VNA User Manual

October 22, 2020

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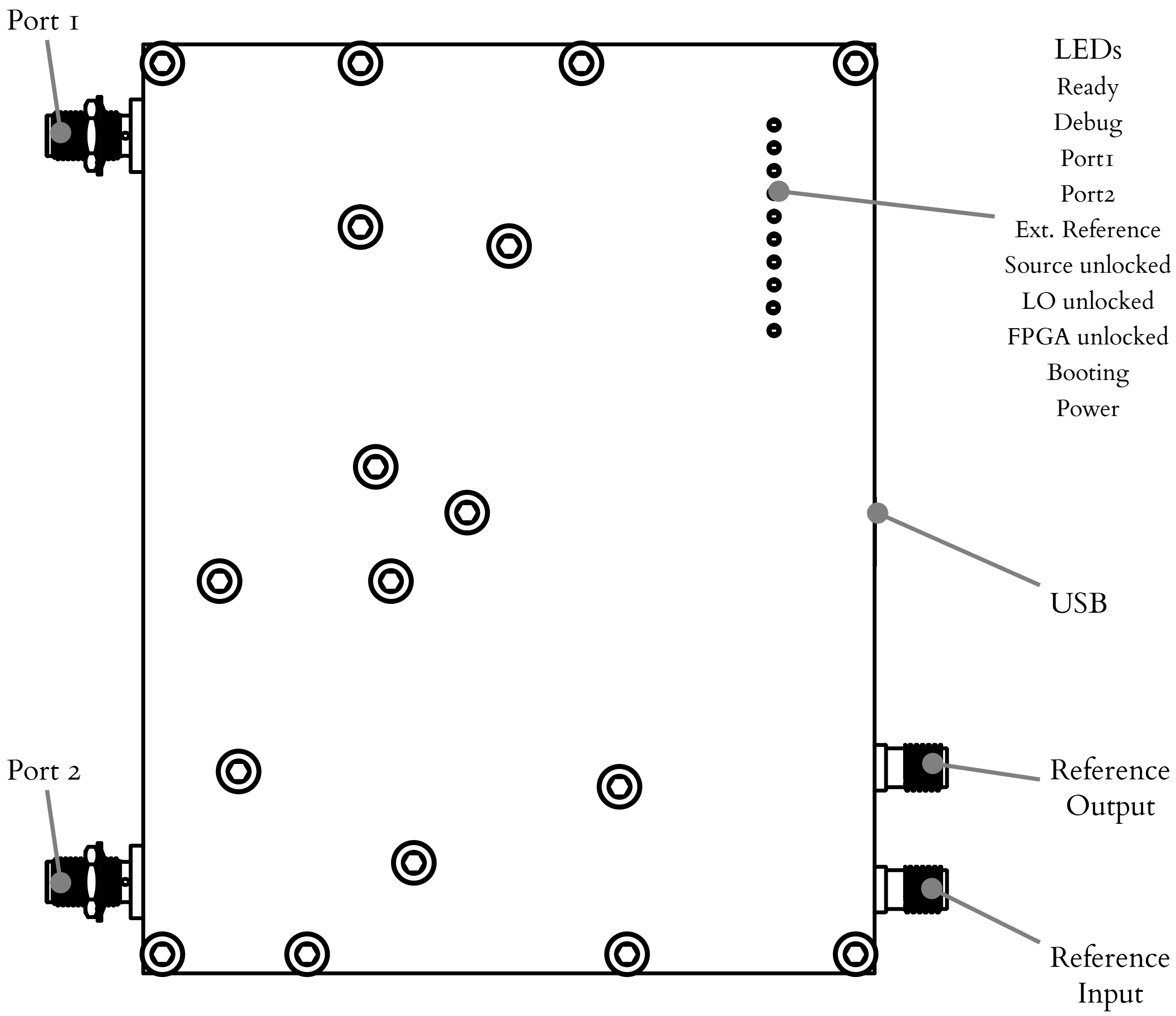
1 Overview



1.1 USB

The VNA uses a USB-C connector as the power supply and for data transmission. The hardware supports the USB power delivery standard[1], requires 5 V and draws up to 1.2 A of current.

