

VNA0440 – VNA0440e
VNA0460 – VNA0460e

User Manual

Version 3.0

How to use the MegiQ VNA0440 (e) – VNA0460 (e) Vector Network Analyzers

- General information
- User software
- Using the Instrument

MegiQ BV
Weegschaalstraat 3
Eindhoven
The Netherlands
www.megiq.com

Revision 3.0 – SW 1.7.0 – FW 1.7.0

© Copyright 2013 – 2017, MegiQ BV. All rights reserved.

No part of this book may be reproduced in any form or by any mechanical or electronic means including information storage and retrieval systems, without permission in writing from MegiQ.

The contents and specifications are subject to change without notification

Table of Contents

1. INTRODUCTION	6
About the VNA0440 / VNA0460 series	6
About this manual	6
Calibration	6
2. FEATURES	7
VNA0440 / VNA0460	7
VNA0440e / VNA0460e	7
3. CAUTIONS.....	8
VNA Port connectors	8
Input levels	8
General	8
4. INSTALLATION	9
Software installation	9
Hardware installation	9
VNA Operating modes	9
5. OVERVIEW	10
Overview of VNA measurements	10
S-Parameters	11
Block diagram	11
Sweep sequences	13
File system	13
User interface software	14
Touch screen	15
6. PERFORMING A MEASUREMENT	16
Simple Measurement	16
Calibration	17
Sweep control bar	17
Saving measurements	17
7. CALIBRATION	18
Why calibrate	18
Calibration and Normalization	18
Device independent calibration	19
OSLT calibration	19
12-term normalization	19
Reference plane	20
Calibration Kits	20
Calibration procedure	21
Single-port calibration (OSL)	22

2-port calibration (OSLT)	24
De-embedding	25
8. MEASUREMENT SETTINGS	27
Measurement elements	27
Setting measurement parameters	27
Screen	27
Measure	28
Sweep	29
Generator	33
Detector	33
Bias	34
Calibration	34
Display	36
9. CALIBRATION KIT MANAGER	38
Cal Element definitions	39
10. GRAPHS	42
Impedance graphs	42
Gain Graphs	43
Graph control	44
11. MATCH CALCULATOR AND SIMULATOR	49
Matching procedure	50
12. SESSION MANAGER	52
The session manager	52
Saving to the session list	52
Saving the session	52
Opening a session	53
Recalling measurements	53
Deleting and renaming	53
Export and Import	53
Export Touchstone	54
13. REPORTS	55
Report generator	55
Copying a single graph	56
14. OPTIONS	57
Screen	57
Reports	58
VNA	59
15. SPECIFICATIONS	62

1. Introduction

About the VNA0440 / VNA0460 series

The MegiQ VNA0440 / VNA0460 series is a USB driven Vector Network Analyzer that can perform full bidirectional 2-port measurements. The e-version adds 3-port measurement, an internal programmable bias generator with bias-Tee's.

We will refer to the different VNAs collectively as **VNA04x0**.

About this manual

This manual is a guide to using the VNA04x0 and the user software that is supplied with the VNA. It will introduce you to the possibilities and features but it is not an in depth book on VNA measurement techniques.

The manual uses the MegiQ **VNA Sandbox**, a UFL learning toolbox, for explanations and examples of VNA measurements. The techniques equally apply to measurements using other connectors and systems.

The VNA Sandbox has its own tutorial manual that goes into the details of the measurements and the theory behind it.

Calibration

The VNA04x0 is **fully calibrated** from the factory to perform measurements **at its RF ports**.

However, in many test setups there are cables and adapters to get from the DUT to the RF ports. This test setup affects the measurements and need to be normalized out of the measurement results. This is achieved through a process called **Calibration**, which must be performed by the user with the actual test setup.

It is important that this calibration is performed with care and consideration of the test setup. Please read the section on Calibration carefully.

2. Features

The VNA04x0 is ideal for measuring all kinds of micro-circuits like antennas, attenuators, amplifiers etc. Its frequency range includes most popular telecom bands like GSM-GPRS-LTE, Wifi, DECT, GPS, ISM, Zigbee, Bluetooth.

VNA0440 / VNA0460

- Dual channel, 2-port Vector Network Analyzer
- Frequency range of 400MHz to 4GHz / 6GHz
- Full port calibration for direct measurements
- Full support for Calibration Kits
- Simple configuration with preset functions
- Complex parametric sweeps
- Built-in match circuit calculator
- Quality report graphics.
- Compact and lightweight design

VNA0440e / VNA0460e

- Built-in bias generator
- Programmable bias voltage and current
- Parametric sweeps with bias voltage / current
- Additional generator port
- Supports 3-port measurements
- Supports external bridge measurements

3. Cautions

As a measuring instrument, the VNA04x0 should be treated with some consideration to avoid damaging the hardware.

VNA Port connectors

- ⚠ **Do not over tighten the SMA connector** to the VNA ports. A little more than hand-tight is sufficient.
- ⚠ **Beware of cheap or poor quality SMA connectors.** The slightest damage or misalignment to the center pin can easily **ruin the SMA** port on the VNA. The warranty does not cover damaged port connectors.
- ⚠ If a connector **does not feel right** when screwing then **DO NOT CONTINUE**. Find out what is wrong or replace the connector.
- ⚠ The SMA port connectors have a **maximum of 500 mating cycles**, after that the reliability and repeatability decreases. If you anticipate many cycles it is a good idea to use a SMA Female to Male adapter as a '**port saver**'.

Input levels

- ⚠ Beware of the **maximum RF input level**. The VNA04x0 can sustain **20dBm RF power**. When measuring power amplifiers it may be necessary to use attenuators.
- ⚠ Beware of the **maximum DC input level**. The VNA04x0 can sustain **±20V DC** without damage.
- ⚠ The **maximum power dissipation** of the port ground resistor is **0.2 Watt** so the user must make sure that a current into this resistor does **not exceed 100mA** and the voltage does **not exceed 2V**.
- ⚠ The standard power supply of the VNA is **not grounded**. This means that the ground of the VNA is floating. If the VNA is connected to a laptop with ungrounded or no supply the whole setup is floating. It may be necessary to connect the setup to a system ground.

General

- ⚠ Connectors easily get **dirty** and tend to spread the dirt all over the lab. Keep the connectors **clean** and regularly brush them with flux remover or other (non-aggressive) solvents.
- ⚠ **UFL connectors** are easy to use but **fragile**. Do not force them on, and pull them off straight up and without too much force.

4. Installation

- Software and hardware installation
- VNA modes

Software installation

To install the VNA software, locate the file ‘SetupMiQVNA.exe’ on the USB stick or download directory and execute this file. The software installation has only a few choices to make, or to leave at default, and is straightforward.

By default, the software is installed in ‘Program files (x86)\MegiQ\VNA’. The subdirectory ‘Data’ contains an example measurement session file. The subdirectory ‘Driver’ contains a driver description file for those installations that need this.

The manual ‘MegiQ VNA Software Setup’ contains details about the installation in different Windows versions.

Command line options

MiQVNA [-c] [session file]

-c: Clean all user settings and return to installation state.

Session file: load a session file when starting up.

Hardware installation

The hardware installation has some different procedures depending on the operating system and version. The procedures for hardware installation are described in the software installation manual.

In Windows 10 there is no hardware installation procedure, just connect the VNA to the computer and Windows will install the correct driver.

VNA Operating modes

The VNA has two operating modes: **Bootloader** and **VNA mode**.

When the VNA is connected to the USB port without the DC supply connected it will enter the bootloader. The LEDs on the front panel will light only dimly. The bootloader only allows uploading new firmware or control files. The normal VNA mode also provides these services. The bootloader is a safety feature in the (extremely rare) case the VNA application would be messed up.

When the VNA is connected to both USB and DC power it will enter the normal VNA mode and the LEDs will light up in green and blue (VNA04x0e).

The PC application software can interact with the VNA in both modes but the bootloader only provides support for uploading and installing firmware.

5. Overview

- Overview of VNA measurements
- Block diagram and internal functions
- The user interface software

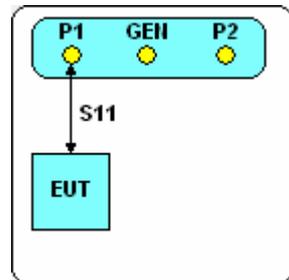
Overview of VNA measurements

A VNA measures impedances and gains at high frequencies. Since it measures both the magnitude and the phase it is called a Vector Network Analyzer.

A measurement typically consists of a sweep over a range of frequencies and the results are usually frequency response curves.

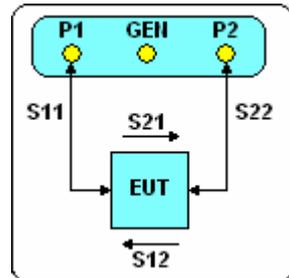
One-port measurement

Measurements can be done on one-port devices such as antennas and circuits. To do this the VNA will transmit a signal on a port towards the DUT, and at the same time receives the signal back from that port. From the measured receive signal the VNA can calculate the impedance connected to the port.



Two-port measurement

A VNA can also perform measurements on two-port devices such as amplifiers and filters. In this setup the VNA will do the impedance measurement on two ports. In addition, the signal is also sent through the DUT and the signal is measured at the other port. This is a measurement of the gain, or loss, of the DUT from one port to the other. The gain measurement is done in both directions to fully characterize the DUT.



Multi-port measurement

In multi-port measurements all port impedances are measured and all combinations of gains between the ports.

The VNA04x0e has an extra generator port that can be used to measure three-port devices but since this port can not measure the impedance connected to it the three-port measurement is not fully complete. This can be completed by changing the DUT ports around.

S-Parameters

The measured DUT characteristics **impedance** and **gain** are called **Scatter Parameters** or **S-Parameters**. They are written as ‘Sxy’, where x and y are port numbers. If the port numbers x and y are the same, an impedance is implied. If the port numbers are different it represents the gain or loss of a signal **from port y to port x**.

These are the S-parameters that the VNA04x0 can measure:

- **S11**: Impedance at port 1
- **S22**: Impedance at port 2
- **S12**: Gain or loss from port 2 to port 1
- **S21**: Gain or loss from port 1 to port 2

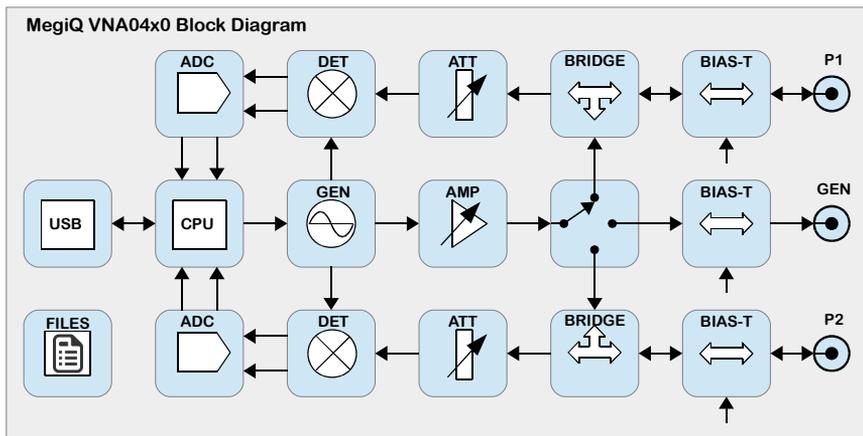
The VNA04x0e can also measure these parameters:

- **S13**: Gain or loss from port 3 to port 1
- **S23**: Gain or loss from port 3 to port 2

The impedance S-parameters can be converted to a number of formats such as complex impedance, return loss, forward loss and SWR. These all represent the impedance.

The Gain S-parameters are usually represented as magnitude and phase. The phase can also be represented as a **Group Delay** which is a dynamic delay characteristic of a multi-port device.

Block diagram



Sweep generator

The signal generator generates a RF signal that sweeps over a frequency range. This signal is used for the measurements. The signal can be switched to one of the output ports **P1** or **P2**, for the 'transmitting' part of the measurement.

The VNA04x0e also has a separate **Generator** Output port. A programmable amplifier allows setting the desired signal level.

Note: you can not only sweep the generator frequency, but also the output power, e.g. to characterize complex impedance versus applied power.

I/Q detectors

For the “receiving” part of the measurement, the carrier is fed into the I/Q detectors. Note that in case of a S11 or S22 measurement the transmit port is the same as the receive port.

There are two receive channels, port 1 and port 2. Each input feeds first into an attenuator for setting the right signal level to the detectors. The I/Q detectors are used to detect the real and the imaginary part of the signal with the generator as reference. This information, converted to digital in the ADC, together with the calibration data, is used to calculate the complex impedances, scattering parameters, etc.

Controller

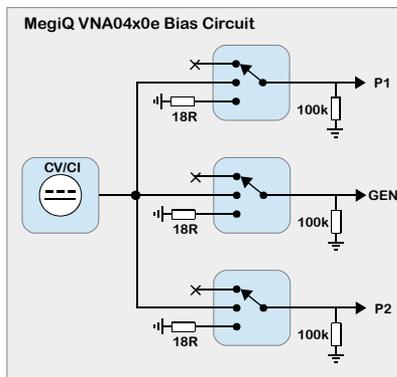
The controller, controls all functions and hardware within the instrument, stores calibration data and processes the raw measurement data. It also communicates over USB to the PC that holds the user interface software, used to make measurements, display and store the results.

