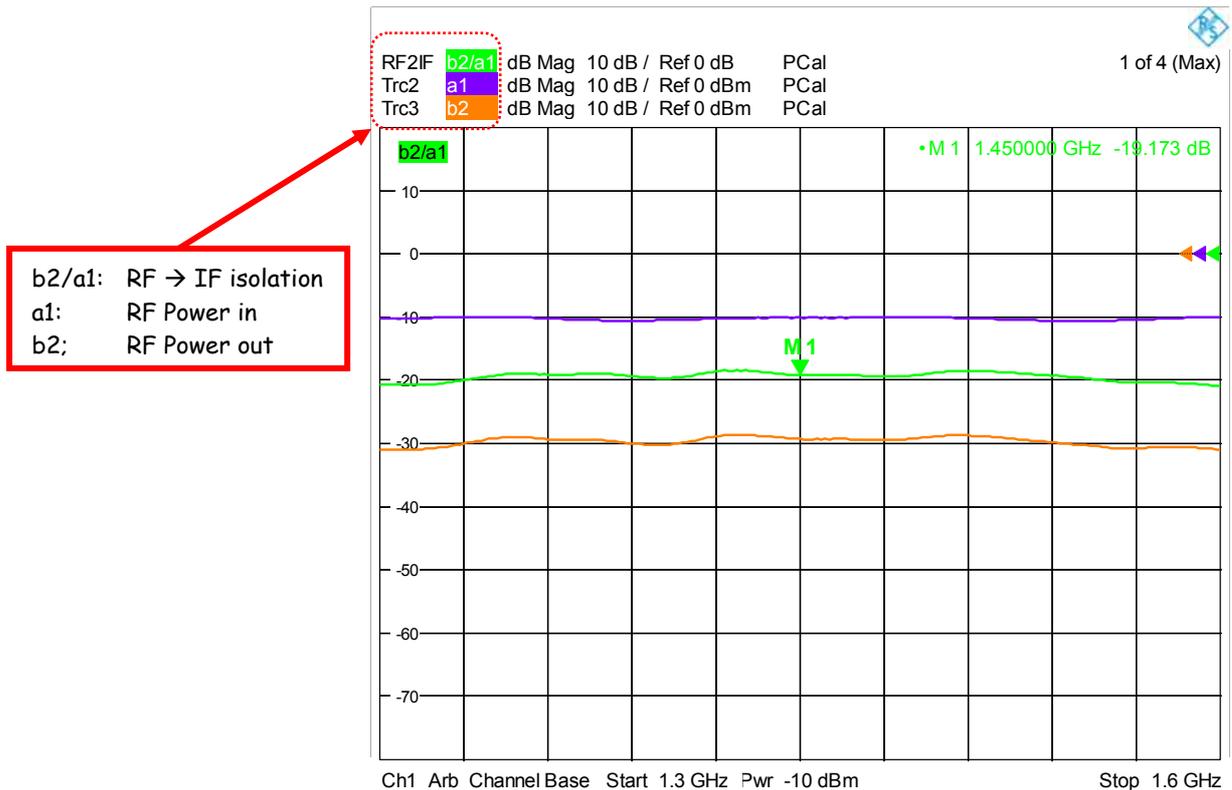
RF to IF Isolation Measurement

Select the **(b2/a1)** as the quantity for RF to IF isolation measurement.

Please note that selecting S21 as the measurement quantity instead of b2/a1, will allow for vector error correction (i.e. TOSM calibration) to be applied to the measurement. This will further improve the measurement accuracy, since vector error correction cannot be applied to the b2/a1 wave quantity measurement.

The result of the RF to IF Isolation measurement can be seen at the green trace labeled RF2IF.

(Trc2) is the RF quantity in and (Trc3) is the RF quantity out (at IF port).

b2/a1:   RF → IF isolation
a1:   RF Power in
b2;   RF Power out

HINT: Use the mouse and Right-Click on the trace name to access the Trace Manager. Here you can change the name of the trace to something more meaningful than Trc1, Trc2, etc.
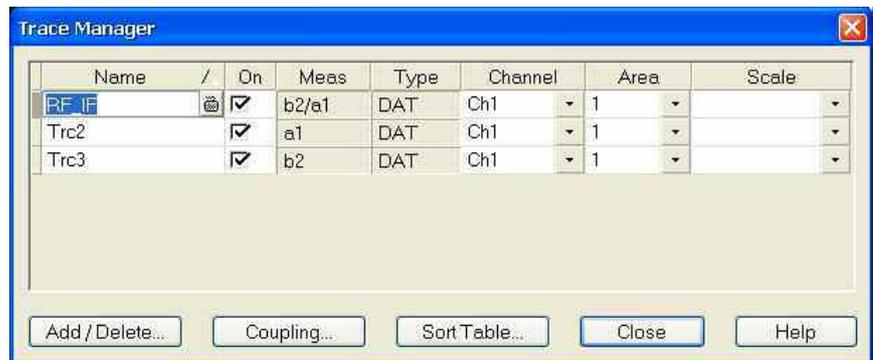
12. LO to IF Isolation Measurement

To start the configuration:

Press [CHAN SELECT], then [Add Channel + Trace + Diag Area] softkey. This will create a second channel in a new diagram area, which is identical to the first channel.

Select the **(b2/a3)** as the quantity for LO to IF isolation measurement (or select S23 to allow for vector error correction).

Press [MODE], then [Port Config] keys to get to the Port Configuration menu.
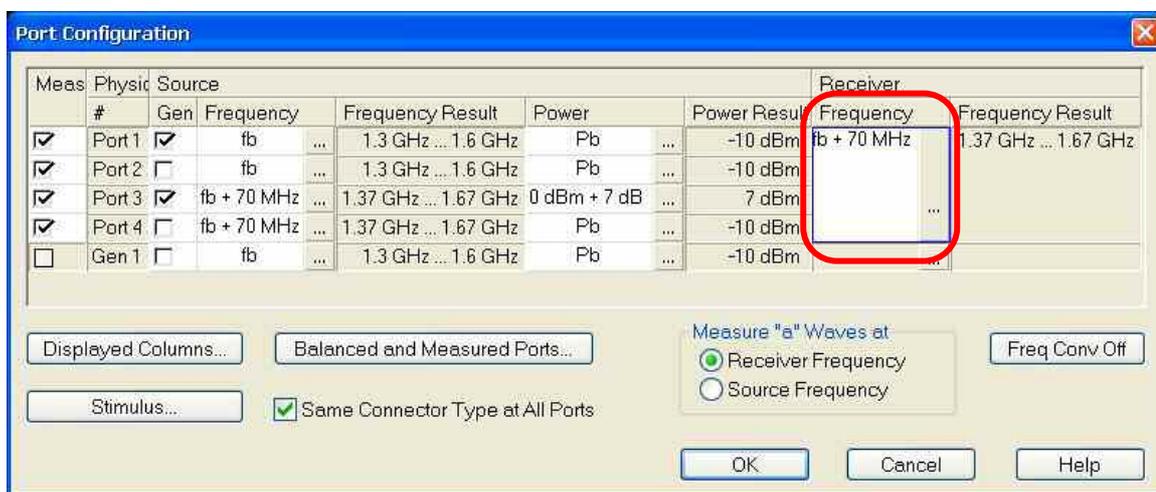
The main difference from the previous measurement is that we want to measure the amount of LO signal at the IF port. All the Source settings are therefore the same as before, but the receiver must be re-configured to measure the LO instead if the RF signal.
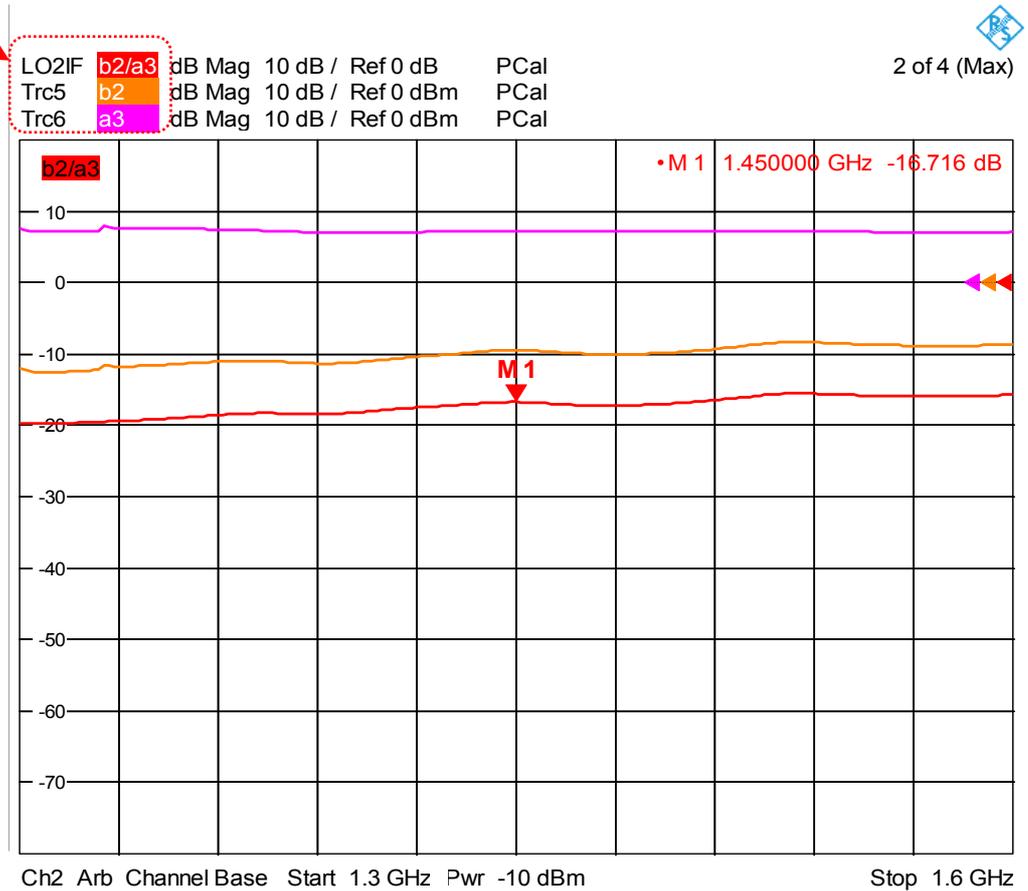
To do this, click on the Frequency field in the receiver section of the Port Configuration menu. Then add the 70 MHz offset so that the configuration result is identical to what is shown above.

