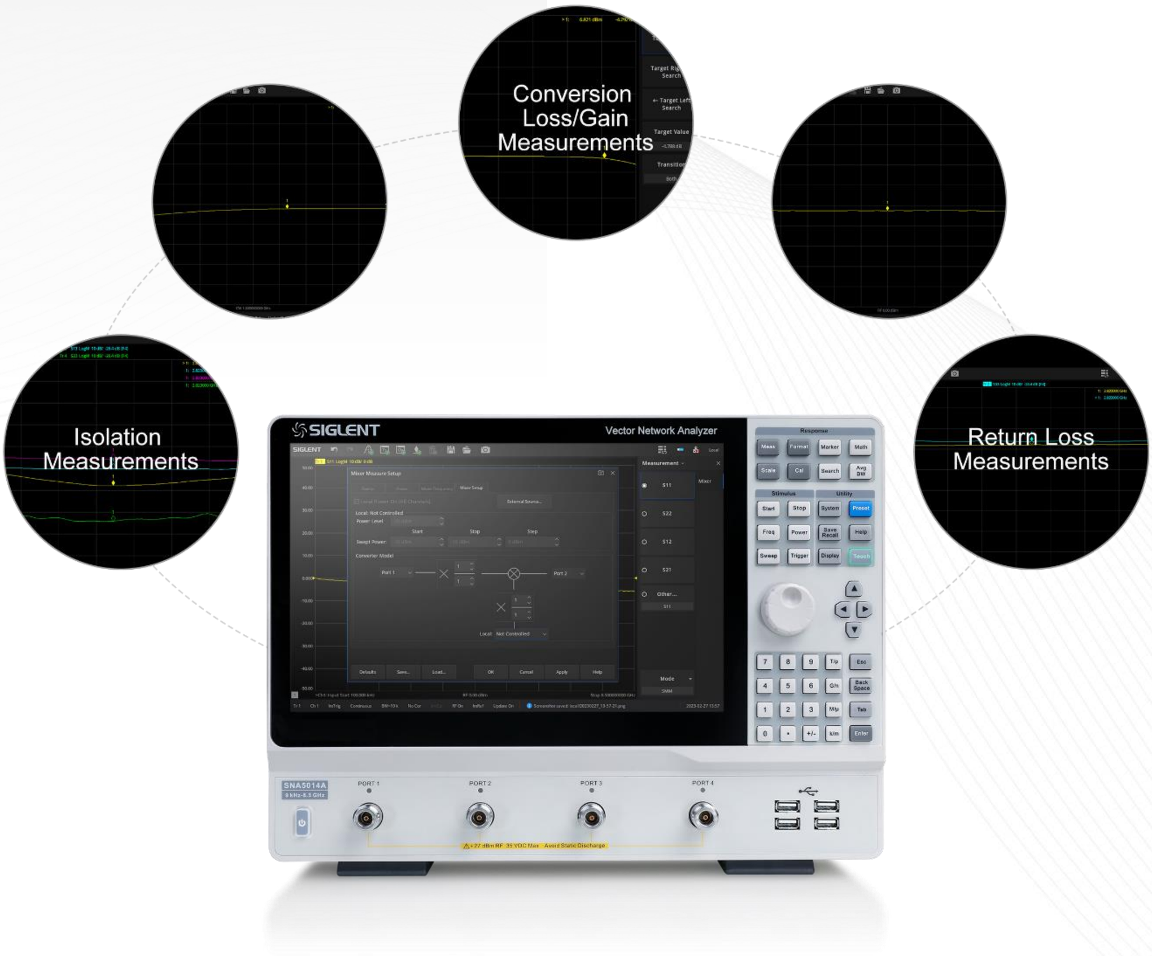
Mixer measurements with a Vector Network Analyzer



SIGLENT TECHNOLOGIES CO.,LTD

History Version

Version	Date	Author	Description
1.0	Feb 28, 2023	Michael Zeng	Create of the app note

CONTENTS

1. Mixer introduction

Mixers are typically 3-port devices that produce the sum or difference of two input frequencies. Most of the mixers are active ones require external power supply. But there are also passive mixers like audio mixer that doesn't require any power because it doesn't have an amplifier.

A typical mixer is shown in Figure 1, the RF and LO are two input signals, while the output is IF. The relationships of their frequencies are as follows.

$f_{out} = f_{in} + f_{LO}$ (1-1)

or $f_{out} = f_{in} - f_{LO}$ (1-2)

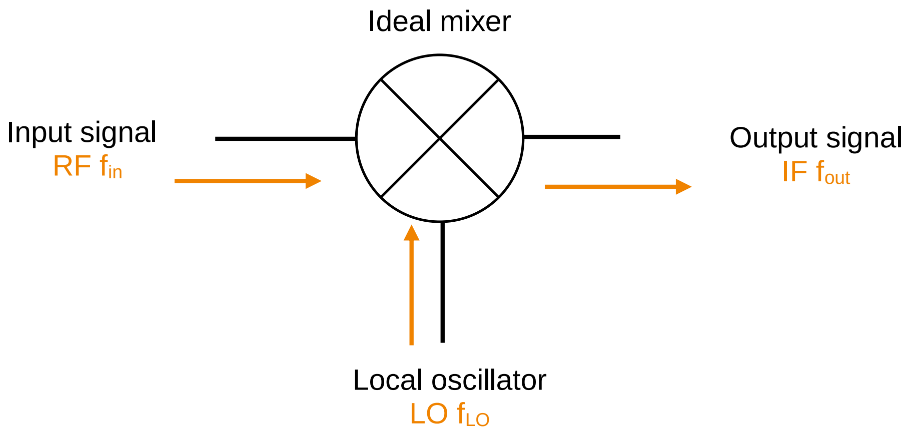


Figure 1. Typical Mixer

For example, if we have f_{in} = 1 GHz, f_{LO} = 500 MHz, then f_{out} = 1.5 GHz or 500 MHz.

Engineers often need to evaluate mixer performance, including conversion loss, phase and group delay, the 1 dB compensation point, isolation between ports and port VSWR. Phase and group delay can be measured with a VNA equipped with Vector Mixer Measurement function. While the others can be achieved with Scalar Mixer Measurement function. In this application note, we give brief introduction about scalar measurements.

2. Test environment setup

A four port VNA like SNA5014A, consists of two internal generators, which enables simultaneously feed of LO and RF input signals. As shown in Figure 2, Port 1 states RF input signal and port 3 provides Local Oscillator signal. Port 2 is connected to mixer output. Because port 1 and 2 shares the same internal source. So, LO and RF port should not be connected to port 1 and port 2 together. Since in mixer measurements, the RF and LO signals usually have different frequencies. For same reason, RF and LO can not be connected to port 3 and 4 at the same time.