Bias circuit

The VNA-04x0e comes with an internal programmable bias generator that acts like a regulated V/I power supply. The range is -12V...+12V and 1...100 mA also both polarities.

The bias generator can be stepped for characterizing circuits under different bias conditions.

The software can set all of the RF ports to connect to the bias generator, to a low resistance to ground, or keep open. The ground resistance provides a return path (through a diode or other device) for the bias current. An open port has a resistance of 100kOhm to ground.



- ⚠ Warning:** The maximum power dissipation of the port ground resistor is 0.2 Watt so the user must make sure that a current into this resistor does not exceed 100mA and the voltage does not exceed 2V.

Sweep sequences

Most VNAs will only sweep the generator frequency at a fixed output power level and, in case of DC-bias, with a fixed voltage or current applied through the bias Tee's.

The VNA04x0 however gives you the possibility to sweep several parameters in one measurement. This makes it possible to characterize different properties of a device.

Some examples:

- Characterize S11 of a class C amplifier at 5 levels of input power over a frequency range, like 2300...2600, (10MHz steps) and input power -20...0 dBm in 5dB steps.
- Characterize S22 of a linear amplifier under 5 different DC power supply levels. The internal bias generator is used to provide the power to the amplifier. This can be done via the bias Tee on the same port, but you may also use another port. Sweep from 1800...2800MHz in 100 steps and use the programmable bias generator as a current source: 30...70mA in 5 steps.
- Characterize S11 and S21 of a voltage controlled low pass filter, sweep 400...4000MHz in 100 steps and the bias voltage from 1...5 volt in 1 volt steps.

You can combine several parameters with many steps but this results in a lot of data and a lot of traces on the screen. This may make the result quite unreadable, but it can be useful when the data is exported for further analysis.

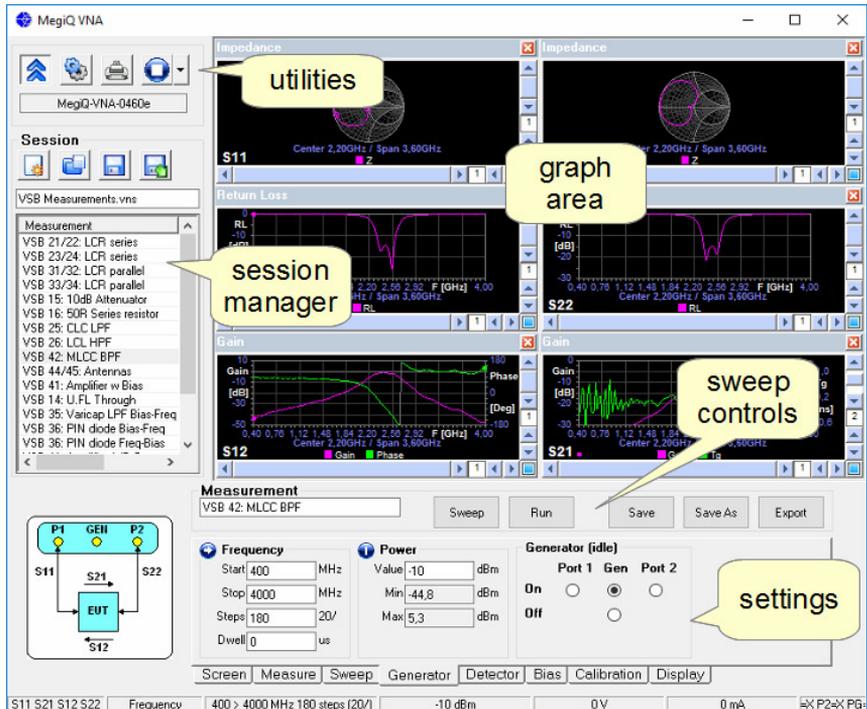
File system

The file system of the VNA04x0 stores device dependent calibration data and functions as intermediate storage for firmware upgrades.

Some of the calibration data is used internally by the VNA. The port calibration data is loaded by the VNA software when it connects to the VNA.

User interface software

The instrument itself has no user interface, but communicates over USB with a PC that provides the user interface software that runs under Windows.



Most important functions of this software are:

- Set up a measurement
- control calibration of the measurement
- Measure and display the results
- set, save and recall measurements and set-ups
- Reporting and exporting the measurement data

There are five main areas on the screen of the user interface.

Utilities

For utilities there are four buttons in the upper left corner; from left to the right:

- toggles USB-link to instrument on / off
- opens the Options screen, with general settings
- opens print screen for exporting and printing graphs
- loads preset measurements

Session manager

The session manager lets you save and recall instrument settings, calibration data and measurement data. These appear in the list, which you can save into a file on disk and recall later.

You can make a file per project, per set of measurements, and so on, and keep track of your work.

Since measurement data is stored, you can recall it later and produce different types of graphs on the same data set later on.

Settings (tabs)

You can change the settings, i.e. the measurement parameters like sweep style, frequencies, output level, etc in the different panes you select by clicking on the tabs below the settings-pane. In the example on the right the Measurements pane is selected, which lets you select what kind of measurement (ports) you want to make.

One special tab is the **Screen-tab**, which minimizes the settings-pane and maximizes the graphing area.

Sweep controls

Allows you to start and stop measurements and save and export the data.

Graphs

The graphs contain the output of your measurements. You can choose what graphs you want to use under the **display-tab**.

Touch screen

If your PC has a touch screen, you can enter parameters and file names with an on screen keyboard. Just double click on an input field to open this touch screen keyboard.

Pressing a position for a few seconds will act as a Double Click.

6. Performing a measurement

- Simple measurement
- Sweep control
- Saving measurements

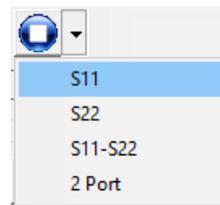
Simple Measurement

If you are measuring directly at the port(s) of the VNA it is very easy to do a measurement. No user calibration is necessary.



One and two port measurements directly at the VNA ports.

1. Connect the VNA to a USB port and start the VNA software.
2. Wait until the software has established communication (the VNA model is shown and the progress bar is finished).
3. Connect your DUT to the VNA port(s).
4. Select a Preset measurement, 1-port (S11 or S22) or 2-port. This will load the measurement setup and setup the graph area.
5. Go to the 'Calibration' tab and, if necessary, turn off the 'Use Calibration' checkbox.
6. Use the Sweep or Run button to perform a measurement.



The VNA software can run single sweeps or continuous sweeps. Some people prefer the continuous sweep mode, and this can be useful to see dynamic effects like hand effects around an antenna or changing characteristics of the DUT device.

The single sweep is very useful during a development or optimization. It allows studying the measurement and saving it to recall it later. This can provide a series of snapshots before and after several modifications and it allows stepping back in the process to compare results.

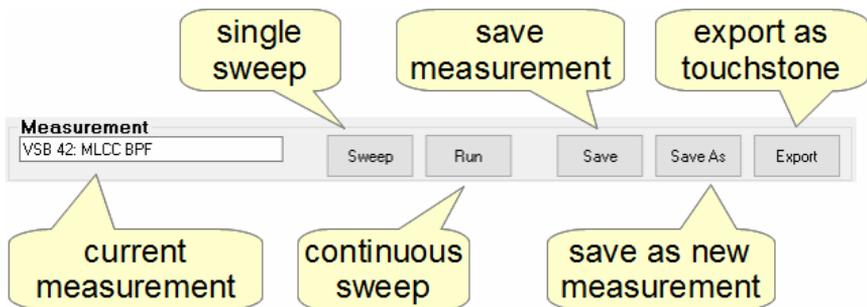
Calibration

While the VNA is calibrated to do measurements at its ports, when cables are used to measure a device then the measurement must be calibrated at the end of the adapters and cables in order to measure the characteristics of the DUT without the cables.

More about the concept and procedure of calibration is explained later in this manual.

Sweep control bar

These are the functions of the sweep control bar:



You perform a single sweep hitting the **Sweep-button**. You can make a repetitive sweep hitting the **Run-button**, which is a run/stop toggle.

The buttons will be disabled when conditions or the setup is not ready for measurement, for example when the VNA is not connected or the measurement is not calibrated yet.

Saving measurements

You can save your measurements. Below is a short overview. More on this in the section about the **Session Manager**.

The **Save As-button** will save the measurement you just made, including settings and calibration data to the session list. Be sure to save this session list to hard disk before closing the program.

The **Save-button** will overwrite the last measurement in the session list.

The **Export-button** will save the measurement data to hard disk in Touch Stone format. This is a format used by e.g. RF simulation SW.

7. Calibration

- Why calibrate
- Calibration elements, normalization and reference plane
- Single-port calibration procedure
- 2-port calibration procedure
- Deembedding

Why calibrate

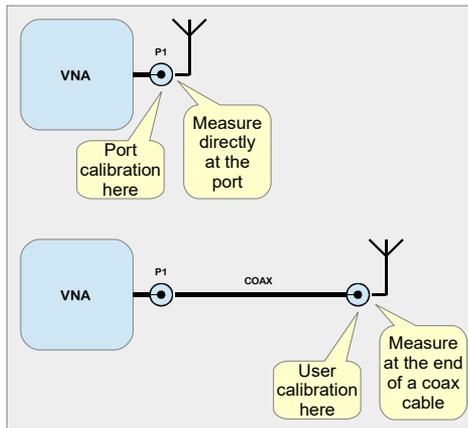
In vector network analysis you are interested in impedances of components and circuits. At high frequencies almost any length of cable will act as an impedance transformer, thus altering the impedance you actually see. Furthermore at even higher frequencies many cables become lossy, which influences gain *and* impedance plots.

Luckily these cables act as linear elements and can be normalized-out' by linear algebra. The software will do this for you, but it should be calibrated with some well known impedances for every frequency of interest before you start the actual measurement.

Therefore before using the instrument you should perform a calibration on the whole set-up, including the cables, connectors, etc. for the frequency range you want to use in your measurement.

The software stores this set of calibration data, and since the MegiQ VNA is very temperature stable, you will not have to perform this calibration routine very often.

But, changing cables, connectors or frequency range means that you must renew the calibration. Avoid bending cables too much after calibration.



Calibration and Normalization

The process of measuring the (unknown) test setup is called **Calibration**. This stores the characteristics of the test setup.

The calibration data is then used during the measurement to **Normalize** the data to become independent of the test setup and the results are the characteristics of the DUT without the influence of the test setup.

Device independent calibration

The calibration data of the VNA04x0 is normalized to the port level. This means that this data is independent of the hardware and is applicable to any VNA that is used in the measurement. It is well possible to perform calibration with one VNA04x0 unit and swap this for another VNA04x0 and continue the measurements.

OSLT calibration

For calibration the MegiQ VNA software uses these impedances and connection:

- **Open:** a well defined open circuit end.
- **Short:** a well defined short circuit end.
- **Load:** a precision impedance of 50 Ohm.
- **Through:** for two-port measurement a well defined through connection between the two ports.

This calibration scheme is often called OSLT or SOLT.

During a calibration procedure each of these terminations is connected in turn and the software makes calibration measurements for each termination.

A set of these impedances for calibration is called a Calibration Kit or Calkit. They can be of different types: SMA Calkit, N Calkit, UFL Calkit, Balanced Calkit etc. It depends on your setup, with which connector type you can get closest to the DUT, which Calkit to use. For small microwave devices the UFL connector is often the most appropriate to use.

For multi-port measurement the MegiQ VNA also measures the isolation between the ports with a Load termination on both cable ends. They do not need to be of as high quality as the Load termination during the Load calibration.

12-term normalization

For 2-port measurements it is important that all properties of the test setup are normalized out of the results. During the calibration of a 2-port measurement the VNA collects 12 different characteristics of the test setup: 2 x Open, 2 x Short, 2 x Load, 2 x Through, 2 x Isolation and 2 x the impedance of the receiving port that is connected to a source port.

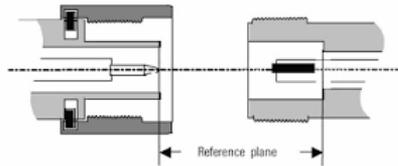
These results are used in a **12-term normalization** to normalize the DUT characteristics as if it was sourced and terminated with a perfect 50 Ohm impedance.

Reference plane

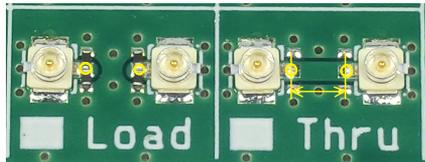
It is important for a Calkit that all impedances are defined at exactly the same point in or after the connector. This point is called the Reference Plane or Calibration Plane. The calibrated measurements will be defined from that point on to the DUT.

For connector Calkits the reference plane is inside the connector, which makes them useful mostly for cable measurements and system measurements.

For PCB based Calkits the reference plane is at the point where the termination is located. These are indicated here in the UFL picture. The Through calibration has some length between the ports. The Through measurements will be compared to this length. If the length in the measurement is shorter than the result can have a negative phase.



Location of the reference plane in a Type-N connector



It is important that the reference plane is as close as possible to the measuring point.

Calibration Kits

For the Open, Short and Load calibration you need calibration elements that define these impedances. Since the whole measurement depends on the quality of these elements they need to be as precise as possible. In addition they need to calibrate at the same reference plane. Also the through measurement needs to be calibrated with a well defined through element.