LO to IF Isolation Measurement

The result of the LO to IF Isolation measurement can be seen at the red trace labeled LO2IF.

(Trc6) is the LO quantity and (Trc5) is also the LO quantity, but measured at the IF port.

b2/a3: LO → IF isolation
a3:   LO Power in
b2;   LO Power out

LO2IF	b2/a3	dB Mag 10 dB / Ref 0 dB	PCal
Trc5	b2	dB Mag 10 dB / Ref 0 dBm	PCal
Trc6	a3	dB Mag 10 dB / Ref 0 dBm	PCal

2 of 4 (Max)

b2/a3

• M 1   1.450000 GHz -16.716 dB

M 1

Ch2 Arb Channel Base Start 1.3 GHz Pwr -10 dBm   Stop 1.6 GHz

13. LO to RF Isolation Measurement

To start the configuration:

Press [CHAN SELECT], then [Add Channel + Trace + Diag Area] softkey. This will create a third channel in a new diagram area, which is identical to the second channel.
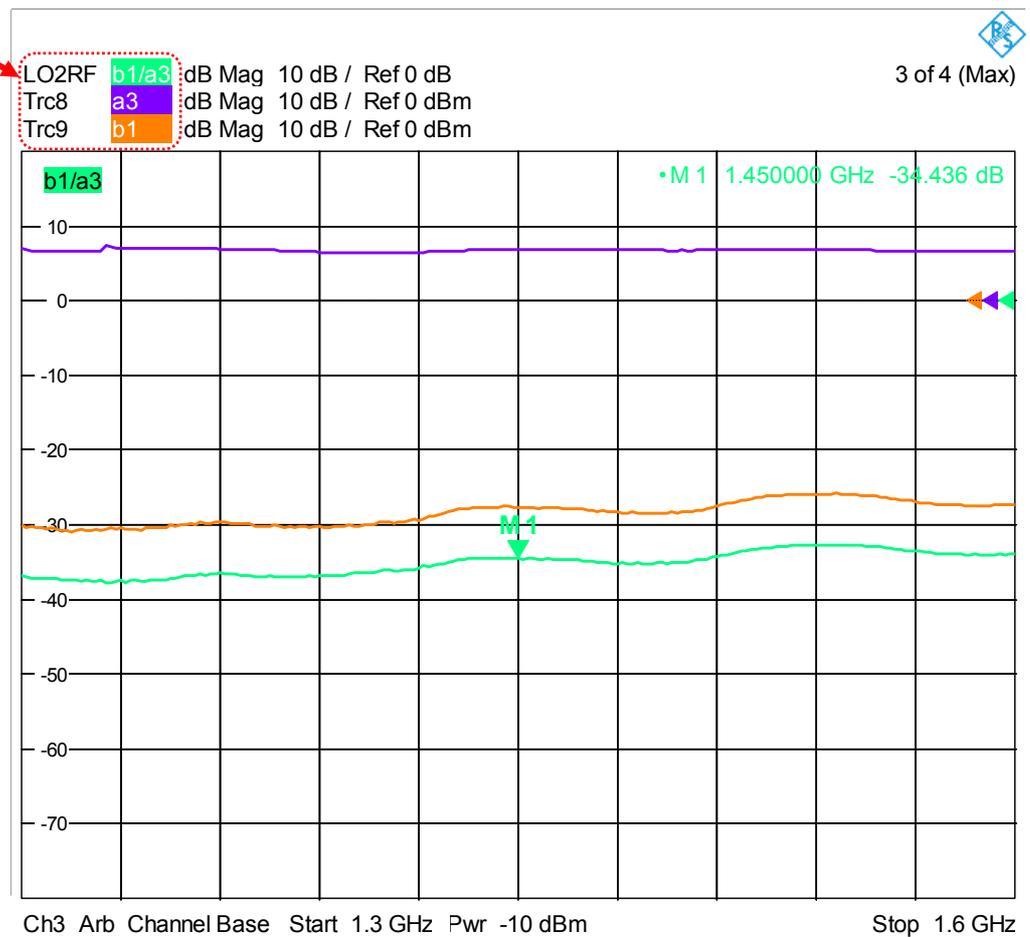
The port configuration for LO to RF isolation is identical to the previous one, so we just need to select the **(b1/a3)** as the measurement quantity for the LO to RF isolation measurement.

(Or as with the previous isolation measurements, select S13 to allow for vector error correction)

The result of the LO to RF Isolation measurement can be seen at the light green trace labeled LO2RF.

(Trc8) is the LO quantity and (Trc9) is also the LO quantity, but measured at the RF port.

b1/a3: RF → IF isolation
a3: LO Power in
b1; LO Power out

LO2RF	b1/a3	dB Mag 10 dB / Ref 0 dB	
Trc8	a3	dB Mag 10 dB / Ref 0 dBm	
Trc9	b1	dB Mag 10 dB / Ref 0 dBm	

3 of 4 (Max)

b1/a3

•M 1 1.450000 GHz -34.436 dB

M 1

Ch3 Arb Channel Base   Start 1.3 GHz Pwr -10 dBm   Stop 1.6 GHz

14. Power Calibration for Isolation Measurement

Unlike in the Mixer wizard for the conversion loss measurements, which also included an intuitive procedure for the power calibration, we need to go through a less automated procedure for the Isolation Measurement Calibration. In other words, we need to make sure that we cover all frequency ranges of interest for both sources and the receiver during our calibration.

In this section we will go through a calibration example for the RF to IF Isolation measurement. See section 11 for details.

In this RF to IF Isolation measurement, we are measuring the RF frequency range from 1.3 GHz to 1.6 GHz with an IF frequency of 70 MHz. Subsequently this will give us an LO frequency range from 1.37 GHz to 1.67 GHz when using IF = LO – RF in the frequency conversion.

