

 Mini-Circuits®

# eVNA

USER GUIDE



**Mini-Circuits**

13 Neptune Avenue  
Brooklyn, NY 11235, USA

**Email:** [testsolutions@minicircuits.com](mailto:testsolutions@minicircuits.com)

**Web:** [minicircuits.com](http://minicircuits.com)

**Phone:** +1-718-934-4500



MORE SOLUTIONS FOR  
TEST & MEASUREMENT!

 Mini-Circuits®

## Important Notice

This guide is owned by Mini-Circuits and is protected by copyright, trademark and other intellectual property laws.

The information in this guide is provided by Mini-Circuits as an accommodation to our customers and may be used only to promote and accompany the purchase of Mini-Circuits' Parts. This guide may not be reproduced, modified, distributed, published, stored in an electronic database, or transmitted and the information contained herein may not be exploited in any form or by any means, electronic, mechanical recording or otherwise, without prior written permission from Mini-Circuits.

This guide is subject to change, qualifications, variations, adjustments or modifications without notice and may contain errors, omissions, inaccuracies, mistakes or deficiencies. Mini-Circuits assumes no responsibility for, and will have no liability on account of, any of the foregoing. Accordingly, this guide should be used as a guideline only.

### Trademarks

Microsoft, Windows, Visual Basic, Visual C# and Visual C++ are registered trademarks of Microsoft Corporation. LabVIEW and CVI are registered trademarks of National Instruments Corporation. Delphi is a registered trademark of Delphi Technologies, Inc. MATLAB is a registered trademark of The MathWorks, Inc. Agilent VEE is a registered trademark of Agilent Technologies, Inc. Linux is a registered trademark of Linus Torvalds. Mac is a registered trademark of Apple Inc. Python is a registered trademark of Python Software Foundation Corporation.

All other trademarks cited within this guide are the property of their respective owners. Neither Mini-Circuits nor the Mini-Circuits PTE (portable test equipment) series are affiliated with or endorsed or sponsored by the owners of the above referenced trademarks.

Mini-Circuits and the Mini-Circuits logo are registered trademarks of Scientific Components Corporation.

### Mini-Circuits

13 Neptune Avenue  
Brooklyn, NY 11235, USA  
Phone: +1-718-934-4500

Email: [testsolutions@minicircuits.com](mailto:testsolutions@minicircuits.com)

Web: [minicircuits.com](http://minicircuits.com)

<b>A-INTRODUCTION</b>	<b>09-13</b>		
<b>1. About the eVNA-63+</b>	09-10		
1.1. Key Features	09		
1.2. Concept & Control Options	10		
<b>2. About this Guide – Prepare, Practice, Calibrate &amp; Measure</b>	11-12		
2.1. Measurement Automation / Programming with SCPI	12		
2.2. Terminology	12		
2.3. Languages	12		
<b>3. Support Contacts</b>	13		
<b>4. Warranty &amp; RMA Returns</b>	13		
<b>5. End of Life</b>	13		
<b>B-PREPARE</b>	<b>14-30</b>		
<b>1. Safety &amp; Cautions</b>	14-15		
1.1. Maximum Input Levels	14		
1.2. Bias Tee Output Levels	14-15		
1.3. Operating Environment	15		
1.4. User Service / Cleaning	15		
<b>2. Factory Calibration</b>	15		
2.1. Standard Factory Cal - Lowest-cost	15		
2.2. Premium Factory Cal - Zero Down-time	16		
<b>3. Software Setup</b>	16-20		
3.1. Software Downloads & Resources	16		
3.2. System Requirements	16		
3.3. eVNA Studio Software Installation	16-20		
<b>4. Graphical User Interface (GUI) Overview</b>	21-23		
4.1. Main Menu / Control Panel Groups	22		
4.2. Settings Bar & Status Bar	22		
4.3. Instrument Status Icons	23		
4.4. Graph Status Notifications	23		
<b>5. Hardware Setup</b>	24-27		
5.1. Front Panel Layout	24		
5.2. Rear Panel Layout	24		
5.3. Initial Connection & Power-On	25		
5.4. Test Port Connections	25		
5.5. Bias-Tee Connections	26		
5.6. Reference Connections	27		
5.7. Trigger In Connection	27		
5.8. Functional Block Diagram	27		
<b>6. Measurement Essentials</b>	28-30		
6.1. Basic VNA Operation	28		
6.2. Transmission & Reflection Measurements	29		
6.3. S-Parameters	30		
<b>C-PRACTICE</b>	<b>31-81</b>		
<b>1. Accessories</b>	31-35		
1.1. Connectors, Connector Savers & Connector Care	31-32		
1.2. Test Cables	32-34		
2.1. System Reset	36		
<b>3. Channels &amp; Traces</b>	37-40		
3.1. Channels	37		
3.1.1. Channel Setup	37		
3.1.2. Active Channel	38		
3.1.3. Channel Display	38		
3.2. Traces	39		
3.2.1. Trace Setup	39		
3.2.2. Active Trace	39		
3.2.3. Trace Display	40		
<b>4. Frequency &amp; Power Stimulus Settings</b>	40-49		
4.1. Frequency Sweeps	41		
4.1.1. Sweep Power Level	41-42		
4.1.2. Sweep Power Slope	42		
4.2. Power Sweeps	43		
4.3. Segmented Frequency Sweep	44-45		
4.3.1. Linear & Order-Based Trace Display	45		
4.4. Advanced Sweep Settings	45		
4.4.1. Fast Sweep Mode	46		
4.4.2. Sweep Time Period	46		
4.4.3. Sweep Delay	46-47		
4.4.4. Spur Suppression	47		
4.5. Sweep Triggers	47		
4.5.1. Trigger Source	47-48		
4.5.2. Trigger Mode	48-49		
<b>5. Measurement &amp; Data Formatting</b>	49-56		
5.1. Measurement Types	49		
5.2. Graph Types	50		
5.2.1. X-Y Plots	50		
5.2.2. Polar Plots	51		
5.2.3. Smith Charts	52-53		
5.3. Electrical Delay	53-54		
5.4. Scaling	54		
5.5. Averaging	55		
5.5.1. Sweep Averaging	55		
5.5.2. Trace Smoothing	55-56		
5.5.3. IF Bandwidth	56		
<b>6. Markers</b>	57-66		
6.1. Marker Setup	57-58		
6.2. Moving Markers	58		
6.3. Clear Markers	59		
6.4. Marker Coupling	59-60		
6.5. Reference Marker & Delta Mode	60		
6.6. Scale Axis from Marker Position	61		
6.7. Marker Searches	61		
6.7.1. Marker Tracking	61		

6.7.2. Search Range	62
6.7.3. Search Coupling	62
6.7.4. Max / Min Search	62
6.7.5. Peak Search	62-63
6.7.6. Target Search	63-64
6.7.7. Bandwidth Search	64-65
6.7.8. Notch Search	65-66
<b>7. Memory Calculations (Memory Math)</b>	<b>66-67</b>
<b>8. Measurement Pass / Fail Tests</b>	<b>67-71</b>
8.1. Specification Limit Test	67-68
8.2. Ripple Test	68-70
8.3. Bandwidth Test	70-71
<b>9. Window / Display Configuration</b>	<b>71-74</b>
9.1. Display Update	71-72
9.2. Main Menu Bar	72
9.3. Channel Labels	72-73
9.4. Axis Labels	73
9.5. Invert Colors	73-74
<b>10. Save &amp; Recall Data</b>	<b>74-77</b>
10.1. Instrument Settings, Calibration State & Measurement Data	74-75
10.1.1. Saving State Data	75
10.1.2. Recalling State Data	75
10.2. S-Parameter Data	76
10.3. Trace Screenshot	77
10.4. Trace CSV Data	77
<b>11. Simulation Mode</b>	<b>77-81</b>
11.1. Starting Simulation Mode	78-79
11.2. Simulation of S-Parameter s2p Files	79-81
<b>D-CALIBRATE</b>	<b>82-112</b>
<b>1. VNA Error Sources</b>	<b>82-84</b>
1.1. Types of Error	82
1.1.1. Random Errors	82
1.1.2. Drift Errors	82
1.1.3. Systematic Errors	83
1.2. Correcting for VNA Error Sources	83
1.3. Isolation Considerations	83-84
<b>2. Calibration Theory</b>	<b>84-85</b>
2.1. Calibration Process Flow	84
2.2. How Often to Calibrate	85
2.3. Reference Plane	85
<b>3. eVNA Calibration Standards</b>	<b>86-95</b>
3.1. SOLT Calibration	86
3.2. Insertable & Non-Insertable	87-88
3.2.1. 12-Term Error Model	88-89
3.3. Automatic / Electronic Calibration (eMCal)	89
3.4. Selecting a Cal Kit	89-90
3.4.1. Mini-Circuits' KSOLT-63-x Cal Kits	90-91

3.4.2. Ideal Cal Kit	91
3.5. Adding / Modifying Cal Kits	91
3.5.1. Select and Name a Cal Kit	92
3.5.2. Define Cal Kit Standards	92-93
3.5.3. Define Subclasses	93-94
3.5.4. Export / Import of XTML Cal Kit Definitions	94
3.6. Enabling Error Correction	95
3.7. Clearing Calibration Data	95
<b>4. Calibration Methods</b>	<b>96-110</b>
4.1. Response Calibration	97
4.1.1. Thru Response (Transmission Tracking)	97-99
4.1.2. Open / Short Response (Reflection Tracking)	99-102
4.2. Enhanced Response Calibration	102-105
4.3. One Port Calibration	105-107
4.4. Two Port Calibration	107-110
<b>5. Optimizing Calibration Conditions</b>	<b>110-111</b>
<b>6. Calibration Verification</b>	<b>111-112</b>
6.1. Smith Chart Analysis	111
6.2. Golden DUT	112
<b>7. Additional Calibration Options</b>	<b>112</b>
7.1. Power Calibration	112
7.2. Receiver Calibration	112
7.3. Cal Trig Source	112

**E-MEASURE 113-123**

<b>1. Measurement Process Flow</b>	<b>113</b>
<b>2. Measurement Examples</b>	<b>114-118</b>
2.1. One Port Device Measurement (Antenna Example)	114-115
2.2. Pair of One Port Device Measurements (Dual Antenna Example)	116
2.3. Two Port Passive Device Measurement (Bad Pass Filter Example)	117-118
<b>3. De-Embedding Measurement Data</b>	<b>119-122</b>
3.1. Port Extension	119-121
3.2. Time Domain Gating	122
3.3. Modify the Cal Kit	122
<b>4. Optimizing Measurement Speed vs Measurement Performance</b>	<b>122-123</b>
4.1. Number of Sweep Points	122
4.2. Turn off Display Update	122-123
4.3. Use a Single Source	123
4.4. IF Bandwidth	123
4.5. Data Averaging	123
4.6. Sweep Power Level	123

# A - Introduction

## 1. About the eVNA-63+

Mini-Circuits' eVNA-63+ is a high performance, software-controlled vector network analyzer (VNA). By moving the complex data processing and calculation required of vector network measurements out of the instrument and into an advanced software package, Mini-Circuits is able to offer a fully-featured but cost effective VNA for every test bench.

The product ships with Mini-Circuits' eVNA Studio software package, providing a powerful GUI which will feel familiar to any engineer with experience of VNA measurements.

### 1.1. Key Features




- Time domain analysis & gating
- Full 2-port, 2-path s-parameter measurement (S11, S21, S12, S22) in a variety of formats
- Complete vector network analysis capability
- Application programming interface (API) for measurement automation
- Robust SCPI command interface (compatible with legacy VNA models)
- Touchstone file support (import & export) for use with Electronic Design Automation (EDA) simulation tools
- Offline simulation mode for measurement preparation, training and analysis of s-parameter data with no hardware present
- Port extension / de-embedding
- Internal bias-tees for powering of active DUT (devices under test)



### 1.2. Concept & Control Options

Mini-Circuits' eVNA concept is a system formed from 3 elements, all of which are required for VNA functionality:

1. Host PC with Microsoft Windows
2. eVNA-63+ hardware connected by USB to the host PC
3. eVNA Studio software package running on the host PC

Label	Meaning
	Meets the requirements of the following applicable European directives and carries the CE marking accordingly: <ul style="list-style-type: none"><li>• Low Voltage Directive 2014/35</li><li>• Electromagnetic Compatibility – Directive 2014/30/EU</li><li>• Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) – Directive 2011/65/EU</li></ul>
	Meets the requirements of the following applicable UK directives and carries the UKCA marking accordingly: <ul style="list-style-type: none"><li>• Electrical Equipment (Safety) Regulations 2016</li><li>• Electromagnetic Compatibility Regulations 2016</li><li>• The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012</li></ul>
	This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

## 2. About this Guide – Prepare, Practice, Calibrate & Measure

VNAs are precision test instruments, based on relative measurements made between the internal source and receivers. To achieve the specified accuracy, careful thought must be given to the complete measurement process, from understanding the features / limitations of the instrument, to the hardware connections, to calibration and instrument settings, to data interpretation.

This user guide is intended for test engineers of any level of experience who intend to perform RF measurements on 1 or 2 port devices with Mini-Circuits' eVNA-63+. It outlines the specific instructions for software installation, hardware setup, VNA calibration and error correction, and provides recommendations on best practice for RF measurements. It is recommended that the user familiarize themselves with all aspects of this guide before starting measurements.

The core sections of this guide are structured into Mini-Circuits' measurement philosophy, as defined below:

### 1. Prepare

- Familiarize yourself with RF and measurement basics and best practices
- Setup and understand the eVNA Studio software
- Review any applicable reference material to support the measurement

### 2. Practice

- Use appropriate, high quality and well-maintained accessories
- Define the measurement goals and requirements
- Trial connections and instrument settings to ensure all needed components and accessories are readily available

### 3. Calibrate

- Inspect the test environment and take steps to minimize sources of random error
- Select and examine calibration standards, ensuring they are clean, high quality and free of damage
- Consider systematic measurement error sources and perform a careful calibration

### 4. Measure

- Configure the eVNA Studio software settings
- Perform the measurement
- Understand the results

## 2.1. Measurement Automation / Programming with SCPI

This guide focuses on VNA measurements using the Graphical User Interface (GUI) of the eVNA Studio software package. The software also includes an Application Programming Interface (API) which allows automation of all eVNA features from most common programming environments, including Python, LabVIEW, C# and many more. The process involves creating a raw socket connection, either within the host PC or from a remote PC across a TCP / IP network, and sending a series of standard SCPI commands for control of the eVNA.

Where possible, this guide also includes a summary of the SCPI sequence used to achieve the particular action being described in the GUI. SCPI sequences will be presented at the end of relevant section in the format below:

```
SCPI
SENSe:FREQuency:STARt 500000
SENSe:FREQuency:STOP 6000000000
SENSe:SWEp:POINts 201
```

Full instructions for programming with the eVNA-63+, including how to implement the SCPI commands, are covered in the programming manual available from our website at:

[minicircuits.com](http://minicircuits.com)

## 2.2. Terminology

For clarity, the following general terms are used throughout our documentation to refer to VNA concepts and the specifics of Mini-Circuits' eVNA implementation.

Term	Intended Meaning
<b>VNA</b>	A reference to Vector Network Analyzer test equipment in general, as available from a range of manufacturers.
<b>eVNA</b>	Mini-Circuits' family of VNA products, including hardware and software elements.
<b>eVNA-63+</b>	Mini-Circuits' eVNA-63+ model, operating over 300 kHz to 6 GHz.
<b>eVNA Studio</b>	The advanced software package required for operation of Mini-Circuits' eVNA family, including a GUI & API.
<b>Host PC</b>	The local PC connected by USB to the eVNA-63+ hardware and running the eVNA Studio software.
<b>Remote PC</b>	A second PC, attached to the same network as the host PC and capable of remotely operating the eVNA via the API.

## 2.3. Languages

Please contact [testsolutions@minicircuits.com](mailto:testsolutions@minicircuits.com) if instructions are required in other languages.

### 3. Support Contacts

We are here to support you every step of the way. For technical support and assistance, please contact us at the email address below or refer to our website for your local support:

[testsolutions@minicircuits.com](mailto:testsolutions@minicircuits.com)

[minicircuits.com/contact/worldwide\\_tech\\_support.html](http://minicircuits.com/contact/worldwide_tech_support.html)

### 4. Warranty & RMA Returns

Mini-Circuits provides a 3-year warranty with all eVNA-63+ systems. Please contact your account manager or refer to our website for full details:

[minicircuits.com/support/ordering.html](http://minicircuits.com/support/ordering.html)

If you have any questions or concerns with your eVNA-63+, please contact us in the first instance through [testsolutions@minicircuits.com](mailto:testsolutions@minicircuits.com). Our team will work with you promptly to understand and resolve any issues. As a software-controlled instrument, it is usually possible to resolve issues remotely without requiring the unit to be returned to the factory. In the event that a return to the factory is necessary, Mini-Circuits will provide an RMA number and full return instructions.

### 5. End of Life

Please contact [testsolutions@minicircuits.com](mailto:testsolutions@minicircuits.com) to review environmentally friendly end of life disposal options.

## B - Prepare

### 1. Safety & Cautions

The eVNA-63+ instrument and external AC / DC power adapter module contain no user serviceable parts and should not be opened. Discontinue use and contact Mini-Circuits in the event of visible damage to any parts.

#### Caution:

- Only use the AC / DC power supply adapter supplied with the instrument.
- The AC plug acts as the mains disconnect for the equipment. The user should ensure the equipment is positioned so that the AC and DC plugs are not obstructed in the event the user needs to remove power from the equipment.

#### 1.1. Maximum Input Levels

Adhere to the published maximum specifications on all ports as stated in the published datasheet.

Ports	Parameter	Specification Limit
<b>Port 1 &amp; 2</b>	Input Power (below 10 MHz)	+15 dBm max per port
	Input Power (10 MHz to 6 GHz)	+20 dBm max per port
	DC Input Voltage	±30 V max per port
<b>Bias 1 &amp; 2</b>	DC Input Voltage	±30 V max per port
	DC Input Current	200 mA max per port
<b>Trigger In</b>	DC Input Voltage	5V Max
<b>Ref In</b>	Nominal Impedance	50Ω
<b>DC Input</b>	DC Supply Voltage to eVNA-63+	5.25 V max
	DC Supply Current to eVNA-63+	3A max
<b>AC Input</b>	AC Input Voltage to AC / DC power adapter	100-240V

#### Caution:

- Observe ESD precautions when handling and connecting the eVNA-63+ to avoid damage.

#### 1.2. Bias Tee Output Levels

The internal bias-tees on Port 1 & 2 allow a DC bias to be passed to components within the test path as required. The DC voltage current / output is determined by the external source input connected at the Bias 1 & 2 ports. Be sure to check that the DC bias output is within the safe limits of any external devices connected within the RF signal path.

### Caution:

- It is recommended to disable the bias-tee outputs when not required in the test application in order to avoid inadvertent damage to external components in the RF signal path.
- The bias-tee outputs should be disabled during calibration.

### 1.3. Operating Environment

The eVNA-63+ is intended for testing of RF components in indoor laboratory or production test environments. Do not use in damp or excessively humid conditions, or in any other condition which exceeds the published environmental specifications.

Condition	Specification
Operating Temperature	+5 to +50°C
Storage Temperature	-35 to +75°C
Relative Humidity	5% to 85% (non-condensing)
Pollution Degree	1 - No pollution or only dry, non-conductive pollution
Altitude	2000 m

### 1.4. User Service / Cleaning

The only user-performed service possible for eVNA models is external cleaning of the case and connectors as needed. Do not use any detergents or spray cleaning solutions. The case can be cleaned with a soft, slightly dampened cloth and the connectors with an alcohol solution. Do not allow any liquid ingress into the case or connectors.

## 2. Factory Calibration

As a precision test instrument, regular factory calibration is necessary to ensure continued operation within the published specifications. The recommended calibration period is annually. Mini-Circuits offers 2 approaches to factory calibration, intended to provide a flexible choice based on your budget and test requirements:

### 2.1. Standard Factory Cal - Lowest-cost

Place your calibration order with any Mini-Circuits sales office, or authorized representative / distributor and ship the unit back to Mini-Circuits with the details provided. Mini-Circuits will calibrate and return the unit, accompanied by the calibration data and certificate.

### 2.2. Premium Factory Cal - Zero Down-time

After receiving your calibration order, Mini-Circuits will send a fully calibrated replacement unit to your door for use while your own unit is returned. Simply replace your own unit in the same packaging and ship back to Mini-Circuits. Mini-Circuits will calibrate and return your unit, accompanied by the calibration data and certificate. The loan unit can then be returned to Mini-Circuits, again using the same packaging.

## 3. Software Setup

### 3.1. Software Downloads & Resources

The full eVNA Studio software package including GUI and API is available for download from:  
[minicircuits.com/softwaredownload/evna.html](http://minicircuits.com/softwaredownload/evna.html)

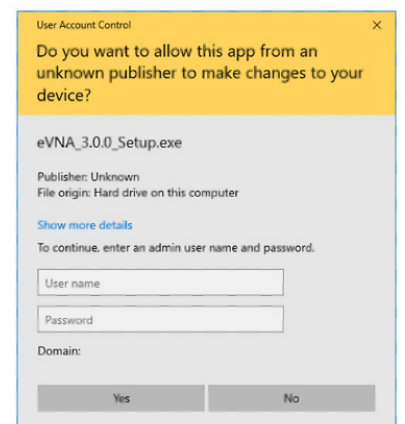
### 3.2. System Requirements

The minimum requirements for installation of the eVNA software package and API on the host PC are:

- Microsoft Windows 7 or 10 (64-bit)
- Intel i3 processor or equivalent
- 8 GB RAM
- USB 2.0 or later

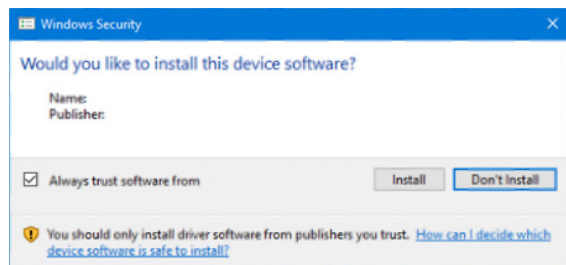
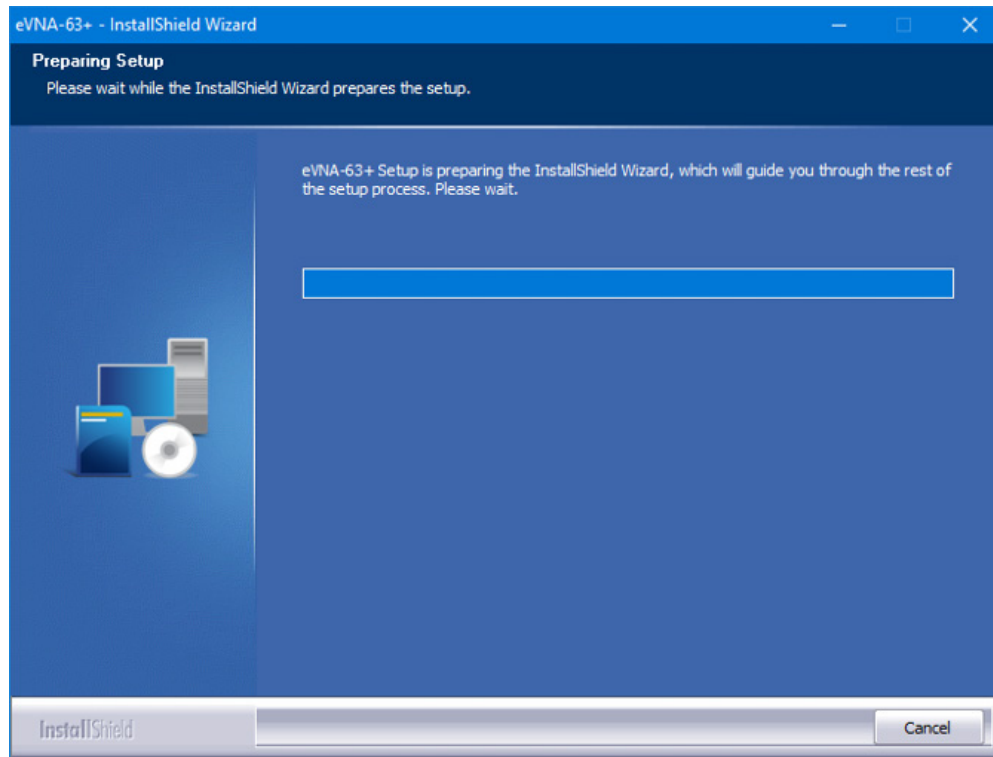
### 3.3. eVNA Studio Software Installation

1. Download the eVNA Studio software package from:  
[minicircuits.com/softwaredownload/evna.html](http://minicircuits.com/softwaredownload/evna.html)
2. Run the eVNA\_x.x.x\_Setup.exe installation program.
3. If Microsoft Defender SmartScreen provides a warning about an unrecognized app, select "More Info" and then "Run Anyway".
4. If prompted by Windows User Account Control, enter the username and password for an account with permission to install software on the PC.