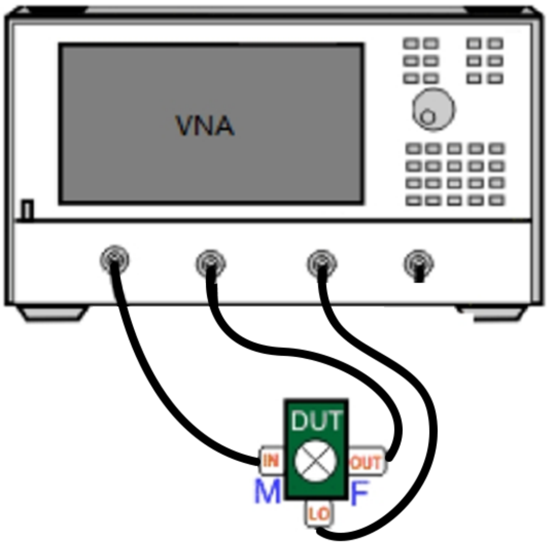


Figure 2. Mixer measurements with a four port VNA

But for a two ports VNA like SNA5012A, there is only one internal generator, so in this case an external RF signal generator is required. All of Siglent SSG series generators can do this job well. The external source can be set independently as a fixed LO, or controlled by VNA to sweep. Directly connect the USB Device end to generator, the USB Host to VNA. VNA will control the external generator automatically.

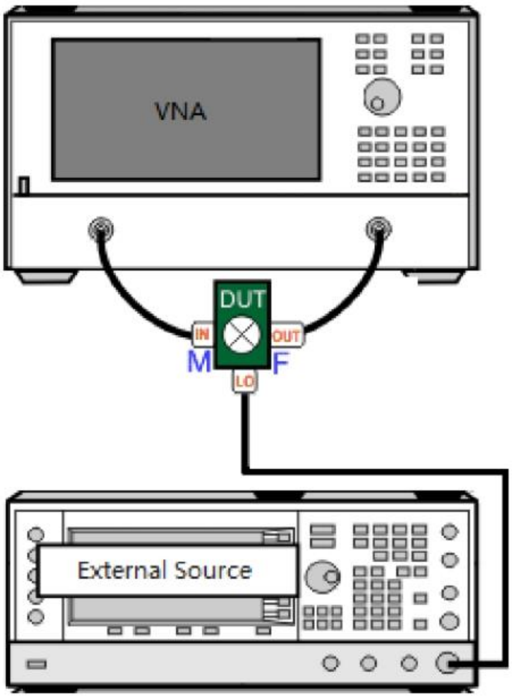
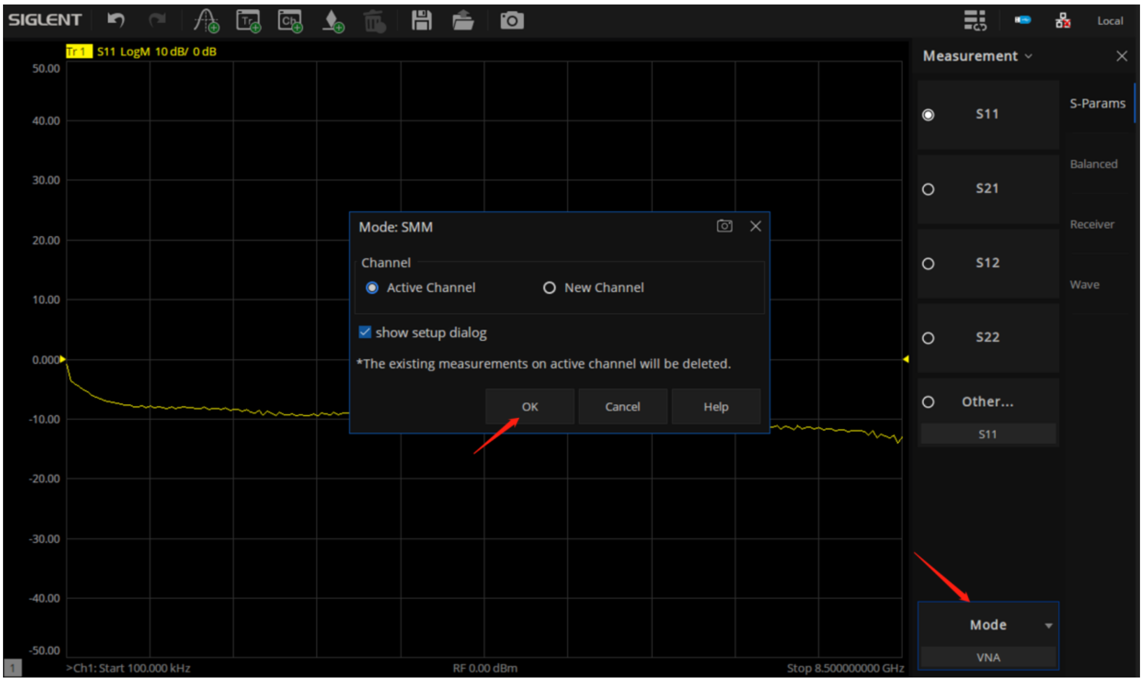


Figure 3. Mixer measurements with a two port VNA

Once the connections done, press Meas -> Mode -> SMM to open the scalar mixer measurement function.



There are four tabs Sweep, Power, Mixer Frequency, Mixer Setup in the mixer measurement setup wizard. Press Cal -> Mixer Cal... to perform calibration. The detail setup guide can be found in SNA5000A user manual. https://int.siglent.com/products-document/sna5000a/#navs

3. Typical Measurements

Following setting values may vary with mixers. Note that the mixer should be properly powered during all of the following tests. Siglent SPD1000X series DC linear power supply is high recommended. In terms of size it's small but has high output stability, an ideal choice for daily lab uses.