The implemented USB device is limited to USB 2.0 Fullspeed and data transmission will work with any USB 2.0 or 3.0 port (no USB-C required). However, the current consumption exceeds the specifications for USB 2.0 and 3.0 ports and the VNA may be unable to fully boot when the USB host limits the current.

1.2 RF ports

RF connector to connect the DUT. Both ports are identical and the device architecture support full S-Parameter measurements (S11, S21, S12 and S22).

⚠ The RF ports have no input protection, do not apply a signal with more than +10 dBm of power.

1.3 LEDs

Ten LEDs indicate the status:

[1] Work in progress, the device will not negotiate USB-PD yet

Ready (green) Indicates fully booted VNA, ready to take measurements

Debug (green) Not used at the moment

Port 1 (green) Active output signal on port 1

Port 2 (green) Active output signal on port 2

Ext. Reference (green) External reference in use

Source unlocked (red) The source PLL failed to lock (it may turn on briefly during a sweep, this is not a problem)

LO unlocked (red) The 1.LO PLL failed to lock (it may turn on briefly during a sweep, this is not a problem)

FPGA unlocked (red) The FPGA clock PLL failed to lock

Booting (red) Indicates boot process, also used for error codes

Power (green) USB power valid

1.4 Reference Output

Optional reference output port (user selectable 10 MHz or 100 MHz). The output power is approximately +3 dBm.