With the connections to the mixer as shown below (left), we can make a graph of the frequency ranges for each port on the ZVA (right) that requires a power calibration.
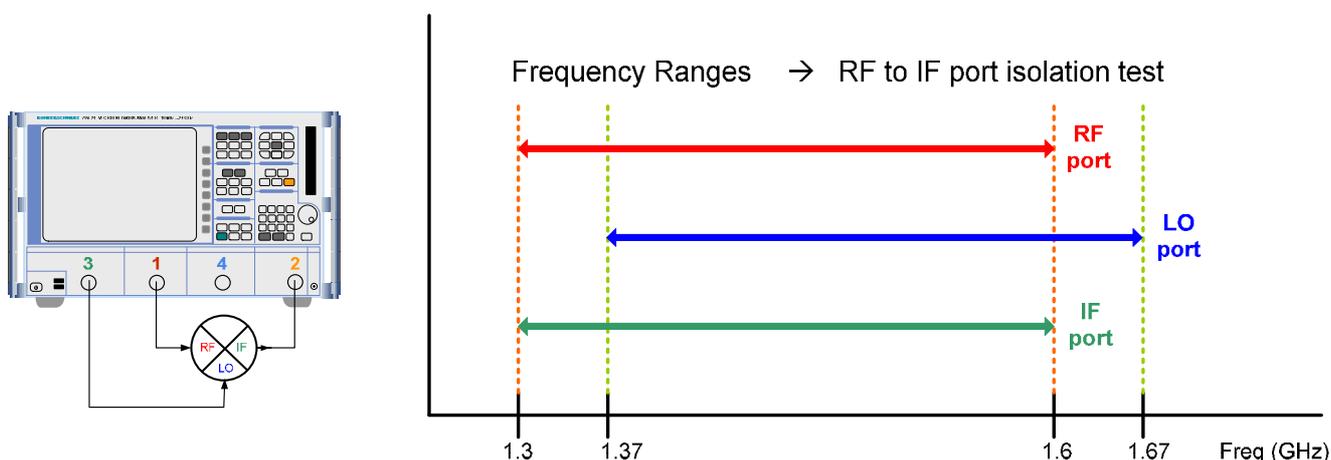
The two sources needs to be calibrated over their respective frequency ranges and the receiver needs to be calibrated, NOT at the IF frequency, but at the RF frequency range. From the plot above we can see that it makes sense to use the port 1 source for calibration of the port 3 receiver.

The 3 calibration measurements required are as follows:

1. Port 1 source calibration using a Power Meter / Sensor.
2. Port 3 source calibration using a Power Meter / Sensor.
3. Port 2 receiver calibration using the calibrated port 1 as the source.

In step 3 we are using the calibrated port 1 as a "transfer standard" from the Power Sensor to the port 2 receiver. The accuracy of the port 2 receiver calibration will be slightly worse than the port 1 source calibration.

The power calibrations should be performed in the order shown above.

To start the source Power Calibration process:

Press [CAL], then [Start Power Cal →] and [Source Power Cal…] softkeys to open the Source Power Cal dialog window.
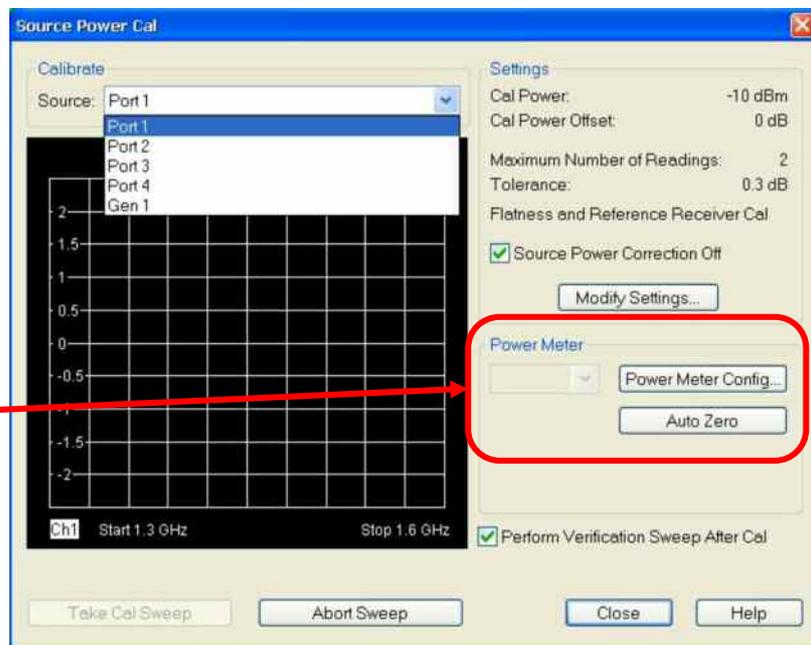
Configuration of a Power Meter/Sensor and optionally zeroing of the Sensor

First step is selecting which port to calibrate using the Source "Drop-down" menu. Select Port 1. Connect the configured Power Sensor to the port 1 cable.

If a Power Meter is not configured, click on the *Power Meter Config* button to access the Power Meter configuration menu. See section 7 for more information on configuring a Power Meter.

Click on Modify Settings… button to access Modify Source Power Cal Settings dialog window. Adjust settings as required. Click OK button when done.

Press *Modify Cal Power* to add Cal Power Offset values in case external matching pads and/or amplifiers are used.

Controls max number of iterations the ZVA should use for reaching the specified Tolerance value.

Check this box if more than one source shares the same calibration point. (Required when two sources are feeding a combiner and they are calibrated at the combiner output)
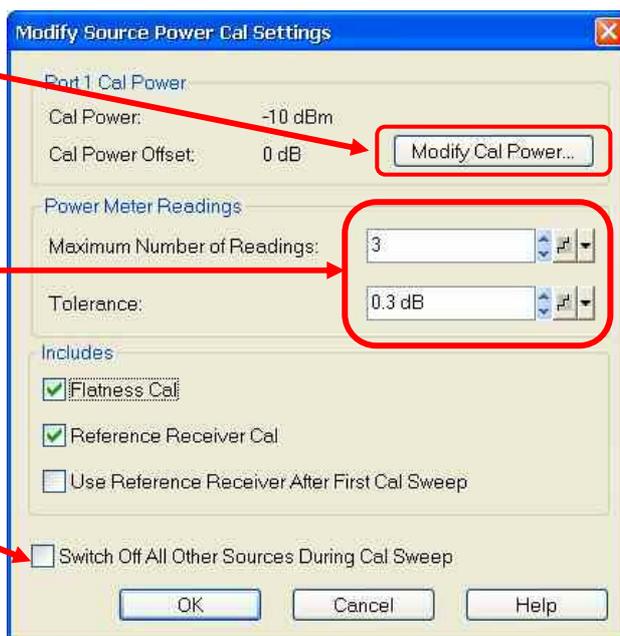
Power Calibration for Isolation Measurement

Click on *Take Cal Sweep* and the power calibration will start with the settings configured. The calibration progress can monitored in the graphical display.
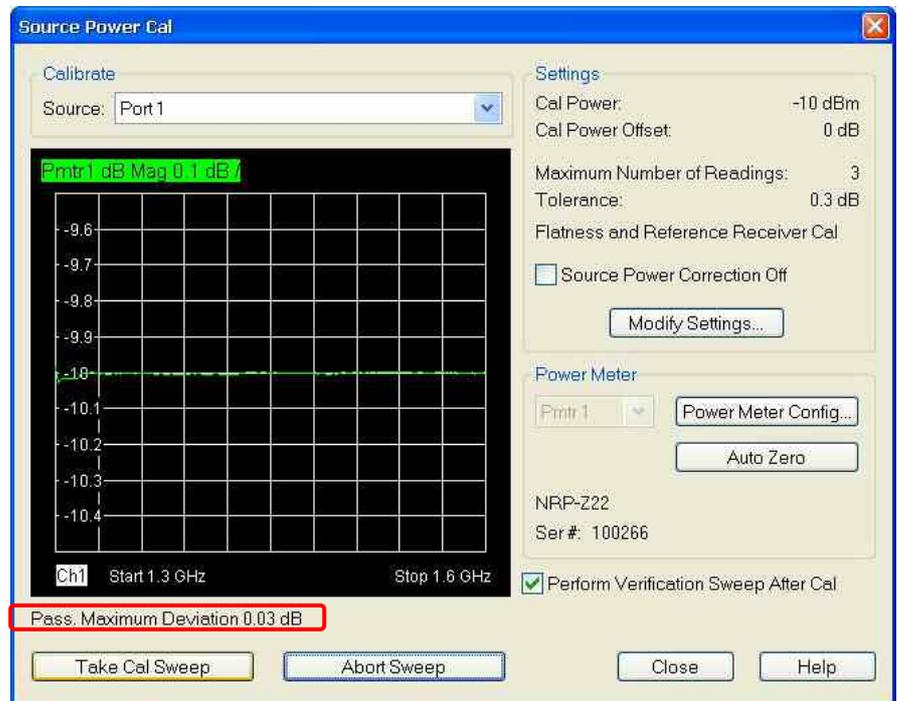
When completed, Pass (or fail) is indicated in the lower left corner together with the maximum deviation value. Click Close to End port 1 calibration.