1) Conversion Loss (or Gain) Measurements

Conversion Loss is defined as the ratio between IF output signal power f_{out} and RF input signal f_{in} and expressed in dB.

$$\text{Conversion Loss} = 10\ \text{Log}\ \frac{P_{out}}{P_{in}} \qquad (3\text{-}1)$$

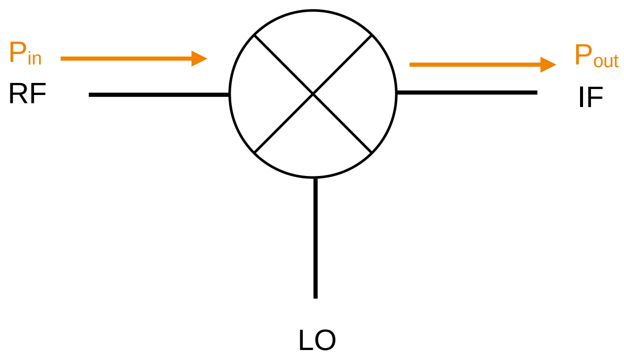
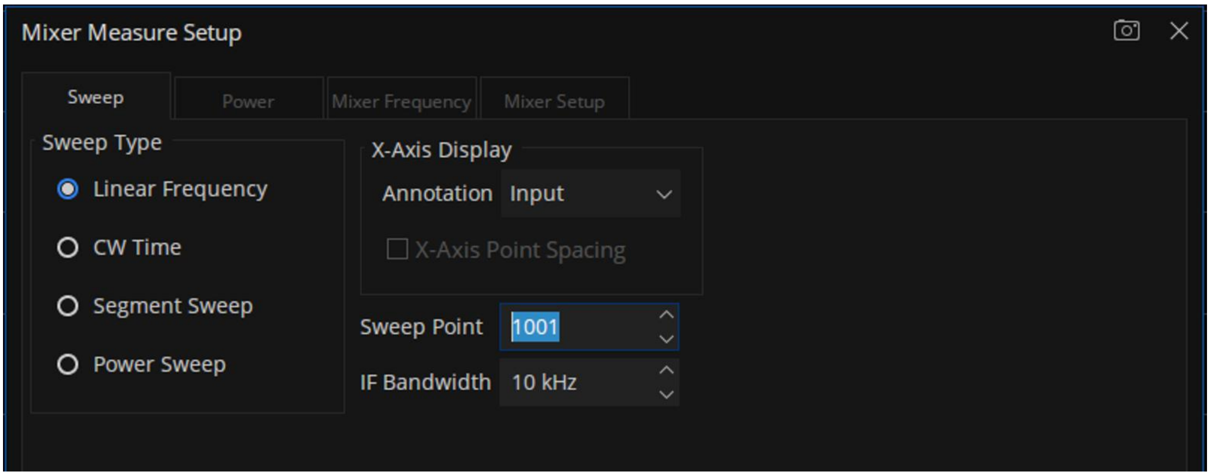


Figure 4. Mixer Conversion Loss/Gain

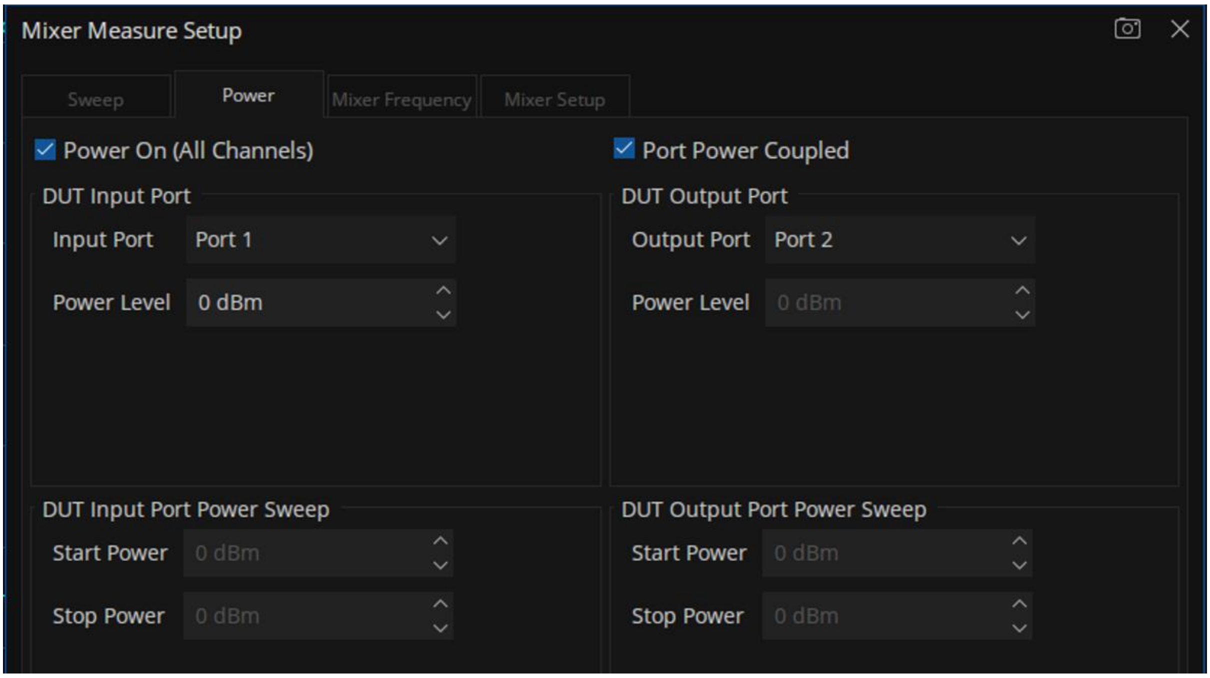
Typical Conversion measurements on a mixer includes following three types.

a) Conversion Loss / Gain – RF port Linear Frequency Sweep

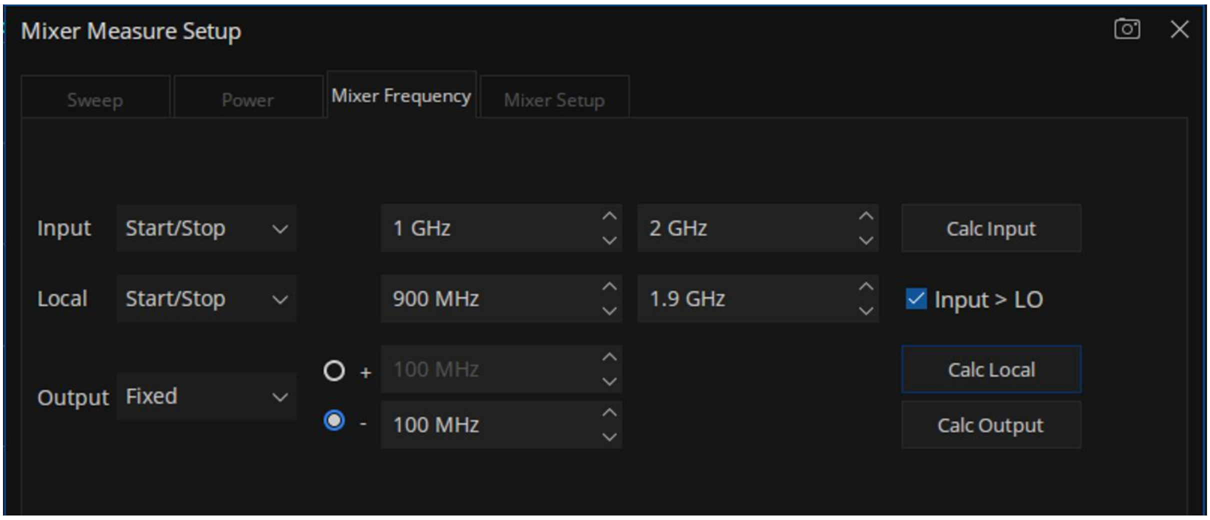
To start the configuration, set Sweep Type as **Linear Frequency**, Sweep point as **1001** or other, IF bandwidth remains as default **10 kHz**.