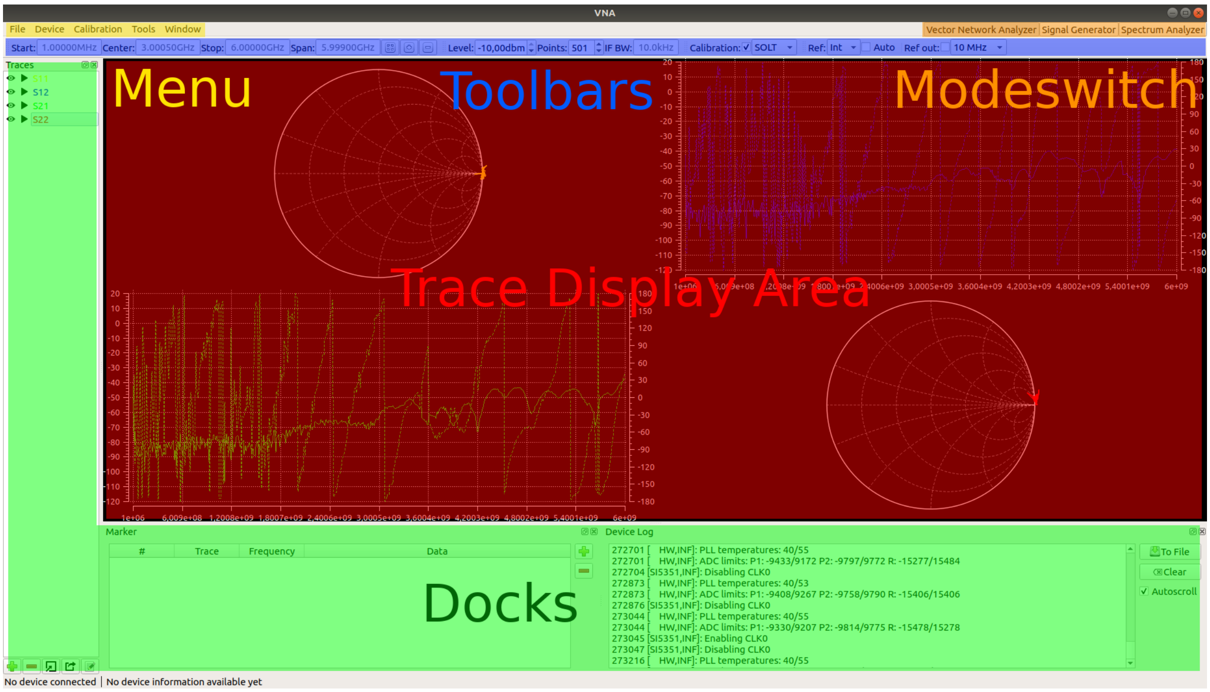
1.5 Reference Input

High impedance reference input port. When applying a 10 MHz input signal, it can be used to overwrite the internal TCXO.

> i Due to the high impedance input, the external input may detect a valid signal when picking up external radiation. If this is a problem, either terminate the reference input connector or disable automatic reference switching.

2 Getting started

1. Connect the VNA to a computer using the USB port. After a couple of seconds, only the "Power" and "Ready" LEDs should stay on. If the "Ready" LED does not turn on or the "Booting" LED indicates an error code, there is a problem und the device will not function properly. See section 4 for possible solutions.
2. Start the PC application to connect to the VNA. The window should look similar to this:



2.1 GUI elements types

The VNA application is made up of six areas containing different types of control:

- The **Trace Display Area** shows the measured data in various diagrams.
- The **Toolbars** provide access to commonly used device settings.
- The **Menu** at the top left handles less common settings or more complex actions (often with additional popup windows).
- The **Docks** mostly provide access to display related settings such as traces and markers.
- The **Statusbar** at the bottom show some basic informations about the connected device.
- The **Modeswitch** at the top right allows changing the VNA operating mode. Although it is primarily designed as a vector network analyzer, the hardware architecture allow some other operating modes with certain limitations.

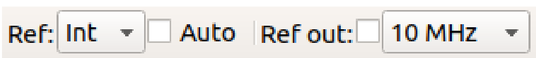
Depending on the current operating mode, the available toolbars, docks and menu entries change. It is also possible to rearrange the docks and toolbars.

2.2 Common GUI elements

Certain control elements are always available, regardless of the selected mode. They control settings of the VNA that are not specific to any of the operating modes.

2.2.1 Reference Toolbar

The reference toolbar controls the external reference output as well as the input.



The reference can be set to "Int" (internal TCXO), "Ext" (external 10 MHz signal) or to automatic mode. In automatic mode, the reference will switch to the external input when a signal is detected, otherwise it will use the internal TCXO.

The external reference output may either be disabled or set to 10 MHz or 100 MHz.