Repeat the calibration process for port 3 following the same procedure.

To start the receiver Power Calibration process:

Press [CAL], then [Start Power Cal →] and [Receiver Power Cal…] softkeys to open the Receiver Power Cal dialog window.

Select the Wave Quantity to Calibrate, in our case it is the b2 quantity.

Select the Used Source, in our case it is port 1 we want to use.

**Connect the calibrated port 1 cable to the port 2 cable.**

Click the Take Cal Sweep button, wait a few seconds until the calibration completes. You can monitor the Sweep progress bar.

Click Close to complete the receiver power calibration.

This completes the Source power calibration process for the two sources at port 1 and 3 and the Receiver power calibration process at port 2.

15. RF and LO Port Return Loss Measurement

With traditional two-port Network Analyzers, S-parameter measurements like the S11 on the RF port had to be carried out using an external Signal Generator supplying the LO signal to the mixer. Since there was no frequency control of the generator, a fixed LO frequency was typically used while sweeping the RF frequency range of interest.
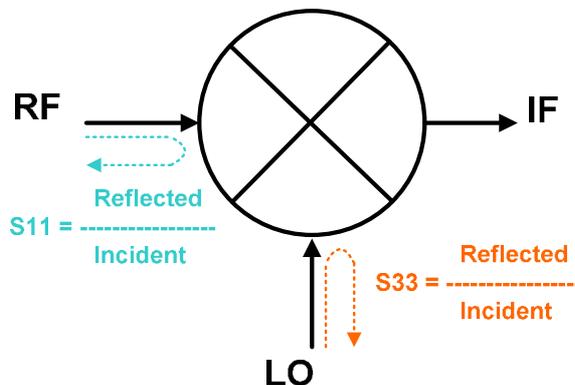
With the ZVA, it is now possible to measure the port matching parameters while the mixer is operating under realistic conditions. That is measuring the S11 of the RF port while the LO port is being feed with both the correct frequency and amplitude. Or measuring the S33 of the LO port with a proper RF signal applied.

Again we will need to use the Port Configuration menu to setup the proper conditions for the mixer, before making the S-parameter measurements.

In this example we will again be measuring the 1.3 to 1.6 GHz frequency range with an IF frequency of 70 MHz.

To start the configuration:

Preset the ZVA, then setup start/stop frequencies and a power level of -10 dBm.

Select S11 as the measurement quantity for RF port Return Loss.

Press [MODE], then [Port Config] keys to get to the Port Configuration menu and make the configuration shown below:
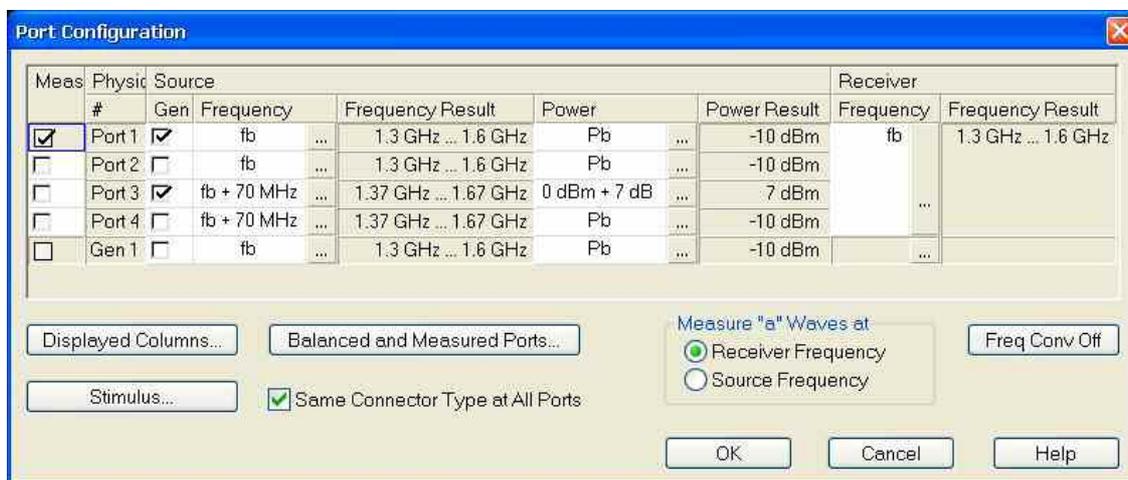
RF and LO Port Return Loss Measurement

To add a S33 measurement (LO) to the configuration:

Press [CHAN SELECT], then [Add Channel + Trace] softkey. This will create a second channel in the same diagram area, which is identical to the first channel.

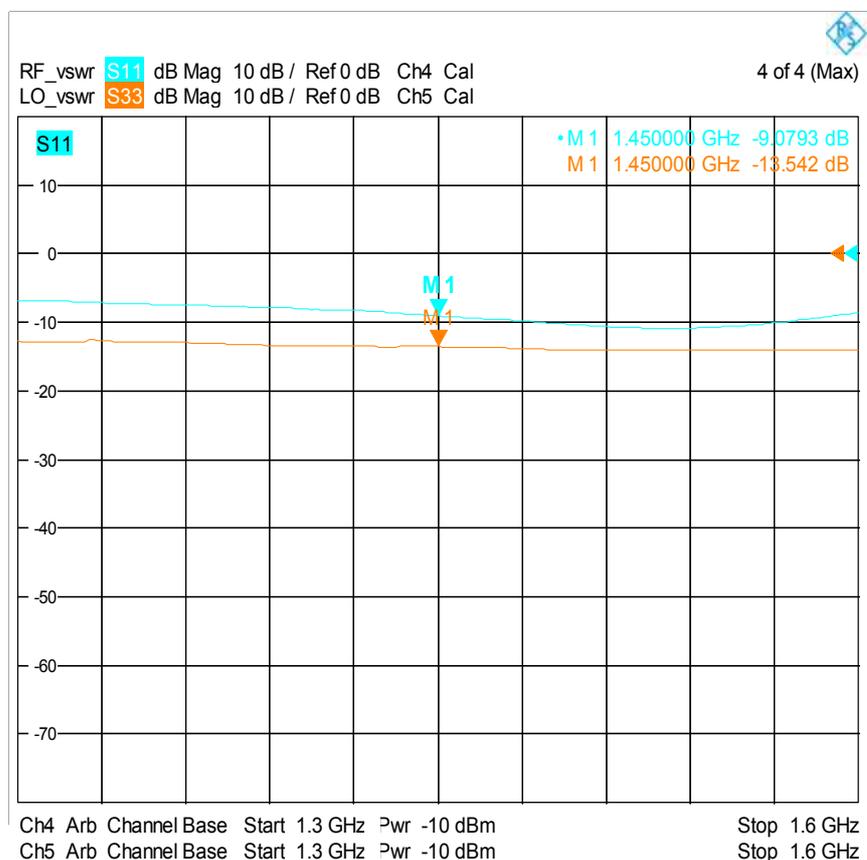Select S33 as the measurement quantity for LO port Return Loss.