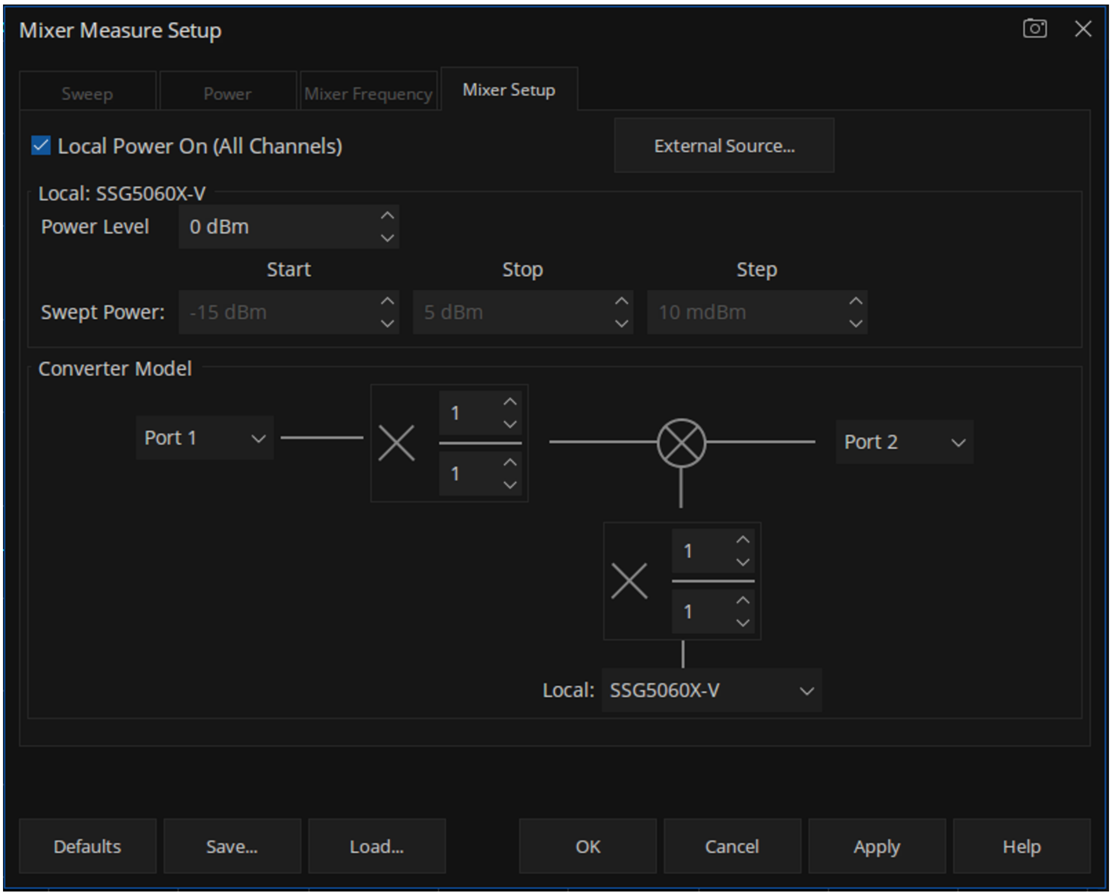
In Power tab, set Input Port as **Port 1**, Power level remain as **0 dBm**, Output Port remain as **Port 2** and with Port Power Coupled selected.



Then set Mixer Frequency tab. Set Input as **Start/Stop**, **1 GHz** to **2 GHz**. Set Output as **Fixed**, **- 100 MHz**. Then click Calc Local**,** the LO frequencies will be calculated automatically.

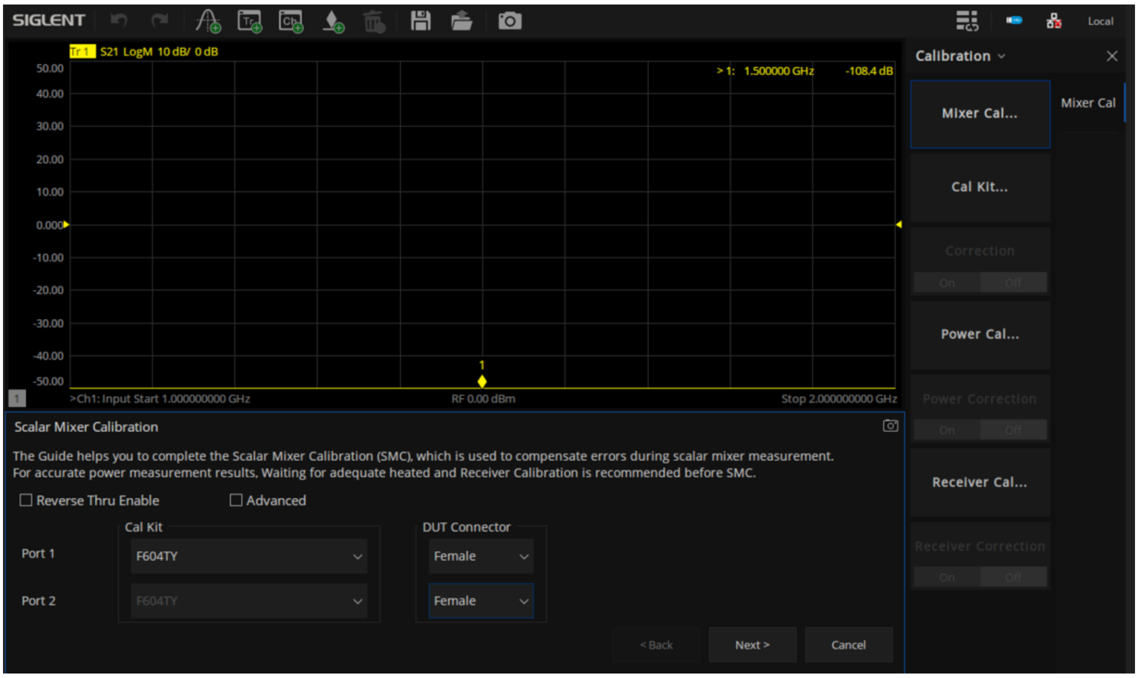


Finally set the Mixer Setup tab, if you have an external source, you should choose the generator connected via USB cable, in this case SSG5060X-V. And then configure the Power Level as **0 dBm** which should be high enough to properly bias the mixer diodes.