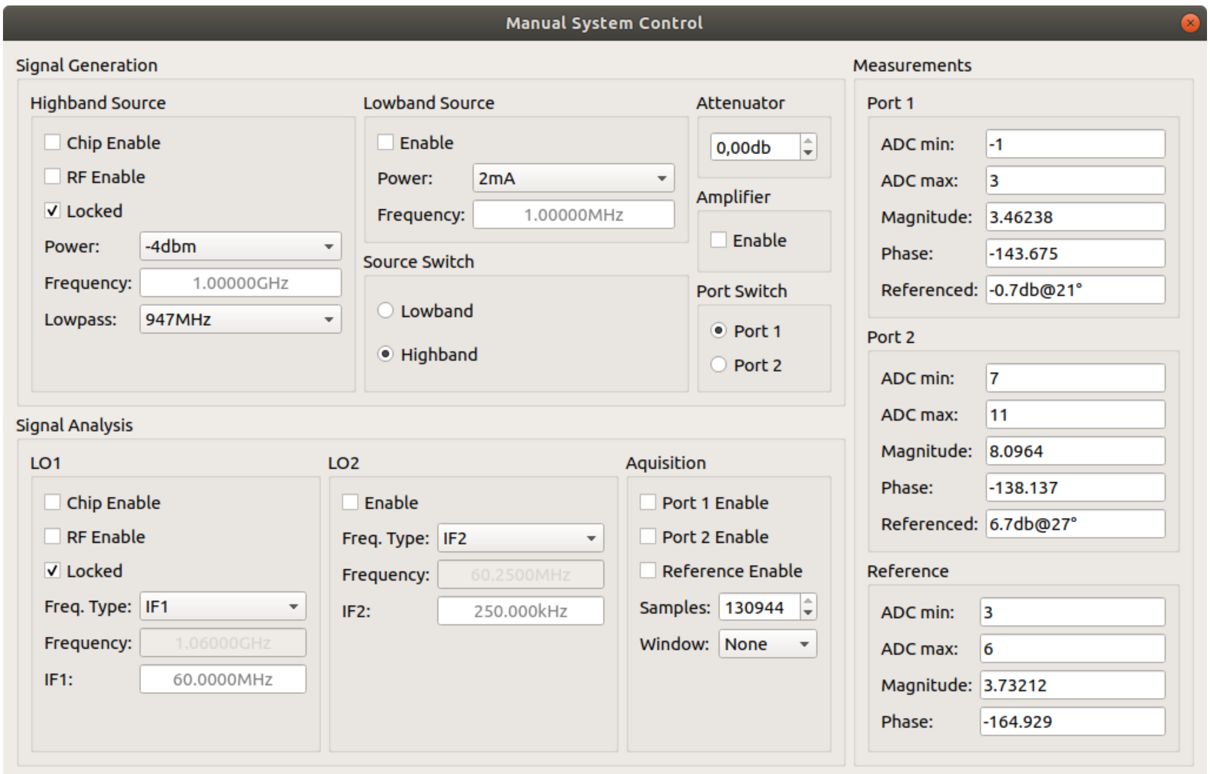
2.2.2 Device Log Dock

This dock shows the debug output of the VNA (the same messages as on the internal UART port). It may help to identify problems, otherwise it is not required for operation.

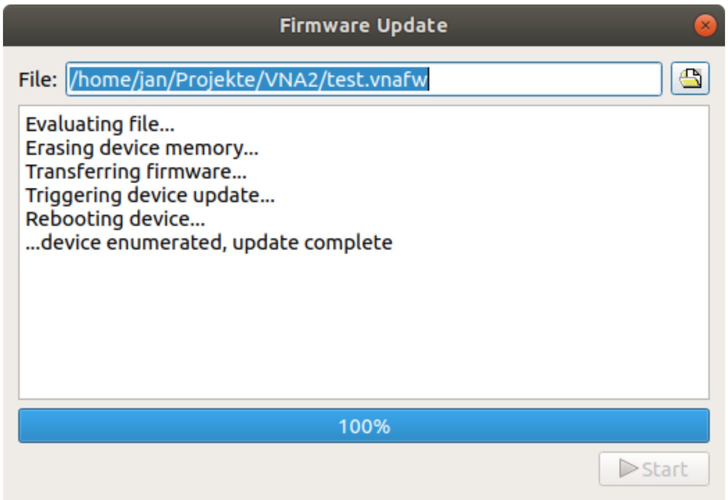
2.2.3 Device Menu

The device menu controls the connection state, allows low level hardware access and to perform firmware updates:

- **Update Device List:** Scans the USB port for connected devices. Clicking this action simply updates the list of devices, no connection is established.
- **Connect to:** Select which VNA to connect to. Different devices are identified by their serial number.
- **Disconnect:** Disconnect from the VNA.
- **Manual Control:** Starts the manual control dialog in which all hardware settings are accessible (mostly used for testing purposes):



- **Firmware Update:** Load a new microcontroller firmware and FPGA configuration into the VNA. Do not disconnect power while updating the firmware!



2.2.4 Window Menu

The window menu allows hiding not needed toolbars and docks. It also contains some application preferences.