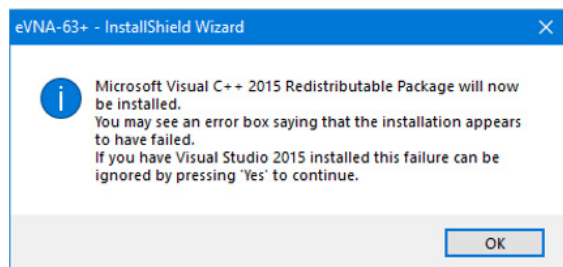




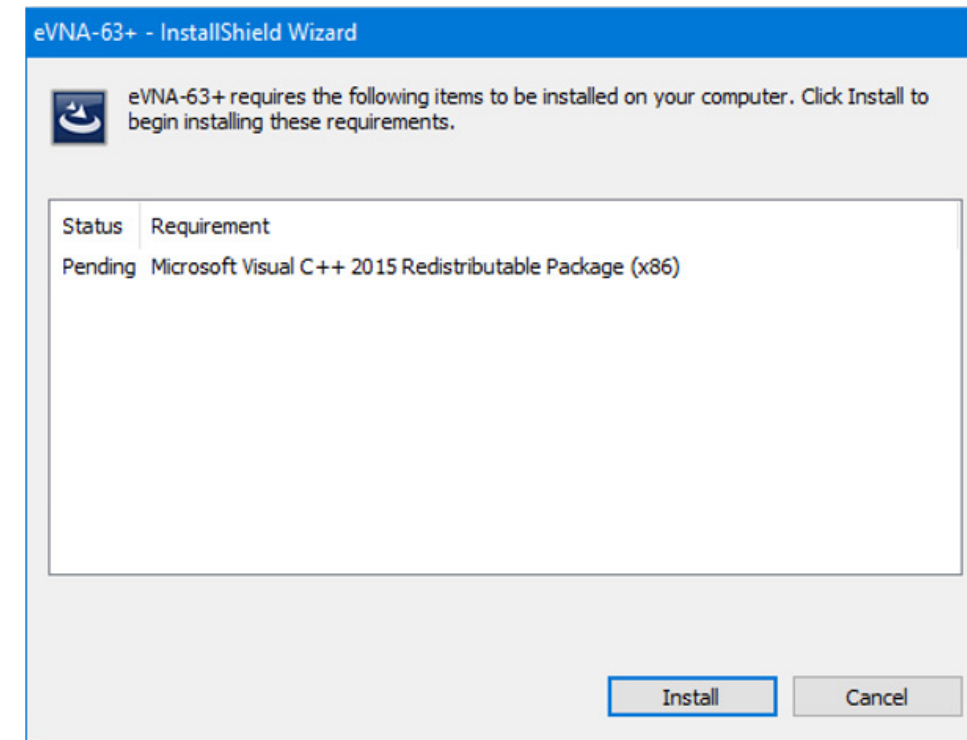
5. The InstallShield Wizard will load, followed by a Windows Security prompt asking for permission to install the software.



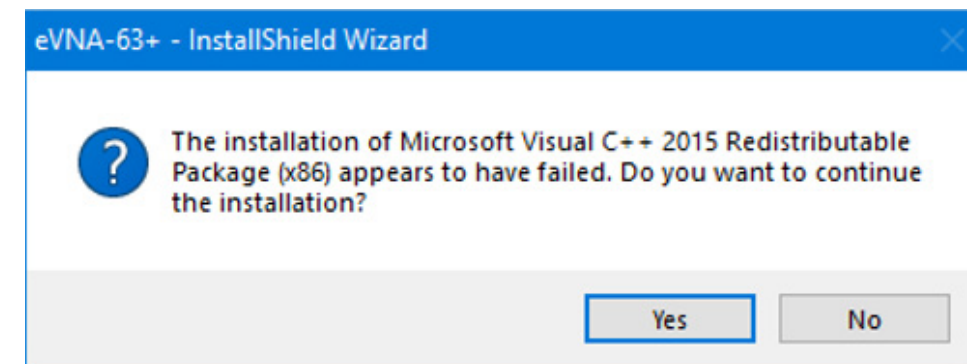
- a. You may optionally select "Always trust software from Mini-Circuits" to avoid similar prompts for Mini-Circuits eVNA software in future.
- b. Click Install to proceed with the installation.
6. Click OK on the prompt confirming that "Microsoft Visual C++ 2015 Redistributable Package" will be installed.



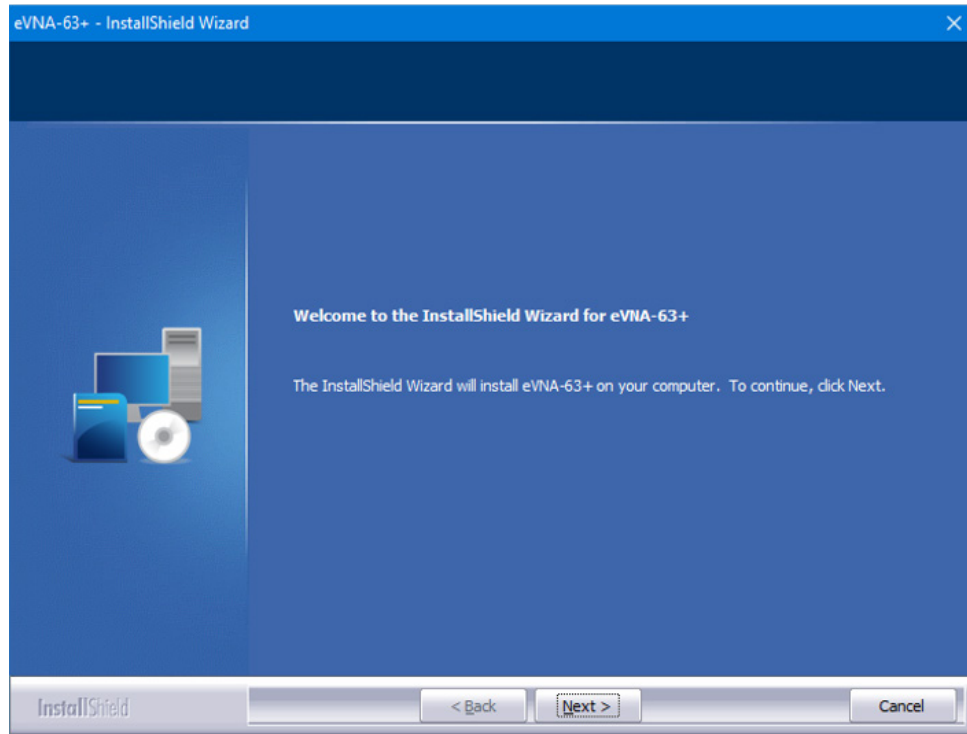
7. Click Install to confirm the installation of "Microsoft Visual C++ 2015 Redistributable Package".



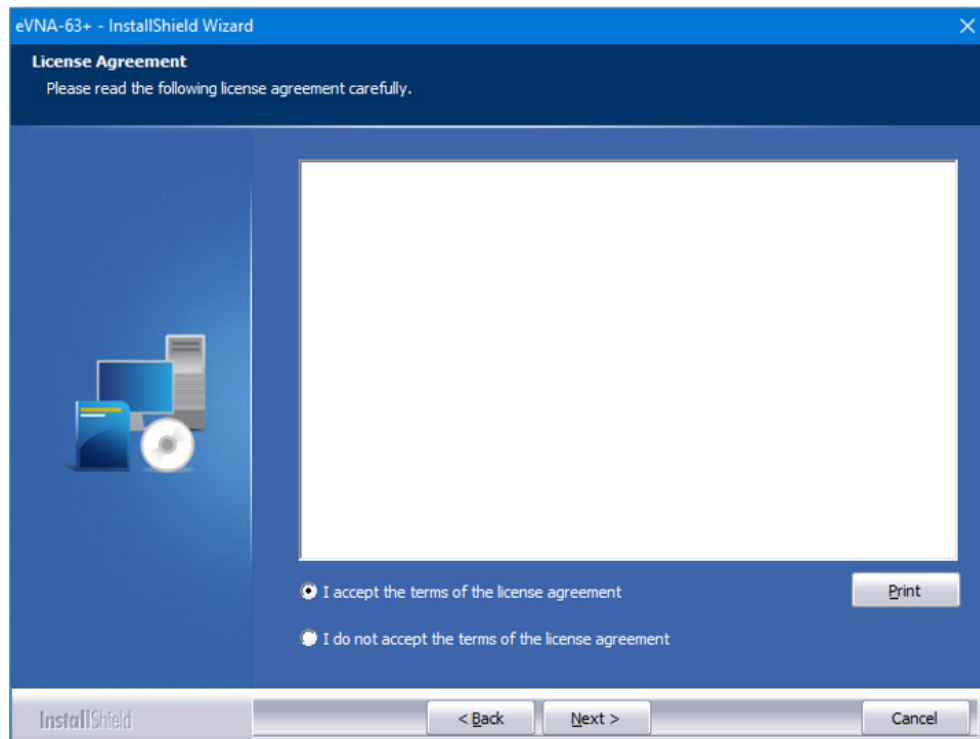
8. A notification may appear to advise that the "Microsoft Visual C++ 2015 Redistributable Package" installation has failed, this is likely due to a different version of the package already existing on the PC. It is recommended to proceed with the installation.



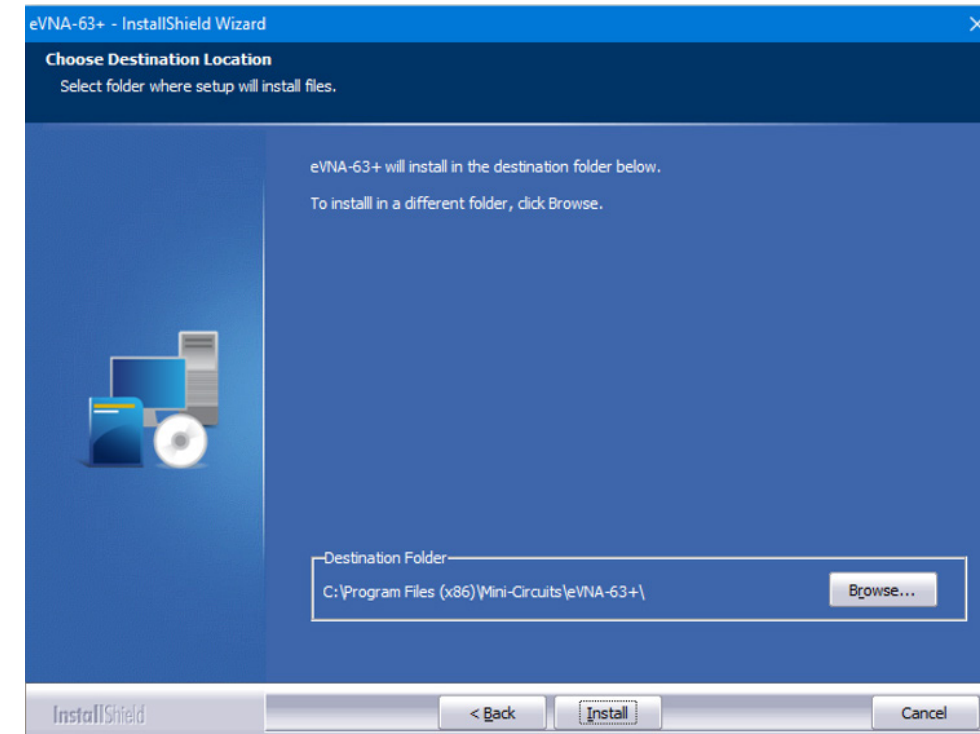
9. The InstallShield Wizard for the eVNA Studio software package will load, click Next to continue.



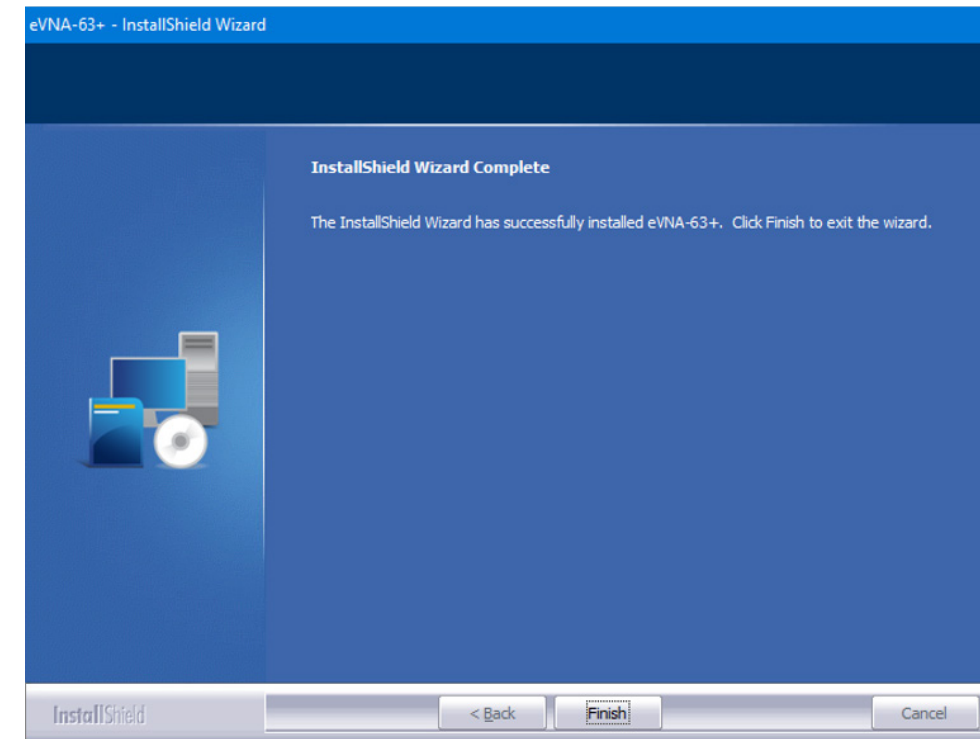
10. Accept the terms of the license agreement and click Next to continue.



11. Click Install to accept the default location (you may first click Browse to select an alternative installation folder if preferred).



12. The final screen will confirm installation of the software, click Finish to finalize.



*In the event of any issues with installation, please refer to the Troubleshooting section of this manual, or [contact testsolutions@minicircuits.com](mailto:testsolutions@minicircuits.com) for support*

## 4. Graphical User Interface (GUI) Overview

The GUI is laid out as shown in figure 1, with a structure that should be familiar to users of legacy VNA instruments. The control panel on the right-hand side provide access to the top-level options with a dynamic sub-panel just to the left providing the next level options based on the user's input. The same set of options are also available from the main menu at the top of the screen, to provide an interface familiar to users of PC software. Table 1 summarizes each of the key elements of the GUI display highlighted in figure 1.

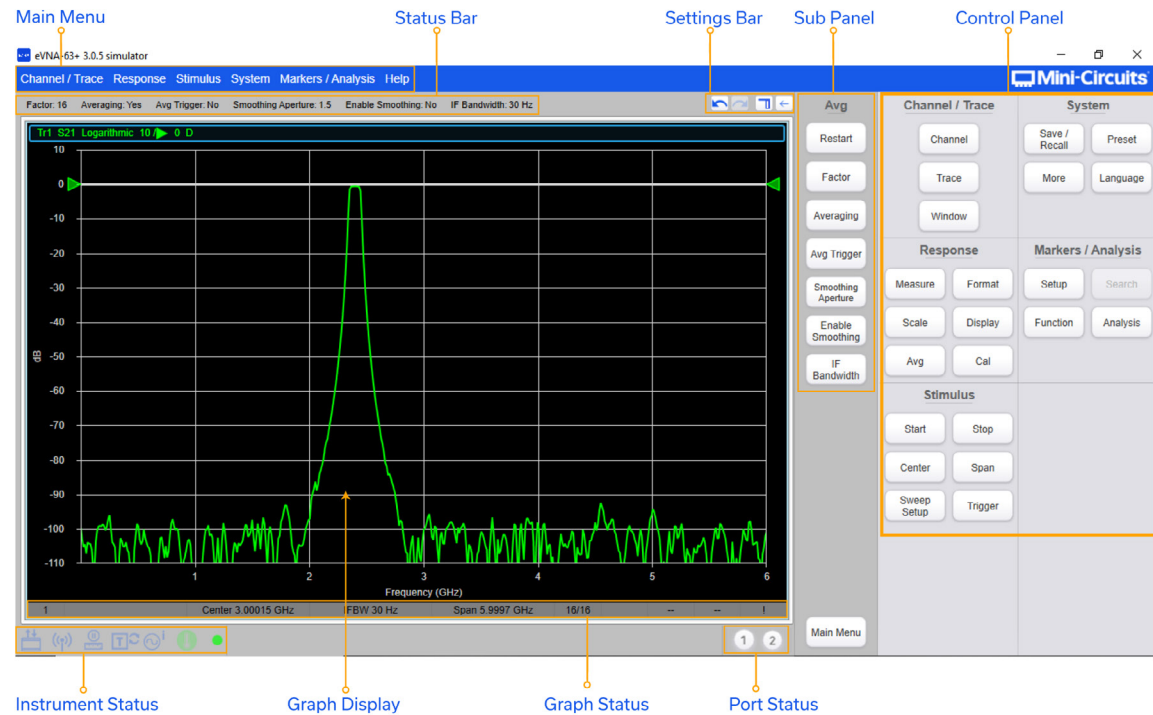


Figure 1: eVNA Studio GUI display

GUI Section	Description
<b>Main Menu</b>	Standard software menu bar with drill down options for all eVNA features.
<b>Control Panel</b>	Control panel with buttons for all top level and second level items accessible from the Main Menu. Provides the same functionality as the Main Menu in a format which should be more familiar to users of legacy VNAs.
<b>Sub Panel</b>	Dynamic panel of buttons which updates to show the relevant options based on the last selection from the Control Panel or Main Menu.
<b>Status Bar</b>	Read-out of the current settings for the last Control Panel / Main Menu selection
<b>Settings Bar</b>	Additional buttons or input fields to specify any parameters required by the Control Panel / Main Menu selection.
<b>Instrument Status</b>	Series of icons indicating the general configuration / status of the eVNA.
<b>Port Status</b>	Icons indicating which of the 2 ports is currently active as the stimulus signal.
<b>Graph Display</b>	Central graphical display showing the measured data and graphs.
<b>Graph Status</b>	Channel and trace parameters for the graph display.

Table 1: Summary of each main section on the eVNA Studio GUI display

### 4.1. Main Menu / Control Panel Groups

The main menu and control panel provide two different interfaces to the same set of features. Navigation through the 2 interface types should feel familiar to users of Windows software and legacy VNA instruments respectively. The top-level groupings are:

1. Stimulus: Define frequency range or time span, power, sweep and trigger parameters. The start and stop frequency, center frequency, or frequency span can be specified.
2. Channel / Trace: Defines the number and arrangement of channels / traces on the data panel
3. Response: Defines the calibration of the DUT, the measurement of the DUT to the stimulus, and the set-up of the graphical display of measurement results.
4. Markers / Analysis: Defines the markers to be used in the graphic display. Markers can be used for peak statistical analysis of the waveform or to mark discrete time / frequency / data points.
5. System: Defines the hardware capabilities of the eVNA system, with options to save and recall different data sets.

### 4.2. Settings Bar & Status Bar

The Settings Bar updates dynamically to provide additional input options where required, for the last selection made through the Main Menu or Control Panel / Sub Panel.

The menu sequence below for example, displays an input box for "Num Traces" to allow the user to enter the number of active traces. The cross icon is used to cancel the input and the tick icon (when shown) or enter key to set the parameter.

Channel / Trace → Trace → Num Traces



The four buttons on the right-hand edge are always shown, from left to right they are:



1. Undo – Undo the last settings change
  2. Redo – Re-apply any change in settings following an "Undo"
  3. Toggle Panels – Toggle the GUI between showing:
    - a. Trace + Control Panel + Sub Panel
    - b. Trace + Sub Panel
    - c. Trace only
    4. Back – Go back to previous level on the sub panel (where it has previously been drilled down through selections made in the Control Panel or Top Menu)
- The status bar is a static read-out of the current settings relevant to the latest menu section.

### 4.3. Instrument Status Icons

The instrument status bar at the bottom of the GUI, beneath the graphical display, contains a series of icons which are either “illuminated” or inactive to indicate the current status of the eVNA instrument. Table 2 summarizes the function of each GUI icon.

Icon	Function	Description
	<b>Bias-tee</b>	Internal bias-tee is enabled <a href="#">System</a> → <a href="#">More</a> → <a href="#">Bias Tee</a>
	<b>Display Updates</b>	Updates to the graph display are enabled <a href="#">Response</a> → <a href="#">Display</a> → <a href="#">Update</a>
	<b>RF Output</b>	RF output is enabled <a href="#">Stimulus</a> → <a href="#">Sweep Setup</a> → <a href="#">Power Menu</a> → <a href="#">RF Out</a>
	<b>Measurement Status</b>	Measurement is initializing or in progress
	<b>Trigger Source</b>	Trigger source selection (internal, external, manual or SCPI): <a href="#">Stimulus</a> → <a href="#">Trigger</a> → <a href="#">More</a> → <a href="#">Trigger Source</a>
	<b>Reference Source</b>	Reference source selection (internal or external) <a href="#">System</a> → <a href="#">More</a> → <a href="#">Reference Clock Source</a>
	<b>Temperature Status</b>	Green (device up to temperature), yellow (device is warming up), or red (over temperature, device will shut down)
	<b>Connection Status</b>	eVNA-63+ instrument hardware or simulator mode is connected <a href="#">System</a> → <a href="#">More</a> → <a href="#">Connections</a>

Table 2: Explanation of each instrument status icon

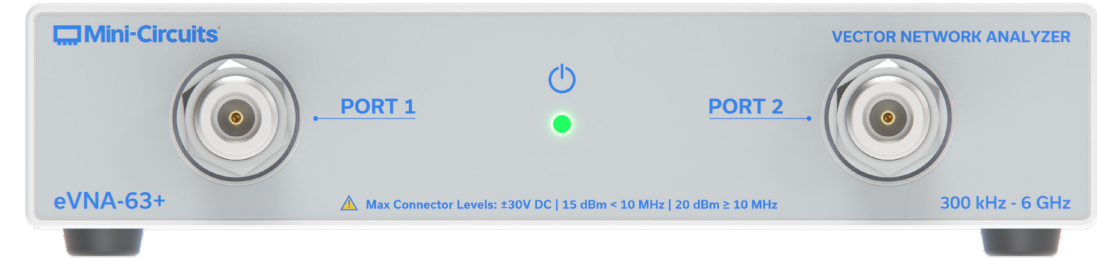
### 4.4. Graph Status Notifications

The graph status bar shows indicates some key parameters / settings for the active channel:

- Active channel number
- Start / Stop / Center / Span frequency
- IFBW - IF bandwidth of the sweep

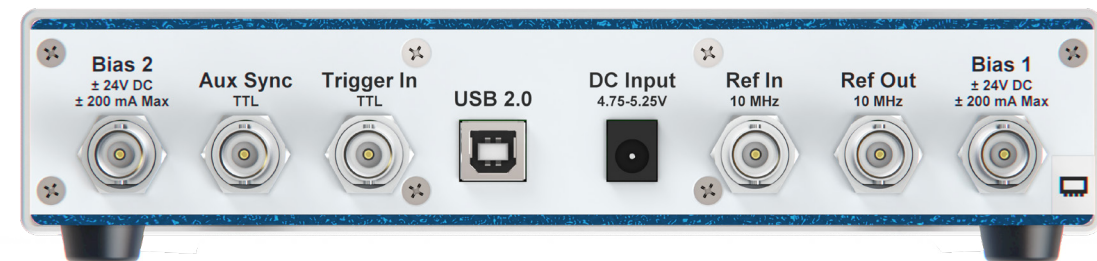
## 5. Hardware Setup

### 5.1. Front Panel Layout



Item Name	Type	Description
<b>Power Indicator</b>	<b>LED</b>	Indicates power and software connection status: <ul style="list-style-type: none"> <li>• Red = Power on but the instrument has not been claimed by the eVNA Studio software on the host PC</li> <li>• Green = Power on and the instrument is assigned to the eVNA Studio software on the host PC (ready to measure)</li> </ul>
<b>Port 1</b>	<b>N-type female</b>	RF source / receiver test port 1
<b>Port 2</b>	<b>N-type female</b>	RF source / receiver test port 2

### 5.2. Rear Panel Layout



Item Name	Type	Description
<b>Bias 1</b>	<b>BNC female</b>	DC voltage input port for bias-tee 1
<b>Bias 2</b>	<b>BNC female</b>	DC voltage input port for bias-tee 2
<b>Aux Sync</b>	<b>BNC female</b>	Auxiliary input (not currently in use)
<b>Trigger In</b>	<b>BNC female</b>	External trigger input
<b>Ref In</b>	<b>BNC female</b>	10 MHz reference input
<b>Ref Out</b>	<b>BNC female</b>	10 MHz reference output
<b>USB 2.0</b>	<b>USB type B</b>	USB control port
<b>DC Input</b>	<b>2.5 mm DC socket</b>	5V DC supply input

### 5.3. Initial Connection & Power-On

#### Note:

- Ensure the eVNA Studio software package is installed on the host PC before proceeding.