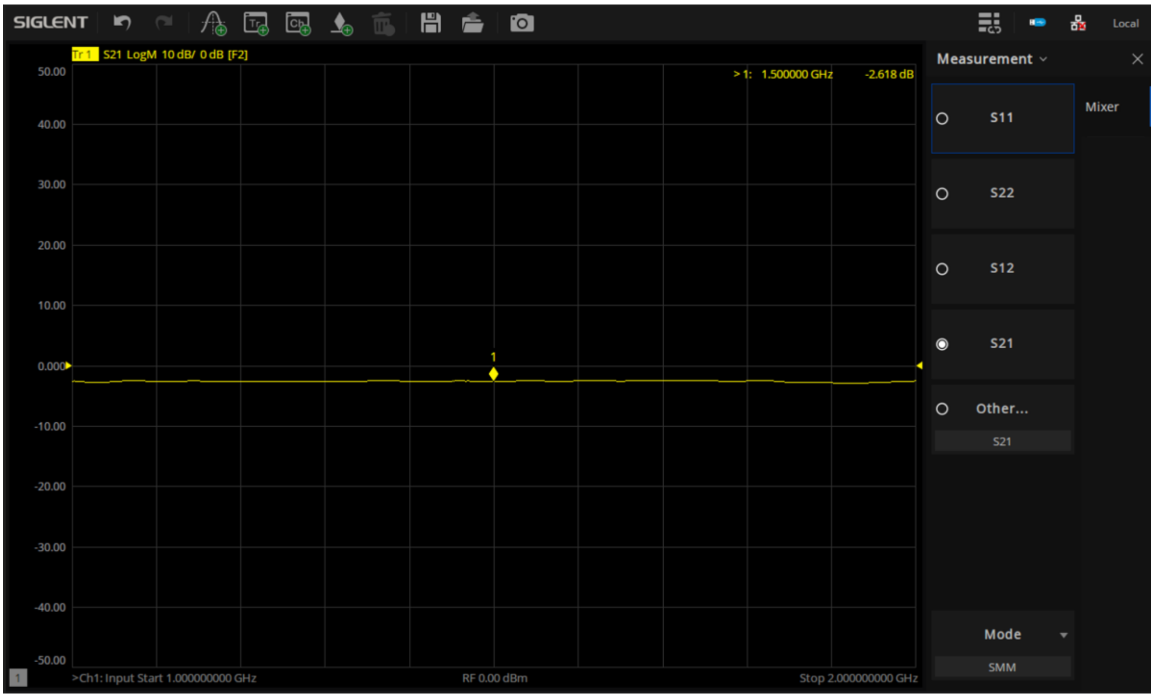


If you want to set the fractional multipliers, please refer to the user manual. After all settings finished, click Apply, then OK.

Press Cal -> Mixer Cal… to perform the mixer measurement calibration. This will perform full two port calibration twice, because RF and IF ports are not in the same frequency range. The final step of the calibration is power calibration which requires an external power sensor. Connect the power sensor to RF port, then click Start Power Measurement. Click Finish to end the calibration procedure.



Press Meas button, choose S21. And press Marker button to add a marker for easy Conversion loss/ Gain readings. Normally the conversion loss of a mixer is from -10 dB to1dB.

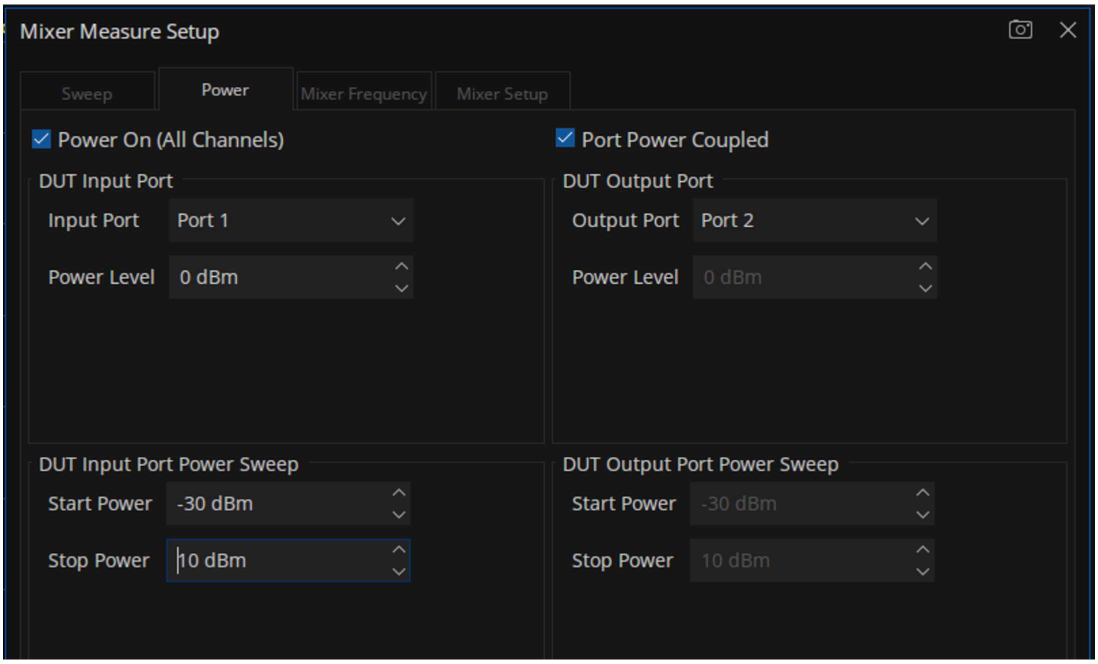


b) 1 dB compression point measurement – RF port Power Sweep

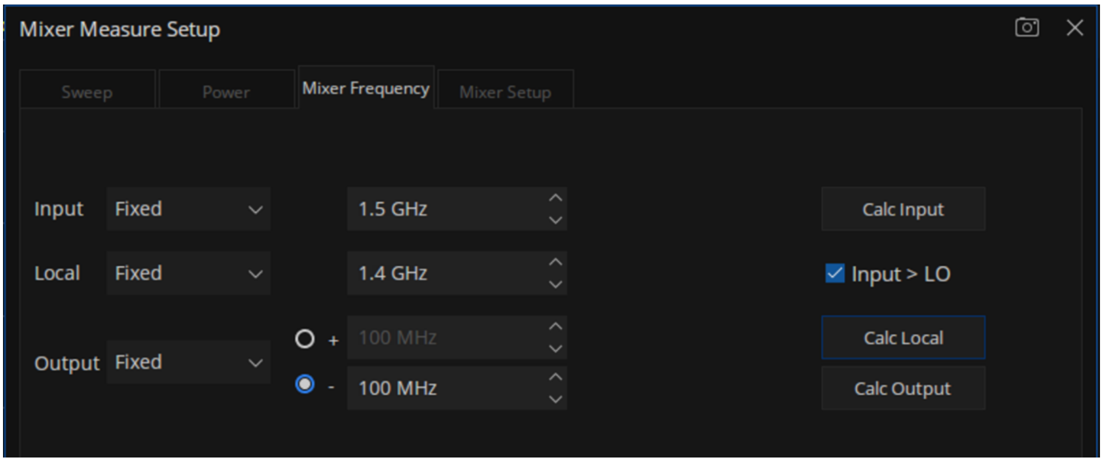
In the RF Input Compression measurement, we will measure the Mixers Conversion Loss as a function of the RF Input power level. We will set a power sweep at a fixed frequency.