3 Operating Modes

3.1 Vector Network Analyzer

In this operating mode, the VNA takes S-parameter measurements. A source signal is generated and alternately applied to the RF ports. The incoming signal at both RF ports is measured, resulting in the four S-parameters S11 and S21 (when the source signal is routed to port 1) as well as S12 and S22 (when it is routed to port 2).

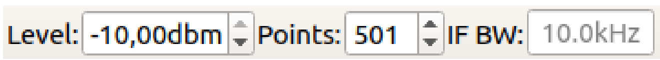
3.1.1 Sweep Toolbar

This toolbar sets the swept frequency range.

The start/stop and center frequency as well as the span can be set directly. To set a frequency type in the number followed by an SI prefix (e.g. to set 3.2 GHz press 3, ., 2, ⇧+G). This works for all number inputs throughout the application.

Additionally, the sweep toolbar contains buttons for zooming in/out around the center frequency and a preset to set the sweep to the full frequency range.

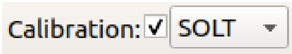
3.1.2 Acquisition Toolbar



- **Level:** The amount of power used for stimulus generation. The dynamic range decreases when using smaller values. It is recommended to use the highest available settings when measuring passive networks. When measuring active devices (e.g. amplifiers), decrease the stimulus power in such a way that the input power into any port does not rise above −10 dBm to stay within the linear range of the VNA.

- **Points:** Amount of measurement points in one sweep. More points provide finer frequency resolution but also increase sweep time.
- **IF BW:** Bandwidth of final IF measurement. Low bandwidths increase the sweep time but improve the noisefloor. At higher frequencies (roughly above 3 GHz), the dynamic range is limited by the isolation between the ports and decreasing the IF bandwidth does not improve the noisefloor anymore.

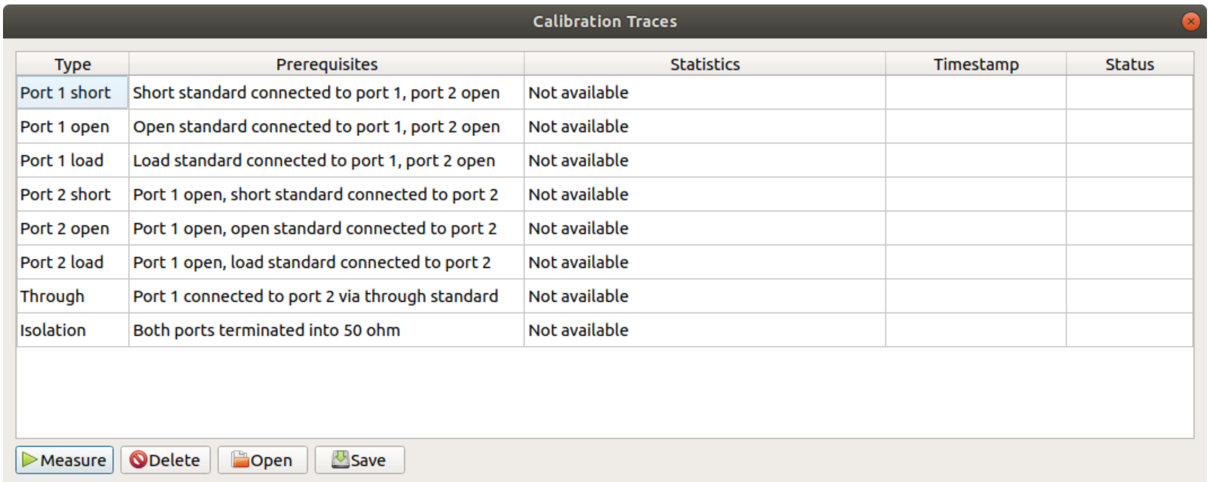
3.1.3 Calibration Toolbar/Menu



To perform a calibration select the desired calibration type and enable the checkbox. If the necessary measurements have already been made, the calibration will be applied immediately, otherwise the calibration data dialog (see 3.1.4) will open and ask for the missing measurements. After these measurements have been taken the calibration can be applied.