The combination of calibration elements is usually sold together and is called a Calibration Kit, or Cal Kit. However, these elements are never ideal and have a deviation from the ideal values and sometime contain a significant delay because the reference point is located behind some transmission line.

To get the calibration more precise the Cal Kit usually comes with a set of coefficients or parameters that can be used by the VNA software to compensate with the calibration element's deviation.

For test fixtures and PCB based measurements there are usually no coefficients because the measurement gets calibrated through the structure, which is hard to model or characterize.

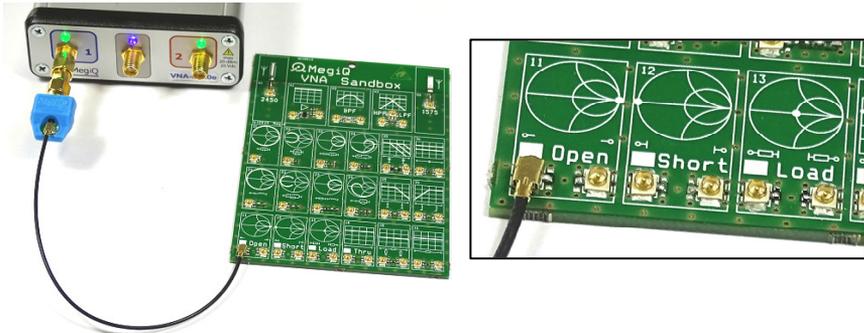
Calibration procedure

The MegiQ VNA Sandbox and Balanced/UFL Calkits contain a double set of calibration terminations on UFL connectors. This makes two-port calibrations a lot quicker than a single Calkit. The circuit numbers are 11 for **Open**, 12 for **Short**, 13 for **Load** and **Isolation**, and 14 for **Through** calibration.

The calibrating process is straight forward; you will find it step by step below. You will find the process for the 1-port and the 2-port measurements. You will need cables with UFL-connectors and SMA/UFL adapters when using the MegiQ VNA-Sandbox. (included in the VNA-Sandbox kit).

Again: during the calibration process, use the very same cables and connectors you are going to use in the actual measurement! Not calibrating the whole set-up will most probably lead to very confusing results!

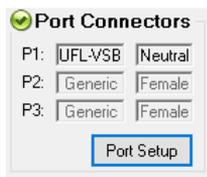
Single-port calibration (OSL)



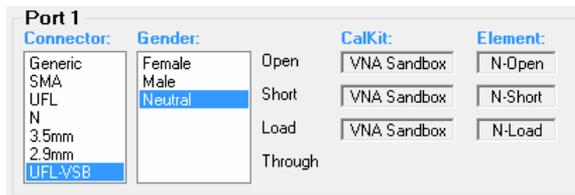
If you are performing a 1-port measurement, you only need the Open, Short and Load.

Instrument set-up

- Select the kind of measurement (1-port), frequency range, generator power, etc.
- Select the **Calibration** tab. This shows the calibrations that are necessary for the measurement as well as the configuration of the measurement port(s).
- Set up the port configuration with the **Port Setup** button.

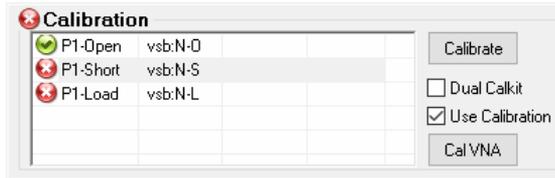


- In the Port Configuration form, select the **Connector** type and **Gender** for the VNA Sandbox. The program will search for the correct Calibration Kit elements. Press **OK**.



- Back in the calibration tab, the calibrations in green are already completed and the ones in red still need to be done. With the **Calibrate** button you can step through the calibrations. But the calibrations can also be made in any other order.

- When the calibrations are all done, the red cross at the upper left will also turn green and the **Use Calibration** box will be turned on automatically, but you can turn it on at any time. It has no effect on the calibration itself.



When this tab is active and a calibration item is selected in the list, the VNA port LEDs will indicate the type of termination that is expected on which port by blinking with a certain color:

- **Red:** Open termination
- **Green:** Short termination
- **Blue:** Load termination
- **Purple:** Through connection between two ports

Open

1. Connect the port to the **Open** termination.
2. Select **P1-Open** and press **Calibrate**.

Short

3. Connect the port to the **Short** termination.
4. Select **P1-Short** and press **Calibrate**.

Load

5. Connect the port to the **Load** termination.
6. Select **P1-Load** and press **Calibrate**.

Final check

When all calibration steps have been completed the indicator will turn green and the **Use Calibration** option will be checked.

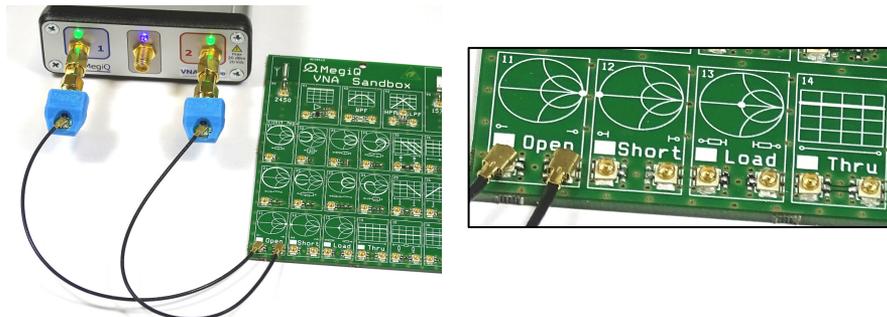
With the port still connected to the **Load** termination, Press **Sweep**. In the Smith chart all measurement points should now be close to the centre (50Ω) and in the Return Loss chart all points should be better then 40dB.

You are ready to measure now, but remember,



after changing cables, connectors or frequency range you'll have to renew the calibration.

2-port calibration (OSLT)



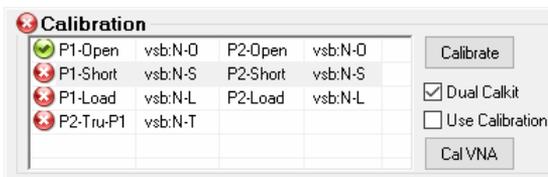
If you are performing a 2-port measurement, you need to do an OSL calibration on two ports and a through calibration between the ports. An Isolation calibration is also required.

Normally a Calkit has one termination of each kind, so there are 8 calibration steps. The MegiQ UFL tools have a dual calibration kit so that calibration steps can be combined. This reduces the calibration to 4 steps.

Here we describe the calibration procedure with a dual calibration kit.

Instrument set-up

- Select the kind of measurement (2-port), frequency range, generator power, etc.
- Select the tab **Calibration** and set up the **port configuration**.
- Since you can use two terminations at the time, check the **Dual Calkit** option.



- For each calibration step the list shows which two connections must be made and to which calibration element(s).

Open

1. Connect both ports to the **Open** terminations.
2. Select **P1-Open / P2-Open** and press **Calibrate**.

Short

3. Connect both ports to the **Short** terminations.
4. Select **P1-Short / P2-Short** and press **Calibrate**.

Load

5. Connect both ports to the **Load** terminations.
6. Select **P1-Load / P2-Load** and press **Calibrate**. This will also calibrate the isolation.

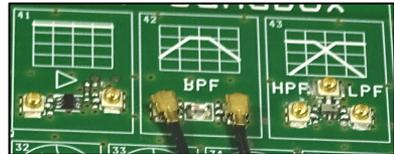
Through

7. Connect the two ports together with the **Through** calibration connector.
8. Select **P2-Tru-P1** and press **Calibrate**.

Final check

With the two ports still connected together, press **Sweep**. In both Smith Charts the measurement points should be close to the center and the return losses lower than -40dB. The Through gain should be near zero.

You are ready to measure now, but remember, after changing cables, connectors or frequency range you'll have to renew the calibration.



De-embedding

It is important that the reference plane is as close as possible to the point where the impedance must be measured, for example at the base of an antenna. Depending on the frequency even a few millimeters distance can change the phase and give misleading results.

If it is not possible to calibrate close to the measuring point, the last piece of trace or transmission line can be de-embedded from the measurement.

For a PCB based UFL measurement the following procedure can be used to de-embed a trace. For connector measurements a similar procedure can be used.

- Calibrate the cables etc with the VNA Sandbox OSL terminations.
- On the DUT, open the circuit where the desired measuring point is located: remove components or cut the trace at that point.

- Connect the measuring cable and press the **Sweep** button to perform an impedance measurement of the open circuit.
- In the **Display tab**, select the appropriate S-parameter and press the **Set Open** button.
- The reference plane has now moved to the position of the open end and the following measurements will be at that point.



The screenshot shows a control panel titled "Deembed S11". It contains two input fields, both with the value "0". The first field is labeled "ps" and has a "Set Open" button to its right. The second field is labeled "dB" and has a "Set Short" button to its right. Below these fields are two buttons: "Reset" on the left and "Set Through" on the right.

It is also possible to perform this procedure with **shorting** the measuring point to ground and use the **Set Short** button.

With a **two-port** measurement a through measurement can be used to deembed the **through** path.

8. Measurement Settings

- Measurement elements
- Setting parameters
- Measurement setup
- Graph setup
- Calibration

Measurement elements

There are several elements that make up a measurement: Port setup, Sweep type, Generator frequency and power, Detector settings and Bias settings and configuration. These elements are accessible through tabs with panels.

This chapter explains the functions of the measurement and other tabs.

Setting measurement parameters

Measurement parameters define the measurement to be made. These parameters can be set by hand, or recalled from a previous saved session or a preset.

The parameters that control the measurements are Frequency, Power, Attenuation, Bias Voltage and Bias Current. These parameters are controlled by a standard edit box.

Depending on the sweep configuration a parameter can be **stepped** or **fixed** during the sweep. The field indicates a sweep parameter with the blue arrow and a fixed parameter with the blue vertical bar.

Frequency	Power
Start <input type="text" value="400"/> MHz	Value <input type="text" value="-10"/> dBm
Stop <input type="text" value="6000"/> MHz	Min <input type="text" value="-40,8"/> dBm
Steps <input type="text" value="1400"/> 4/	Max <input type="text" value="6,3"/> dBm
Dwell <input type="text" value="0"/> us	

The sweep parameters allow entry of start, stop and step values as well as the dwell time (time during each measurement point).

The fixed parameters allow setting the fixed value and show the minimum and maximum allowed values.

When a field is double-clicked a numerical entry screen allows entry of a number by mouse or touch screen. It also shows the minimum and maximum allowed value.

Sweep parameters always yield **one more measurement point than the number of steps**: the endpoint of the sequence will be included.

Screen

The screen tab minimizes the control panel in order to maximize the graph area.

Measure

The measure panel shows which signals are measured during several measuring cycles when the generator signal is applied on different measurement ports.

Measurements									
Gen:	P1	P3	P2	Gen:	P1	P3	P2	Select Measurement	Port Setup
Measure on Port 1	<input type="radio"/> x <input checked="" type="radio"/> S11	<input checked="" type="radio"/> x <input type="radio"/> S33 <input type="radio"/> S13	<input checked="" type="radio"/> x <input type="radio"/> S22 <input type="radio"/> S12	Measure on Port 2	<input checked="" type="radio"/> x <input type="radio"/> S11 <input type="radio"/> S21	<input checked="" type="radio"/> x <input type="radio"/> S33 <input type="radio"/> S23	<input checked="" type="radio"/> x <input type="radio"/> S22		

Screen Measure Sweep Generator Detector Bias Calibration Display

These values are read-only and can only be changed by changing the measurement through the ‘Select Measurement’ button.

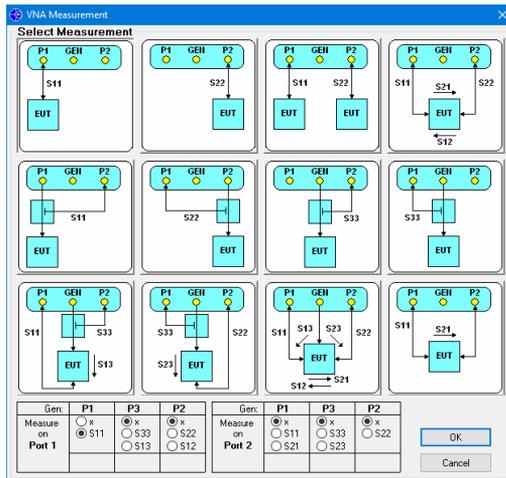
The connection diagram of the measurement is displayed at the left of the main screen.

Selecting a measurement

The Measure-pane indicates the set-up that has been selected. If you want to change the set-up, click on **Select Measurement** which opens the VNA-Measurement dialogue box.

In the **Measurement screen** you select the measurement set-up, i.e. on which ports you want to connect the DUT. Here you can also indicate that you want to use an external directional coupler.

The top row and the second last box at the bottom are regular setup for **1, 2 and 3-port measurements**. The last box is a **one-way Through** measurement (without 12-term normalization) that measures only S11 and S21. This can be used for faster through measurements. The other setups allow using external bridges and mixers.