1. Connect the USB cable between the eVNA-63+ instrument and the host PC
2. Connect the supplied AC / DC power adapter between the eVNA-63+ and a suitable AC mains power source
3. The eVNA-63+ will power on as soon as the AC supply is turned on, RF measurement functions can then be enabled through the software
4. It is strongly recommended to allow the unit to warm up before calibration or test measurements are carried out. This takes approximately 15 minutes and the temperature indicator in the eVNA Studio GUI will appear green once the instrument has reached a stable temperature.

### 5.4. Test Port Connections

Ports 1 and 2 are the RF test ports, both with the option to be configured as either source or receiver. It is important to use good quality accessories and cables, properly connected and torqued with a suitable torque wrench. Mini-Circuits supplies a full suite of test and calibration accessories.

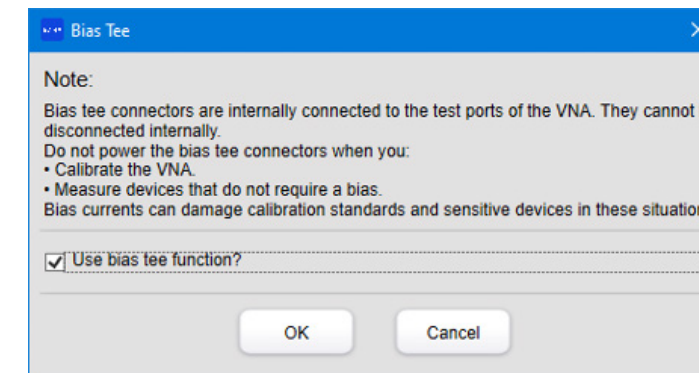
Accessory connectors should be inspected regularly for damage and discarded at the first sign of wear and tear. N-type connector savers are recommended in environments where frequent or high numbers of connections are required on ports 1 and 2. These can then be discarded and replaced in the event of damage, rather than requiring repair to the eVNA-63+ instrument.

### 5.5. Bias-Tee Connections

The bias 1 and bias 2 ports accept a DC voltage from a suitable source (up to 24V, 200 mA on each port). The DC bias can be fed to the measurement ports, Port 1 and Port 2 to support testing of amplifiers and other components which draw the DC supply from the RF path. The DC bias output on ports 1 and 2 can be disabled or enabled together using the software:

1. Select the bias-tee feature:

[System](#) → [More](#) → [Bias-Tee](#)



2. Check the "User bias tee function?" option and click OK to enable the DC voltage outputs
3. Repeat and uncheck the option to disable the DC voltage outputs

#### Caution:

- It is important to disable the DC bias during calibration.
- Both bias-tees are enabled or disabled simultaneously, ensure that all devices connected on both RF ports will tolerate the DC voltages / currents supplied at the respective bias-tee input ports.

#### SCPI

`SYSTem:BIAStee [0|1]`

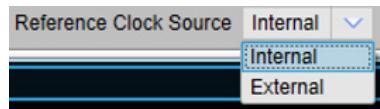
## 5.6. Reference Connections

The Ref In & Ref Out ports allow synchronization of measurements with external test instruments. The reference source can be switched between the internal and external (when connected) sources.

1. Open the reference clock source settings bar

System → More → Reference Clock Source → Internal | External

2. Select from the Internal or External option



### SCPI

SENSe:ROSCillator:SOURce [INTernal|EXTernal]

## 5.7. Trigger In Connection

The Trigger In port allows eVNA measurements to be synchronized with external equipment.

Stimulus → Trigger → ...

### SCPI

TRIGger:...

## 5.8. Functional Block Diagram

Figure 2 is a functional representation of the eVNA-63+ design, including the source, receiver, coupler and bias-tee routing.

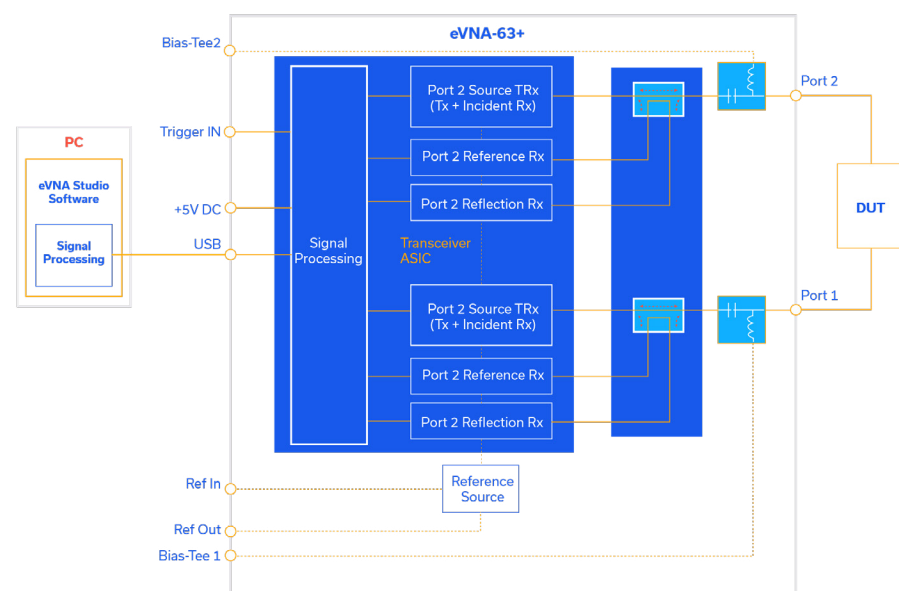


Figure 2: Functional block diagram of the key eVNA sections

## 6. Measurement Essentials

### 6.1. Basic VNA Operation

Figure 3 summarizes the basic elements and signal flows of a generic VNA. Unlike a legacy VNA, the eVNA moves the display and the majority of the processing out of the instrument and on to an external host PC, with the eVNA Studio software package. This simplifies and reduces the cost of the VNA instrument and reduces the risk of obsolescence from an integrated PC within a legacy VNA.

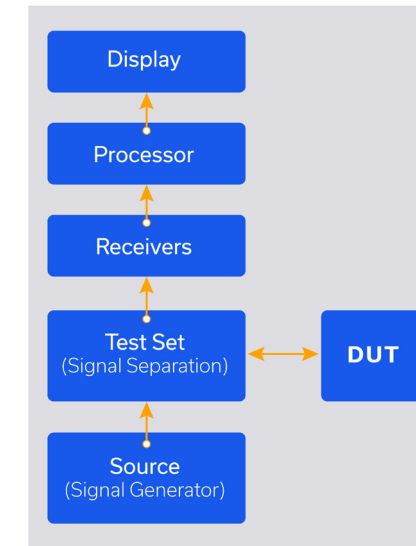


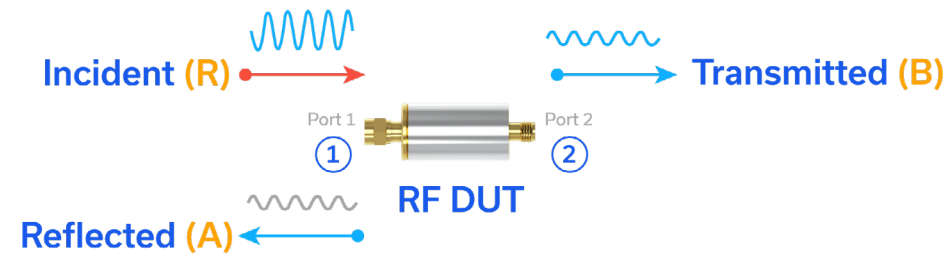
Figure 3: Basic elements of a VNA

The basic components are:

- **Source**  
Signal generator capable of swept or stepped frequency
- **Test Set / Signal Separation**  
Separates incident and reflected waves  
Measures incident signal to use as the reference
- **Receivers**  
Measure real / imaginary data pairs for each measurement  
Can be thought of as small VSA (vector signal analyzers) sharing a common LO (local oscillator)
- **Processor**  
Performs the required number crunching  
Can be an internal processor or external PC
- **Display**  
Screen and user interface

## 6.2. Transmission & Reflection Measurements

Vector network analysis measurement are based on ratios of transmitted and reflected signals, as described in figure 4.



$$\text{Incident (R)} = \text{Reflected (A)} + \text{Transmitted (B)}$$

$$\text{Transmission Coefficient} = T = B/R$$

$$\text{Reflection Coefficient} = \Gamma = A/R$$

Figure 4: Transmitted & reflected signal paths in VNA measurements

These ratio measurements can be analyzed and presented as a number of metrics:

Reflections = $\frac{A}{R} = \frac{\text{Reflected}}{\text{Incident}}$	Transmissions = $\frac{B}{R} = \frac{\text{Transmitted}}{\text{Reflected}}$
Reflection Coefficient ( $\Gamma$ )	Transmission Coefficient ( $\Gamma$ )
S-parameters ( $S_{11}, S_{22}$ )	S-parameters ( $S_{12}, S_{21}$ )
Standing Wave Ratio (SWR)	Gain, Loss
Gain, Loss	Insertion Phase
Impedance, Admittance	Group Delay

## 6.3. S-Parameters

S-parameters (scattering parameters) describe the reflections and transmissions within a network as complex ratios. They are one of the more widely used set of measurement parameters for characterization of RF & microwave devices for linear / steady-state operation.

The signal flows for s-parameter measurement of a 2-port device with a 2-port VNA are summarized in figure 5.

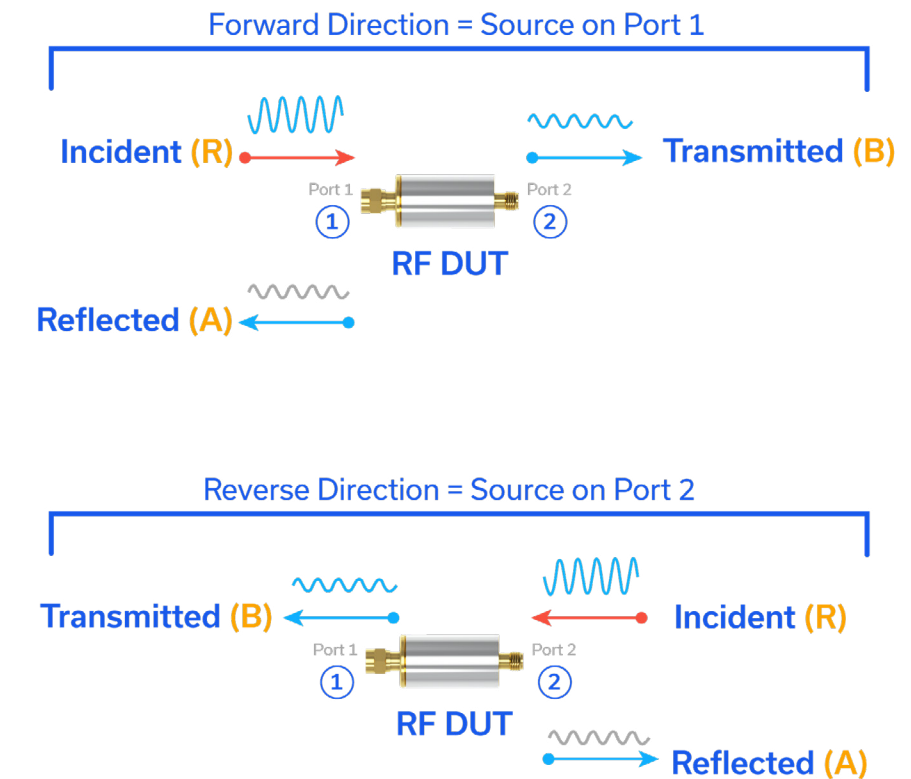


Figure 5: Signal flows in the forward and reverse directions within a 2-port network

The signal relationships for a 2-port device are described by:

Forward Direction	$S_{11} = \frac{A}{R}$ Input return loss	$S_{12} = \frac{B}{R}$ Forward insertion loss / gain
Reverse Direction	$S_{21} = \frac{B}{R}$ Reverse insertion loss / gain	$S_{22} = \frac{A}{R}$ Output return loss

# C - Practice

Accurate and reliable VNA measurements are reliant on a well-designed test setup. For any measurement, a VNA needs to be properly calibrated, with careful consideration given to the external accessories and connectors used, including:

- High quality RF cables from ports 1 and 2
- High quality connector adapters if required for connection to the DUT
- Torque wrench to achieve proper mating on all VNA, cable, adapter and DUT connections

## Note:

- To ensure reliable measurements, cables and connector adapters should be regularly inspected for damage and discarded in the event of any deficiency.

## 1. Accessories

Mini-Circuits provides a complete set of components, accessories, and tools to support any RF and microwave test application. Our full range of catalog components is available from our website but a list of carefully selected accessories is summarized below, recommended for use with the eVNA.



Figure 6: 2-port DUT connected with 1 cable - Ensure a connector saver is used on port 2

### 1.1. Connectors, Connector Savers & Connector Care

It is important to select accessories and cables to match the connector types and genders of the DUT. This may require opposite connector types being presented from the port 1 and port 2 test cables where the DUT has “in-line” connectors (for example male input and female output, or vice versa). All accessories required to connect the DUT must be used during the calibration steps, with the swapping of DUT and calibration standards being the only changes in the setup.

To avoid wear out or damage to the precision RF connectors on the eVNA front panel, it is recommended to use “connector savers” where a device that needs frequent connections / disconnections would otherwise be connected directly to the eVNA. A connector saver for the eVNA is just an adapter with N-type male input and a convenient output connector type for the measurement. This can be left attached to the eVNA and should be discarded in the event of any damage. An example use for the connector saver would be between port 2 and the DUT in figure 6.

For more information, see the application note at:

<https://blog.minicircuits.com/a-simple-trick-to-protect-your-high-frequency-vna-and-save-on-lab-expenses/>

It is important to regularly inspect all connectors used in VNA measurements and discard any worn cables or adapters at the first sign of damage.

Torque wrenches should always be used to ensure a good mate between any accessories and the eVNA. If the connection is too loose then measurement instabilities / inaccuracies may be introduced. Over-tightened connections on the other hand risk damage to the eVNA instrument.

### 1.2. Test Cables

An important factor in ensuring accurate, repeatable measurements in RF test applications is the stability of performance of the test cable used. In most test environments, cables undergo frequent bending during normal use, which can result in changes in phase and other performance parameters. Depending on the cable, these changes can be significant enough to degrade the accuracy and precision of your measurements. Therefore, it is important to consider how bending affects cable phase performance and how a cable is qualified for stability of phase versus flexure.

Phase stability is desirable in test cables because it:

- Ensures tight phase tracking with changing temperature, lowering residual errors and uncertainties
- Extends the length of time between calibrations by minimizing drift

In general, phase is affected by the physical length of the cable assembly, the cable bend radius, and the cable assembly technique. Cables are typically designed to operate over a wide frequency range and minimize attenuation (insertion loss).



The longer the electrical length, the greater the loss. Since electrical length (and loss) is directly proportional to the square root of  $\epsilon_r$ , the dielectric of the cable material, most RF cables are manufactured from materials with a low dielectric constant, usually PTFE (Teflon) and in some cases  $\text{SiO}_2$ . PTFE is more common because it's easy to bend without damaging, while  $\text{SiO}_2$  is brittle and only suitable for semi-rigid cable assemblies.

All Mini-Circuits' cables use PTFE, as a good degree of flexibility is needed in most test applications. One drawback of the flexible PTFE construction is, of course, the potential for phase changes (and other performance changes) due to bending. Bending the cable changes the physical length at the point of bend. It may also constrict and loosen the dielectric, shielding, and braiding around the center conductor, which can also affect the electrical length and result in phase changes.

Consequently, it is important to observe measurement best practice to minimize these effects on VNA measurements:

1. Select only high quality, stable RF test cables, such as Mini-Circuits CBL series
2. Discard cables at the first sign of damage (check the cable, connectors, and the joins between cable and connectors)
3. Use the shortest cable runs possible, but not so short that it impedes the following notes
4. Avoid tight bend radii in the cable arrangements (a longer cable with gentle 270° loop is preferable to a very short, sharp cable bend)
5. Arrange the cables in such a way that the DUT and calibration standards can be swapped in and out without significantly altering the cable arrangements

Figures 7 and 8 present typical applications of these notes.



Figure 7: 2-port DUT connected with 2 sharply bent cables



Figure 8: 2-port DUT connected with 2 longer cables to allow gentle bend

### 1.3. Recommended Accessories

These selected Mini-Circuits accessories are recommended for best performance with the eVNA. A range of connector types are listed to cover any requirements with SMA or N-type DUT.

Cables: [minicircuits.com/WebStore/Cables.html](http://minicircuits.com/WebStore/Cables.html)

Model Name	Description
<b>CBL-2FT-NMNM+</b>	N Male to N Male, Precision Test
<b>CBL-2FT-SMNM+</b>	N Male to SMA Male, Precision Test
<b>CBL-2FT-SFNM+</b>	N Male to SMA Female, Precision Test

Adapters: [minicircuits.com/WebStore/adapters.html](http://minicircuits.com/WebStore/adapters.html)

Model Name	Description
<b>SF-SM50+</b>	Adapter SMA-M to SMA-F
<b>SM-SM50+</b>	Adapter SMA-M to SMA-M
<b>SF-SF50+</b>	Adapter SMA-F to SMA-F
<b>NF-NM50+</b>	Adapter N-M to N-F
<b>NM-NM50+</b>	Adapter N-M to N-M
<b>NF-NF50+</b>	Adapter N-F to N-F
<b>NF-SF50+</b>	Adapter N-F to SMA-F
<b>NF-SM50+</b>	Adapter N-F to SMA-M
<b>NM-SF50+</b>	Adapter N-M to SMA-F
<b>NM-SM50+</b>	Adapter N-M to SMA-M

Terminations: [minicircuits.com/WebStore/terminations.html](http://minicircuits.com/WebStore/terminations.html)

Model Name	Description
<b>ANNE-50+</b>	Termination SMA Male
<b>ANNEF-50+</b>	Termination SMA Female
<b>KARN-50+</b>	Termination N Male

Torque Wrenches: [minicircuits.com/WebStore/PortableTestAccessories.html](http://minicircuits.com/WebStore/PortableTestAccessories.html)

Model Name	Description
<b>TRQ-516-08</b>	SMA Torque Wrench
<b>TRQ-N34-8</b>	N-Type Torque Wrench 3/4" 8 lb-in
<b>TRQ-N20-8</b>	N-Type Torque Wrench 20mm 8 lb-in

## 2. Hardware Connection

After connecting and powering on the eVNA-63+ instrument hardware it needs to be connected to the eVNA Studio GUI on the host PC.

1. Launch the eVNA Studio GUI

2. Find the instrument:

System → More → Connections

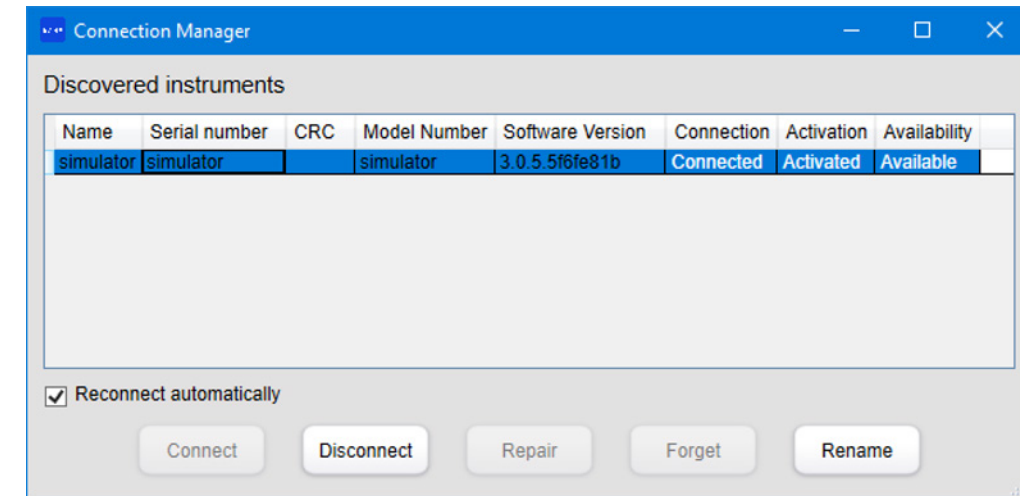


Figure 9: eVNA Studio connection screen showing all available instruments

3. If multiple eVNA-63+ instruments are connected to the PC, select the correct unit by serial number and click Connect

4. If no hardware is available then simulator can be selected instead.

See section Section C 11. Simulation Mode (page 77) for details.

#### SCPI

```
SYSTEM:DISCOVER?
SYSTEM:CONNECT <name>
```

### 2.1. System Reset

To reset the eVNA system (software and hardware) to its default state, for example to start a new measurement configuration from scratch:

System → Preset → OK

#### SCPI

```
SYSTem:PRESet:MODE USER
```

## 3. Channels & Traces

The eVNA supports up to 16 measurement channels with up to 16 traces per channel. Measurement and formatting operations are applied to specific channels and traces so it is important to make sure the relevant channel / traces is selected as the active one when making settings changes.

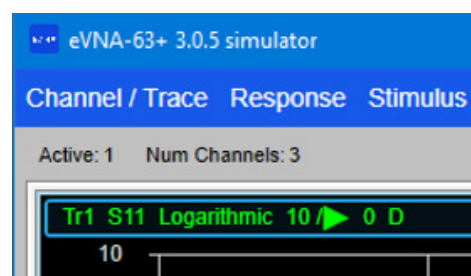
### 3.1. Channels

Whilst all channels have to share physical resources, they can be thought of as completely independent measurement setups, analogous to having a separate eVNA for each measurement set. Each channel can be configured with different cal sets and stimulus settings.

#### 3.1.1. Channel Setup

Additional channels can be added one at a time using the menu. The Status Bar indicates the number of available channels and which one is currently active.

[Channel / Trace → Channel → Allocate Channel](#)



Alternatively, the required number of channels can be specified by opening the Num Channels setting:

[Channel / Trace → Channel → Num Channels](#)



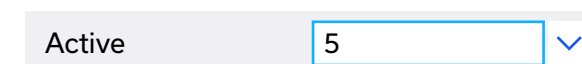
#### SCPI

[DISPlay:CHANnel <number>](#)  
[DISPlay:CHANnel:ACTivate](#)

#### 3.1.2. Active Channel

Most measurement operations and eVNA settings are applied to the active channel. If the required channel is included in the current screen display then clicking it will set it as the active channel. Alternatively, the channel number can be specified by opening the Active channel setting:

[Channel / Trace → Channel → Active](#)



The Previous and Next buttons can be used to quickly toggle between available channels and set each one as active in turn:

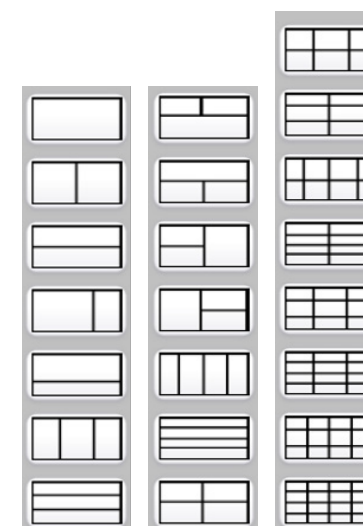
[Channel / Trace → Channel → Previous](#)

[Channel / Trace → Channel → Next](#)

#### 3.1.3. Channel Display

The eVNA Studio GUI can be configured to show a single channel or multiple channels, arranged side by side. The menu presents a list of icons which approximately show the number and arrangement of the channels on screen, up to a 4 x 4 grid for all 16 channels (select the More button to scroll through the full list of options).