3.1.4 Calibration Data Dialog and Calibration Workflow

Calibration measurements are handled through the Calibration Data Dialog: (Calibration › Calibration Data)



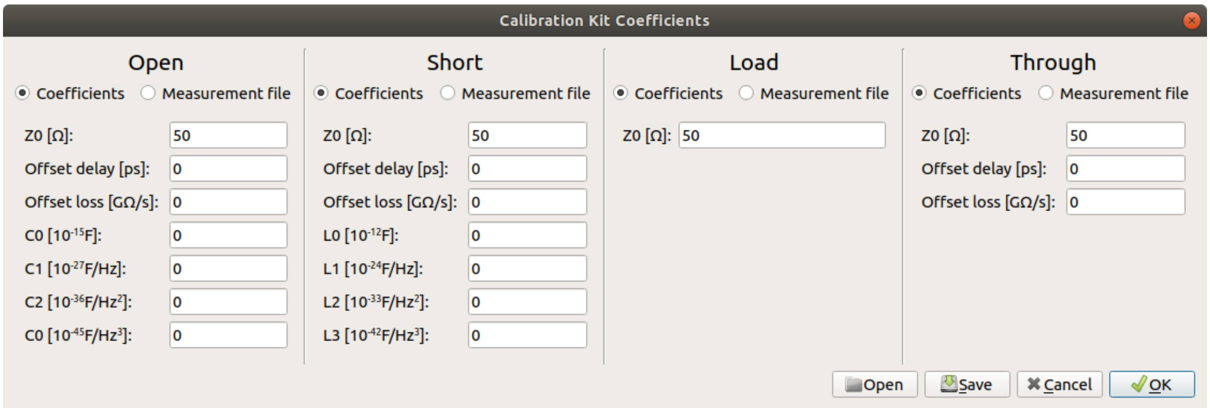
Type	Prerequisites	Statistics	Timestamp	Status
Port 1 short	Short standard connected to port 1, port 2 open	Not available		
Port 1 open	Open standard connected to port 1, port 2 open	Not available		
Port 1 load	Load standard connected to port 1, port 2 open	Not available		
Port 2 short	Port 1 open, short standard connected to port 2	Not available		
Port 2 open	Port 1 open, open standard connected to port 2	Not available		
Port 2 load	Port 1 open, load standard connected to port 2	Not available		
Through	Port 1 connected to port 2 via through standard	Not available		
Isolation	Both ports terminated into 50 ohm	Not available		

To take a calibration measurement select the corresponding line in the table, setup the device ports as described under prerequisites and press [Measure]. Likewise, a measurement can be removed by selecting it and pressing [Delete].

The calibration data can also be stored/loaded by using [Open] and [Save]. If the calibration should be automatically applied when connecting the device, save the calibration first and then select Device › Default Calibration › Assign....

3.1.5 Calibration Kit Dialog

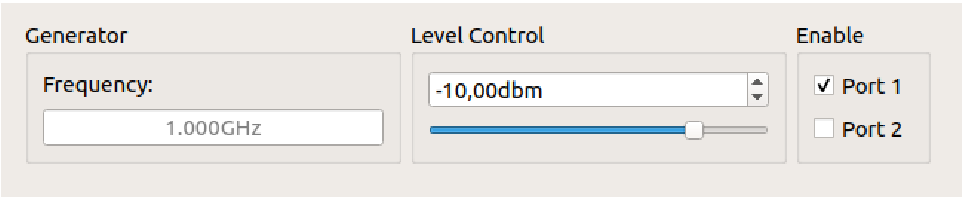
The calibration kit dialog allows to take imperfections of the calibration standards into account. It can be reached via Calibration › Edit Calibration Kit.



Each calibration standard can either be defined through its coefficients or by measured data from a Touchstone file. The calibration kit data is stored together with the calibration data when saving it in the Calibration Data Dialog.