Press any button of Start / Stop / Freq / Power / Sweep, then click Mixer Measure… to get back to the Mixer Measurement Setup menu.

Set Sweep Type as **Power Sweep**, then in Power tab set Start Power as **-30 dBm** and Stop Power as **+10 dBm**.

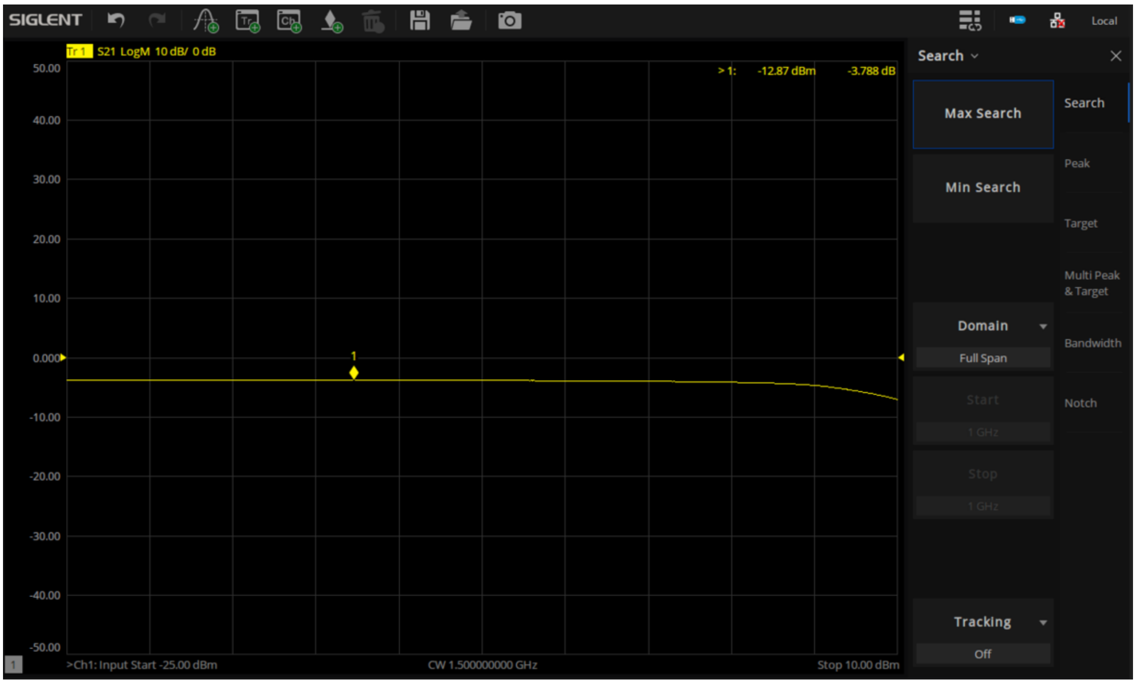


In Mixer Frequency tab, set Input , Local and Output as **Fixed**. Input frequency **1.5 GHz**, then click Calc Local.

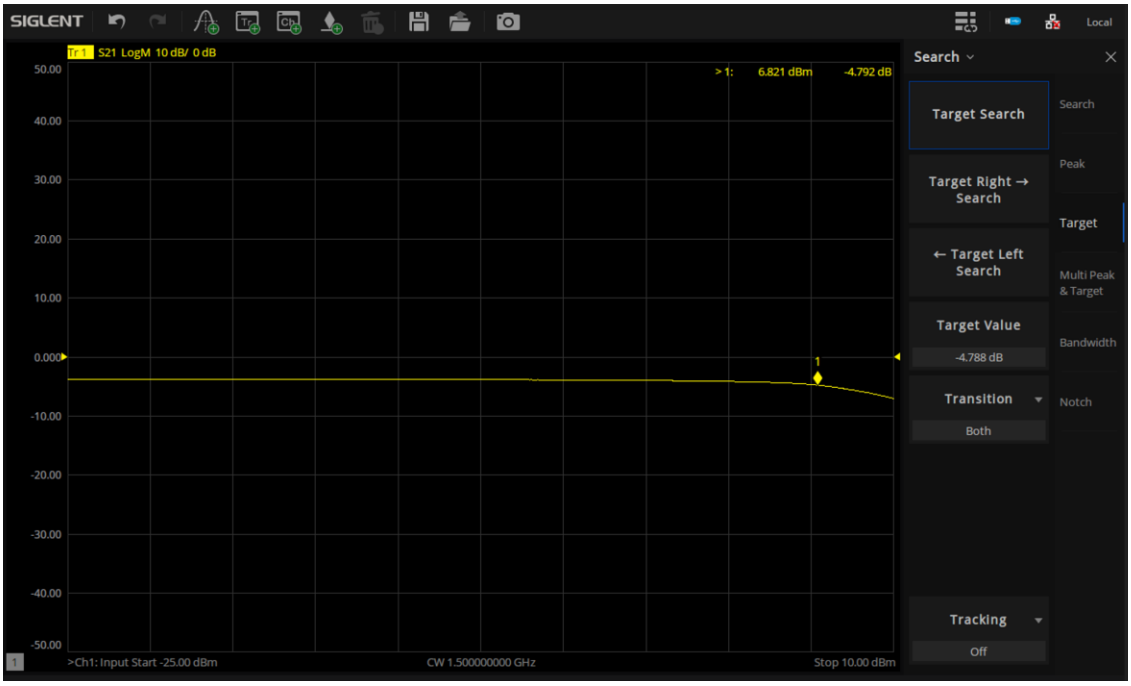


LO power level remains as **0 dBm**. Click Apply -> OK.

Press Search -> Max Search to get the normal gain value as -3.788 dB. So 1 dB compression value is -4.788 dB.