[Channel / Trace → Channel → Channel Layout → ...](#)



To quickly maximize the current channel to occupy the full screen, select:

[Channel / Trace → Channel → Max](#)

#### SCPI

[DISPlay:CHANnel:SPLit <value>](#)

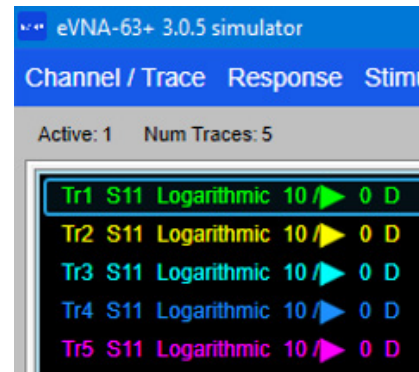
### 3.2. Traces

Within each channel, multiple traces can be configured to display the measured data. Each trace is a separate data plot but all are generated from the same data set captured for the given channel. Traces within a channel all share the same calibration and stimulus settings but can be configured to show different graphs and formats, derived from the same data.

#### 3.2.1. Trace Setup

Additional traces can be added one at a time using the menu. The Status Bar indicates the number of available traces and which one is currently active.

[Channel / Trace → Trace → Allocate Trace](#)



Alternatively, the required number of traces can be specified by opening the Num Traces setting:

[Channel / Trace → Trace → Num Traces](#)

Num Traces

#### 3.2.2. Active Trace

Trace configurations (for example setting the measurement type) are applied to the active trace. Any trace can be designated as the active one by clicking on its summary text in the top-left of the trace display, or by selecting the trace number through the menu:

[Channel / Trace → Trace → Active → n](#)

The Previous and Next buttons can be used to quickly toggle between traces and set each one as active in turn:

[Channel / Trace → Trace → Previous](#)

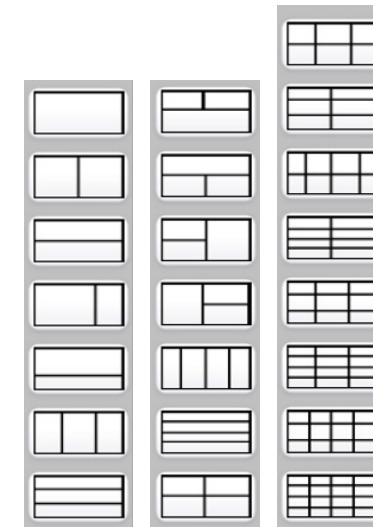
[Channel / Trace → Trace → Next](#)

```
SCPI
DISPlay:CHANnel:TRACe <number>
DISPlay:CHANnel:TRACe[:STATe] 1
```

#### 3.2.3. Trace Display

The GUI can be configured to show multiple traces in the same display, or spread over multiple trace displays. The menu presents a list of icons which approximately show the number and arrangement of the traces on screen, up to a 4 x 4 grid for all 16 traces (select the More button to scroll through the full list of options).

[Channel / Trace → Trace → Trace Layout → ...](#)



To quickly maximize the current channel to occupy the full screen, select:

[Channel / Trace → Trace → Max](#)

```
SCPI
DISPlay:SPLit <value>
```

## 4. Frequency & Power Stimulus Settings

The stimulus settings define the frequency and power of the output ports and any parameters related to the measurement sweep. During normal operation the sweep output is always active but the RF output can be turned off if necessary. To toggle the RF output on or off:

[Stimulus → Sweep Setup → Power Menu → RF Out](#)

```
SCPI
OUTPut[:STATe] <0|1>
```

## 4.1. Frequency Sweeps

The eVNA can operate a frequency sweep with linear or logarithmic values plotted. The default condition is a linear frequency sweep. To configure a frequency sweep:

1. Set the relevant frequency sweep type:

[Stimulus](#) → [Sweep Setup](#) → [Sweep Type](#) → [Lin Freq](#) | [Log Freq](#)

2. Set the frequency sweep range, either in terms of start and stop frequencies, or center and span values

[Stimulus](#) → [Start](#) | [Stop](#) | [Center](#) | [Span](#)

Frequency  KHz

3. Set the number of discrete measurement points required for the sweep (increasing the number of points increases the resolution of the data but takes longer to complete the measurement)

[Stimulus](#) → [Sweep Setup](#) → [Sweep Type](#) → [Points](#)

Points

4. The current sweep settings are displayed in the status bar:

Start: 300K Hz   Stop: 6 GHz   Center: 3.00015 GHz   Span: 5.9997 GHz

### SCPI

```
SENSe:SWEEp:TYPE <LINear|LOGarithmic>
SENSe:FREQuency:STARt <frequency>
SENSe:FREQuency:STOP <frequency>
SENSe:FREQuency:CENTer <frequency>
SENSe:FREQuency:SPAN <frequency>
SENSe:SWEEp:POINts <number>
```

### 4.1.1. Sweep Power Level

The default output power level for the sweep is 0 dBm. This can be adjusted as required for the DUT test scenario, for example to improve signal to noise ratio (SNR) by increasing the port power level, or to protect a sensitive DUT by remaining within its input power rating.

#### Caution:

- Review the power ratings of all devices connected in the test path before selecting an output power level

To set the power level for both ports to the same value, open the simultaneous power input setting:

Power Level  dBm

Ports 1 & 2 can be uncoupled so that power settings can be applied individually to each port.

To toggle port coupling on and off:

[Stimulus](#) → [Sweep Setup](#) → [Power Menu](#) → [Port Couple](#)

Power Level: 5 dBm   Port Couple: No

To set the power level for an individual port, open the power input setting for that port:

[Stimulus](#) → [Sweep Setup](#) → [Power Menu](#) → [Port Power](#) → [Port 1 Power](#) | [Port 2 Power](#)

Port 1 power  dBm

#### Note:

- If port coupling is enabled then this power setting will be applied to both ports.

### SCPI

```
SOURce:POWer[:LEVel][:IMMediate][:AMPLitude] //Power on both ports
SOURce:POWer:PORT:COUPlE <0|1> // Uncouple / couple
SOURce:POWer:PORT <1|2> // Specify port
SOURce:POWer:PORT[:LEVel][:IMMediate][:AMPLitude] <power> // Power on port above
```

### 4.1.2. Sweep Power Slope

The port power level for the sweep can be set to have a positive slope with frequency (specified in dB / GHz). To configure the slope:

1. Specify the slope value

[Stimulus](#) → [Sweep Setup](#) → [Power Menu](#) → [Slope Value](#)

Slope Value  dB/GHz

2. Toggle the slope on and off as needed

[Stimulus](#) → [Sweep Setup](#) → [Power Menu](#) → [Slope](#)

3. The current configuration is indicated in the status bar

Power Level: 5 dBm   Port Couple: No   Slope Value: 2dB/GHz   Slope: Yes

## 4.2. Power Sweeps

Setting the stimulus to power sweep mode allows measurement of a DUT response to increasing power level, for example to plot the compression point of an amplifier. To configure a power sweep:

1. Set the sweep type to power sweep:

[Stimulus](#) → [Sweep Setup](#) → [Sweep Type](#) → [Power](#)

2. Set the fixed frequency for the sweep:

[Stimulus](#) → [Sweep Setup](#) → [Power Menu](#) → [Sweep Frequency](#)

Sweep Frequency  GHz

3. Set the power sweep range, either in terms of start and stop power levels, or center and span values

[Stimulus](#) → [Start | Stop | Center | Span](#)

Power  dBm

4. Set the number of discrete measurement points required for the sweep (increasing the number of points increases the resolution of the data but takes longer to complete the measurement)

Points

5. The current sweep settings are displayed in the status bar:

Start: -32 dBm   Stop: 10 dBm   Center: -11 dBm   Span: 42 dB

### SCPI

```
SENSe:SWEEp:TYPE POWer
SENSe:FREQuency[:CW|FIXed] <frequency>
SOURce:POWer:STARt <power>
SOURce:POWer:STOP <power>
SOURce:POWer:CENTer <power>
SOURce:POWer:SPAN <power>
SENSe:SWEEp:POINts <number>
```

## 4.3. Segmented Frequency Sweep

Segmented sweeps allow a compromise to be made between data resolution and overall sweep time, by setting the measurement points in a sweep to be focussed at the particular frequency ranges of the DUT characteristic where the highest resolution is required. The sweep for a band pass filter measurement for example, could be configured to have more points in the transition regions where a large variation in data is expected, with fewer points in the pass band and far into the stop band.

To configure a segmented sweep:

1. Open the segment table

[Stimulus](#) → [Sweep Setup](#) → [More](#) → [Edit Segment Table](#)

	Start	Stop	Number of points	IF BW	Power Level	Sweep Mode
1	300 kHz	2 GHz	51	1 kHz	-50 dBm	Fast
2	2.000000001 GHz	3 GHz	101	1 kHz	-50 dBm	Fast
3	3.000000001 GHz	6 GHz	51	1 kHz	-50 dBm	Fast
4						

Display Mode  
 Center / Span  
 Start / Stop

Optional Fields  
 IF BW       Power Level  
 Delay         Sweep Mode  
 Time

Import ...   Export to ...   OK   Apply   Cancel

2. Set the display mode to specify whether frequency ranges will be entered as start / stop values or center / span values

Display Mode  
 Center / Span  
 Start / Stop

3. Check any optional fields (IF bandwidth, delay, sweep time, power level, sweep mode) required to configure those parameters individually for each segment. The global sweep settings will be applied for any options left unchecked.

Optional Fields  
 IF BW       Power Level  
 Delay         Sweep Mode  
 Time

- Enter the frequency range, number of points and any optional parameters required in the table
- To delete any row, click on it and then use the delete key
- The segment table can be saved to a CSV file as a back-up and to allow easy recall for future test sessions, click the "Export To..." button and specify the filename. Use the "Import To..." button to recall a previous CSV file.



- Click Apply, then OK to apply the sweep segment configuration
- Set the sweep type to segmented  
[Stimulus](#) → [Sweep Setup](#) → [Sweep Type](#) → [Segmented](#)

**Note:**

- Sweep segment frequency ranges must be unique and cannot overlap

**SCPI**

SENSe:SWEp:TYPE SEGMENT  
 SENSe:SEGMENT:DATA <...> // Array of data values (refer to programming manual)

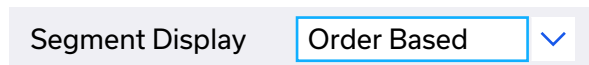
**4.3.1. Linear & Order-Based Trace Display**

The segmented sweep trace can be switched between linear and order-based displays.

The linear display maintains the typical x-axis frequency scale, with gaps in the trace for any frequency ranges not included in the segment table. The order-based display shows a single continuous trace, with the x-axis divided equally over the total number of measurement point. The x-axis is not a continuous scale in order-based mode so no frequency labels are displayed but markers can be used to identify key frequencies.

To toggle between linear and order-based displays:

[Stimulus](#) → [Sweep Setup](#) → [More](#) → [Segment Display](#)



**SCPI**

DISPlay:CHANnel:X:SPACing <LINear|OBASe>

**4.4. Advanced Sweep Settings**

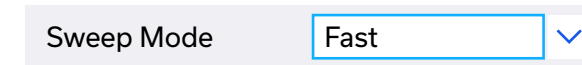
Sweep parameters can be further optimized based on the measurement application, including sweep speed and trigger responses.

**4.4.1. Fast Sweep Mode**

VNA performance is typically a trade-off between best accuracy and fastest measurement time. By default, the eVNA is configured in "normal" mode for best measurement accuracy. "Faster" mode can be selected to optimize for a faster frequency sweep, at the expense of marginally reduced accuracy.

To toggle between fast and normal sweep modes:

[Stimulus](#) → [Sweep Setup](#) → [More](#) → [Sweep Mode](#)



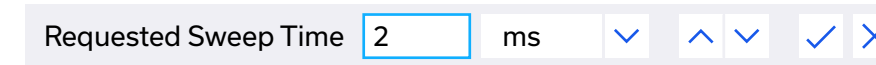
**SCPI**  
 SENSe:SWEp:GENeration <STEPped|FSTepped> // Normal / fast mode

**4.4.2. Sweep Time Period**

The eVNA allows a specific time period to be requested for the sweep. If the requested period is longer than the minimum period required (based on the current sweep configuration), the sweep will be slowed down to fit the request. If the time period requested is shorter than the minimum possible period, the sweep will run at the fastest speed and the actual time taken will be reported in the status bar.

To request a specific sweep time period:

[Stimulus](#) → [Sweep Setup](#) → [Requested Sweep Time](#)



Requested Sweep Time: 2 ms    Actual Sweep Time: 20.1 ms

To reset to automatic sweep time period (toggles on and off):

[Stimulus](#) → [Sweep Setup](#) → [Auto Sweep Time](#)

**SCPI**

SENSe:SWEp:TIME:AUTO <0|1>  
 SENSe:SWEp:TIME[:DATA] <time>

**4.4.3. Sweep Delay**

An arbitrary time delay can be inserted before a sweep commences to allow for any settling time required by the DUT:

[Stimulus](#) → [Sweep Setup](#) → [Sweep Delay](#)

Sweep Delay  sec ⌵ ⬆ ⬇ ✓ ✕

```
SCPI
SENSe:SWEp:DElay
```

**4.4.4. Spur Suppression**

The eVNA automatically removes certain low-level, narrow band, spurious signals from the measurement data to improve measurement quality. These signals are typically generated due to spurious interactions between the internal timing functions of the eVNA. For measurement of a very narrow band DUT (in the order of 1 kHz) it may be necessary to disable the spur suppression to ensure accurate measurements.

To toggle the automatic spur suppression on and off:

[Stimulus](#) → [Sweep Setup](#) → [More](#) → [Avoid Spurious](#)

Avoid Spurious: No

**4.5. Sweep Triggers**

Measurement sweeps commence in response to a trigger signal. By default, the eVNA is set to the internal trigger source in continuous mode, meaning sweeps repeat continuously.

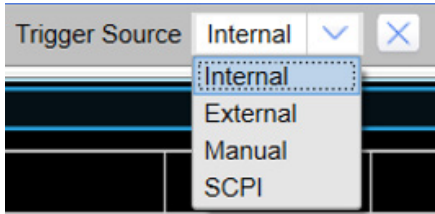
**4.5.1. Trigger Source**

The eVNA supports 4 trigger sources:

1. Internal – Default mode, sweeps run continuously
2. External – Sweeps are triggered by a TTL signal on the Trig In port
3. Manual – Sweeps are triggered using the Trigger button in the eVNA GUI
4. SCPI – Sweeps are triggered by a SCPI command sent using the API connection

To select the trigger source:

[Stimulus](#) → [Trigger](#) → [More](#) → [Trigger Source](#)



To initiate a trigger signal in Manual mode:

[Stimulus](#) → [Trigger](#) → [More](#) → [Trigger](#)

To insert a fixed time delay in External mode, between an external trigger input being received and the sweep commencing (1 second max):

[Stimulus](#) → [Trigger](#) → [More](#) → [Ext Trig Delay](#)

Exit Trig Delay  ps ⌵ ⬆ ⬇ ✓ ✕

The trigger scope can be toggled between all channels and the active channel only:

[Stimulus](#) → [Trigger](#) → [More](#) → [Trigger Scope](#)

Trigger Scope  ⌵ ✕

```
SCPI
TRIGger:[SEQuence]:SOURce <INTernal|EXTernal|MANual|BUS>
TRIGger:[SEQuence][:IMMEDIATE] // Initiate trigger (manual mode)
TRIGger:EXTernal:DElay <time>
TRIGger:[SEQuence]:SCOpe <ALL|ACTive>
```

**4.5.2. Trigger Mode**

The trigger mode controls the sweep repetition in response to a trigger signal, the options are:

1. Continuous – The sweep restarts on the active channel with every trigger signal
2. Hold – Pauses the sweep on the active channel (measurement traces remain static on the display)
3. Single – A single sweep is run for each trigger signal (the trigger mode then switches to Hold)
4. Hold All Channels – Pauses the sweep on all channels
5. Continuous All Channels – The sweep restarts on all channels with every trigger signal

The trigger mode options are selected at:

[Stimulus](#) → [Trigger](#) → ...

The default behaviour is for a complete sweep to run for each trigger signal. Alternatively, the trigger can be toggled to point mode, where each trigger signal initiates a single measurement.

To toggle between sweep and point triggers:

[Stimulus](#) → [Trigger](#) → [More](#) → [Point Trigger](#)

The current sweep can be aborted with:



```
SCPI
INITiate:CONTinuous <1|0> // Internal / Continuous (1) or Manual / Hold (0)
TRIGger:[SEQuence]:POINT <0|1>
ABORT
```

## 5. Measurement & Data Formatting

### 5.1. Measurement Types

The eVNA supports a number of measurement types, as summarized in table 3. Full 2-port, 2-path s-parameter measurements are available (S11, S12, S21, S22) as well as the absolute signal levels at each receiver.

These measurement types can be specified using:

[Response → Measure → ...](#)

Measurement Type	Description
<b>S11</b>	S-parameter measurement (reflected / incident at port 1). Typically, input return loss for a 1-port device.
<b>S21</b>	S-parameter measurement (transmitted at port 2 / incident at port 1). Typically, forward loss for a 2-port device.
<b>S12</b>	S-parameter measurement (transmitted at port 1 / incident at port 2). Typically, reverse loss / isolation for a 2-port device.
<b>S22</b>	S-parameter measurement (reflected / incident at port 2). Typically, output return loss for a 2-port device (or input return loss for a 1-port device on port 2).
<b>Absolute → A1</b>	Absolute signal level at port 1, when sourced from port 1
<b>Absolute → A2</b>	Absolute signal level at port 1, when sourced from port 2
<b>Absolute → B1</b>	Absolute signal level at port 2, when sourced from port 1
<b>Absolute → B2</b>	Absolute signal level at port 2, when sourced from port 1
<b>Absolute → R11</b>	Absolute reference level at port 1, when sourced from port 1
<b>Absolute → R12</b>	Absolute reference level at port 1, when sourced from port 2
<b>Absolute → R21</b>	Absolute reference level at port 2, when sourced from port 1
<b>Absolute → R22</b>	Absolute reference level at port 2, when sourced from port 1

Table 3: Summary of measurement types supported by the eVNA

```
SCPI
CALCulate:PARAmeter:DEFine S11|S21|S12|S22|A|B|R1|R2 // Set measurement
CALCulate:PARAmeter:SPORT 1|2 // Set source port
```

### 5.2. Graph Types

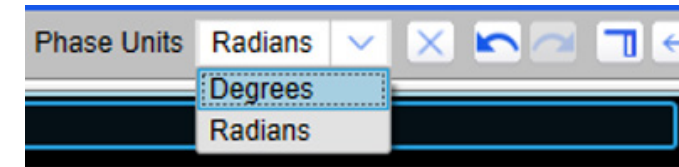
Graphical displays can be configured in a range of formats to suit the measurement type, as summarized in the following sections. Where applicable, the preferred phase unit can be set between degrees or radians:

1. Open the phase units setting:

[Response → Format → More → Phase Units](#)

2. Specify the required units:

[Response → Format → More → Phase Units](#)



#### 5.2.1. X-Y Plots

The eVNA supports the data formats summarized in table 4, on a standard rectangular x-y plot. Measurement results are plotted on the y-axis against stimulus values (typically frequency) on the x-axis.

Each of these options can be set using:

[Response → Format → ...](#)

Format	Description
<b>Log Mag</b>	Logarithmic magnitude (dB)
<b>Lin Mag</b>	Linear magnitude
<b>Real</b>	Real component
<b>Imaginary</b>	Imaginary component
<b>Phase (Deg)</b>	Phase (degrees), "wrapped" to appear on a 1 cycle, ±180 degrees scale
<b>Phase (Rad)</b>	Phase (radians), "wrapped" to appear on a 1 cycle, ±π radians scale
<b>Positive Phase</b>	Phase (degrees or radians), "wrapped" to appear on a 1 cycle, 0 to 360 degrees or 0 to 2π radians scale
<b>Expanded Phase</b>	Expanded / continuous / "unwrapped" phase, presents a clear view of phase linearity
<b>Group Delay</b>	Group delay (seconds)
<b>SWR</b>	Standing wave ratio

Table 4: Rectangular plot data options

```
SCPI
CALCulate[:SELeCted]:FORMat MLOG|MLIN|PHASe|GDELay|UPHase|PPHase|SWR|REAL|IMAGinary
CALCulate[:SELeCted]:PHASe DEGrees|RADIans // Set phase if required
```

### 5.2.2. Polar Plots

Polar plots are available to display complex magnitude and phase data, as shown in figure 10. The magnitude of the measured data is the radial distance from the reference point at the center of the diagram. The phase angle is measured counter-clockwise from the reference axis (indicated as 0 degrees on the plot). Since polar plots do not include a frequency parameter, markers can be used to indicate significant frequencies and data.

Table 5 summarizes the marker data options for the polar plot.

To enable the polar plot and specify the marker data:

[Response](#) → [Format](#) → [More](#) → [Polar](#) → ...

Format	Description
Lin / Phase	Markers summarize linear magnitude and phase (degrees or radians)
Log / Phase	Markers summarize dB magnitude and phase (degrees or radians)
Real / Imag	Markers summarize real and imaginary values

Table 5: Polar plot data options

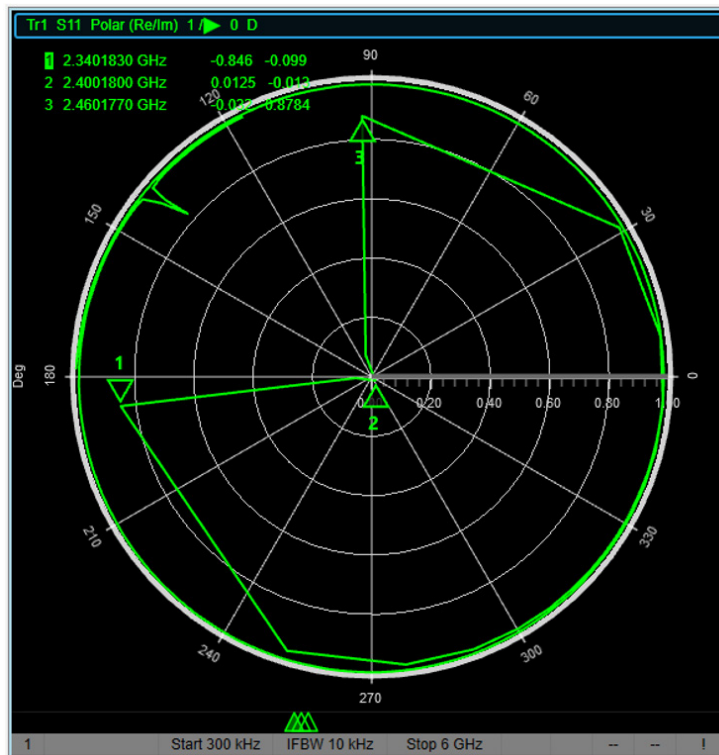


Figure 10: Polar plot representation for a 2.4 GHz BPF S11, with markers set at key frequencies

#### SCPI

```
CALCulate:PARAMeter:DEFine S11|S21|S12|S22|A|B|R1|R2 // Set measurement
CALCulate:PARAMeter:SPORt 1|2 // Set source port
```

### 5.2.3. Smith Charts

The Smith chart is plotted on the complex reflection coefficient plane and scaled in normalized impedances. Similar to the polar plot, frequencies can be indicated using markers since there is no frequency parameter on the Smith chart. Table 6 summarizes the marker data options for the Smith chart.

To enable the Smith chart and specify the marker data:

[Response](#) → [Format](#) → [More](#) → [Smith](#) → ...