Measurements									
Gen:	P1	P3	P2	Gen:	P1	P3	P2	OK	Cancel
Measure on Port 1	<input type="radio"/> x <input checked="" type="radio"/> S11	<input checked="" type="radio"/> x <input type="radio"/> S33 <input type="radio"/> S13	<input checked="" type="radio"/> x <input type="radio"/> S22 <input type="radio"/> S12	Measure on Port 2	<input checked="" type="radio"/> x <input type="radio"/> S11 <input type="radio"/> S21	<input checked="" type="radio"/> x <input type="radio"/> S33 <input type="radio"/> S23	<input checked="" type="radio"/> x <input type="radio"/> S22		

Set up the port configuration

During calibration the software needs to know what type of connectors are used on the ports (cables) so that it can select the correct Calibration Kit element for correcting the calibration. This port configuration can be set up through the **Port Setup** button. This brings up the **Port Configuration** screen.

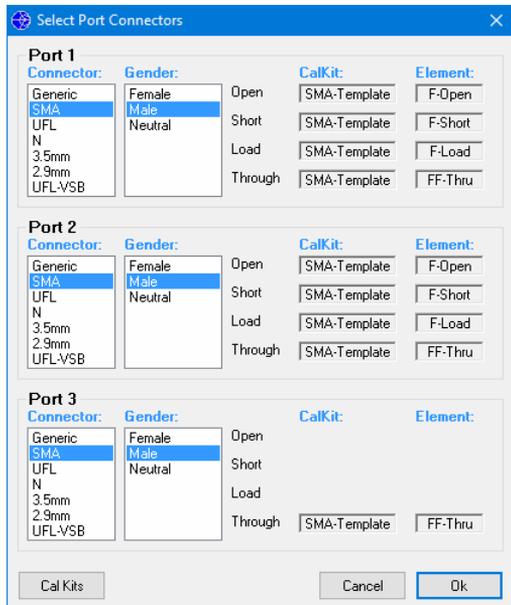
Depending on the measurement one or more of the port panes are enabled. For each port select the **Connector Type** and **Gender**. The software will automatically search the available calibration kits for suitable and matching calibration elements.

Connectors can have a **Female** or a **Male** gender. The **Neutral** gender is used for calibration kits without a gender, like PCB or test fixture calibration kits.

These are the **Genders** of the **Measurement Connectors**.

When one or more calibration elements are not found in the kits, the screen can be closed but the setup is not complete and no calibrations can be made.

The **Cal Kits** button opens the **Calibration Kit Manager** screen. This feature is described elsewhere in this manual.

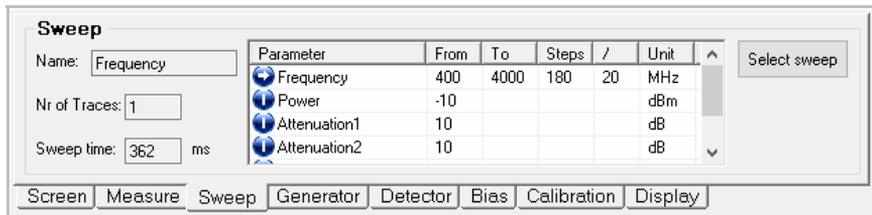


Sweep

The VNA can sweep one or more parameters to make a measurement. The most common sweep is the simple Frequency sweep, with the frequency going from the start to stop value. All other parameters stay at a fixed value during the measurement.

Other useful sweeps include stepping the measurement power for linearity measurements or stepping the bias voltage or current to measure active elements.

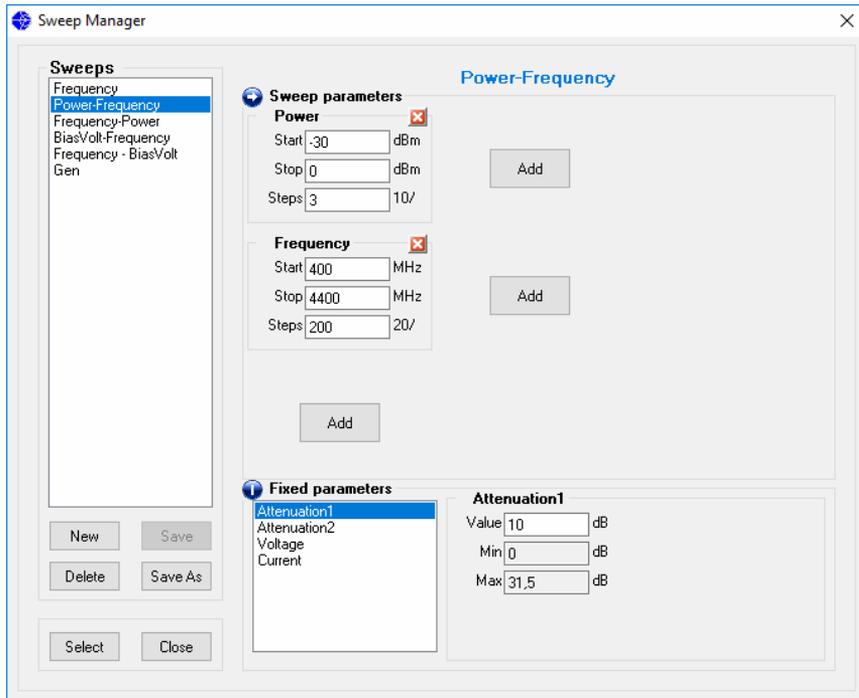
The sweep tab shows the VNA parameters and which of them are involved in a sweep (blue arrow) and which are fixed value (blue vertical bar).



The sweep can be changed by using the **Select sweep** button. This will open the **Sweep Manager** screen.

Sweep Manager

The sweep manager allows you to select sweeps and to define new sweeps or deleting one.



On the left is a list with available sweeps. When one of them is highlighted the right part of the screen shows the setup of the sweep.

To select a sweep, highlight it in the list and use the **Select** button. One can also **double-click** the desired sweep.

Nested sweeps

The **Power-Frequency** sweep shown here has two sweep parameters: Power and Frequency. A sweep is performed from top to bottom: for each step in the upper parameter a sweep of the lower parameter is performed.

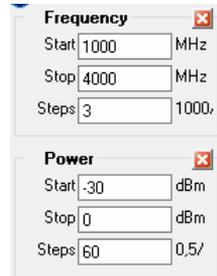
The lowest parameter in a setup results in a measurement trace. The higher parameters yield a measurement trace of the lowest parameter for each of its steps.

The Power-Frequency sweep as shown above results in 4 frequency traces, one for each of the stepped power settings -30, -20, -10 and 0 dBm

The lower right part of the screen shows those parameters that are fixed during a measurement.

The values of the parameters in this screen are template values. When a sweep is selected all parameters will be set to this default value but they can be changed in the different measurement control panels.

The **Frequency-Power** sweep has these two parameters reversed. This sweep will result in power sweeps from -30 to 0 dBm for each frequency 1000, 2000, 3000 and 4000 MHz.

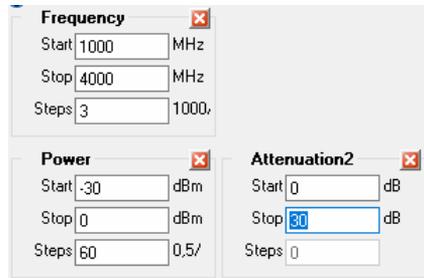


The screenshot shows two control panels. The top panel is titled 'Frequency' and contains three input fields: 'Start' with the value '1000' and unit 'MHz', 'Stop' with the value '4000' and unit 'MHz', and 'Steps' with the value '3' and a secondary unit '1000'. The bottom panel is titled 'Power' and contains three input fields: 'Start' with the value '-30' and unit 'dBm', 'Stop' with the value '0' and unit 'dBm', and 'Steps' with the value '60' and a secondary unit '0,5/'.

Parallel parameters

Multiple parameters can be used in parallel during a sweep. For example, when stepping up the measurement power, the attenuator of one of the detectors (or both) can be stepped up in parallel to make sure that the measured power (through an amplifier for example) will not exceed the maximum measurement power of the detector.

The steps used for a particular sweep level are those of the left parameter.

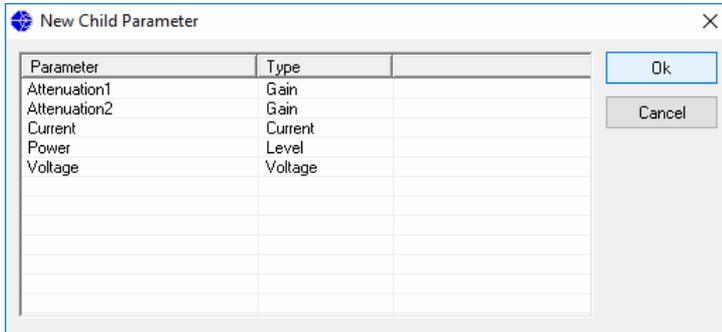


The screenshot shows three control panels. The top panel is titled 'Frequency' and contains three input fields: 'Start' with the value '1000' and unit 'MHz', 'Stop' with the value '4000' and unit 'MHz', and 'Steps' with the value '3' and a secondary unit '1000'. The middle panel is titled 'Power' and contains three input fields: 'Start' with the value '-30' and unit 'dBm', 'Stop' with the value '0' and unit 'dBm', and 'Steps' with the value '60' and a secondary unit '0,5/'. The bottom panel is titled 'Attenuation2' and contains three input fields: 'Start' with the value '0' and unit 'dB', 'Stop' with the value '30' and unit 'dB', and 'Steps' with the value '0'.

Creating a new sweep sequence

It is possible to create your own sweep sequence. Use the **New** button to start a new sweep and enter the name of the new sweep.

Then use the **Add** buttons to select the parameters for the sweep.

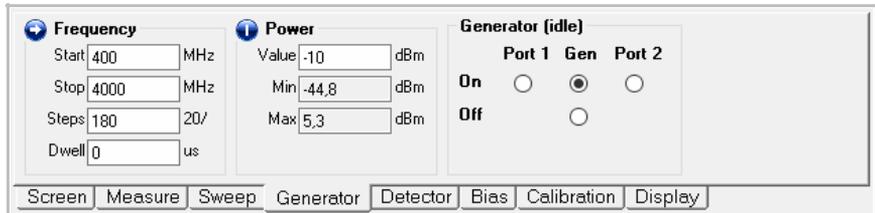


This process goes from top to bottom, so the lowest parameter selected will be the one that yields measurement traces.

Store the sweep using the **Save** button.

Generator

The most used settings in a VNA are of the frequency generator and most of the time it a frequency sweep.



The screenshot shows the Generator panel with the following settings:

Frequency	Power	Generator (idle)
Start: 400 MHz	Value: -10 dBm	Port 1: <input type="radio"/> Gen: <input checked="" type="radio"/> Port 2: <input type="radio"/>
Stop: 4000 MHz	Min: -44,8 dBm	On: <input type="radio"/> Off: <input type="radio"/>
Steps: 180 20/	Max: 5,3 dBm	
Dwell: 0 us		

Navigation buttons: Screen, Measure, Sweep, Generator, Detector, Bias, Calibration, Display

In the Generator panel you choose start- and stop frequency and the number of steps. The number next to the **steps-field** indicates the step size in MHz.

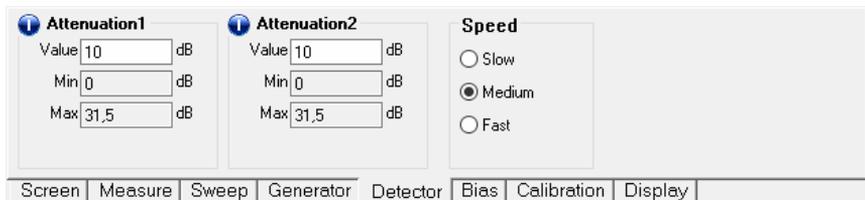
Setting a too high a generator power may overdrive the circuit under test, giving unpredictable results. This is especially true for amplifier circuits, which boost the power to an even higher level.

A generator level that is too low will affect dynamic range.

⚠ Warning: When measuring amplifiers or generators, make sure that the total power to one of the VNA ports does not exceed its absolute maximum rating of 20dBm input power.

Detector

The Detector panel allows setting the input attenuator for the two detector channels. The measurement power range of the detectors is **up to 0dBm**. With the input attenuators this range can be extended.



The screenshot shows the Detector panel with the following settings:

Attenuation1	Attenuation2	Speed
Value: 10 dB	Value: 10 dB	Slow: <input type="radio"/> Medium: <input checked="" type="radio"/> Fast: <input type="radio"/>
Min: 0 dB	Min: 0 dB	
Max: 31,5 dB	Max: 31,5 dB	

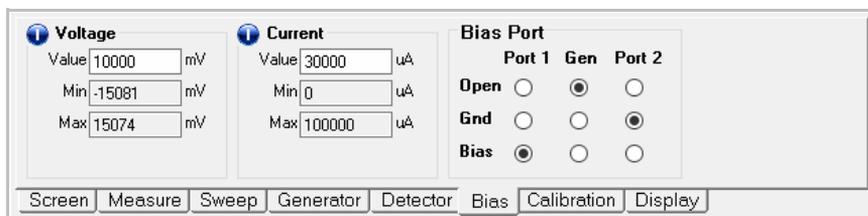
Navigation buttons: Screen, Measure, Sweep, Generator, Detector, Bias, Calibration, Display

⚠ Warning: These settings do not change the absolute maximum power rating of **20dBm**.

The **Speed** option allows making a choice between fast sweeping with higher noise levels or slow sweeping with lower noise and better accuracy. The measurement speed for Slow / Medium / Fast are approximately 4 / 2 / 1 ms per point respectively.