3.2 Signal Generator

In the signal generator mode, measurements are stopped and the VNA only outputs a CW signal.



The hardware is not optimized for signal generation which means that the output level is not very accurate, especially at higher frequencies. Also, the signal will contain higher levels of harmonics than one would normally expect from a signal generator.

3.3 Spectrum Analyzer

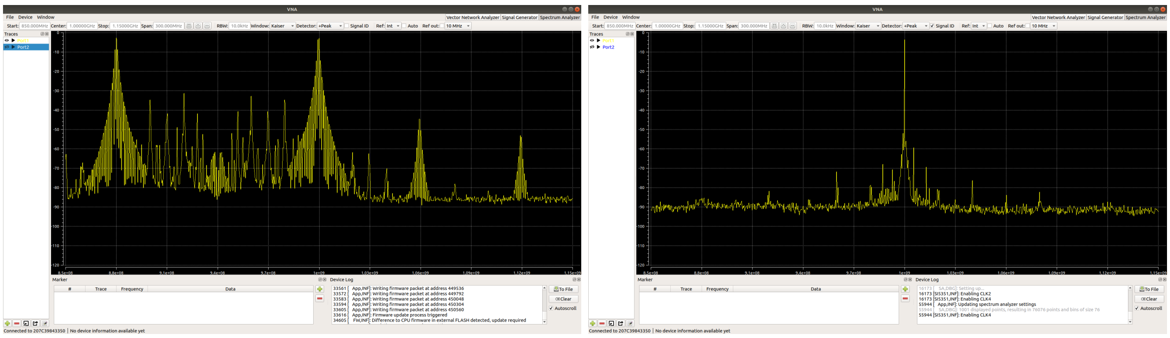
Although the VNA hardware is not designed to be used as a spectrum analyzer, the general hardware architecture of a spectrum analyzer is similar enough to that of a VNA to implement basic two-channel spectrum measurements. This is in no way on the same performance level as a dedicated spectrum analyzer but for simple measurements it might suffice if no other equipment is available. The main differences to a real spectrum analyzer are:

- **No input attenuator or pre-amplifier:** This means that the measurement range is essentially fixed to approximately −110 dBm to −10 dBm.
- **No amplitude calibration:** The displayed signal level is not very accurate, especially at higher frequencies.
- **No image rejection filters:** This is probably the most severe limitation, because it means that for every real signal several other signals will show up in the spectrum that are not actually present at the input.
- **Highest resolution bandwidth is quite low:** The sweep speed is too slow to cover the complete frequency range of 1 MHz to 6 GHz in an acceptable time.

The control elements are mostly identical to the vector network analyzer mode, apart from the acquisition toolbar:

- **RBW:** Resolution bandwidth. Lower values allow differentiating between signals at closer frequencies. Lower values also result in a reduced noisefloor but significantly increase sweep time.
- **Window:** Window type used in the DFT of the final IF.
- **Detector:** For every point displayed, several measurements are taken. The detector type determines which one of these measurement will be displayed.
- **Signal ID:** Signal identification. This can help to determine whether a displayed signal is actually present or the result from internal imaging. When enabled, the VNA changes the LO frequencies for every measurement point and observes how the final IF signal is affected by that. This removes almost all of the mirror images but at the cost of increased sweep time.

  The following example shows the effect of signal ID. For both measurements the only signal at the input was a 1 GHz tone with a level of −10 dBm. On the left, signal ID is turned off, resulting in a lot of extra tones. On the right, signal ID has removed most of these tones:



4 Troubleshooting

If the was an error in the boot process, the "Booting" LED will blink an error code repeatedly:

Error Code	Meaning	Possible solution
1	Failed to detect FLASH memory	
2	Invalid FLASH content	Perform firmware update
3	Failed to configure FPGA	Check FPGA bitstream generator settings
4	Hardware initialization failed	Verify that FPGA bitstream and uC firmware are created from the same release