Format	Description
Lin / Phase	Markers summarize linear magnitude and phase (degrees or radians)
Log / Phase	Markers summarize dB magnitude and phase (degrees or radians)
Real / Imag	Markers summarize real and imaginary values
R + jX	Markers summarize resistance and reactance values
G + jB	Markers summarize conductance and susceptance values

Table 6: Smith chart data options

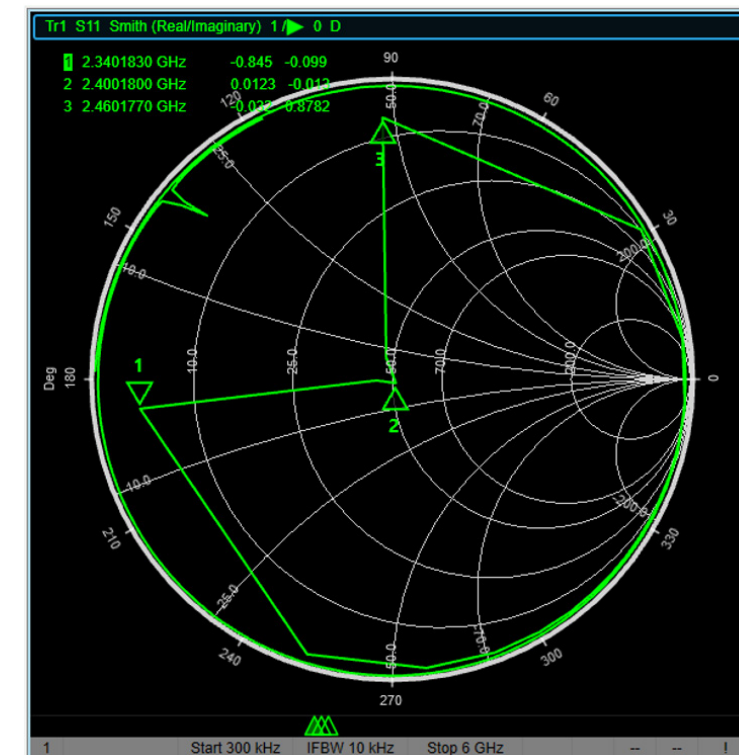


Figure 11: Smith chart representation for a BPF S11, with markers set at key frequencies

#### SCPI

```
CALCulate[:SElected]:FORMat SLINear|SLOGarithmic|SCOMplex|SMITH|SADMittance
CALCulate[:SElected]:PHASe DEGrees|RADIans // Set phase if required
```

Plotting S11 enables the input impedance of a device to be determined over frequency. The closer to the center of the Smith chart the trace is, the closer matched to the 50Ω characteristic impedance. The annotated Smith chart of figure 12 summarizes the characteristics which can be observed. The impedance only has a real resistive component if it lies directly on the x-axis, from 0Ω at the left-hand edge, 50Ω in the center, to infinity on the right-hand edge. If there is an imaginary reactive component to the impedance (either capacitive or inductive), the impedance will have an x-axis and y-axis component to it.

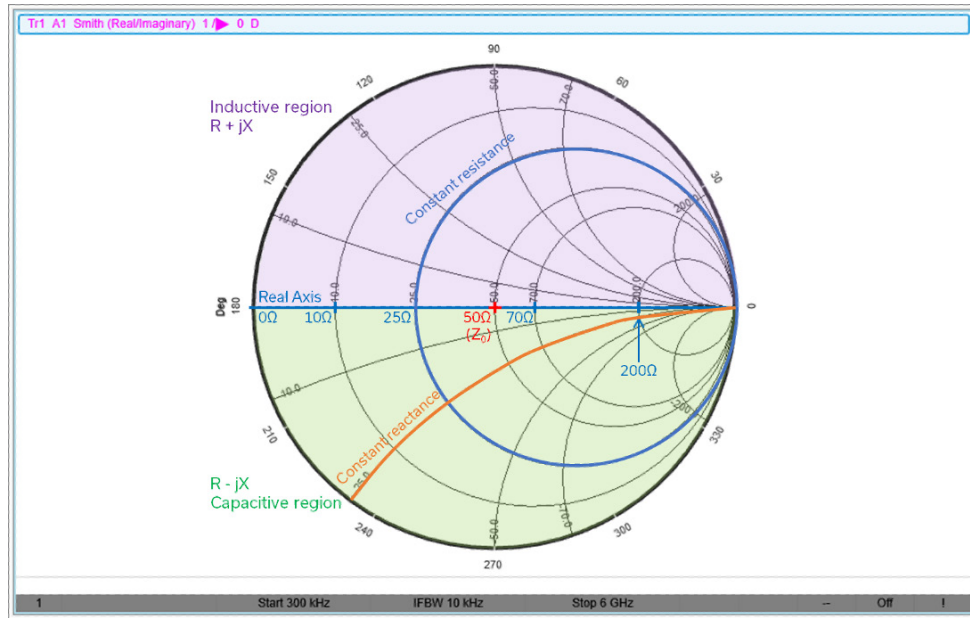


Figure 12: Annotated Smith chart plot

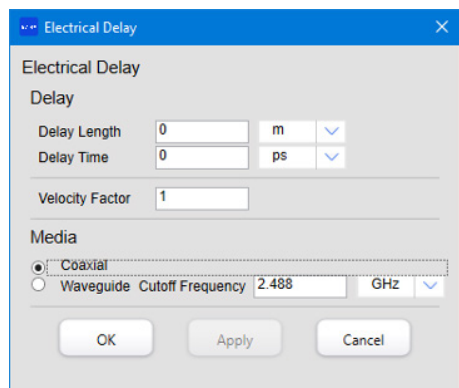
### 5.3. Electrical Delay

A custom electrical delay can be set to shift the phase of the measured data. This feature can be useful for observing the deviation from linear phase.

To move the reference place:

1. Select the electrical delay properties

Response → Scale → More → Electrical Delay



2. Specify the electrical delay time required. If delay length is known instead, enter this and the software will automatically calculate and populate the equivalent delay time value. Delay time must be between -10 and +10 seconds.
3. Adjust the velocity factor for the medium as required
4. The media type can also be set between coaxial and waveguide (the cut-off frequency must be specified for waveguide).
5. Click Apply and OK to set the electrical length

#### SCPI

```
CALCulate[:SElected]:CORRection:EDELay:MEDium <COAXial|WAVeguide>
CALCulate[:SElected]:CORRection:EDELay:TIME <value>
CALCulate[:SElected]:CORRection:EDELay:WGCutoff <value>
```

### 5.4. Scaling

Table x summarizes the options for adjusting the scale on the y-axis. The Auto Scale features are convenient for quickly adjusting the graph to fit the current measurement but a number of specific customization options are also available.

To access the scale options:

Response → Scale → ...

Scale Option	Description
<b>Auto Scale</b>	Automatically adjust the y-axis on the active trace to best present the data
<b>Auto Scale All</b>	Automatically adjust the y-axis on all traces to best present the data
<b>Divisions</b>	Set the number of divisions / increments on the vertical scale
<b>Scale / Div</b>	Set the scale (eg: the number of dB) per division / increment on the y-axis
<b>Reference Position</b>	Set the position of the reference line based on number of divisions from the bottom of the trace screen
<b>Reference Value</b>	Set the reference line value (the y-axis data value at which the reference line intersects the y-axis)
<b>Marker → Reference</b>	Set the reference line value to the data value indicated by the active marker Note: requires at least 1 marker to be active on the trace

#### SCPI

```
DISPlay:WINDow:TRACe:Y[:SCALE]:AUTO // Auto Scale
DISPlay:WINDow:Y[:SCALE]:DIVisions // Divisions
DISPlay:WINDow:TRACe:Y[:SCALE]:PDIVision <value> // Scale / Div
DISPlay:WINDow:TRACe:Y[:SCALE]:RPOSition <divisions> // Reference Position
DISPlay:WINDow:TRACe:Y[:SCALE]:RLEVEL <value> // Reference Value
CALCulate[:SElected]:MARKer:SET RLEVEL // Marker → Reference
```

## 5.5. Averaging

Averaging provides a means to reduce the fluctuations in measurement traces attributable to random noise, allowing a more consistent trace to be presented.

### 5.5.1. Sweep Averaging

With sweep averaging enabled, each discrete data point in a sweep is calculated as an average across a set number of sweeps, therefore minimizing the effect of any random noise fluctuations on the data. This enables a trade-off to be made between measurement speed and measurement accuracy.

To enable data averaging:

1. Specify the number of sweeps over which measurements should be averaged (from 1 to 999):

[Response](#) → [Avg](#) → [Factor](#)

Factor

2. Toggle averaging mode on or off:

[Response](#) → [Avg](#) → [Averaging](#)

The averaging can be restarted if required, to clear all saved averages and begin re-calculating, using:

[Response](#) → [Avg](#) → [Restart](#)

#### SCPI

SENSe:AVERage:COUNT <number>

SENSe:AVERage[:STATe] <0|1>

SENSe:AVERage:CLEar

### 5.5.2. Trace Smoothing

Trace smoothing is distinct from sweep averaging. A moving average is calculated from consecutive points along a single sweep in order to smooth out sudden variations in signal levels. Consequently, measurement speed is faster than the sweep averaging method but there can be a significant reduction in measurement accuracy, particularly for higher smoothing factors. Trace smoothing is usually not recommended.

To enable trace smoothing:

1. Specify the smoothing aperture (from 1.5 to 25):

[Response](#) → [Avg](#) → [Smoothing Aperture](#)

Smoothing Aperture

2. Toggle smoothing on or off:

[Response](#) → [Avg](#) → [Smoothing](#)

#### SCPI

CALCulate[:SElected]:SMOothing:APERture <number>

CALCulate[:SElected]:SMOothing:STATe <0|1>

### 5.5.3. IF Bandwidth

IF bandwidth can be adjusted to trade measurement accuracy against measurement speed. Narrower bandwidths reduce the incidence of random noise on the measurement, increasing the signal to noise ratio. Part of the effect of a narrower IF bandwidth is an increase in data sampling for each point in a sweep, therefore slowing down measurement speed. Wider bandwidths allow a faster measurement speed but at the expense of noise and therefore measurement accuracy.

To set the IF bandwidth (from 1 Hz to 500 kHz):

[Response](#) → [Avg](#) → [IF Bandwidth](#)

IF Bandwidth

## 6. Markers

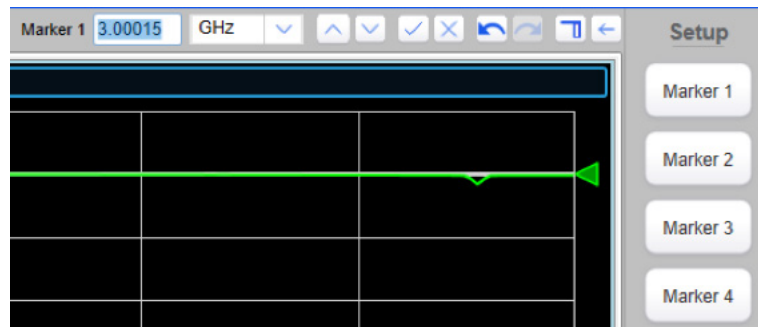
Markers provide a flexible set of options for highlighting significant data points and statistics, performing calculations and searching for particular signal characteristics. The eVNA supports up to 9 markers per trace.

### 6.1. Marker Setup

Up to 9 markers can be added to each trace at specific frequencies:

1. Select the relevant marker (1 to 9), if the marker doesn't already exist it will be placed on the graph at the sweep center frequency

[Markers / Analysis](#) → [Setup](#) → [Marker](#)



2. The marker frequency can be adjusted by overwriting the frequency in the settings bar
3. To add additional markers or switch between existing markers, select the marker in the same way as above
4. Markers will display the frequency and the corresponding data value in the top-left of the trace display



#### SCPI

```
CALCulate [:SElected]: MARKer <number> // Specify marker number
CALCulate [:SElected]: MARKer: ACTivate // Set as the active marker
CALCulate [:SElected]: MARKer: X <stimulus> // Specify the stimulus value
CALCulate [:SElected]: MARKer [:STATe] <0|1> // Disable or enable the marker
CALCulate [:SElected]: MARKer: Y? // Read the marker value
```

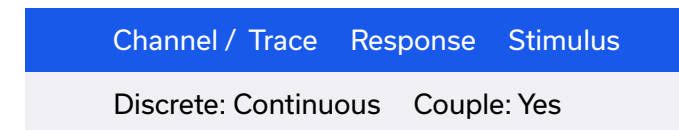
2. The marker frequency can be adjusted by overwriting the frequency in the settings bar
3. To add additional markers or switch between existing markers, select the marker in the same way as above
4. Markers will display the frequency and the corresponding data value in the top-left of the trace display

### 6.2. Moving Markers

Markers can be moved on the trace by editing the frequency input or by clicking and dragging the triangular marker indicator on the trace. By default, the markers are in discrete mode so will only settle on actual measured frequencies when dragging. Each marker can alternatively be set to continuous mode to allow them to be dragged and settle on interpolated frequency points between the measured data:

[Markers / Analysis](#) → [Function](#) → [Discrete](#)

The current marker mode for the active marker is shown in the settings bar:



The current marker mode for the active marker is shown in the settings bar:

#### SCPI

```
CALCulate [:SElected]: MARKer: X <stimulus> // Specify the stimulus value
CALCulate [:SElected]: MARKer: DIScrete <0|1> // Set continuous/discrete mode
```

### 6.3. Clear Markers

To remove an individual marker from the trace:

Markers / Analysis → Setup → More → Clear → Marker n

To remove all markers from the trace:

Markers / Analysis → Setup → More → Clear → All Off

#### SCPI

```
CALCulate [:SElected]: MARKer [:STATe] 0 // Disable the marker
```

### 6.4. Marker Coupling

TMarkers can be coupled together across multiple traces within a single channel, to allow them to be moved simultaneously on the respective traces. A typical example would be a configuration with S11 and S21 displayed side by side, coupling the markers together allows any change in frequency made to the marker position on the S11 trace to be mirrored on the S21 trace.

Only markers with the same number are coupled and coupling is applied independently for each marker number. For example:

- Marker 1 on trace 1 will couple to marker 1 on every other trace
- Marker 1 on trace 1 cannot be coupled with marker 2 on any trace

#### To enable marker coupling:

1. Set up multiple traces
2. Add the required markers on each trace (ensuring markers with the same number are used where coupling is required)
3. Select the marker to be coupled (on any of the traces)  
Markers / Analysis → Setup → Marker n
4. Toggle coupling on for that marker  
Markers / Analysis → Function → Couple
5. The Couple setting can be toggled again to disable coupling, with the current status displayed in the settings bar

Channel / Trace	Response	Stimulus
Discrete: Continuous	Couple: Yes	

#### SCPI

```
CALCulate [:SElected]: MARKer: COUPle <0|1> // De-couple / couple the marker
```

### 6.5. Reference Marker & Delta Mode

In normal mode each marker displays the frequency to which it is pinned and the corresponding y-axis measurement value. In delta mode, the marker displays the delta between the measurement value and a reference value. The reference marker readout shows the pinned frequency and measurement value, with any delta markers showing the delta. Each of markers 1 to 9 can be individually toggled between normal and delta mode but only one reference level can be set for all markers. Figure 13 shows an example trace with markers in normal mode and figure 14 shows the same trace with the markers set to delta mode.

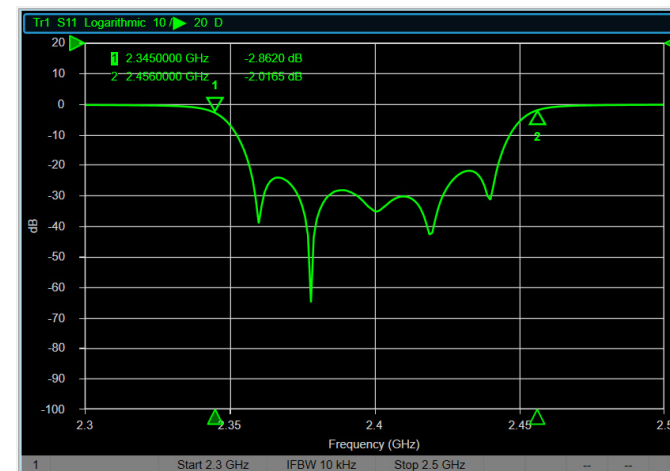


Figure 13: S11 trace with markers 1 & 2 in normal mode

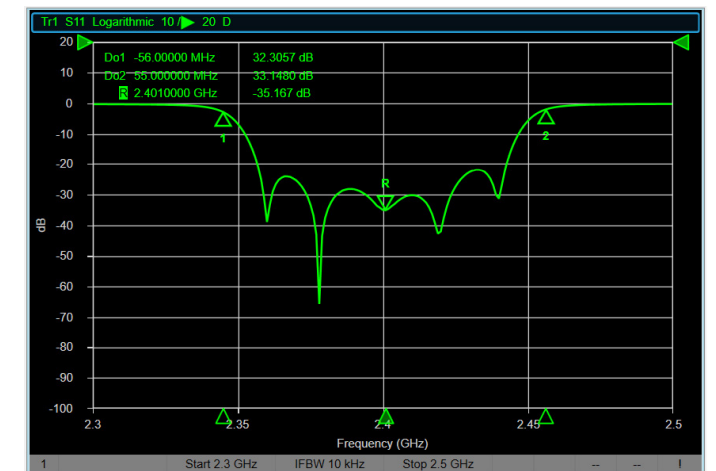


Figure 14: S11 trace with markers 1 & 2 in delta mode from the reference marker

#### SCPI

```
CALCulate [:SElected]: MARKer: REFerence [:STATe] <0|1> // Disable / enable reference marker
CALCulate [:SElected]: MARKer: ACTivate // Set as the active marker
CALCulate [:SElected]: MARKer: X <stimulus> // Specify the stimulus value
CALCulate [:SElected]: MARKer [:STATe] <0|1> // Disable or enable the marker
```

## 6.6. Scale Axis from Marker Position

Markers can be used to quickly adjust the scaling on the x and y-axis based on the current marker position. The scale options are summarized in table below can be accessed using:

[Markers / Analysis](#) → [Function](#) → ...

Scale Option	Description
Marker → Start	Set sweep start frequency to the frequency of the active marker
Marker → Stop	Set sweep stop frequency to the frequency of the active marker
Marker → Center	Set sweep center frequency to the frequency of the active marker, the current span will be maintained
Marker → Reference	Set the reference line value (the y-axis data value at which the reference line intersects the y-axis) to the data value of the active marker
Marker → Delay	Change the line length at the receiver input to remove the phase slope at the marker position

### SCPI

CALCulate [:SElected]: MARKer: SET < START | STOP | CENTer | RLEVel | DELay>

## 6.7. Marker Searches

Marker searches allow specific data points and frequencies to be highlighted automatically based on characteristics of the measured data.

### 6.7.1. Marker Tracking

By default, the search is run only at the point of selecting the option from the menu. The marker frequency will then remain static even if the measured data subsequently changes. Alternatively, marker tracking can be enabled to force the search to run again after each measurement sweep.

To toggle marker tracking on / off:

[Markers / Analysis](#) → [Search](#) → [Tracking](#)

Tracking: Yes

### SCPI

CALCulate [:SElected]: MARKer: FUNCtion: TRACking

## 6.7.2. Search Range

Marker searches can be configured to look across the entire sweep range (default behaviour), or within a specific sub-range.

To set the range type:

[Markers / Analysis](#) → [Search](#) → [Search Range](#) → [Search Range](#)

Search Range Arbitrary Range

Start and stop values must be specified for an arbitrary sweep range:

[Markers / Analysis](#) → [Search](#) → [Search Range](#) → [Start | Stop](#)

Start 2.3 GHz

### SCPI

CALCulate [:SElected]: MARKer: FUNCtion: DOMain [:STATe] <0|1> // Entire (0) or arbitrary (1)  
 CALCulate [:SElected]: MARKer: FUNCtion: DOMain: START <value> // Start for arbitrary range  
 CALCulate [:SElected]: MARKer: FUNCtion: DOMain: STOP <value> // Stop for arbitrary range

## 6.7.3. Search Coupling

Marker searches can be coupled together across multiple traces within a single channel, allowing one search to be specified for all traces. Markers with the same number are coupled.

To toggle marker search coupling on and off:

[Markers / Analysis](#) → [Search](#) → [Search Range](#) → [Couple](#)

### SCPI

CALCulate [:SElected]: MARKer: FUNCtion: DOMain: COUPlE <0|1>

## 6.7.4. Max / Min Search

Moves the active marker to the frequency of the maximum or minimum data point trace:

[Markers / Analysis](#) → [Search](#) → [Max | Min](#)

## 6.7.5. Peak Search

To specify the peak polarity (positive, negative or both):

[Markers / Analysis](#) → [Search](#) → [Peak](#) → [Peak Polarity](#)

Peak Polarity Positive

To search the nearest peak to the current marker frequency:

[Markers / Analysis](#) → [Search](#) → [Peak](#) → [Search Peak Left](#) | [Search Peak Right](#)

**Note:**

- The marker will not move if it is already located on a relevant peak

The peak excursion value can be adjusted from the default value (3 dB) if required. This is the value by which a peak must deviate from the previous crest / trough to be considered a peak.

A higher value is beneficial with noisy measurement traces to prevent all noise picks appearing in the search. To set the excursion value:

[Markers / Analysis](#) → [Search](#) → [Peak](#) → [Peak Excursion](#)

Peak Excursion  dB

### 6.7.6. Target Search

Target searches allow a specific measurement data value to be found on the trace. To configure a target search:

- Set the target value

[Markers / Analysis](#) → [Search](#) → [Target](#) → [Target Value](#)

Target Value  dB

- Specify whether the target value should be searched on a positive or negative transition (or both)

[Markers / Analysis](#) → [Search](#) → [Target](#) → [Target Transition](#)

Target Transition

- To search the nearest target value to the current marker frequency:

[Markers / Analysis](#) → [Search](#) → [Target](#) → [Target](#)

**Note:**

- The marker will not move if it is already located on a relevant target

- The search can also be run for the next target to the left or right of the current marker frequency:

[Markers / Analysis](#) → [Search](#) → [Target](#) → [Search Left](#) | [Search Right](#)

Peak Excursion  dB

### 6.7.7. Bandwidth Search

The bandwidth search displays the following parameters for a trace, based on the current marker position, useful for plotting the pass band of a DUT:

[Markers / Analysis](#) → [Search](#) → [Search Range](#) → [Couple](#)

- Center frequency
- Lower frequency cut-off
- Higher frequency cut-off
- Pass bandwidth
- Insertion loss at the marker position
- Q value, calculated as:

$$Q = \frac{\text{Center Frequency}}{\text{Passband}}$$

To enable the bandwidth search for a marker:

1. Set the bandwidth value

[Markers / Analysis](#) → [Search](#) → [More](#) → [Bandwidth Value](#)

Bandwidth Value  dB



2. Drag the marker or set its stimulus value to the trace section where bandwidth is to be analyzed
3. Toggle the bandwidth search and marker display on or off  
[Markers / Analysis](#) → [Search](#) → [Bandwidth](#)
4. The bandwidth values are displayed with the marker in the top-left corner of the trace:



### 6.7.8. Notch Search

The notch search displays the following bandwidth parameters for a trace, searching for the first notch to the left of the current marker position:

- Center frequency
- Lower frequency cut-off
- Higher frequency cut-off
- Notch bandwidth
- Insertion loss at the marker position
- Q value, calculated as:

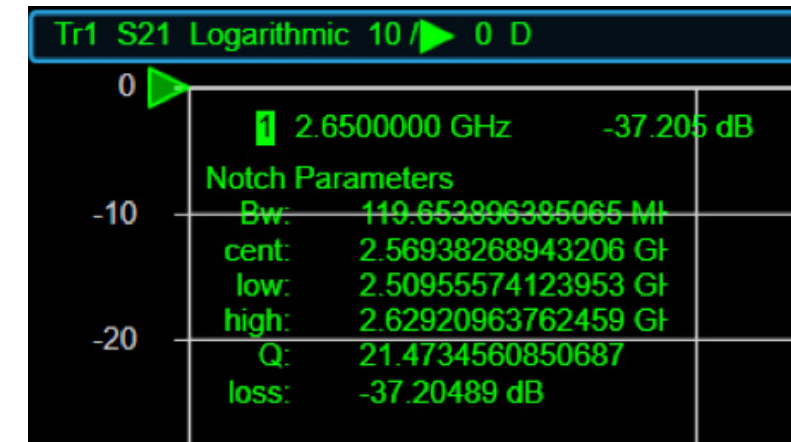
$$Q = \frac{\text{Center Frequency}}{\text{Passband}}$$

To enable the notch search for a marker:

1. Set the notch value  
[Markers / Analysis](#) → [Search](#) → [More](#) → [Notch Value](#)

Notch Value  dB

2. Toggle the notch search and marker display on or off  
[Markers / Analysis](#) → [Search](#) → [More](#) → [Notch](#)
3. The notch bandwidth values are displayed with the marker in the top-left corner of the trace:



## 7. Memory Calculations (Memory Math)

The current sweep trace can be saved to memory and used as a reference for calculations against later sweeps. A common application for this feature is “normalization” of data, where the reference trace is divided from the latest measurement in order to plot deviations from the reference.