Bias

The VNA04x0-e version comes with an internal programmable bias generator. This is a regulated power supply where you can set limits to voltage (-12...+12V) and current (+/- 1...100 mA), just as with most regulated laboratory power supplies, where it serves as a current- of voltage source. The levels are specified at the input of the bias-Tee's.



The screenshot shows the Bias configuration panel with the following settings:

Voltage		Current		Bias Port		
Value	Unit	Value	Unit	Port 1	Gen	Port 2
10000	mV	30000	uA	Open	<input checked="" type="radio"/>	<input type="radio"/>
Min: -15081	mV	Min: 0	uA	Gnd	<input type="radio"/>	<input checked="" type="radio"/>
Max: 15074	mV	Max: 100000	uA	Bias	<input checked="" type="radio"/>	<input type="radio"/>

Navigation buttons: Screen, Measure, Sweep, Generator, Detector, Bias, Calibration, Display

The current or voltage can also be swept when it is configured so in the **Sweep Manager**. In the above example both Bias Voltage and Bias Current are fixed values.

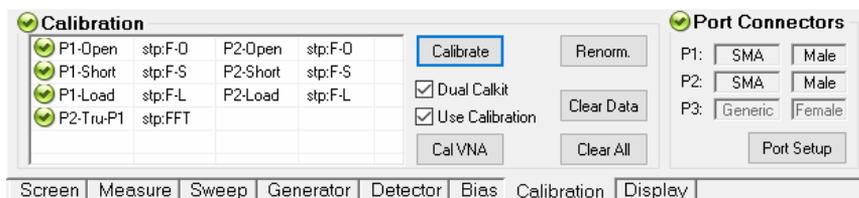
The right side of the panel defines the Bias configuration of each of the VNA ports:

- Open: The port has a default ground resistance of 100kOhm.
- Gnd: The port has a low ground resistance of about 200Ohm, to provide a ground path for bias currents through the DUT.
- Bias: The port is connected to the bias generator with its voltage and current settings.

⚠ Warning: The maximum power dissipation of the port ground resistor is 0.2 Watt so the user must make sure that a current into this resistor does not exceed 100mA and the voltage does not exceed 2V.

Calibration

This panel controls the calibration settings of the measurement and allows the user to step through the calibration procedure. This procedure is explained in detail elsewhere in this manual.



The screenshot shows the Calibration and Port Connectors panels with the following settings:

Calibration				Port Connectors	
<input checked="" type="checkbox"/> P1-Open	stp:F-0	<input type="checkbox"/> P2-Open	stp:F-0	P1:	SMA Male
<input checked="" type="checkbox"/> P1-Short	stp:F-S	<input type="checkbox"/> P2-Short	stp:F-S	P2:	SMA Male
<input checked="" type="checkbox"/> P1-Load	stp:F-L	<input type="checkbox"/> P2-Load	stp:F-L	P3:	Generic Female
<input checked="" type="checkbox"/> P2-Tru-P1	stp:FFT				

Buttons: Calibrate, Renorm., Clear Data, Cal VNA, Clear All, Port Setup

Navigation buttons: Screen, Measure, Sweep, Generator, Detector, Bias, Calibration, Display

The list shows the **calibrations** that are required for the current port setup. When the calibration has been performed it will be marked with the green checkbox. When an item is highlighted in the list the VNA device will show what kind of termination is required on what port by blinking its LED colours.

The list also shows the **Cal Kit Elements** that are used for the calibration. The format is for example 'stp:F-O'. This means that element Female-Open is used from the SMA Template kit.

The **Calibrate** button will perform the calibration for a highlighted item in the list. After that the list will step to the next item. Note that calibrations can be done in any order; they do not need to follow the order of the list.

With the **Dual Calkit** box the calibration procedure can be simplified for multi-port calibration if a dual calibration kit is available. This box can be toggled without losing calibrations that are already performed.

When the **User Calibration** box is off, the VNA will use its port calibration and the measurements will be normalized to the port calibration of the VNA.

When the **User Calibration** box is checked the user calibration will be used and the **Sweep** and **Run** buttons will only be enabled when all calibration items are complete. This box has no effect on performing the actual calibrations.

After a measurement is done and normalized by the software, it is possible to re-do the calibration. With the **Renormalize** button this new calibration can be applied to the current measurement. This button will first (re) apply the current Calibration Kit to the calibrations and then use this calibration for the measurement normalization.

The **Clear Data** button clears the measurement data but not the calibration data. The **Clear All** button clears both measurement and calibration.

Instrument calibration

The VNA will perform internal hardware calibration to keep the measurements accurate. This is necessary when the temperature changes or when the measurement setup has changed. When starting a sweep, the software will perform this internal calibration when necessary.

When using the continuous sweep mode the software will do an automatic calibration check at the start of this mode and during sweeping. The continuous mode may get interrupted by a calibration sweep every now and then, especially during warm up of the hardware.

The **Cal VNA** button can be used to force an internal calibration. This is usually not necessary because it is handled automatically.

Port Connectors

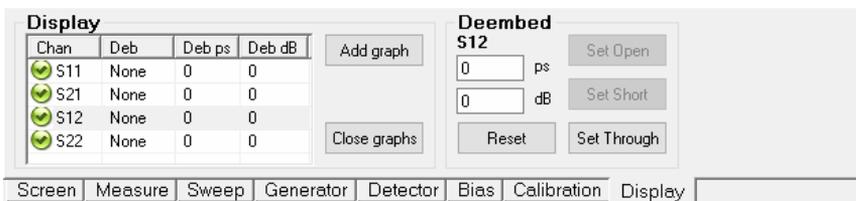
For the Cal Kit Manager to be able to assign the correct calibration compensation coefficients it needs to know what connectors are used and their gender. This setup is shown in the Port Connectors panel.

The **Port Setup** button shows the Port Connectors selection screen, the same as with the Port Setup in the Measure tab.

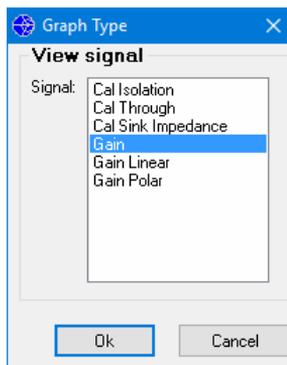
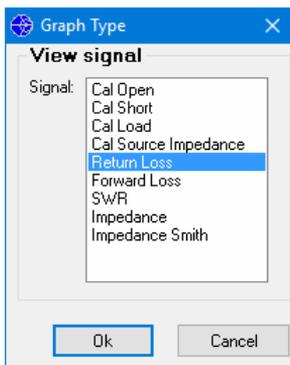
Display

The software stores the calibration and measurement data in a Trace set. Depending on the sweep setup this trace set can contain multiple traces per measurement.

The Display panel allows selecting the graphs to display in the graph area. This also includes display of the calibration data.



The type of graph that can be added to the screen depends on the S-parameter. For S11 and S22 the graphs represent an impedance in some form. For S12 and S21 (and S13/S23) the graphs represent a gain or loss and its phase.



Adding graphs is straight forward: Select the signal you want to display in the list and click **Add graph** (or double-click) to open a dialogue box with a list of graphs available for this signal. Pick your graph from the list and it will appear on screen.

More about the graph types later in this manual.

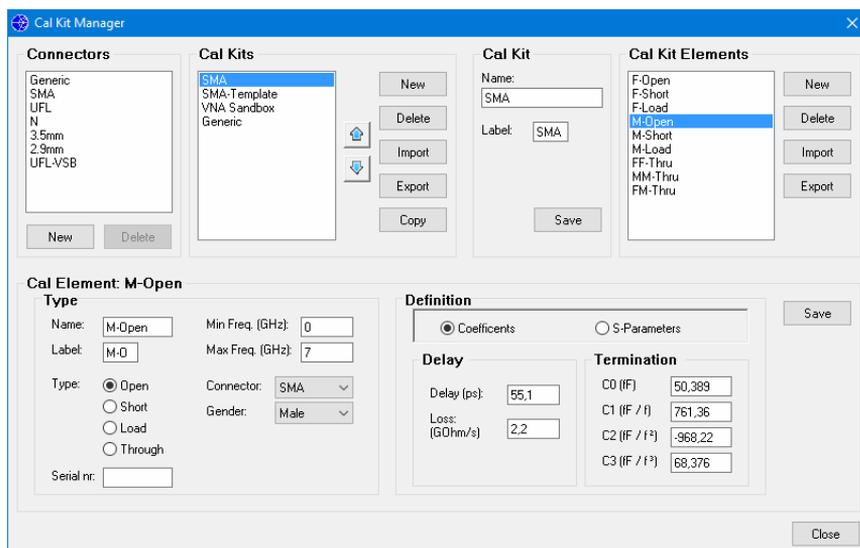
Deembedding

Deembedding is the process of ‘taking out’ a part of the measurement setup from the results. The deembedding parameters can be entered manually in picoseconds and decibels, or an Open or Short measurement can be used with the **Set Open** and **Set Short** buttons. This process is explained in the section about **Calibration**.

9. Calibration Kit Manager

- Connector definition
- Cal Kits and priority
- Cal Kit Element definition

The VNA software has a Cal Kit Manager that keeps track of available and required calibration elements and their coefficients. The software needs to know what kind of connectors are used and their gender so that it can apply the correct compensation coefficients for each calibration.



On the left is a list of available connector types. These are the types that you can select for each measurement port. You can add new types or remove them, unless a connector type is in use by one of the calibration kits. If a calibration kit is imported with a new connector type this type will be added to the list automatically.

The Cal Kits panel shows the available calibration kit types. You can add new kits or remove them, or import a kit from a Cal Kit file (.vck). You can also export a Cal Kit.

The Copy key can be used to copy the selected Cal Kit to a new one, to make it easy to start a new Cal Kit.

With the arrows you can move a Cal Kit up or down in the list. The list position provides a priority in case there are multiple Cal Kits with the same connector. The software will assign a calibration element from the highest Cal Kit in the list.

The Cal Kit panel shows the properties of the selected Cal Kit in the list. The name and label can be changed. The label is used for a short notation of the kit in an element definition.

The Cal Kit Elements panel shows the calibration elements in the selected Cal Kit. You can again add new elements, export and import them from a Cal Element file (.vce).

The bottom panel shows the properties of the selected Cal Element. On the left are general properties and on the right are the coefficients or S-parameters that define the measurement compensation for the element.

The **Label** is used for short notation of the calibration element. The **frequency range** is used to determine if an element is suited for the current measurement range. A zero value for the max frequency causes the software to ignore the max frequency.

The type selection identifies the **type of calibration** and the connector and gender boxes allow for the selection of **connector** and **gender** of the element. The **serial number** allows identifying a specific Cal Element from a specific Kit.

There are actually three Genders: **Female**, **Male** and **Neutral**. Neutral can be used for sexless connectors or for test fixtures and PCB Cal Kits that don't calibrate at a connector. Neutral is **not compatible** with Female or Male.

The **Gender** is that of the **Cal Kit Element itself** while the gender of the port setup is that of the measurement port. The software will **match a Male Element with a Female Port and Neutral with Neutral**.

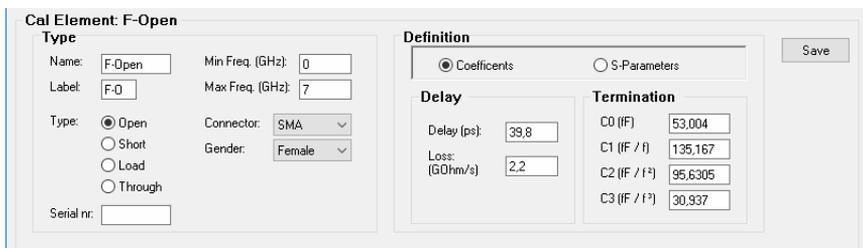
Cal Element definitions

The electrical properties of the calibration elements can be defined with **Coefficients** or by measured **S-parameters**.

In the **Coefficient** mode all element have a **Delay** and **Loss** property. Some elements have a small length of transmission line (or adapter). The Delay is the distance (travel time) from the reference plane to the actual calibration impedance. The Loss is the skin effect loss of that transmission line.

The other coefficient definitions depend of the type of the Cal Element.

Open Element



The screenshot shows the configuration window for a Cal Element named 'F-Open'. The window is divided into two main sections: 'Type' and 'Definition'.

Type Section:

- Name: F-Open
- Label: F-O
- Min Freq. (GHz): 0
- Max Freq. (GHz): 7
- Type: Open, Short, Load, Through
- Connector: SMA
- Gender: Female
- Serial nr.: (empty)

Definition Section:

- Mode: Coefficients, S-Parameters
- Delay (ps): 39.8
- Loss (GHzm/s): 2.2
- Termination values:
 - C0 (fF): 53,004
 - C1 (fF / f): 135,167
 - C2 (fF / f²): 95,6305
 - C3 (fF / f³): 30,937
- Save button

The coefficients C0 through C3 define the (parasitic) fringe capacitance at the calibration point.

Short element

Cal Element: F-Short

Type

Name: Min Freq. (GHz):

Label: Max Freq. (GHz):

Type: Open Short Load Through

Connector: Gender:

Serial nr:

Definition

Coefficients S-Parameters Save

Delay

Delay (ps):

Loss: (GOhm/s)

Termination

L0 (pH)

L1 (pH / f)

L2 (pH / f²)

L3 (pH / f³)

The coefficients L0 through L3 define the (parasitic) fringe inductance at the calibration point. Several Cal Kits have all these coefficients at zero.