Press [MODE], then [Port Config] keys to get to the Port Configuration menu.
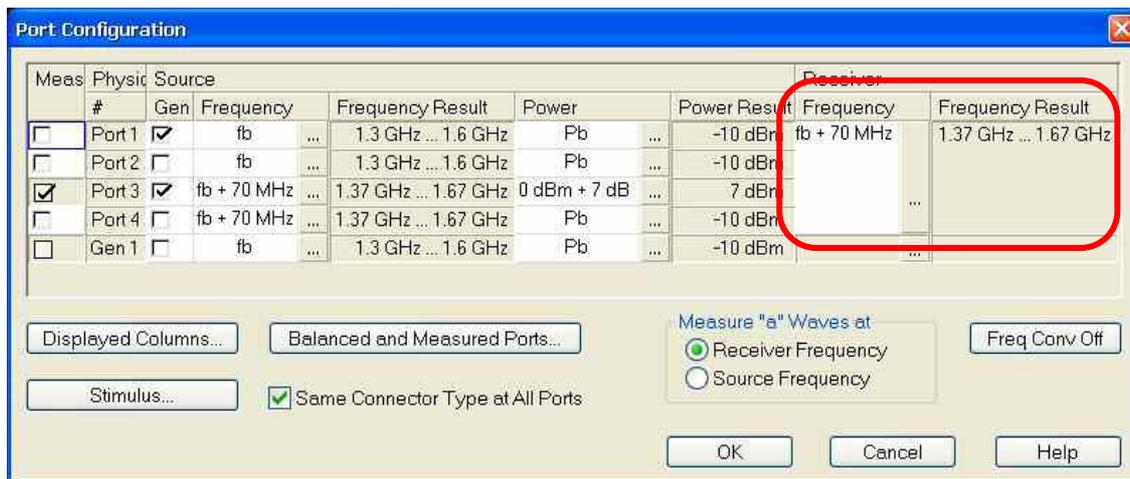
Change the Receiver Frequency setting, so that it is the LO frequency that is being measured.

The result of the S11 and S33 measurements can be seen below.

HINT: The **S11** and **S33** plots are shown in Return Loss format. Use [FORMAT] and [SWR] or [Lin Mag] softkeys to display the reflection measurements in VSWR or Reflection Coefficient formats respectively.

[dB Mag] returns the reading to the Return Loss format.

RF and LO Port Return Loss Measurement

To ensure the best accuracy possible in the mixer S-parameter measurements, the following calibrations should be made:

- S11 One-port calibration

- S33 One-port calibration

- Port 1 Power Calibration

- Port 3 Power Calibration

The screenshots below summarizes the Isolation and the Reflection measurements, configured in the previous sections.
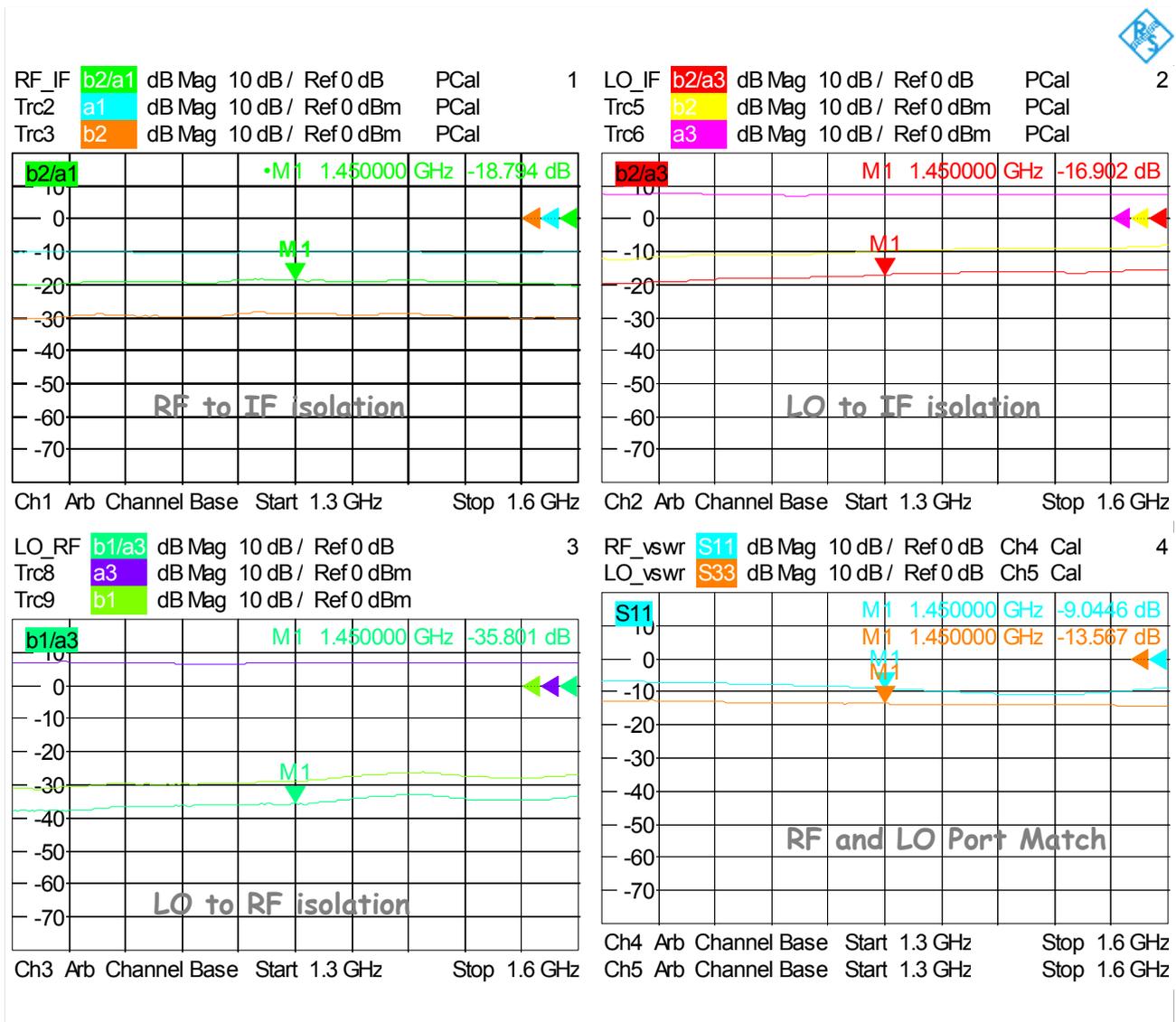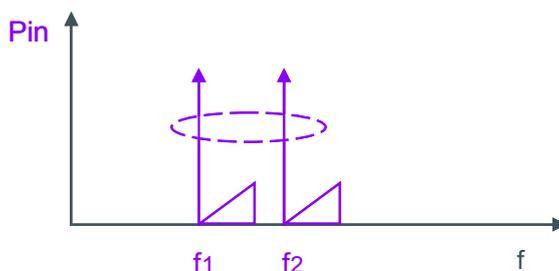
16. Intermodulation Measurement

The multiport / multisource concept of the ZVA and the ability to control external Signal Generators allows us to take mixer measurements even further and measure parameters like the Third Order Intermodulation (or IP3) product. For this, a 4-port ZVA and an external Signal Generator is required.

Please note that if a 6 port (3 generators) or 8 port ZVT (4 generators) is available, no external Signal Generator is required. The ZVT can then provide all the signals required.

Furthermore, a passive combiner is required to combine the two RF signals before applying them to the mixer. The signal generator will provide the LO signal to the mixer, as shown in the setup below. Low pass filters for reducing harmonic products from the sources are optional, but sometimes required.
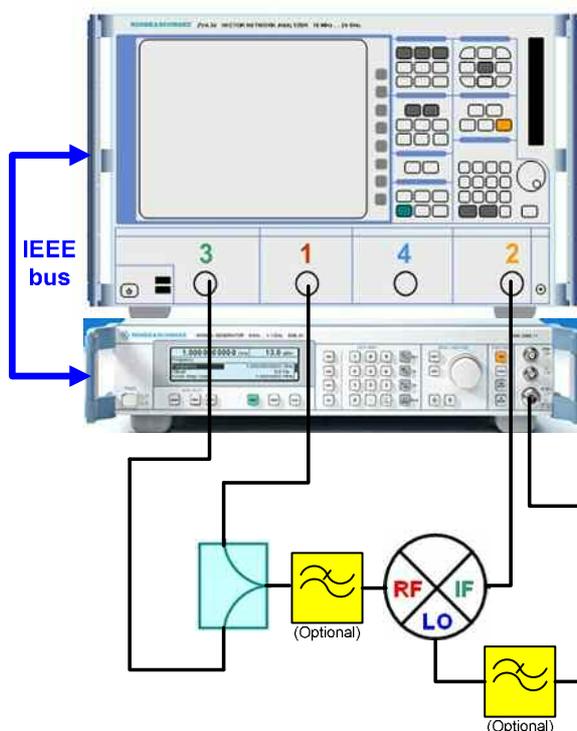
We will in our example here again measure the mixer in the RF frequency range from 1.3 GHz to 1.6 GHz with an IF frequency of 70 MHz. We will use an LO which is higher than the RF (IF = LO – RF), so the LO frequency range is 1.37 GHz to 1.67 GHz.