To normalize the data:

[Display](#) → [Memory](#) → [Normalize](#)

### Note:

- This performs two steps in 1 command, first saving the current trace to memory, then performing a division from subsequent traces
- All other data memory operation require the trace to be manually saved to memory

To save the current trace to memory:

[Display](#) → [Memory](#) → ["Data → Mem"](#)

The trace display can be configured to show either the current data, the saved data from memory, or both:

[Display](#) → [Memory](#) → [Display Content](#) → [Data | Mem | Data & Mem | Off](#)

To perform a calculation between the latest data trace and the memory trace, select the relevant option as summarized in the table below:

[Display](#) → [Memory](#) → [Data Math](#) → ...

Data Math Operation	Summary
Data / Mem	Latest measurement data divided by memory trace (point by point). Same effect as normalizing data
Data * Mem	Latest measurement data multiplied point by point with memory trace (point by point).
Data - Mem	Difference between measured data and the memory trace (point by point)
Data + Mem	Sum of the measured data and memory trace (point by point)
Off	Turn off memory math calculations (any calculated traces will revert to showing current data only)

## 8. Measurement Pass / Fail Tests

### 8.1. Specification Limit Test

The limit test allows a number of frequency bands to be defined with minimum or maximum test specifications per band. The limit lines and a clear failure indicator can be displayed on the trace, as shown in figure 15.

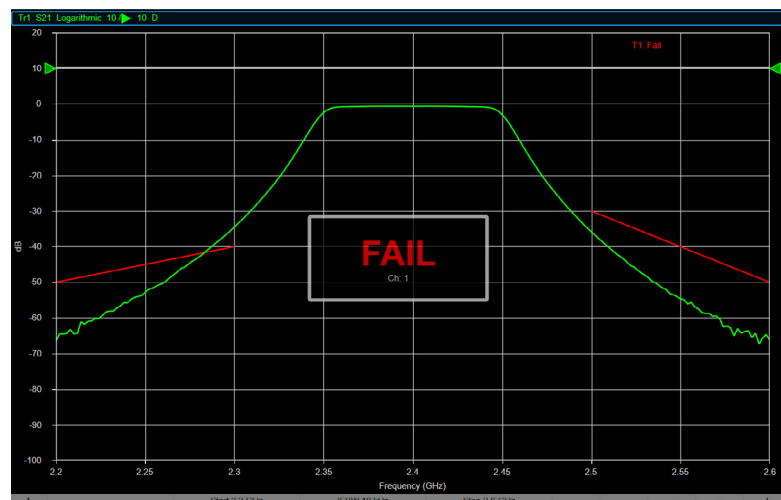


Figure 15: Trace display showing the limit bands to be tested

1. Toggle the limit test on and off with

[Markers / Analysis](#) → [Analysis](#) → [Limit Test](#) → [Limit Test](#)

2. Open the limit table and specify the begin and end points (stimulus and data value) for each test limit, including whether the test is against an upper or lower limit

[Markers / Analysis](#) → [Analysis](#) → [Limit Test](#) → [Limit Table](#)

Type	Begin Stimulus	End Stimulus	Begin Response	End Response
1 Upper Limit	2.2 GHz	2.3 GHz	-50 dB	-40 dB
2 Upper Limit	2.5 GHz	2.6 GHz	-30 dB	-50 dB
3				

3. The limit table can be saved to a CSV file as a back-up and to allow easy recall for future test sessions, click the "Export To..." button and specify the filename. Use the "Import To..." button to recall a previous CSV file.

4. Click Apply and OK to load the limit table

5. Toggle the limit line display on and off

[Markers / Analysis](#) → [Analysis](#) → [Limit Test](#) → [Display Limit Line](#)

6. Toggle the Failure notice on and off (when enabled, a prominent "FAIL" label will be displayed on the trace when the limit test fails)

[Markers / Analysis](#) → [Analysis](#) → [Limit Test](#) → [Fail Sign](#)

### 8.2. Ripple Test

The ripple test allows a number of frequency bands to be specified with a maximum ripple value per band. The eVNA can be configured to mark-up the trace display with the measured ripple value, the ripple bands and a clear failure indicator, as shown in figure 16.

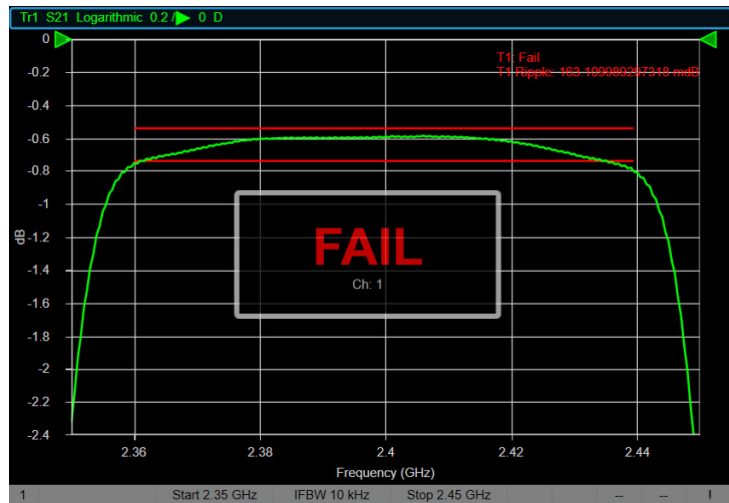
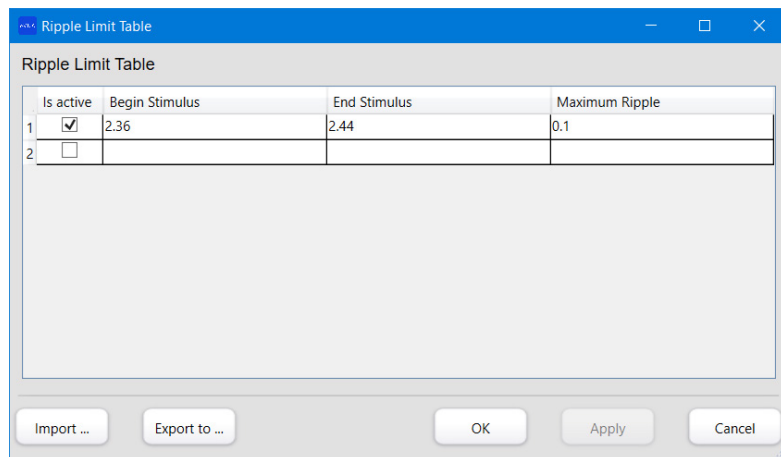


Figure 16: Trace display showing the ripple bands, ripple value and test failure notice

To configure the ripple test:

1. Toggle the ripple limit test on and off with  
Markers / Analysis → Analysis → Ripple Limit → Ripple Limit Test
2. Open the ripple limit table and specify the begin and end stimulus values for each band to test, along with the maximum ripple value allowed for the band  
Markers / Analysis → Analysis → Ripple Limit → Ripple Label Table



3. Check the “Is active” option to enable the test
4. The limit table can be saved to a CSV file as a back-up and to allow easy recall for future test sessions, click the “Export To...” button and specify the filename. Use the “Import To...” button to recall a previous CSV file.
5. Click Apply and OK to load the ripple limit table

6. Toggle the ripple line display on and off (2 horizontal lines highlighting the stimulus band, placed on the trace at the mean value within the band, ± ripple limit value)  
Markers / Analysis → Analysis → Ripple Limit → Ripple Lines
7. Toggle the Failure notice on and off (when enabled, a prominent “FAIL” label will be displayed on the trace when the ripple limit test fails)  
Markers / Analysis → Analysis → Ripple Limit → Fail Sign
8. If multiple ripple limit bands have been defined, specify which band should be indicated by the marker details  
Markers / Analysis → Analysis → Ripple Limit → Ripple Band

### 8.3. Bandwidth Test

The bandwidth test identifies the pass band of the trace and compares to specified min / max limits. The pass / fail result can be displayed on the trace, as shown in figure 17.

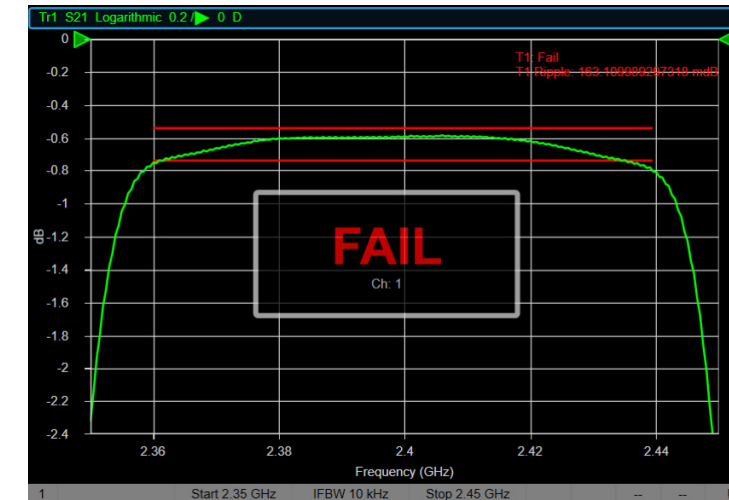


Figure 17: Trace display showing the bandwidth test

To configure the bandwidth test:

1. Toggle the bandwidth test on and off with  
Markers / Analysis → Analysis → Bandwidth Test → BW Test
2. Set the threshold (dB) used to determine the bandwidth of the trace  
Markers / Analysis → Analysis → Bandwidth Test → Threshold



- Set the minimum and maximum stimulus specification limits for the pass / fail test

Markers / Analysis → Analysis → Bandwidth Test → Min BW

Min BW  MHz ▼ ▲ ▼ ✓ ✕

Markers / Analysis → Analysis → Bandwidth Test → Max BW

Max BW  MHz ▼ ▲ ▼ ✓ ✕

- Toggle the display of calculated bandwidth on and off

Markers / Analysis → Analysis → Bandwidth Test → BW Display

- Toggle the bandwidth trace marker display on and off

Markers / Analysis → Analysis → Bandwidth Test → BW Marker

- Toggle the Failure notice on and off (when enabled, a prominent "FAIL" label will be displayed on the trace when the limit test fails)

Markers / Analysis → Analysis → Limit Test → Fail Sign

## 9. Window / Display Configuration

The eVNA includes a number of options to customize the graph display and configuration.

### 9.1. Display Update

By default, the graph display is constantly updating live with new measurement data. Where fastest speed is critical and the measurement does not need to be viewed live, the display update can be turned off and the trace will pause at its last value. Measurement operations continue in the background and the display update can be re-enabled again when needed.

To disable or enable display update, toggle the Update option:

Response → Display → Update

eVNA-63+ 3.0.5 simulator

Channel / Trace    Response

Invert Color: Normal    Update: Yes

### SCPI

DISPlay: ENABle <0|1>

DISPlay: UPDate

// One time display update when updating is disabled

### 9.2. Main Menu Bar

The main menu bar can at the top of the display can be toggled on and off as shown in figure 16:

Response → Display → Display Menu Bar

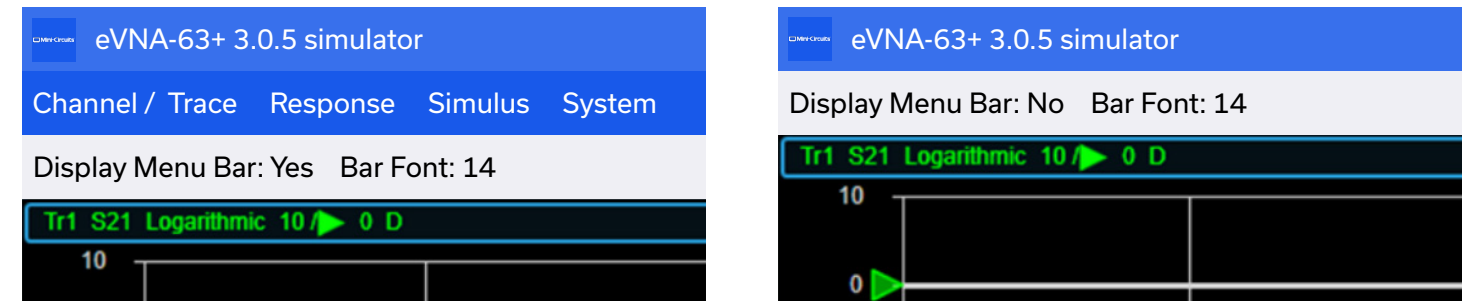


Figure 16: Menu bar visible (left) and hidden (right)

To adjust the menu bar font size:

Response → Display → Bar Font

### 9.3. Channel Labels

The channel title label can be displayed and edited separately for each active channel visible on the display. Figure 17 shows the how the label appears above the top left corner of the channel's trace display.

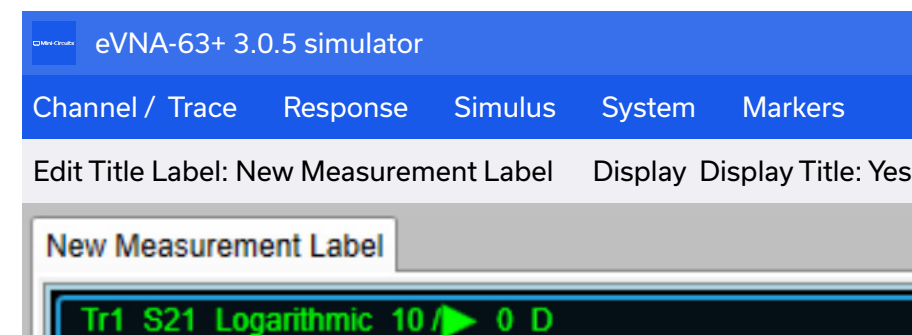


Figure 17: Channel 1 with title label displayed as "New Measurement Label"

To show / hide the label:

[Response](#) → [Display](#) → [Labels](#) → [Display Title Label](#)

To edit the text for the channel label, open the title input in the settings bar and overwrite the label as needed:

[Response](#) → [Display](#) → [Labels](#) → [Edit Title Label](#)

#### SCPI

```
DISPlay: WINDow: TITLe: DATA <title_text> // Set the label text
DISPlay: WINDow: TITLe [:STATe] <0|1> // Hide show the label
```

### 9.4. Axis Labels

The x-axis and y-axis labels can be turned on and off on the trace display.

To toggle the graticule label (y-axis):

[Response](#) → [Display](#) → [Labels](#) → [Graticule Label](#)

To toggle the x-axis frequency label:

[Response](#) → [Display](#) → [Labels](#) → [Display Frequency](#)

#### SCPI

```
DISPlay: WINDow: LABel <0|1>
DISPlay: ANNotation: FREQuency [:STATe] <0|1>
```

### 9.5. Invert Colors

The default eVNA trace color scheme with black background should be familiar to users of legacy VNA instruments. The colour scheme can also be inverted to show the traces on a white background, which can be more convenient when printing screenshots. Figure 18 shows the comparison between the 2 color schemes.

1. To change the color scheme:

[Response](#) → [Display](#) → [Update](#)

2. Toggle between Normal and Invert in the Settings bar:

[Markers / Analysis](#) → [Analysis](#) → [Bandwidth Test](#) → [Threshold](#)

Invert Color  ▾

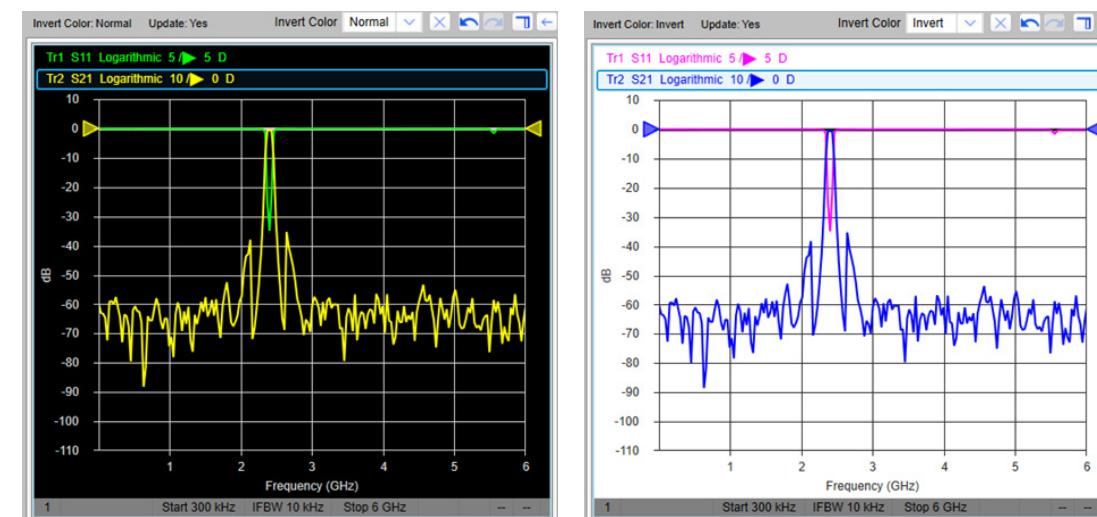


Figure 18: Side by side comparison of normal (left) and inverted (right) color schemes

#### SCPI

```
DISPlay: IMAGe <NORMal | INVert>
```

## 10. Save & Recall Data

### 10.1. Instrument Settings, Calibration State & Measurement Data

Instrument settings, calibration state and measurement data can all be saved to a file on the host PC. All data associated with a measurement is exported, including calibration data, match networks, measurement data, parameters, setup, and graphs, with zoom and marker information. Any number of configurations can be saved to the file system in this way and then recalled to the eVNA in an instant, to save time setting up regular measurement profiles time and again.

#### Note:

- All data saved in this process is specific to the instrument and calibration that generated it. It cannot be recalled to another VNA, including to another eVNA-63+ instrument.
- Instrument and calibration states may change over time so recalled data may no longer be valid.

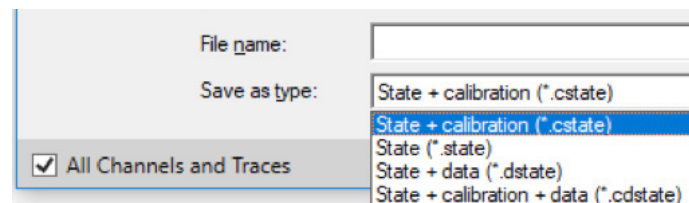
Content	File Type	Description
State	.state	Full instrument settings including channel, trace and formatting
State + Calibration	.cstate	Full instrument settings + the current calibration data / configuration
State + Data	.dstate	Full instrument settings + the current measurement data
State + Calibration + Data	.cdstate	Full instrument settings + the current calibration data / configuration + the current measurement data

Table 7: Summary of different data save options and the respective file types

### 10.1.1. Saving State Data

To save the instrument state data:

1. Launch the save file dialog box  
System → Save / Recall → Save
2. Enter a filename and set the file type according to the table below, to specify the content of the configuration file.  
Markers / Analysis → Analysis → Bandwidth Test → Threshold



3. The "All Channels and Traces" option is checked by default to save full data to the file. This option can be unchecked if data is required only for the active channel and trace.

#### SCPI

```
MMEMory: STORe: STYPe <STATe | CState | DState | CDState>
MMEMory: STORe: SALL <1|0>
MMEMory: STORe [:STATe] <path/filename.extension>
```

### 10.1.2. Recalling State Data

Specify the state file to recall with one of the 4 file types above. The GUI will load the configuration and update the display as required based on the file type.

System → Save / Recall → Recall

#### SCPI

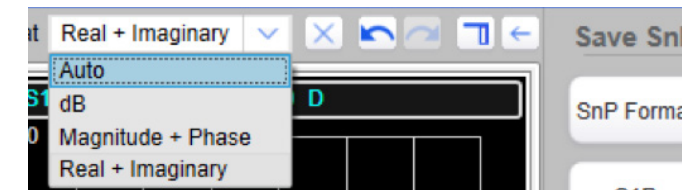
```
MMEMory: LOAD [:STATe] <path/filename.extension>
```

### 10.2. S-Parameter Data

The eVNA can export s-parameter measurement data in Touchstone format as an s1p or s2p file. The full measurement data is included, independent of the current trace settings. To save the snp data:

1. Specify the required data format for snp file from the following options:
  - a. dB & phase angle
  - b. Magnitude & phase angle
  - c. Real & Imaginary impedance

System → Save / Recall → Save SnP → SnP Format



2. Then save the data for the required ports:
  - a. 1-port s-parameters (S11) for port 1  
System → Save / Recall → Save SnP → S1P → 1
  - b. 1-port s-parameters (S11) for port 2  
System → Save / Recall → Save SnP → S1P → 1
  - c. Full 2-port s-parameters (S11, S21, S12, S22)  
System → Save / Recall → Save SnP → S2P
3. You will be prompted to specify a path and filename to create the s1p / s2p file on the host PC

#### SCPI

```
MMEMory: STORe:SNP:FORMat <MA|DB|RI>
MMEMory: STORe:SNP: NPORTS <1|2>
MMEMory: STORe:SNP: PORTS <1|1,2>
MMEMory: STORe:SNP: TYPE:S1P <1|2> | MMEMory:STORe:SNP:TYPE:S2P <1,2>
MMEMory: STORe:SNP [:DATA] <path/filename.extension>
```

### 10.3. Trace Screenshot

The current trace display can be saved as an image file in .png or .bmp format. The image will be exactly as the trace is shown on the GUI, including all visible notations and markers. Where the GUI has been configured to show multiple separate traces, only the active trace is included in the screenshot. To save screenshots of additional traces, click each one in turn to set it as the active trace before saving.

[System](#) → [Save / Recall](#) → [Save Screenshot](#)

### 10.4. Trace CSV Data

Data from the current trace can be exported as a CSV file. The data columns will reflect the formatting specified in the trace display. Where the GUI has been configured to show multiple separate traces, only the active trace is included in the data.

[System](#) → [Save / Recall](#) → [Save Trace Data](#)

## 11. Simulation Mode

Simulation mode is a powerful tool within the eVNA Studio software which enables the user to explore a fully operational VNA with no up-front cost, hardware, or even a DUT (device under test). Connect to an internal simulator in the same way as you would connect to the real hardware and then explore the VNA's capability around a built-in band pass filter measurement. The software also accepts imported Touchstone s-parameter files to allow simulated vector network analysis of a wide range of RF components.

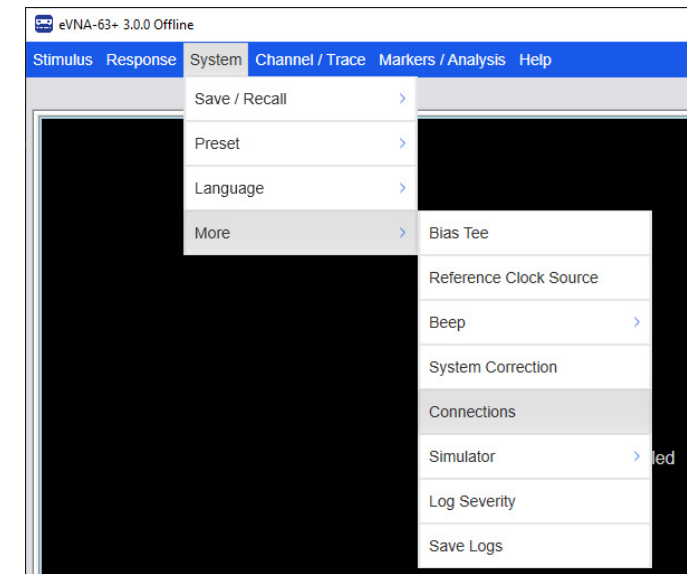
1. Explore the full eVNA capability prior to purchase
2. Educate yourself on proper VNA configuration and usage
3. Design and practice measurement sequences in advance of DUT availability
4. Visualize and interact with standard Touchstone s-parameter data files to properly analyze new RF component choices

Mini-Circuits has 1000s of s-parameter files available for download from our website for our full range of surface mount components.