Load Element

Cal Element: F-Load

Type

Name: Min Freq. (GHz):

Label: Max Freq. (GHz):

Type: Open Short Load Through

Connector: Gender:

Serial nr:

Definition

Coefficients S-Parameters Save

Delay

Delay (ps):

Loss: (GOhm/s)

Termination

R (Ohm):

For the Load element the actual termination impedance can be specified.

Through Element

Cal Element: FF-Thru

Type

Name: Min Freq. (GHz):

Label: Max Freq. (GHz):

Type: Open Short Load Through

Connector: Gender:

Connector 2: Gender 2:

Serial nr:

Definition

Coefficients S-Parameters Save

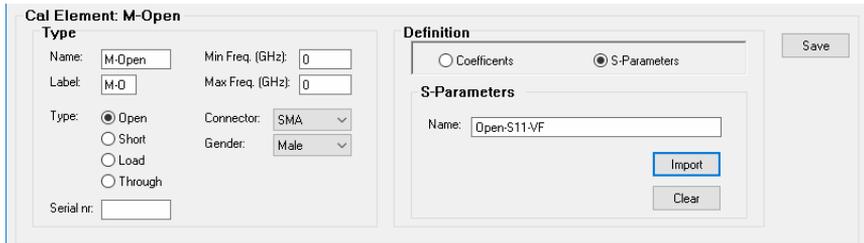
Delay

Delay (ps):

Loss: (GOhm/s)

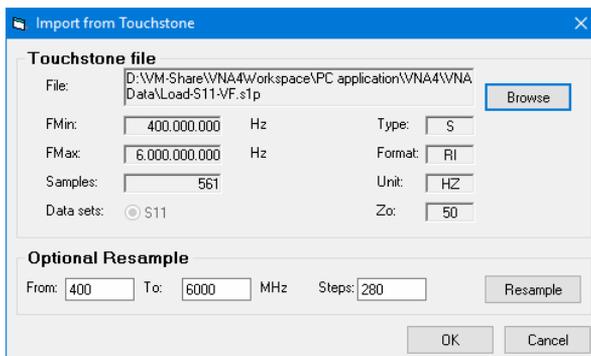
The Through element has no coefficients other than Delay and Loss.

Element S-parameters



Several Cal Kits are provided with the S-parameter files of the Elements. These should be the **raw S-parameters** without any deembedding for length. These S-parameters must of course be measured against a better calibration kit.

The S-parameters can be imported from a Touchstone format file (.S1P or .S2P), version 1.0.



After browsing a Touchstone file the screen shows the properties of the file. With a two-port file you can select the desired data set (S11, S22).

It is recommended to have 10MHz or less between sample points. The optional Resample feature can be used to limit the frequency range or decrease the number of samples to store.

10. Graphs

- Impedance graphs
- Gain graphs
- Graph control
- Context menu
- Arranging graphs

There are many different graph types but they are all derived from the S-parameters of the measurement. These S-parameters represent either an impedance or a Gain. There are different graph types depending on the trace type: Impedance or Gain.

Impedance graphs

The measured impedance can be represented in different graph types, but they are all derived from the measured S-parameter (S11 or S22).

Return Loss

The Return Loss graph is scalar, thus without phase information, and gives the ratio between the transmitted signal and the signal that is ‘reflected’ back because of a mismatch between the source port and the DUT impedance. This ratio is displayed in dB and has no phase information. The lower the value the better the impedance match. A perfect match yields a return loss of minus infinite and a perfect mismatch gives a Return Loss of 0dB. For antennas often a limit of better than -10dB return loss is used.

Forward Loss

The forward loss (or transmission loss) is the relative amount of power that is lost because of the mismatch between source port and DUT impedance. With a perfect match the Forward loss will be 0dB.

SWR

The SWR is similar to Return Loss but it represents the ratio of **Standing Waves** compared to the **Forward Waves**. A value of 1 represents a perfect match and a perfect mismatch (open or short circuit) gives an infinite value.

Impedance

The impedance graph is a straight representation of the measured impedance magnitude and its phase.

Impedance Smith

The Smith chart is often used to show complex impedances in a complex plane and is very well suited to calculate graphically how to match circuits. It also gives you a quick overview of matching (The closer to the center, the better the match into 50 ohm). The Smith chart can also show complex admittances and matching (SWR circles).

Impedance calibration graphs

The software also allows displaying the calibration measurements Open, Short and Load. These are displayed as the measured S-parameter of the calibration termination, through the used measurement setup.

Cal Source Impedance

When the Open, Short and Load calibrations have been done, the software can calculate the actual source impedance that the test setup presents at the reference plane. The DUT is excited with this source impedance. It is represented in a Smith Chart.

Gain Graphs

There is less abundance of graphs to represent the measured gain.

Gain

The Gain chart gives you gain (or attenuation) in a two port measurement. It show magnitude and phase with two separate lines. The phase can also be represented as a **Group Delay** which is an indication of phase distortion of a DUT.

Gain Linear

The Linear Gain chart is the same gain and phase but with the gain on a linear scale.

Gain polar

The polar gain graph gives you the same information as the gain graph (magnitude and phase), but in a single line and in the complex polar plane.

Gain calibration graphs

The Isolation and Through calibrations can be displayed in the respective graphs.

Cal Sink Impedance

During the Through calibration, the VNA measures not only the signal that arrives at a port from the other port but the VNA also has the opportunity to measure the impedance that the receiving port presents (through the test setup) to the signal source. This Sink Impedance can be presented in a Smith Chart.

Graph control

Graphs can be controlled and manipulated with the mouse in several ways.

Traces

Traces represent the measured data. Depending on the type of measurement there can be one or several traces. For parametric sweeps (with more than 1 variable) there will be a multitude of traces.

The legend at the bottom of the graph indicates the color and type of each trace. With parametric sweeps the legend will indicate at which parameter value the trace was measured.

Zoom

To pan and zoom in/out use the arrows at the right / bottom side of the graphs. The number indicates the zoom factor. The small square at the lower right corner restores the default value of the scaling. There are controls for the vertical and for the horizontal scale.

Smith charts are always zoomed as a whole, the horizontal and vertical zoom controls have the same effect.

Cursors and markers

When you move the pointer of the mouse over the graph it will act as a cursor and show the value at the bottom of the graph. As soon as you move the cursor over a measurement in a trace the cursor gives you the data of that point.

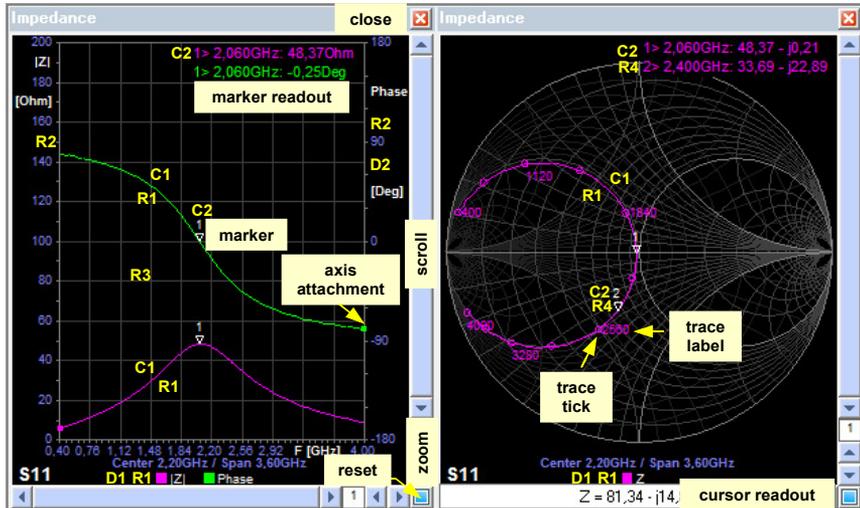
You can click on a trace to set a marker: There will be a mark on the trace and a value readout at the top of the graph.

To remove a marker, just click on the marker or on the marker readout.

Markers can only be set on a measurement point. For traces with few measurement points it can be a little difficult to find the nearest measurement point. The **Show Trace Points** feature can be used to mark each trace point so it can be found easily.

Mouse control

There are several functions for the mouse when it moves over the graph and when clicked, right clicked or double clicked. The picture below shows special locations where mouse clicks have different functions. ‘C’ stands for (left) Click, ‘R’ for Right click and ‘D’ for Double click.

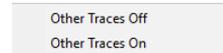
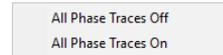
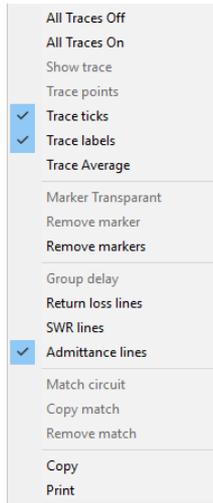


- C1: Click on a trace to set a marker at that point
- C2: Click on a marker or marker readout to remove the marker.
- R1: Right click on a trace for the context menu where it is possible to turn the trace on or off, or to turn other traces on or off.
- R2: Right click on an axis for the context menu where it is possible to turn all traces belonging to that axis on or off.
- R3: Right click in the general graph area for the context menu.
- R4: In the Smith chart, right click on a marker or marker readout for the context menu where it is possible to open the Match Calculator for that particular point.
- D1: Double click on a legend to toggle the trace point markers on or off. If the trace is off, double clicking the legend will make the trace visible.
- D2: Phase axis only: double click on the phase axis will toggle it to Group Delay mode and back to Phase.
- D3 (not shown): Double click on a Smith chart to toggle trace labels on or off.

Context menu

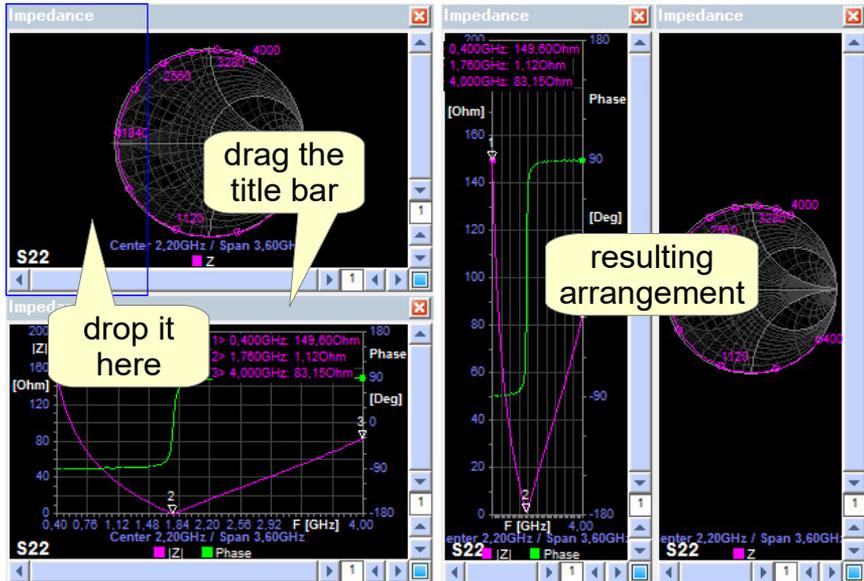
Right clicking on different locations shows the context menu of the graph. It mostly has the same list with available options enabled.

Only the two upper items are different depending on the location or axis where it was pulled up.



Arranging graphs

To arrange graphs in the graph area use drag & drop. This will also resize the graphs to make maximum use of display area.



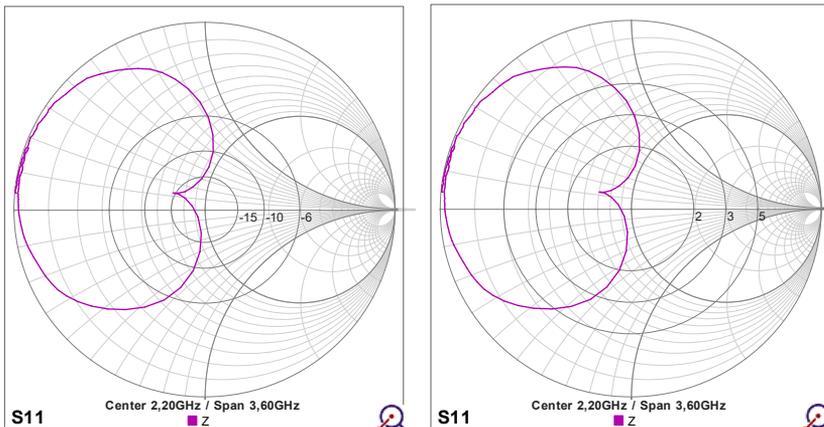
Drag a graph by grabbing the title bar and drag it over another graph. A blue square indicates where the graph will land. In the above left picture the Impedance graph is being dragged to the left of the Smith chart, resulting in the ordering in the right picture.

Smith Chart line sets

A Smith Chart is usually drawn with impedance lines that make it easy to determine what happens when impedances are connected in series by following the circles.



It is also possible to draw **admittance lines** that show what happens when impedances are connected in parallel. This is shown in the right graph above.