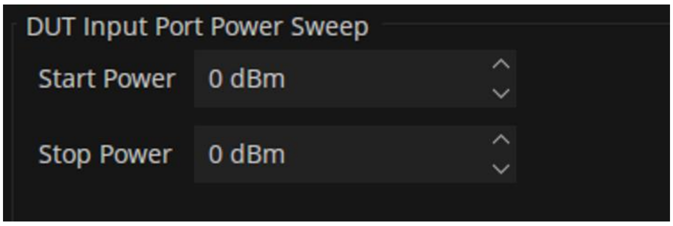


Click Target -> Target Value, input -4.788, click Target Search. The marker reading means at the frequency of 1.5 GHz, when RF input power is 6.821 dBm, the conversion loss/gain of the mixer is -4.792 dB. It starts to get into compression area.

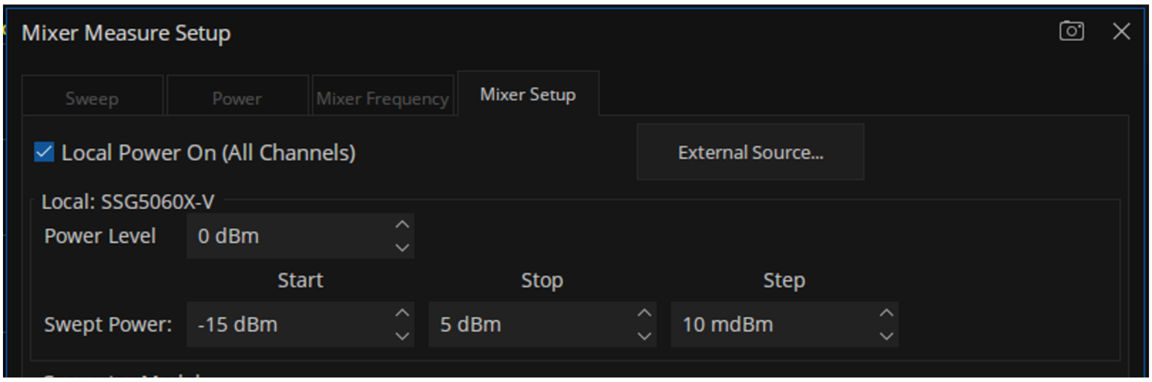


c) Conversion Loss / Gain as a function of LO power level.

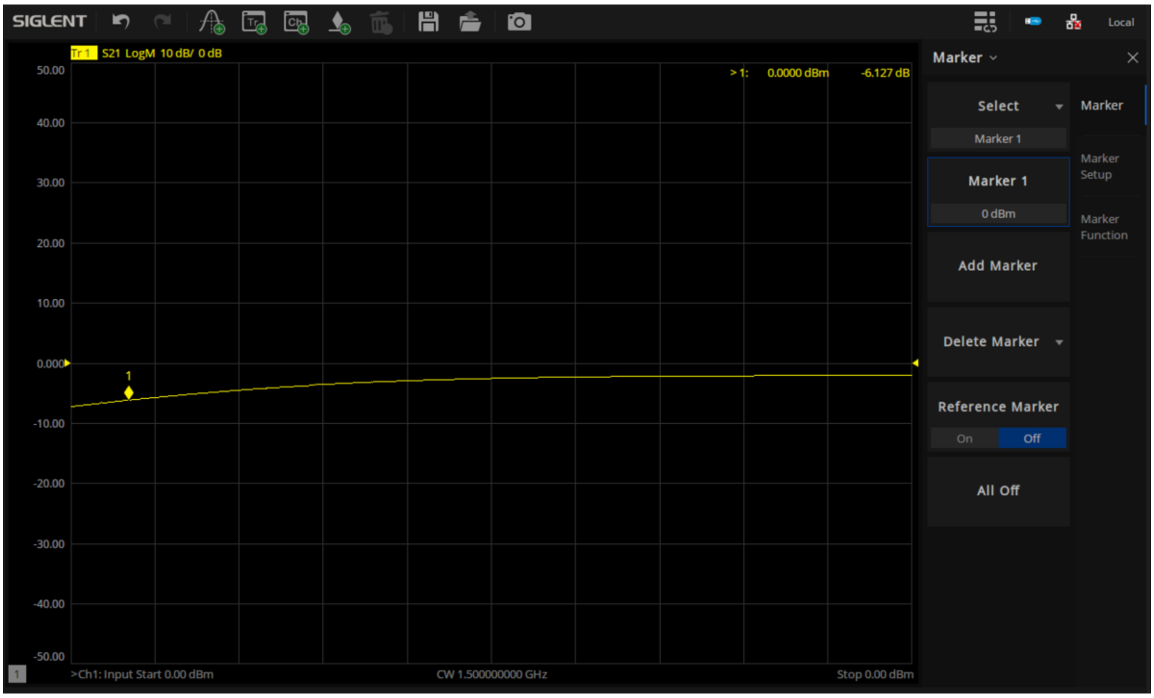
Another important measurement is the Mixer Conversion Loss as a function of LO power. Minimum Conversion Loss is obtained when the LO power level can properly bias the mixer diodes.
So RF input power is fixed. Set Start and Stop power as the same.



Set LO power sweep from **-15 dBm** to **5 dBm**.



From the S21 curve, we can see for low level LO power, the conversion loss is high. When the LO power level is high enough, the conversion loss trace is flattened out. If we use a four port VNA, we can add a measurement of LO port output power and see exactly the turning point.



2) Isolation Measurements

Isolation measurements usually including four parts. LO-RF, LO-IF, RF-LO, RF-IF. LO-RF means the signals leak from LO to RF port, the other three represent in an analogous way.
Unbalance of the internal transformers or lead inductances are the main cause of leakage. Good isolation corresponds to low leakage or feed-through.