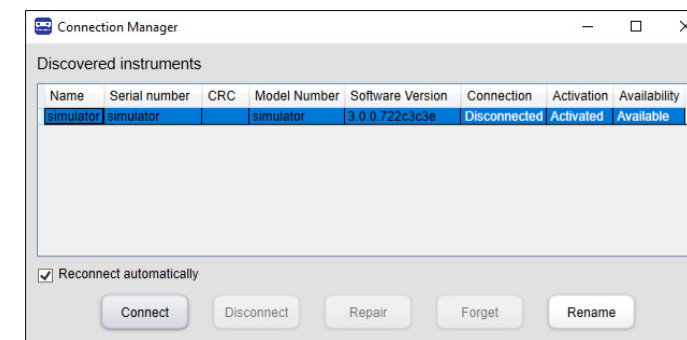
### 11.1. Starting Simulation Mode

The eVNA can export s-parameter measurement data in Touchstone format as an s1p or s2p file. The full measurement data is included, independent of the current trace settings. To save the snp data:

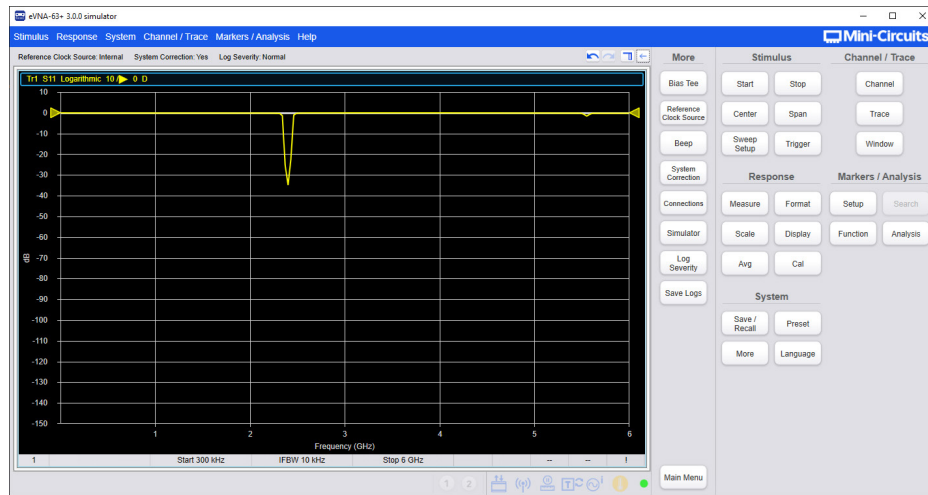
1. Launch the GUI
2. From the top menu, select [System](#) → [More](#) → [Connections](#) to open the Connection Manager with a list of available instruments



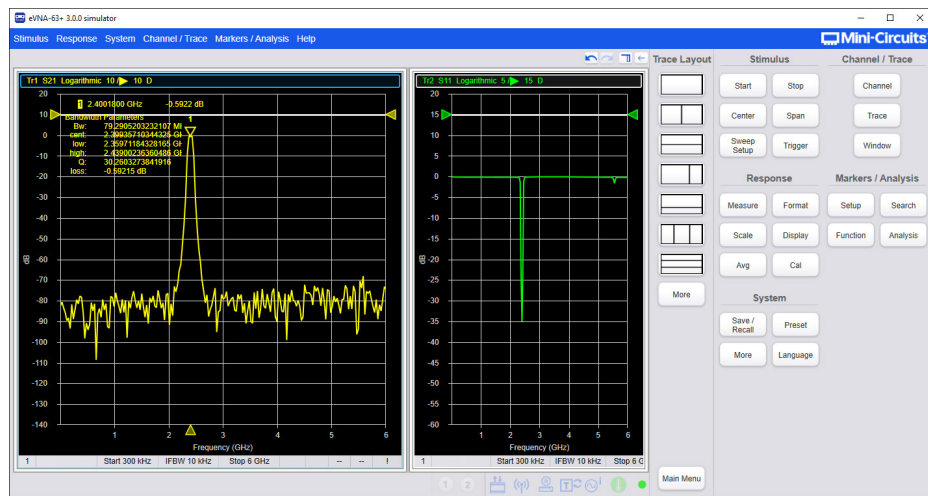
3. If no eVNA hardware is detected then [simulator](#) will be the only option shown, select it and click [Connect](#)



4. The software will configure itself as if a real eVNA-63+ instrument is connected, with a measurement underway on a band-pass filter, centered at 2.4 GHz

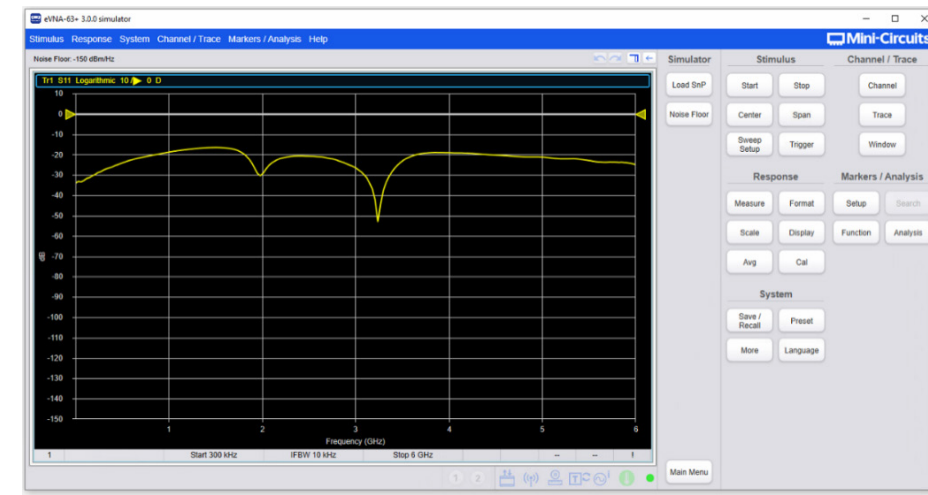


- The S11 trace is displayed initially but the full range of VNA capabilities can be explored based on this simulation, including different measurements, traces, markers and calculations

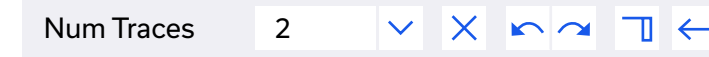


### 11.2. Simulation of S-Parameter s2p Files

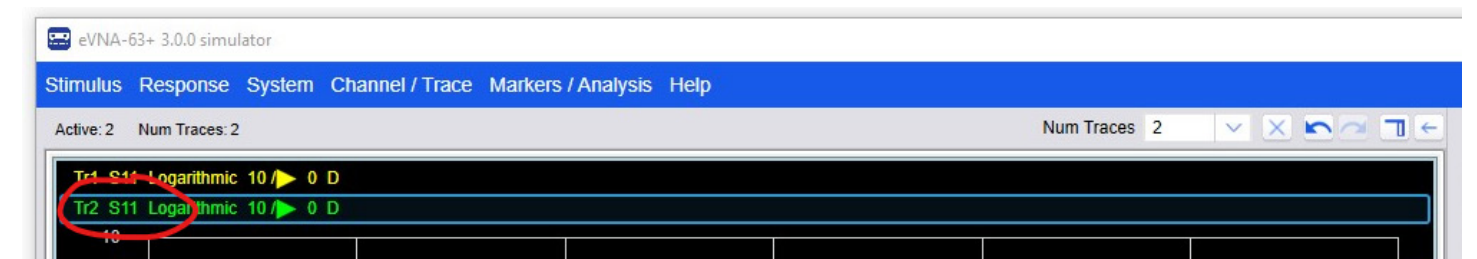
- Once simulation mode is running you can use the eVNA Studio software as a tool to visualize standard Touchstone s-parameter files for other components
- The example below uses [https://www.minicircuits.com/pages/s-params/XBF-282+\\_S2P.zip](https://www.minicircuits.com/pages/s-params/XBF-282+_S2P.zip) to simulate Mini-Circuits' XBF-282+ reflectionless band pass filter
- In simulator mode, select **System** → **More** → **Simulator** → **Load SnP** from the menu
- The trace for S11 will appear initially



- To add additional traces, select **Channel / Trace** → **Trace** → **Num Traces** and enter the number of traces required in the Settings Bar



- Initially all traces will appear on a single graph, with a title for each in the top left-hand corner, click on the relevant title to modify a particular trace

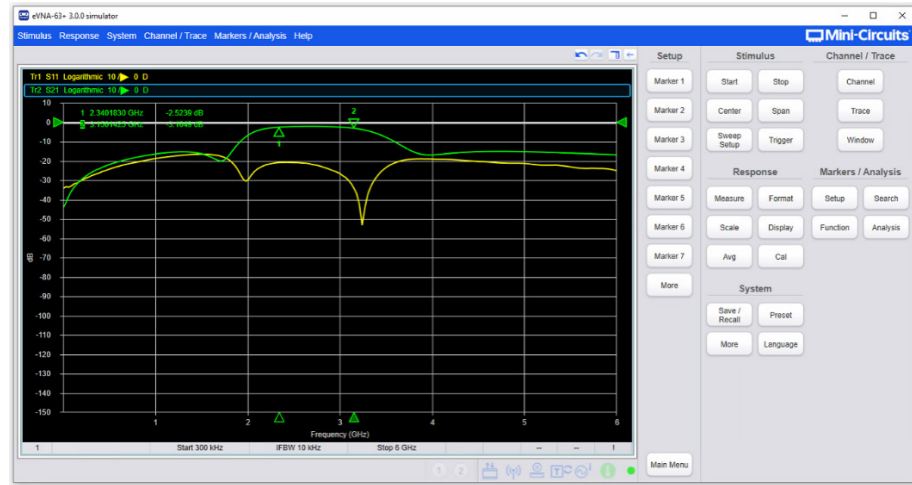


- To show the S21 s-parameter response on the additional trace, select **Response** → **Measure** → **S21**
- To add a marker, select **Markers** → **Setup** → **Marker 1** and then specify the frequency (repeat for additional markers as required)





9. All traces are overlaid on the same graph initially

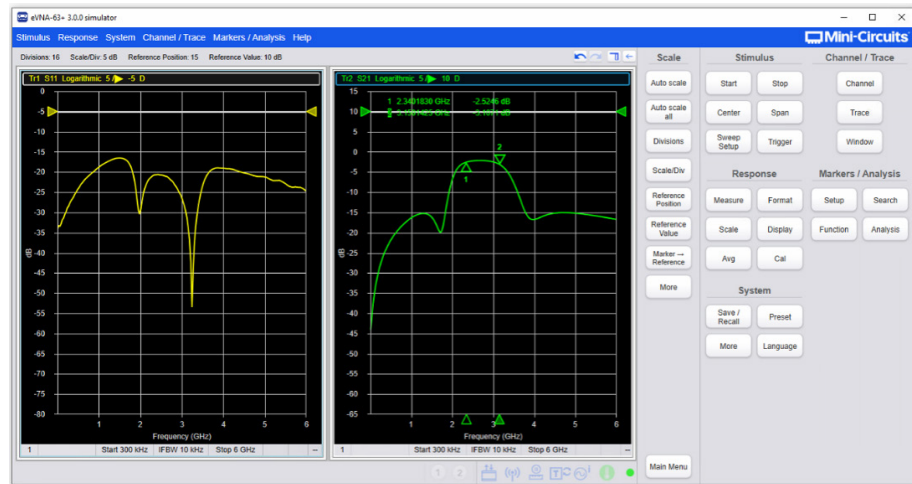


10. To separate traces on to separate graph displays, select **Channel / Trace** → **Trace** → **Trace Layout**, then scroll through the icons in the Sub Panel to select an appropriate layout

11. To show 2 graphs side by side select the icon below



12. Select **Response** → **Scale** → **Auto Scale All** to adjust both graphs to an appropriate scale



# D - Calibrate

## 1.VNA Error Sources

VNAs are precision test instruments, based on relative measurements made between the internal source and receiver. To achieve the specified accuracy, the system must be calibrated carefully to correct to minimize the sources of error and remove the effects of all accessories (cables, adapters and test fixtures) in the VNA to DUT path.

### 1.1. Types of Error

VNA measurement error sources typically fall into 3 distinct categories, random, drift and systematic.

#### 1.1.1 Random Errors

Random errors are non-repeatable errors in a VNA measurement which can't be eliminated by calibration. Care should be taken to minimize random sources of error in the VNA operating environment by employing best measurement practices. This includes:

- Stable temperature and humidity
- Minimize sources of electromagnetic noise (e.g., transmitters, motors, high power devices)
- Use of high-quality components and accessories
- Properly torque all RF connections
- Replace worn or damaged connectors, cables, etc.

#### 1.1.2 Drift Errors

Drift errors begin to appear in any VNA measurement from the time it is calibrated. One of the main sources of drift error is temperature variation since the initial calibration. To minimize the effect of these errors it is important to allow the instrument sufficient time to warm up before calibrating and then maintain a consistent room temperature (25oC ±5oC is recommended). The eVNA-63+ has an operating temperature range specification of 0oC to +55oC but using the instrument at the extremes of this range is likely to degrade measurement accuracy.

Since these errors increase over time from the last calibration, they can be eliminated by performing a new calibration.

### 1.1.3 Systematic Errors

Systematic errors are errors associated with a VNA measurement system itself. These are typically consistent for a given VNA instrument and so can be compensated for by performing a user calibration.

### 1.2. Correcting for VNA Error Sources

The purpose of user calibration is to minimize the systematic measurement errors associated with a VNA test setup. The calibration process requires taking measurements of a known set of reference standards to produce a set of error correction factors. These error correction factors are stored in the VNA and subtracted from the DUT measurements. The process has a dual effect on the measurement data:

1. Remove the effect of any cables and accessories in the test path to set the measurement reference plane as close as possible to the DUT input / output ports
2. Minimize the systematic and drift errors typical of a VNA test setup

The eVNA-63+ calibration process is based on known Short, Open, Load, and Thru (SOLT) standards, which must be characterized across the full frequency span required for the DUT measurements.

It is important to match the calibration kit to the connector type being used for the measurement.

### 1.3. Isolation Considerations

VNA port-to-port crosstalk isolation is a limiting factor when performing high dynamic range measurements at high frequencies. Crosstalk is the leakage from one port to another when no device is present at either port, and can be corrected for as part of the calibration process. This correction is especially useful for a DUT with high loss at some point in the measurement band, including SAW filters with high stop band rejection, or switches in the open position. It should be performed when the port-to-port isolation requirement is >100 dB across the frequency span.

The isolation calibration will contribute noise to the measurement close to the VNA noise floor. Setting a low IF bandwidth can help to minimize the noise contribution and improve measurement accuracy.

A full 2 port (12 error term) calibration is recommended for measurement of a DUT with high isolation or poor return losses. The Load standard is typically used during the isolation calibration but for a highly reactive DUT, such as a filter response in the cut-off region, an open or short provides better results.

## 2. Calibration Theory

### 2.1. Calibration Process Flow

Any connectors, cables, or adapters connected to a VNA as part of the measurement process should be included in the calibration so that the reference plane of the measurement can be set at the DUT connectors. The general flow diagram for the process to perform a calibration is shown in Figure 19. The loop to connect the next standard and run the calibration sweep is repeated for each calibration step required in the software, which varies depending on the type of calibration selected (for example Short, Open, Load & Thru on both ports 1 and 2). At each stage it is crucial to ensure good connections are made. The software indicates which standards and tests are needed at each stage.

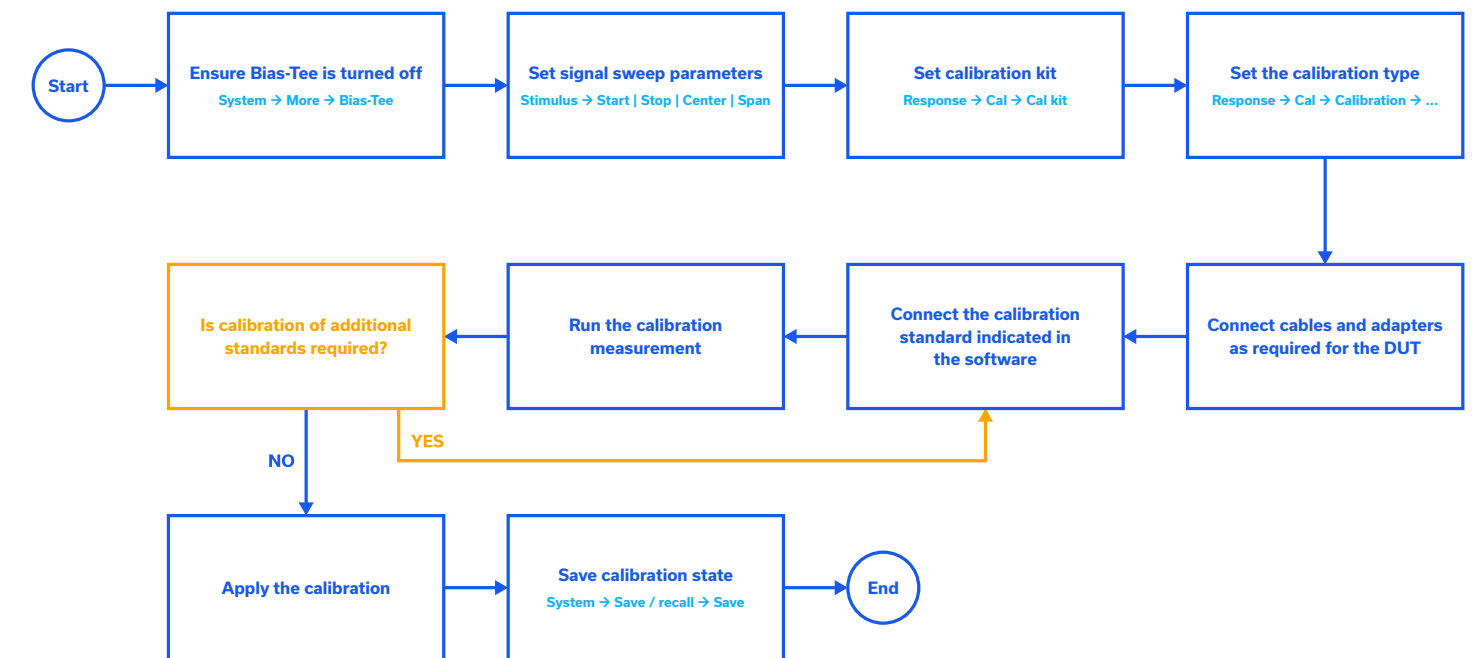


Figure 19: Calibration process flow diagram

## 2.2. How Often to Calibrate

The frequency of user calibrations depends on the specifics of your test setup, including the level of accuracy required and the likelihood of changes in the test setup or environmental conditions. As a general rule of thumb, it is recommended to re-calibrate the eVNA for any of the following reasons:

1. **Per day or session** – VNA systems should be re-calibrated at the start of a new day or test session
2. **After changes in external connections** – VNA calibrations apply to the specific set of external cables and accessories (excluding the DUT) so the system should be re-calibrated after changing any external cables, adapters or accessories up to the DUT interface, even when swapping accessories like for like. Changes in cable flexure will also affect system performance, so for best accuracy you should consider re-calibrating if the cables have been subject to significant movement.
3. **After changes in environmental conditions** – All RF components / systems are affected by their environment so re-calibration may be required if there has been a significant change in operating temperature or humidity since the last calibration.
4. **Between VNA instruments** – Calibrations apply to the specific VNA instrument for which they were calculated so a new calibration will be required when setting up on a new VNA.

## 2.3. Reference Plane

The reference plane for a VNA measurement should be set as close as possible to the DUT connectors, after any cable and adapter accessories connected in the test path. This is achieved by keeping the accessories in the path during the calibration process, so any calibration standards required are connected to those accessories at the same point and with the same connector gender as the DUT. Careful consideration must be given to the connector types and genders of the DUT to ensure the correct calibration standards are available.

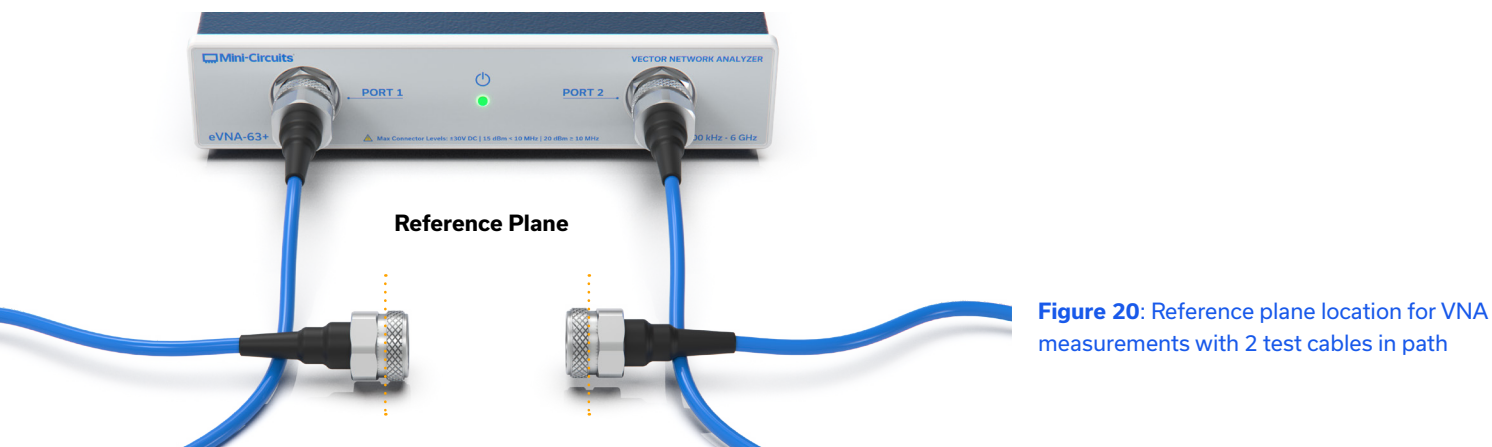


Figure 20: Reference plane location for VNA measurements with 2 test cables in path

## 3. eVNA Calibration Standards

### 3.1. SOLT Calibration

SOLT (Short, Open, Load & Thru) calibrations are ideal for measurement of connectorized devices. They involve a set of well-defined standards with an appropriate connector type for the DUT. The standards are typically accompanied by a set of definitions which need to be incorporated into the software. Mini-Circuits' KSOLT calibration kits are pre-loaded into the software to allow easy selection by the user. Cal kit standards from other suppliers can be uploaded as summarized later in this section.

Once the cal kit is defined, the eVNA Studio software walks the user through the process to connect each standard and characterize across the sweep frequency range. The software compares the measured response against the pre-defined characteristics and computes a correction factor to be applied to all future measurements.

The cal kit for any set of measurements typically includes:

- SOL (short, open and 50Ω load) of the same connector type as the DUT, these are typically supplied as 1 component with 3 separate connectors for the individual standards, or as 3 separate components
  - Note: SOL standards with both male and female connectors are required for an "insertable" DUT, with male input and female output connectors (or vice versa)
- Thru standards
  - Female to female, male to male, and female to male standards with the same electrical length (commonly referred to as "phase equal" or "swap equal" adapters) are required for measurements of a DUT with the same input and output connector gender

Depending on the type of measurement to be carried out on the DUT, it may only be necessary to use a sub-set of the above SOLT standards. For example, characterization of a 1-port device would only require short, open and load standards with a single connector gender, to connect to a single port on the eVNA.

### 3.2. Insertable & Non-Insertable Devices

Insertable devices are those with input and output connectors of opposite genders (male to female or female to male) whereas non-insertable devices have input and output connectors of the same gender. Typical examples of these are presented in figure 21.



Figure 21: Examples of non-insertable (left) and insertable (right) devices

Insertable devices are simpler to connect when a thru calibration is required as the two VNA cables can be connected together directly. For a non-insertable device, the two VNA cables will have the same outward connector gender so cannot be connected together directly. In this event, a set of phase-equal (or swap-equal) Thru standards is required for calibration and measurement, as shown in figure 22.