The ZVA will provide the two signals required for the IP3 measurement. A default spacing of 1 MHz will be used.

f1 will sweep from 1.300 GHz to 1.600 GHz and f2 will sweep from 1.301 GHz to 1.601 GHz.

Due to the mixer conversion, new carriers are created as follows:

C1 = LO – F1   example : 1370 MHz – 1300 MHz   = 70 MHz

C2 = LO – F2   example : 1370 MHz – 1301 MHz   = 69 MHz

And the IP3 products created are as follows:

IP3+ = 2*C1 – C2   example : 2*70 MHz – 69 MHz   = 71 MHz

IP3- = 2*C2 – C1   example : 2*69 MHz – 70 MHz   = 68 MHz

The Third Order Intercept (TOI) point can be calculated as follows:

TOI Point Calculation

$$TOI = Pout + \frac{IP\ dBc}{2}$$
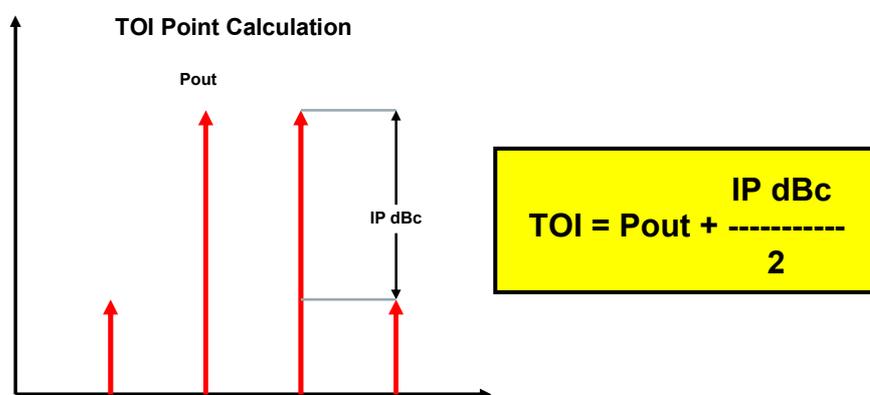
In our example, we will use C1 (70 MHz) and IP3+ (71 MHz) when we configure the IP3 measurement on the ZVA. First we will configure a classic Spectrum Analyzer view, measuring at a single frequency. Then we will configure a swept IP3 measurement

To start the IP3 measurement configuration, connect the hardware as shown on the previous page, then do the following:

Press [PRESET]

Press [START CENTER] and enter a start frequency of *65 MHz*

Press [STOP SPAN] and enter a stop frequency of *75 MHz*

Press [PWR BW AVG] and enter a power level of *0 dBm*

Press [PWR BW AVG], then [Meas Bandwidth] and [Fine Adjust] softkeys.
Enter 50 kHz bandwidth and select High Selectivity.

Please note that the measurement bandwidth selected must be smaller than the frequency spacing of the two tones. This is required in order for the ZVA to be able to distinguish between them in the receiver.

Now the (fb), (Pb) terms and the bandwidth are set and we can start the actual configuration of the test ports.

Press [MODE], then [Port Config] keys to get to the Port Configuration menu.

Port Configuration

Meas	Physic #	Source Gen	Frequency	Frequency Result	Power		Power Result	Receiver Frequency	Frequency Result
☑	Port 1	☑	1.5 GHz	1.5 GHz	Pb	...	0 dBm	fb	65 MHz ... 75 MHz
☑	Port 2	☐	1.5 GHz	1.5 GHz	Pb	...	0 dBm		
☑	Port 3	☑	1.501 GHz	1.501 GHz	Pb	...	0 dBm		
☑	Port 4	☐	1.501 GHz	1.501 GHz	Pb		0 dBm	...	
☐	Gen 1	☑	1.57 GHz	1.57 GHz	0 dBm + 8 dB	...	8 dBm	...	

Displayed Columns...   Balanced and Measured Ports...

Stimulus...   ☑ Same Connector Type at All Ports

Measure "a" Waves at
  ⦿ Receiver Frequency
 ◯ Source Frequency

Freq Conv Off

OK   Cancel   Help
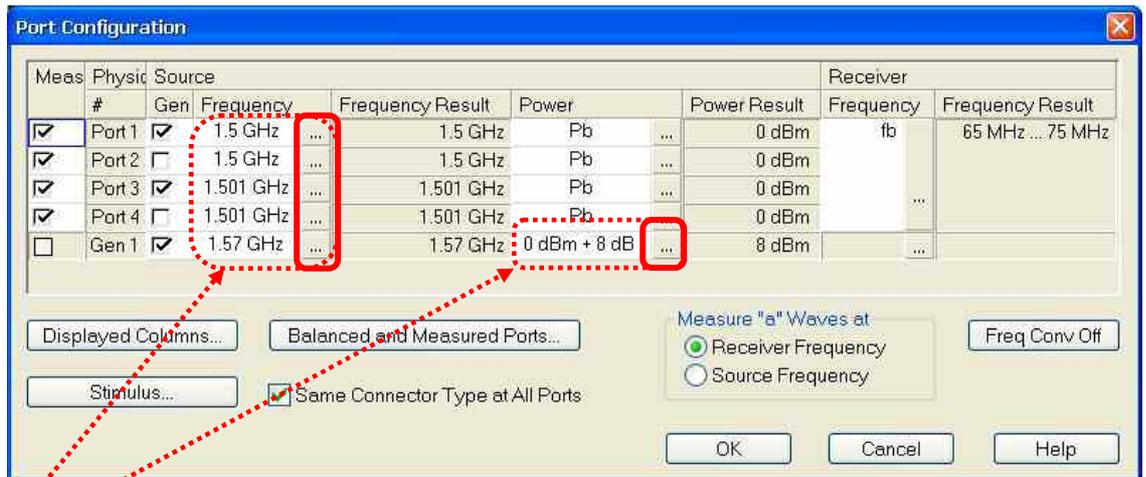
See chapter 11 (page 18) for details on frequency and power configuration menus.

Configure the generators at port 1 and 3 to produce a CW (non-sweeping) signal with 1 MHz spacing. Configure the external generator to produce a CW signal of 1.57 GHz for the LO port. Set the LO power to +8 dBm.

Select the **(b2)** as the measurement quantity.