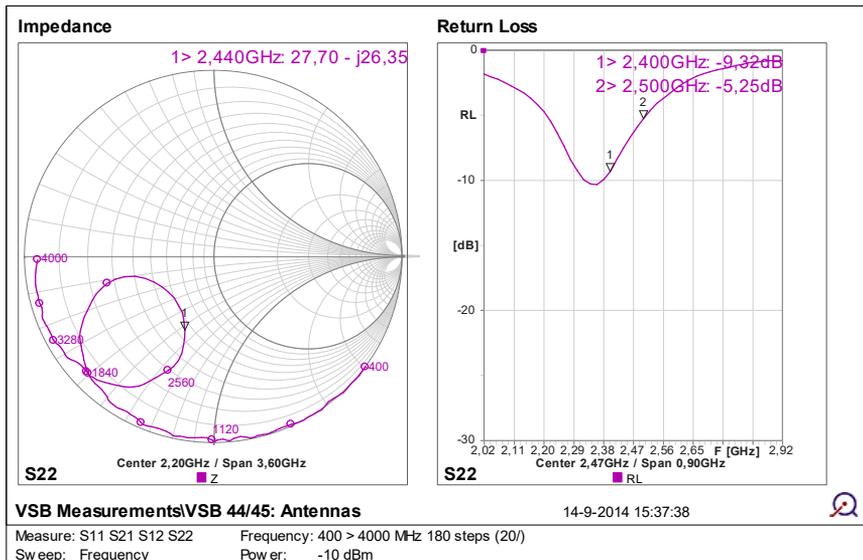


Since the distance to the center of the Smith Chart is a measure of the match, it is possible to draw circles of **constant Return Loss** around the center, as in the left graph above. The right graph shows circles of **constant SWR**.

11. Match Calculator and simulator

- Match calculator
- Matching procedure
- Optimizing the bandwidth

A powerful feature of the VNA software to assist in antenna development is the built in Match calculator.



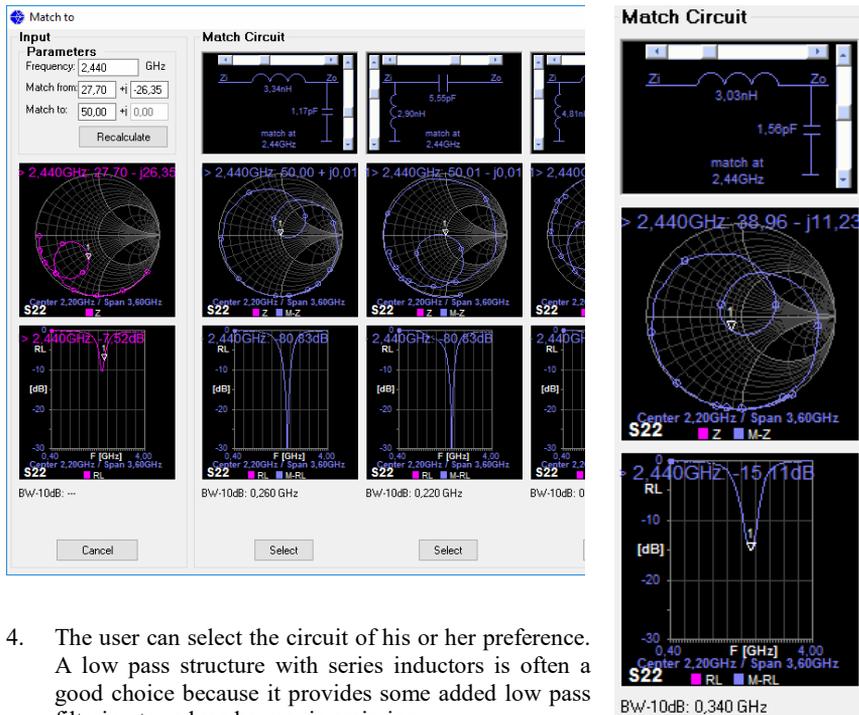
The above graphs show the characteristics of the Wifi antenna that is incorporated in the VNA Sandbox. The antenna was implemented according to the specifications of the datasheet but the resulting impedance is not very well matched to the Wifi band. The return loss graph has two markers at the boundaries of this band and we would like the antenna to have at least -10dB return loss in this band.

A match circuit consisting of a combination of reactive components like capacitors and inductors is commonly used to transform the antenna impedance to the desired values.

The MegiQ VNA software has a match calculator that makes it easy to design this match circuit and to simulate the results in real-time.

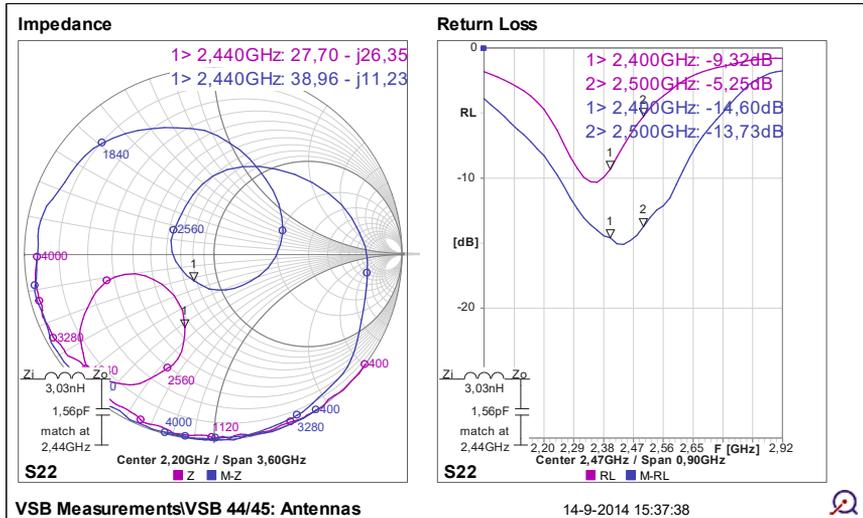
Matching procedure

1. In the Smith chart, put a **marker** on the center of the frequency band that needs to be matched. This is Marker 1 in the previous graph.
2. Right-click on the marker or on the readout and from the menu select **Match Circuit**.
3. The VNA software opens the **Match Calculator**. Depending on the original impedance, this will give you two or four possible match circuits and the resulting impedances. The resulting -10dB bandwidth is indicated at the bottom of each possibility.



4. The user can select the circuit of his or her preference. A low pass structure with series inductors is often a good choice because it provides some added low pass filtering to reduce harmonic emissions.
5. The **sliders** around the matching components can be used to fine-tune the values, to optimize the **bandwidth** of the resulting match and to set them to E-series values. The right picture shows that it is advantageous to make the Smith graph swing around the center (50ohm) to increase the -10dB bandwidth to 340MHz.

- Use the **Select** button to select the desired matching circuit. The software will apply this circuit on the Smith chart and show the result of the match. Use the **Copy Match** item of the context menu to copy this match to other graphs of the same parameter (in this case S22).



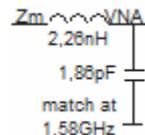
The resulting antenna implementation has a very nice return loss of about -14dB throughout the Wifi band.

You can use the **Run** sweep button to run continuous sweeps and the matched results will be updated with each measurement. This mode can be used to evaluate the matched impedance when the environment of the antenna changes with a cabinet or hand effects.

When the calibration of this measurement was done carefully and **close to the matching** point, the circuit can often be built on the DUT and the matched results then closely match the simulation. In some cases an iteration of the matching procedure may be required to optimize the circuit implementation.

We have modified the labelling of the matching circuit for clarity.

Zm on the left side is the **Measured impedance** that needs to be matched and **VNA** on the right side is the (normally) **50 Ohm** side.



12. Session manager

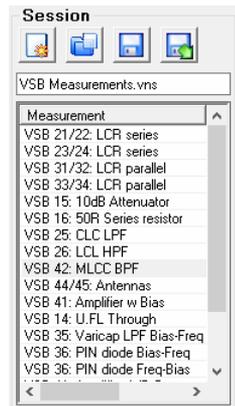
- Session manager
- Saving and loading measurements and setups
- Exporting and importing Touchstone files.

The session manager

You are very likely to perform all kind off measurements, make changes to your design, redo the same measurements, comparing them to previous ones, and so on. The **Session Manager** gives you a very handy tool for this.

A session may consist of various measurements in one project, or of a standard measurement used in several projects. In fact a Session consists of a file on hard disk, where you can save and recall data and settings.

Each measurement you perform you can name and save to the Session List and recall later by double clicking on it the Session List. All data of the measurement is stored, including measurement data, calibration data, measurement setup, sweep and parameters, graphs and zoom, markers and match circuits.



Saving to the session list

Saving a recently made measurement to the open session list is done by clicking the **Save As-button**. This opens a window where you can enter the measurement-name. Note: this is NOT the file name of the session, de measurements are not saved to hard disk until you save the Session. Choose a (new) name for the measurement and press **OK** or **Enter**. De new measurement will now appear in the session list. Please also note that the name you give to a measurement in the list does necessarily need to be unique. You can use the same name several times; their difference will be the time stamp.

If you want to overwrite a measurement, first delete it from the list and then use **Save As** to store the newer measurement. Select it from the list, perform the new measurement and press the **Save-button**.

You can change appearance on the screen of a saved measurement, like inserting markers in the plots and then store it back again. To do so, use the **Save-button**.

Saving the session

Do not forget to save the Session to disk before exiting the program. To do this press the **diskette-icon** to overwrite or the icon to the right to choose for a new file on disk. (a file dialogue box will appear).

Session files have the extension **.vns**.

To create a new, empty session, press the “Start a new Session” icon

Opening a session

You recall previous saved Session files by clicking the **Open a session file**-icon. This opens a file dialogue box where you can navigate and select the right Session file.

You can also double-click a session file from the Windows file explorer to open the VNA program and load the session file. Note that this action will not load a measurement from the session file.

Recalling measurements

Select a previously saved measurement, by selecting it from the Session list.

Note this not only recalls the measurement data but also graphs, calibration data and other settings.

So beware, **this overwrites calibration data** stored in the VNA before the recall. The instrument cannot know whether this calibration is valid or not, i.e. whether you changed the set-up since you saved the measurement.

Saving measurements thus also stores the calibration data and you can make good use of that, since a 2-port calibration can take some time. If you work with very well defined set-ups (cables, fixtures, connectors etc.) you can save a measurement after calibrating and use this merely for recalling the calibration data-set. Still you will have to recalibrate every now and then to be on the safe side.

Deleting and renaming

If you right-click on the name of a measurement in the session list, you can rename it, or delete it.

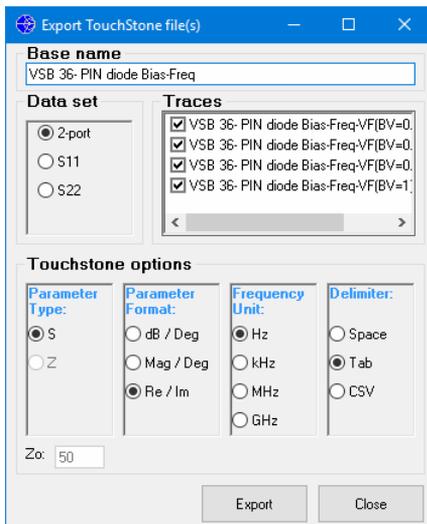
Export and Import

The data of a measurement in the session file can be exported by right clicking the item and select **Export as SnP** from the context menu. This opens the same export screen as the **Export** button in the measurement control bar.

A touchstone file can also be imported as a measurement by using the **Import from SnP** item in the context menu. This allows the measurement data to be displayed in graphs or manipulated by the program. You can even use the match calculator to calculate a match circuit for the imported data. After loading an imported measurement you have to add the graphs to the screen manually. You can then save the measurement with the display setup.

Export Touchstone

The Export Touchstone screen is used to select measurement items to export and where to export them to.



A commonly used format for S-Parameters is the **Touchstone format**. This supports 1, 2 and multi-port S-parameters and can have extensions like .S1P, .S2P, .S3P etc. The Touchstone format can easily be imported in Excel.

Since a measurement can have multiple traces the export screen will allow you to write a Touchstone file for each of the traces.

This screen allows you to change the base name of the files, select the S-parameter(s) and the trace(s) to save.

When you press the **Export** button it opens a file dialog where you have to select the **Directory** to store the trace file(s).

The software will confirm the number of files exported.

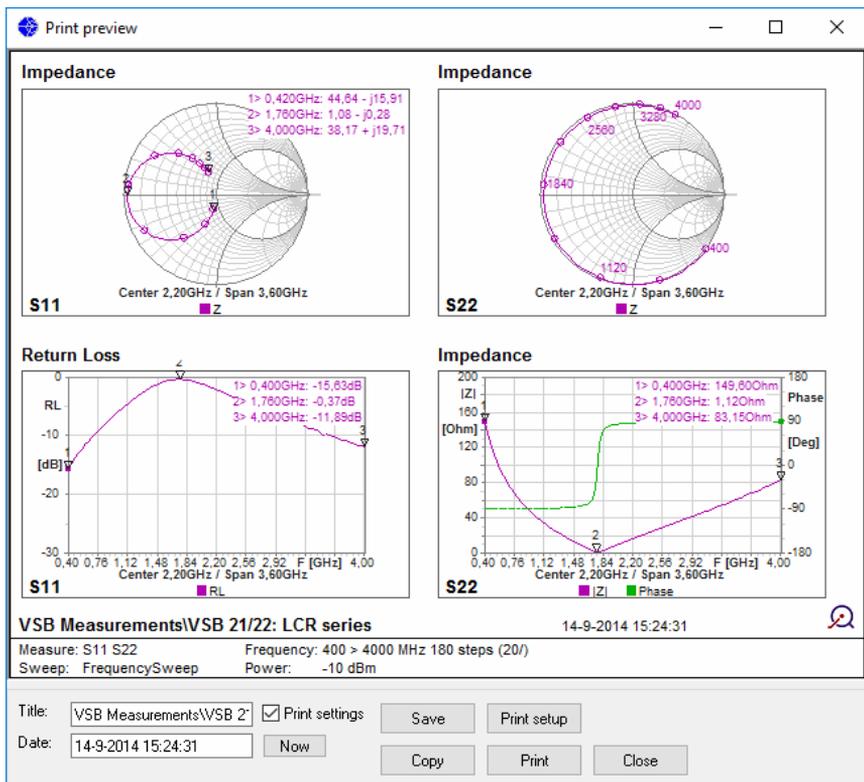
The Touchstone format allows for different types of data format. These options can be selected in the export screen. The ‘CSV’ setting will write a CSV file with the .CSV extension.