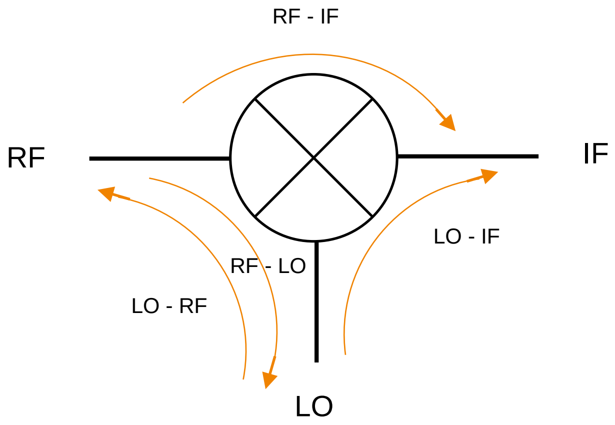
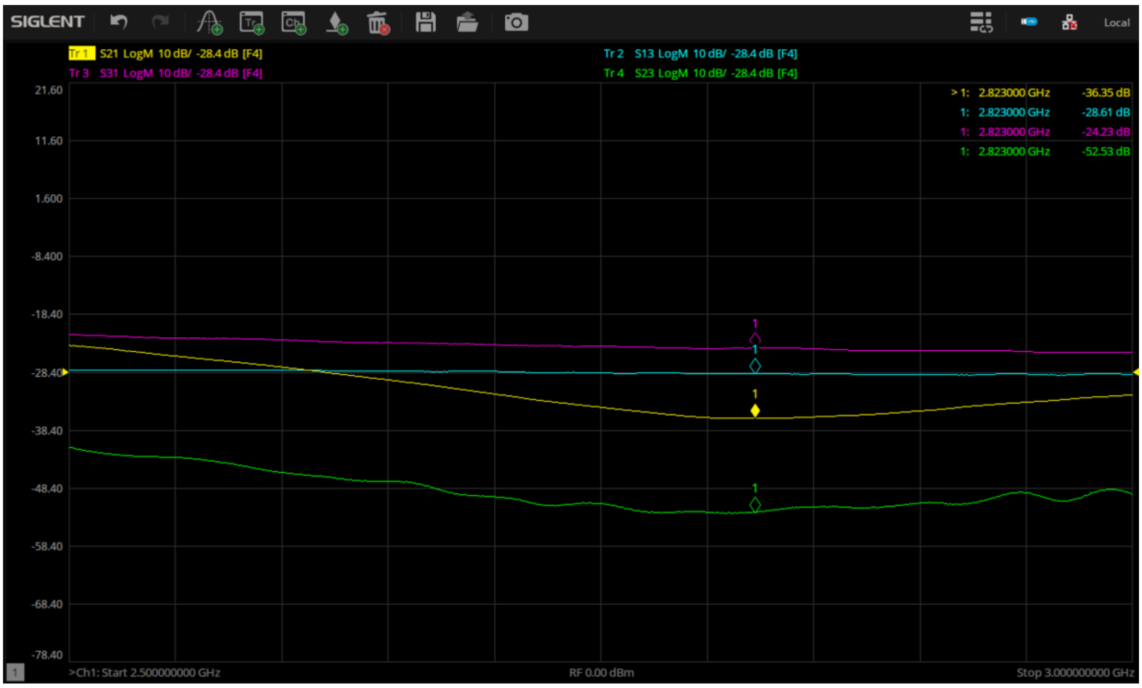


Figure 5. Signals leakage or feed-through

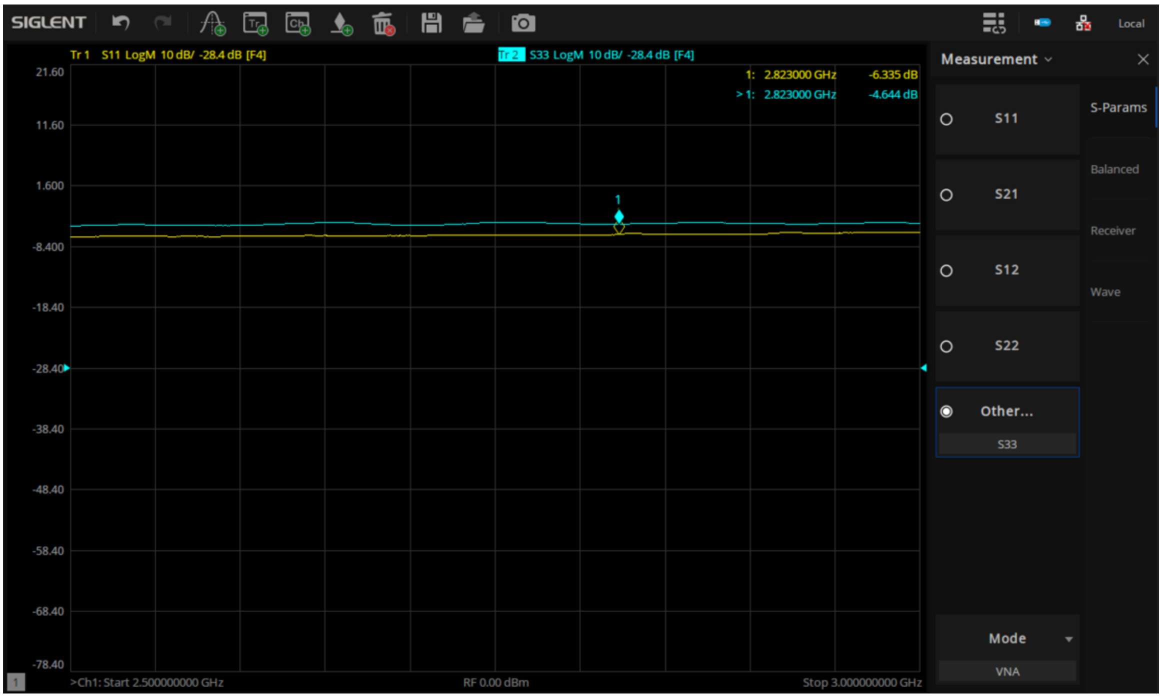
For isolation measurements and return loss measurements, we will go back to normal VNA mode, SMM mode is not anymore required.
Connect RF to port 1, IF to port 2, LO to port 3. Press Meas -> VNA mode. Set Sweep Type as **Linear Frequency**, frequency range, sweep points, IF BW. Then press Cal to perform normal calibration.
Press Meas or simply drag the trace icon to present channel to add **S21, S31, S13, S23** measurements.



The higher the absolute value of these S parameters, the better the isolation of mixer.

3) RF and LO port Return Loss Measurements

Return Loss of RF and LO port can be easily performed on the 4 port SNA series VNA. But always consider to supply power to the mixer under test.
With the same connections in isolation measurements. Press Meas -> S11, S33. Traces as below.



4. Conclusion

In scalar mixer measurements, SNA5000A four port models enable a simple wiring. Its output level is from -55 dBm to +10 dBm, it can properly bias most of the components without external PA or attenuator. It can also calculate the frequency settings automatically, which is a time saver. The Siglent SNA5000A series vector network analyzer is a powerful tool in RF components verification.

About SIGLENT

SIGLENT is an international high-tech company, concentrating on R&D, sales, production and services of electronic test & measurement instruments.

SIGLENT first began developing digital oscilloscopes independently in 2002. After more than a decade of continuous development, SIGLENT has extended its product line to include digital oscilloscopes, isolated handheld oscilloscopes, function/arbitrary waveform generators, RF/MW signal generators, spectrum analyzers, vector network analyzers, digital multimeters, DC power supplies, electronic loads and other general purpose test instrumentation. Since its first oscilloscope was launched in 2005, SIGLENT has become the fastest growing manufacturer of digital oscilloscopes. We firmly believe that today SIGLENT is the best value in electronic test & measurement.

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