The result of the non-sweeping IP3 measurement can be seen at the graphical plot below. The main products we are looking for are marked with red circles. The other signals shown in the measurement plot are spurs caused by mixing with the LO signal.
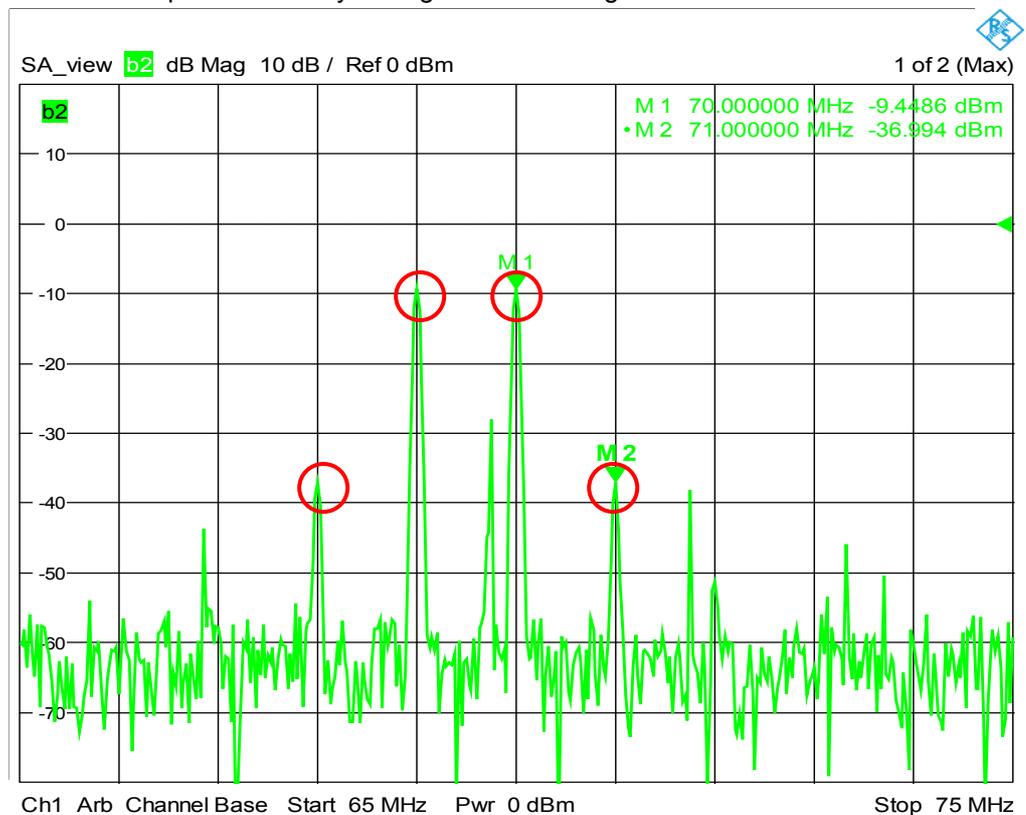
The benefit of starting with this measurement setup is that it gives us a good overview of the configuration made. Do we have a good S/N ratio in the measurement? Are the ZVA source levels appropriate for the measurement? If not, then it can be adjusted using this view before we start the swept IP3 measurement.

Intermodulation Measurement

In the swept IP3 measurement we will focus on the C1 (70 MHz) and IP3+ (71 MHz) products. To start the configuration of the swept IP3 measurement:

Press [CHAN SELECT], then [Add Channel + Trace + Diag Area] softkey. This will create a second channel in a new diagram area.

Select the **(b2)** as the measurement quantity.

Press [MODE], then [Port Config] keys to get to the Port Configuration menu.

Make the configuration shown below. Please note that the ZVA sources and the external generators are now sweeping and that the ZVA receiver is fixed at the C1 frequency (70 MHz).
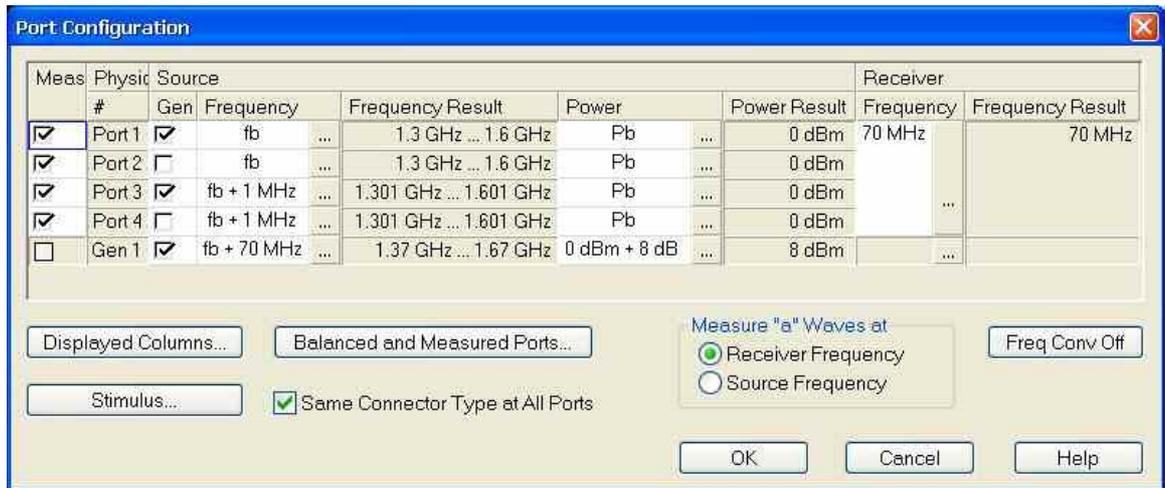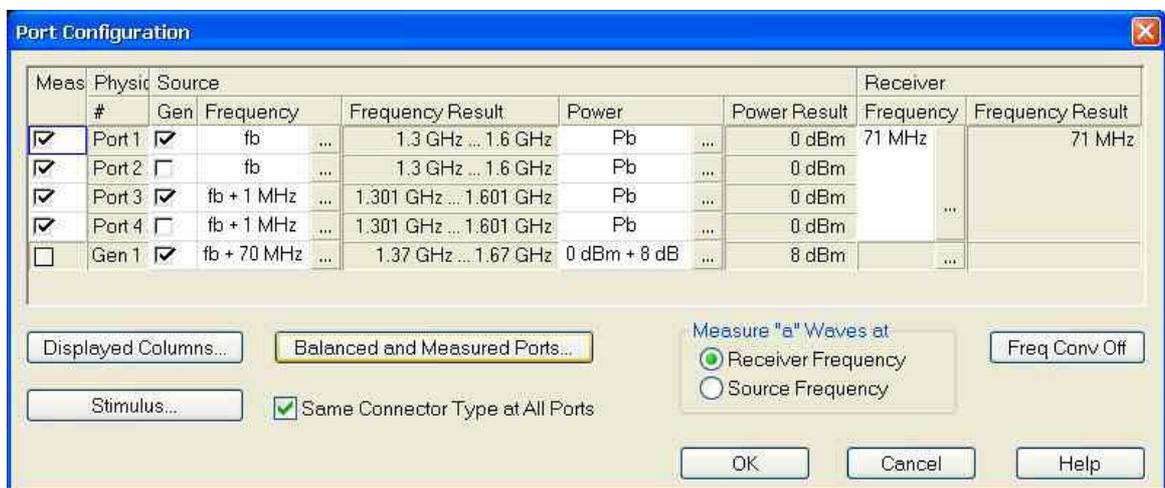

Press [CHAN SELECT], then [Add Channel + Trace] softkey. This will create a third channel in the same diagram area.

Select the **(b2)** as the measurement quantity.

Press [MODE], then [Port Config] keys to get to the Port Configuration menu.

Make the configuration shown below. Please note that the only change required is setting the ZVA receiver for the IP3+ frequency (71 MHz).
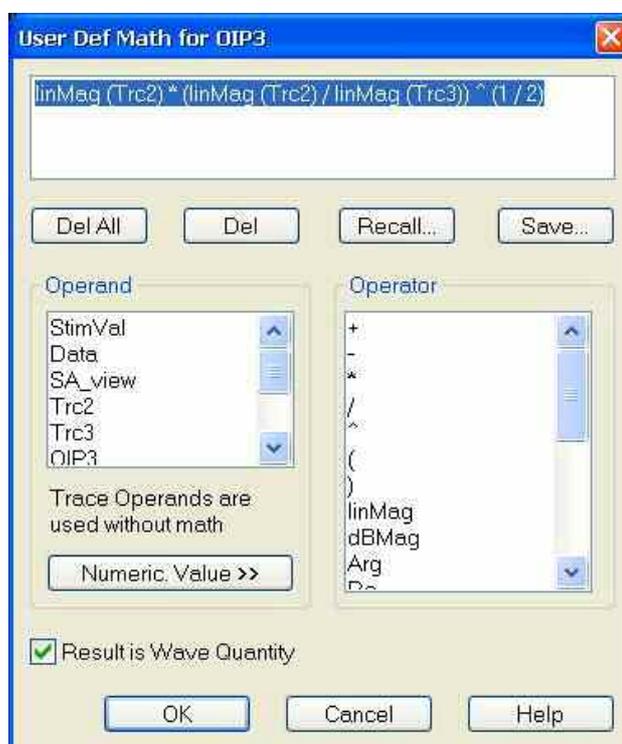
Intermodulation Measurement

We now have the 2 traces for measuring the C1 and IP3+ frequencies defined. Since the 3rd Order Intercept point is a calculated value, we need to create a trace that takes the data from the C1 and IP3+ traces and calculate the values. The ZVA offers the possibility to display traces based on calculated values, rather than measured values. The data used for these calculations can be data from other traces, mathematical operators, constants, etc.