13. Reports

The VNA program can generate quality graphs for further use in reporting. An efficient way of working is to save measurements to a network location from the lab computer that is connected to the VNA and to have the VNA software on a desk computer to pull up the measurements and create report graphs.

Report generator

The software generates report figures with the **Print** button in the utility bar. This button opens the **Print preview** screen.



The exact screen layout of the graph area is printed to this screen, along with the filename, measurement name and VNA settings. These can be changed manually in the text boxes.

This figure can be **copied** to the clipboard for easy pasting into a report, **saved** to a file or **printed** directly to a printer.

All figure items are saved as scalable graphics into the **Enhanced Metafile Format** (emf) so that it can be scaled with high quality.

The original size of the graph area is used as the size of the report figure. This gives you the possibility to increase or decrease the relative size of the graph text items: if you start with a large screen and scale the figure down in a document you will get small text items. If you use a small screen the resulting graphs will have larger text items.

The **colour scheme, logo** and other options for this screen can be selected in the Options screen of the program. In the option screen you can also choose to omit admittance lines in the smith charts, whether they are shown on screen or not.

The Print menu item will open the report screen for the whole graph area.

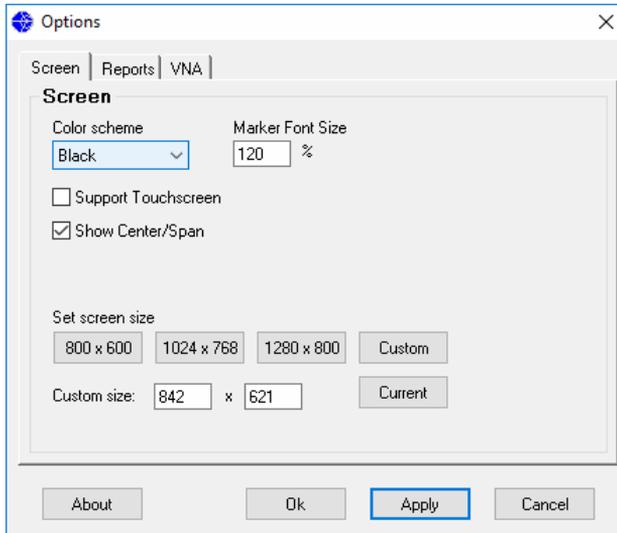
Copying a single graph

You can copy single graph by using the Copy item in the graph context menu.

14. Options

There are several program options that are selected in the **Options** screen that is accessible from the **Utilities** bar. This screen also has a tab for showing VNA information and uploading new firmware to the VNA.

Screen

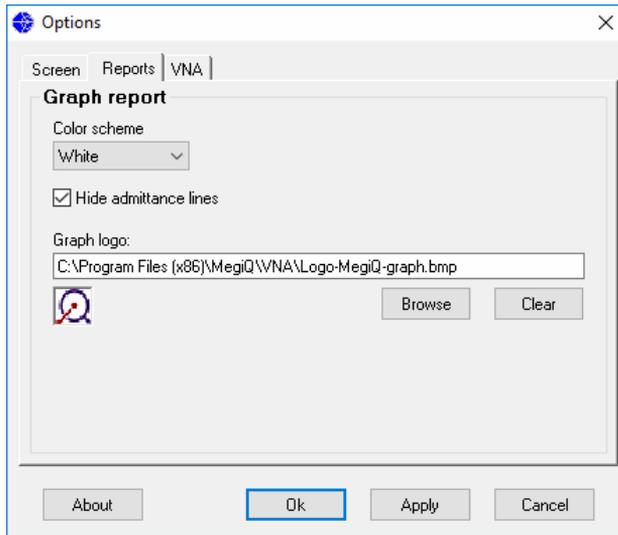


This tab allows changing several options for the screen.

- **Colour scheme:** selects the colour scheme for the graphs, such as black background, white background, white with monochrome traces and others.
- **Marker Font Size:** allows increasing the font size in the graphs to make them better readable on larger screens.
- **Touch screen:** turns on some features to support touch screen operation such as on screen keyboard and recognizing long screen press as a right click. This may or may not be in the way with your operating system's touch screen support.
- **Show Center/Span:** turns on or off the display of 'center/span' in the graphs.
- **Set screen size:** For generating reports it may be useful to always use a certain screen size. This can be selected with these buttons. A custom size can be entered or taken from the current screen size.

Reports

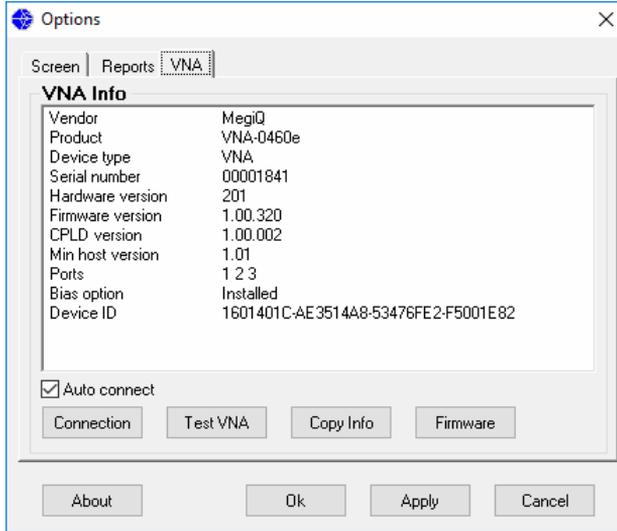
This screen has options for generating reports.



- Colour scheme: the colour scheme used for reports.
- Hide admittance lines: this lets you hide admittance lines in Smith Charts. These lines can make the graph very busy and difficult to read.
- Graph logo: Allows setting a logo to be printed in the right bottom corner of the graphs.

VNA

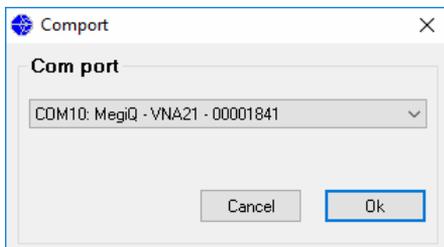
Shows information about the currently connected VNA and provides some VNA control.



- VNA Info: information about the hardware such as product name, serial number, versions, options and a unique device ID number.
- Autoconnect: When checked, the software will automatically connect to the VNA when it is detected.
- Connection: Controls the connection with the VNA.
- Test VNA: Runs a VNA hardware test and reports the result. The VNA must be rebooted after this test (newer software versions will automatically reboot the VNA).
- Copy Info: Copy the list info.
- Firmware: Opens a screen to upload new firmware.

Connection screen

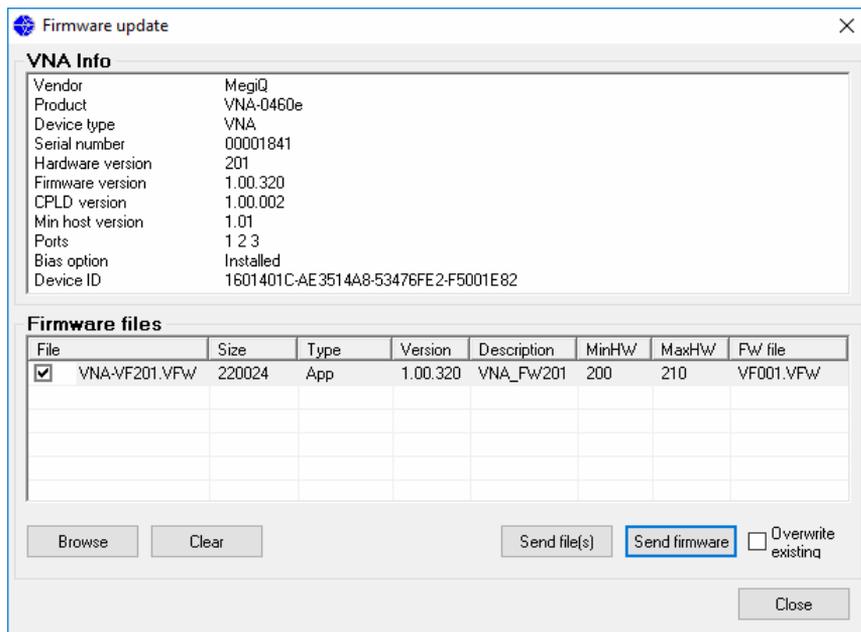
When running the VNA software in a virtual machine, the software may not automatically detect when the VNA is connected.



This screen can be used to select the COM port where the VNA is connected. The actual text of the COM port differs for some Windows versions; sometimes the name of the device is not shown in the list, just the COM port with a generic name. This does not necessarily mean that the software can not detect the VNA.

Firmware screen

This screen is for uploading new firmware to the VNA.



- VNA Info: The same VNA info as in the VNA screen.
- Firmware files: List of files to be uploaded.

- Browse: Button to browse for file(s) to upload.
- Clear: Clear the file list.
- Send file(s): Send files to the VNA without rebooting.
- Send firmware: Send files to the VNA with a reboot afterwards.
- Overwrite existing: Flag for overwriting existing files. Rarely used.

When uploading firmware, the VNA will store the file in its file system. At the following reboot the bootloader will install this firmware and, when successful, delete the firmware file from its file system.

This feature can also be used to install other kind of files or control options created by MegiQ. These files may be locked to a particular Device ID.

15. Specifications

parameter	VNA0440 – VNA0460	VNA0440e – VNA0460e	unit
frequency			
- range	400 ... 4000 / 6000	400 ... 4000 / 6000	MHz
- accuracy	2	2	ppm
- resolution	5	5	kHz
output			
- level	+5 ... -40	+5 ... -40	dBm
- accuracy	+/- 1	+/- 1	dB
- resolution	0.5	0.5	dB
- harmonics	better than -35	better then -35	dBc
input			
- max. RF input level, no damage	20	20	dBm
- max. DC input level, no damage	+/- 20 ⁽¹⁾	+/- 20	V
- detector range 400 – 4000 MHz	+20 ... -70	+20 ... -70	dBm
- detector range 4000 – 6000 MHz	+20 ... -60	+20 ... -60	dBm
- overall measurement accuracy	0.5	0.5	dB
- overall directivity accuracy (calibrated)	better than 55	better than 55	dB
bias generator			
- control	-	software control V/I source and sink	-
- bias Tee's	-	internal, software controlled switch	-
- bias voltage set-range	-	-12 ... +12	V
- bias current set-range	-	+/- 1 ...100	mA
general			
ports	2 x bidirectional	2 x bidirectional & 1 x generator output	-
impedance	50	50	Ω
Port Return Loss	better than -15	better than -15	dB
power supply (AC adapter included)	8 ... 24	8 ... 24	V _{DC}
DC power consumption	8	10	W
interface	USB 2.0	USB 2.0	-
measurement speed	1000	1000	pts/s
sweep length	> 100k	> 100k	points
dimensions	145 x 82 x 32	145 x 82 x 32	mm
RF-connectors	SMA	SMA	-
extension connector	no	yes	-

VNA Sandbox

For those that are new to RF development we have created the VNA Sandbox. This kit contains a PCB with a dual UFL calibration kit and all kinds of 1-port and 2-port circuits such as resonant circuits, filters, antennas and active circuits.

The Sandbox kit comes with an extensive tutorial how to calibrate and measure circuits and explains the results and the behavior of real-world components and circuits.

With all adapters and spare connectors included the VNA Sandbox kit provides a quick way to get started and get results.



VNA Sandbox provides an easy learning curve



UFL and Balanced Calkit

This is the calibration kit for more precision UFL calibrations and for balanced measurements.

- Facilitates balanced and UFL VNA measurements
- Includes in-depth tutorial
- Dual UFL OSLT Calibration Kits for 3 PCB layer thicknesses
- Balanced OSLT kits
- SMA-UFL adapters
- SMA-Balanced adapters
- UFL-Balanced adapters
- UFL-Differential adapter
- UFL Cables
- UFL Sockets for measuring
- PIN headers for measuring
- Use with any VNA
- Use UFL up to 6GHz, Balanced up to 3GHz



Radiation Measurement System

The RMS0740 measures antenna radiation patterns of active and passive devices.

The Radiation Measurement System (RMS) is a unique turnkey system that will measure Radiation Patterns and Total Radiated Power (TRP) from a 3-axis rotation from 600MHz to 4GHz.

While this is usually measured in an anechoic chamber to avoid reflections to affect the measurement, the RMS has a smart antenna design to reduce the sensitivity for reflections. This allows radiation measurements to be made in relatively small lab or office spaces.



www.megiq.com