Press [CHAN SELECT], then [Add Channel + Trace] softkey. This will create a fourth channel in the same diagram area.

Press [TRACE FUNCT], then [User Def Math] keys to get to the User Def Math menu. Use the Operand and Operator fields to create the highlighted equation.

Please note that the equation editor does its calculations in linear format, so we need to convert the measured trace data before we can used them.

Set a checkmark in *Results is Wave Quantity* and press OK.
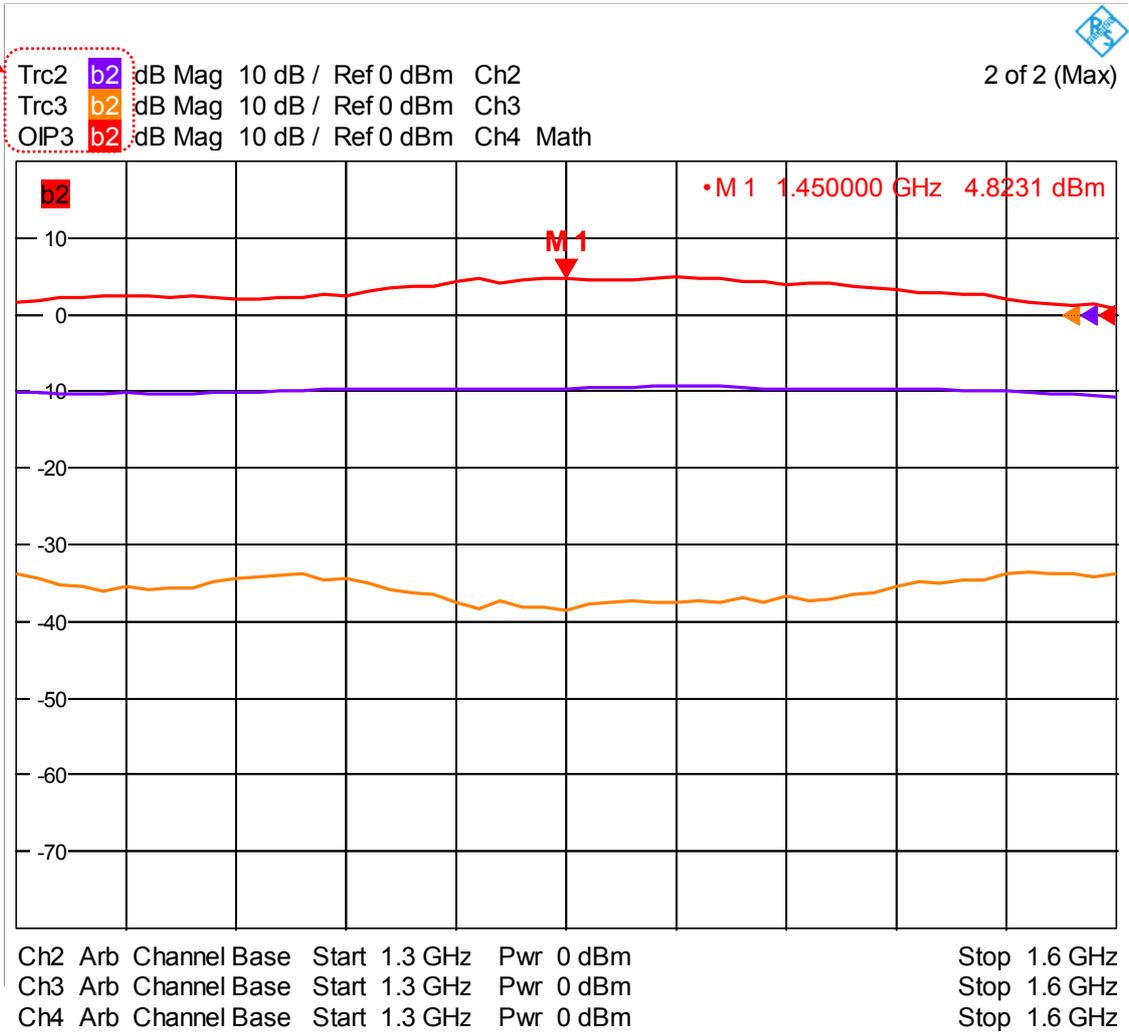

Press [TRACE FUNCT], then [Math = User Def] keys to enable use of the user defined math trace.

Intermodulation Measurement

The **calculated** result of the swept IP3 measurement can be seen at the **red** trace labeled **OIP3**.

(**Trc2**) is the C1 quantity and (**Trc3**) is the IP3+ quantity, measured at the mixers IF port.

Trc2:   C1 quantity
Trc3:   IP3+ quantity
OIP3 : TOI intercept

Trc2 b2 dB Mag 10 dB / Ref 0 dBm Ch2
Trc3 b2 dB Mag 10 dB / Ref 0 dBm Ch3
OIP3 b2 dB Mag 10 dB / Ref 0 dBm Ch4 Math

• M 1   1.450000 GHz   4.8231 dBm

b2

M 1

10

0

-10

-20

-30

-40

-50

-60

-70

Ch2 Arb Channel Base   Start 1.3 GHz   Pwr 0 dBm   Stop 1.6 GHz
Ch3 Arb Channel Base   Start 1.3 GHz   Pwr 0 dBm   Stop 1.6 GHz
Ch4 Arb Channel Base   Start 1.3 GHz   Pwr 0 dBm   Stop 1.6 GHz

Again, In order to ensure the best accuracy possible, power calibrations must be performed on both ZVA sources (port 1 and 3) and the external generator. Also the ZVA receiver on port 2 should be calibrated.

Calibration point for the ZVA sources should be at the power combiner Output. Make sure that other sources are switched off during calibration of the individual sources.

Refer to section 14 for more information on power calibration.

17. Additional Information

This Application Note is updated from time to time. Please visit the website **www.rohde-schwarz.com** to download the latest versions.

Please send any comments or suggestions about this application note to **info.rsdk@rohde-schwarz.com**.

18. Ordering Information

Listed are all R&S ZVA/T network analyzers and most important options. Of course, accessories like test cables, or manual and automatic calibration kits are available in addition. There is also a wide variety of R&S NRP test heads for power measurement and power calibration. For details, please contact your local R&S sales office, or the R&S web site.

Order No.	Type	Designation
1145.1110.08	R&S ZVA8	Vector Network Analyzer, 2 Ports, 8 GHz
1145.1110.10	R&S ZVA8	Vector Network Analyzer, 4 Ports, 8 GHz
1145.1110.24	R&S ZVA24	Vector Network Analyzer, 2 Ports, 24 GHz
1145.1110.26	R&S ZVA24	Vector Network Analyzer, 4 Ports, 24 GHz
1145.1110.40	R&S ZVA40	Vector Network Analyzer, 2 Ports, 40 GHz
1145.1110.42	R&S ZVA40	Vector Network Analyzer, 4 Ports, 40 GHz
1145.1110.50	R&S ZVA50	Vector Network Analyzer, 2 Ports, 50 GHz
1145.1110.52	R&S ZVA50	Vector Network Analyzer, 4 Ports, 50 GHz
1300.0000.08	R&S ZVT8	Vector Network Analyzer, 2 - 8 Ports, 8 GHz
1300.0000.20	R&S ZVT20	Vector Network Analyzer, 2 - 6 Ports, 20 GHz
1164.1657.02	R&S ZVA-K2	Time Domain (TDR)
1164.1863.02	R&S ZVA-K4	Frequency Conversion
1164.1540.02	R&S ZVA-K6	True Differential Measurements
1164.1511.02	R&S ZVA-K7	Pulsed Measurements
1302.5544.02	R&S ZVAB-B44	USB-to-IEC/GPIB Adapter