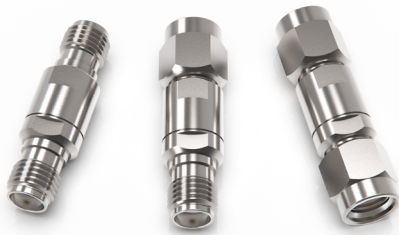


Figure 22: Set of phase-equal Thru standards—Male to Male is required for the above example

The additional steps for calibration of a non-insertable device are:

1. Select either the male to male or female to female Thru standard as required to mate to the two VNA cables



Figure 23: Female to female test cables, requiring male to male Thru standard

2. Use the Thru standard to interconnect the two VNA cables for the thru calibration measurement



Figure 24: Male to male Thru, used to interconnect the two VNA test cables

3. Connect the phase-equal male to female Thru standard on one of the eVNA test cables for all other calibration and DUT measurements



Figure 25: Male to female Thru connected on test cable 2—The same connector genders are now presented to the DUT

4. This ensures the phase length of the Thru standard is compensated for at all stages of the measurement

#### 3.2.1. 12-Term Error Model

There are 12 measurement error terms that can be calibrated out using the SOLT (Short, Open, Load, Thru) calibration model. All 12 terms need to be characterized for a full 2-port calibration but only a subset is required for other calibration types, such as a response, enhanced response or 1-port calibration. The complete set of 12 error terms comprises the 6 terms below in both the forward and reverse directions:

1. Directivity
2. Port 1 match
3. Port 2 match
4. Transmission tracking
5. Reflection tracking
6. Leakage

The correction factors are calculated during the calibration process and are subsequently applied to the DUT measurements. The calibration standards used to determine these error correction factors will be dictated by the type of calibration needed and whether the DUT is an insertable (with connectors of opposite genders) or non-insertable (with connectors of the same gender) device.

### 3.3. Automatic / Electronic Calibration (eMCal)

Mini-Circuits is developing an automatic, electronic calibration module (eMCal-63+) which will be available at the beginning of 2022. This can be used to replace the multiple mechanical SOLT standards with a single 2-port device which is connected between the 2 ports of eVNA-63+ at the measurement reference plane (after any cables and accessories in the RF path). The device is controlled directly from the eVNA Studio software, interfacing with the eMCal via USB. Internally, the eMCal switches through a set of well-defined impedances to calibrate the instrument.

- Only 2 connections required, eliminating common sources of user error
- Fast and repeatable process, automated through the software
- Internally temperature stabilized
- Available in a range of connector types
- Calibration constants stored internally and loaded automatically
- Please contact [testsolutions@minicircuits.com](mailto:testsolutions@minicircuits.com) for more information and to be kept informed on availability.

### 3.4. Selecting a Cal Kit

eVNA Studio is preset with two Mini-Circuits mechanical calibration kits (SMA and N-type) plus an ideal calibration response. In addition, 17 slots are available for new calibration kits to be defined by the user.

Select [Response](#) → [Cal](#) → [Cal Kit](#) to see the list of defined cal kit options shown in Figure 26.

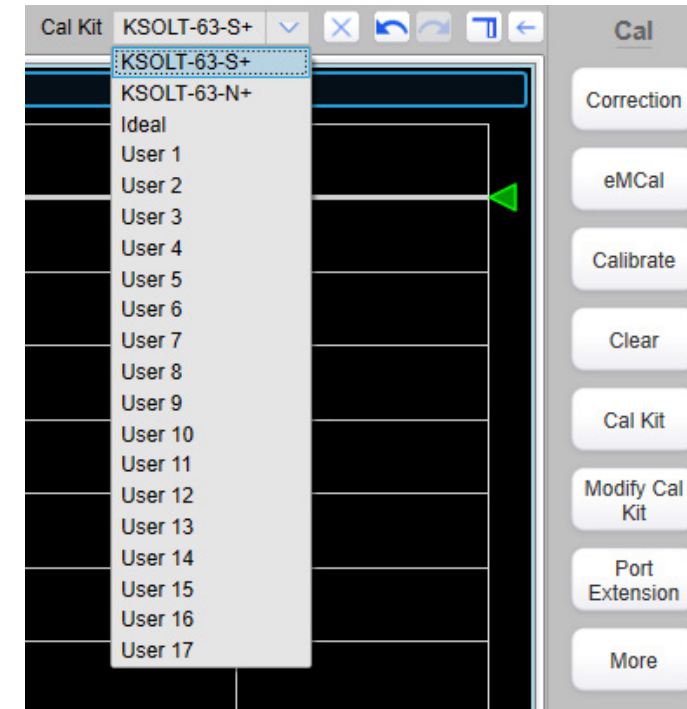


Figure 26: Cal kit options defined in the eVNA Studio GUI

#### 3.4.1. Mini-Circuits' KSOLT-63-x Cal Kits

Mini-Circuits' KSOLT-63 mechanical calibration kits to cover all DUT measurement requirements with SMA and N-type connections. These precision cal kits are typically available from stock, with all parameters and definitions preloaded in the software.

The available cal kits are:

- KSOLT-63-S+
  - Complete set of calibration standards and torque wrench with SMA connectors
- KSOLT-63-N+
  - Complete set of calibration standards and torque wrench with N-type connectors

Each kit contains the following items with the relevant connector type:

- Short / Open / Load standards (female)
- Short / Open / Load standards (male)
- Through standard (female to male)
- Through standard (male to male)
- Through standard (female to female)
- Torque wrench

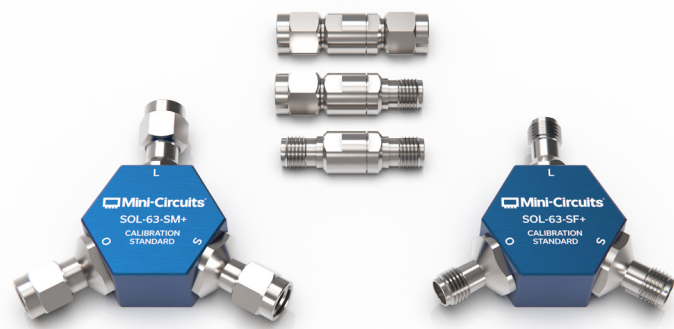


Figure 27: SMA KSOLT-63-S+ kit, including SOL (f & m) and Thru (f<=>f, f<=>m, m<=>m) standards



Figure 28: N-type KSOLT-63-N+ kit, including SOL (f & m) and Thru (f<=>f, f<=>m, m<=>m) standards

### 3.4.2. Ideal Cal Kit

The “Ideal” option in the Cal Kit menu loads ideal 50Ω parameters for the calibration. This option can be used for basic measurements where only an indication of performance is required, with no guarantee on accuracy. The ideal option is suitable for a response calibration where no calibration kit is required.

### 3.5. Adding / Modifying Cal Kits

Existing calibration kit definitions can be modified and new definitions can be created through the Cal Kit menu by following the general steps summarised in figure 29. User defined cal kits are automatically saved and will persist on future use of the eVNA software.

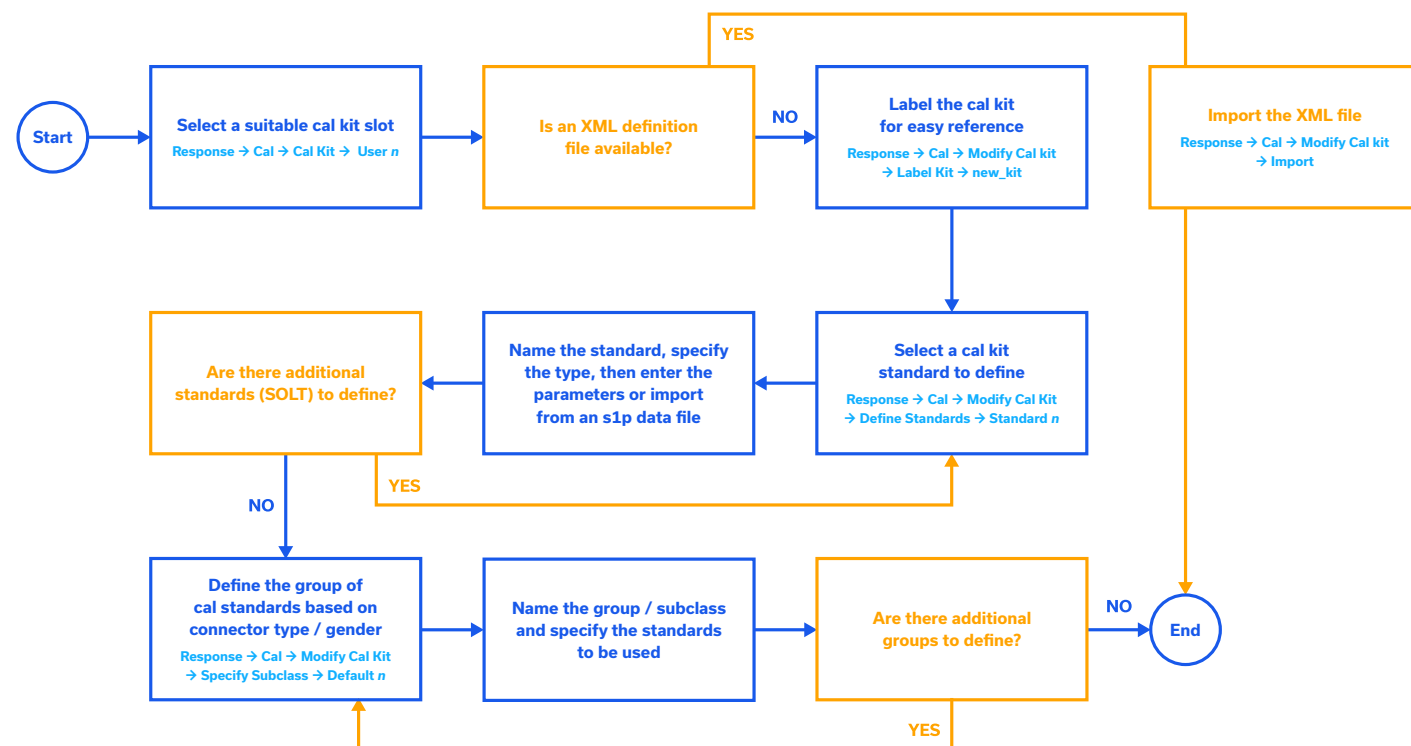


Figure 29: General steps to add or modify a cal kit

### 3.5.1. Select and Name a Cal Kit

The eVNA comes pre-populated with 2 Mini-Circuits calibration kits, an ideal response kit and 17 blank slots names User 1 to User 17. It is recommended to select a blank User slot for a new cal kit definition.

1. Select the cal kit to modify

Response → Cal → Cal Kit → ...

2. Set the name / label for the cal kit

Response → Cal → Modify Cal Kit → Label Kit → ...

#### SCPI

SENSe: CORRection: COLLection: CKIT <number>

SENSe: CORRection: COLLection: CKIT: LABEL <name>

### 3.5.2. Define Cal Kit Standards

The calibration coefficients for each standard can be defined through two methods. One method is model-based, using an nth order polynomial equation derived from a set of parameters entered by the user. The second method is data-based, where the data required to characterize the standard is imported from a Touchstone s1p file. The manufacturer of the cal kit should be able to provide either the parameters to be entered manually, or the s1p data file to define the standard.

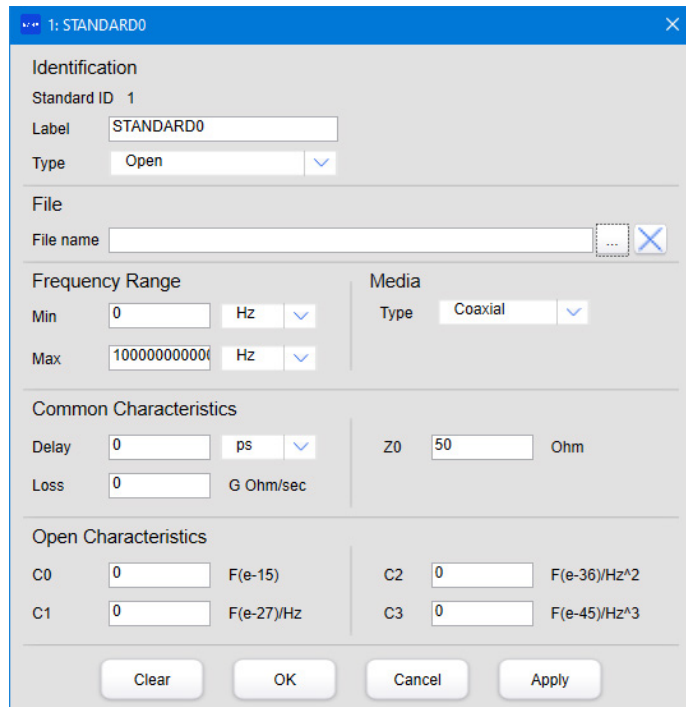
By default, the eVNA contains 21 blank slots named “Standard 0” to “Standard 20”.

#### Note:

- If two standards have the same model coefficients (for example the male and female broadband loads), it is acceptable to define a single standard to be used in both cases.

1. Select the standard to edit

Response → Cal → Modify Cal Kit → Define Standards → ...



2. Specify the label and type for the individual cal kit standard
3. If the manufacturer has made available a Touchstone s1p data file for the standard, it can be imported by clicking the ellipsis button next to the filename
4. If no Touchstone s1p file is available, the coefficients can be entered manually, exactly as provided by the manufacturer.
5. Repeat the above steps for each cal kit standard

#### SCPI

SENSe: CORRection: COLLection: CKIT: STAN <standard\_number>  
 SENSe: CORRection: COLLection: CKIT: STAN: ...

### 3.5.3. Define Subclasses

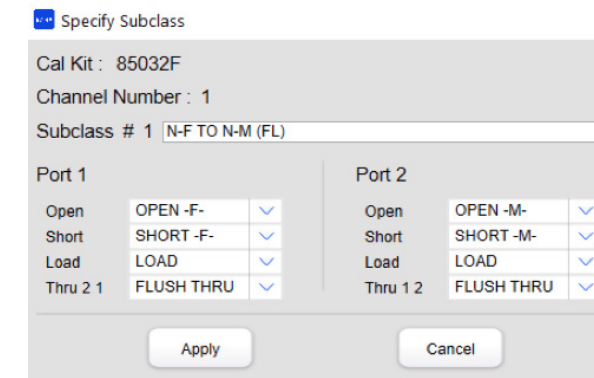
After defining cal kit standards, it is important to specify the subclasses / groups to be used in each calibration scenario. A subclass is used to specify which set of standards are used for a particular DUT connection type and gender configuration. For example, a 1-port DUT with male input connector requires a different set of SOL standards from a 1-port DUT with female input connector.

By convention, the subclass names should reference the connector types and genders of the DUT, rather than the connectors of the cable connecting to the DUT. For example, a subclass named "N-F to N-M" would be appropriate for a subclass of standards intended for measurement of a 2-port DUT with N-type female input and N-type male output connectors.

By default, 8 subclass slots are available per cal kit (each named "Default").

To specify the subclass:

1. Select the subclass slot  
[Response](#) → [Cal](#) → [Modify Cal Kit](#) → [Specify Subclass](#) → ...
2. Label the subclass



3. Specify which of the previously defined standards will be used for the Open, Short, Load and Thru on each of ports 1 and 2, then click Apply to save

#### SCPI

SENSe: CORRection: COLLection: CKIT: ORDeR [:SELection] <subclass\_number>  
 SENSe: CORRection: COLLection: CKIT: ORDeR:...

### 3.5.4. Export / Import of XML Cal Kit Definitions

Cal kit definitions can be exported to an XML file for easy recall in the event of accidental user changes, and to speed up transferring cal kits between different instances of the eVNA Studio software.

To export the active cal kit:

[Response](#) → [Cal](#) → [Modify Cal Kit](#) → [Export](#) → ...

To import a cal kit:

1. Specify the path and file name of the XML file  
[Response](#) → [Cal](#) → [Modify Cal Kit](#) → [Import](#) → ...
2. It is recommended to review the name, standards and subclasses to confirm the details are correct, by referring to the sections above

### 3.6. Enabling Error Correction

Error correction must be enabled in order to apply the specified calibration to the measured data. Conversely, error correction can be disabled to view raw uncorrected measurement data. Error correction is automatically enabled on completion of a user calibration. To toggle error correction on / off:

Response → Cal → Correction

The settings bar will show the latest error correction status, in the top-left corner of the GUI, just below the main menu, as shown in figure 32.

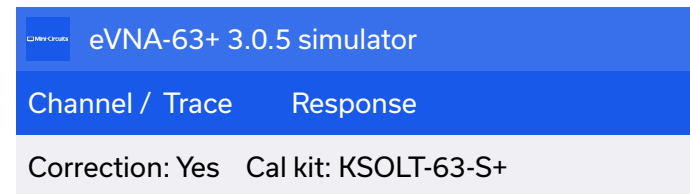


Figure 32: Current error correction status indicated in the settings bar

```
SCPI
SENSe: CORRection: STATe <0|1>
```

### 3.7. Clearing Calibration Data

To delete stored calibration data and turn off error correction:

Response → Cal → Clear → OK

**Note:**

- This does not affect stored calibration standards and subclasses

```
SCPI
SENSe: CORRection: CLear
```

## 4. Calibration Methods

There are a number of calibration methods possible, the choice of which is dictated by the goals of the measurement session including the required accuracy and the type of device to be measured. Figure 33 presents a flow chart of questions which can be asked to determine which calibration process is best for a given measurement requirement. Table x summarizes the accuracy, errors and merits of the processes available.

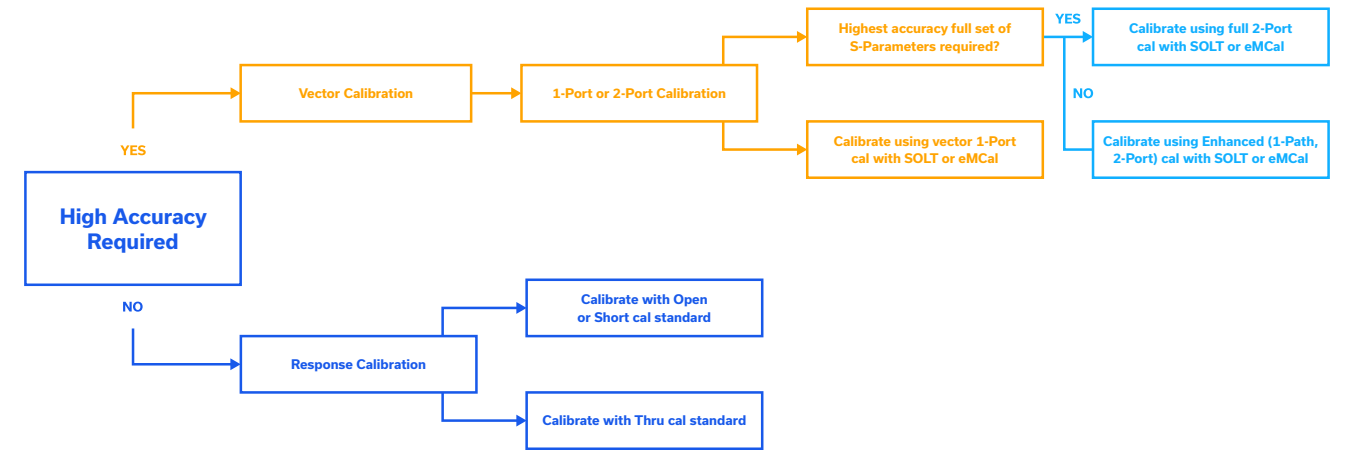


Figure 33: Flow chart for choice of calibration process

Calibration Type	Standards Required	Effort / Accuracy	Errors Removed	Typical Usage
Uncorrected	N/A	No effort / Not accurate	None	Course indication of performance
Response (Transmission)	T	Low effort / Low accuracy	Transmission tracking	First pass evaluation with frequency response of test setup removed (S12 & S21)
Response (Reflection)	SO	Low effort / Low accuracy	Reflection tracking	First pass evaluation with frequency response of test setup removed (S11 & S22)
EnhancedResponse	SOLT	Medium effort / Medium accuracy	Directivity, source match, transmission & reflection tracking	2-port, 1-path measurements (S11 & S12 or S21 & S22)
1-Port SOL	SOL	Medium effort / High accuracy	Directivity, source match & reflection tracking	Reflection measurements (S11 or S22)
2-Port SOLT	SOLT	High effort / High accuracy	Directivity, source & load match, reflection & transmission tracking, isolation	Best accuracy; full 2-port / 2-path s-parameters (S11, S12, S21 & S22)
Automatic (eMCal)	eMCal	Low effort / High accuracy	Directivity, source & load match, reflection & transmission tracking, isolation	Best accuracy, fastest setup, minimal user error risk; full 2-port / 2-path s-parameters (S11, S12, S21 & S22)

Table 9: Comparison of calibration methods



## 4.1. Response Calibration

The response calibration removes only the transmission or reflection tracking error terms so cannot provide a high degree of measurement accuracy. This can be performed using the Short, Open and Thru from an SOLT cal kit, or with no cal kit standard at all since accuracy of the measured data will already be limited. The response cal can be used to obtain a first pass indication of the DUT performance, with the frequency response of the fixture / cable loss removed.

### 4.1.1. Thru Response (Transmission Tracking)

The Thru response process is a 2-port calibration using the Thru standard to eliminate the transmission tracking error, which effectively removes the cable loss from the measurement. An isolation calibration can optionally be performed to eliminate isolation errors.



Figure 34: Thru connection for response thru calibration

#### Caution:

- Ensure the bias-tee outputs are disabled to prevent damage to calibration standards

#### 1. Select a calibration kit

Response → Cal → Cal Kit → ...

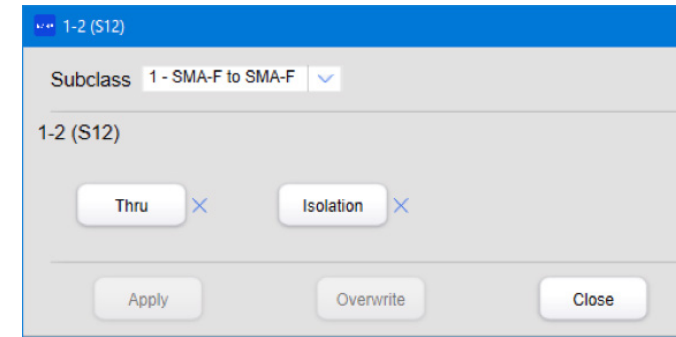
#### 2. Specify the Thru calibration type and the source / receiver ports for the measurement:

- a. Port 2 as source, port 1 as response:

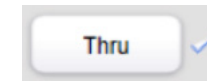
Response → Cal → Calibrate → Response → Response Thru → 1-2 (S12)

- b. Port 1 as source, port 2 as response

Response → Cal → Calibrate → Response → Response Thru → 2-1 (S21)



3. Connect the Thru to the port 1 and 2 test cables using a torque wrench, as shown in figure 35
4. Select the correct subclass based on the input / output connectors of the DUT
5. Click the Thru button in the calibration window to run the calibration sweep, a tick symbol will appear next to Thru when complete



6. If an isolation calibration is to also be run, connect a Load standard using a torque wrench on both the port 1 and port 2 cables, as shown in figure 35



Figure 35: Load connections for response isolation calibration

7. Click the Isolation button on the calibration window to run the sweep, a tick will appear next to the button when complete
8. Click Apply and then Close to complete the process and apply the calibration coefficients to the measured data
9. Save the instrument and calibration state so it can be recalled later if needed (enter a filename and select the .cstate file type)  
[System](#) → [Save / Recall](#) → [Save](#)

After the full calibration has been completed, it is possible to repeat the calibration measurement for an individual standard if needed. Follow the steps above but measure only the standard which needs to be updated, then click the Overwrite button to complete, instead of Apply.

#### SCPI

```

SYSTEM: BIAStee 0
SENSe: CORRection: COLlect: CKIT <number>
SENSe: CORRection: COEFFicient: METHod [:RESPonse]: THRU <1,2|2,1>
SENSe: CORRection: COLlect [:ACQuire]: THRU <1,2|2,1>
SENSe: CORRection: COLlect [:ACQuire]: ISOLation <1,2|2,1>
SENSe: CORRection: COEFFicient: SAVE

```

#### 4.1.2. Open / Short Response (Reflection Tracking)

The Open / Short response process is a 1-port calibration (carried out on either port) using either the Open or Short standards to eliminate the reflection tracking error.

An isolation calibration can optionally be performed to eliminate isolation errors.



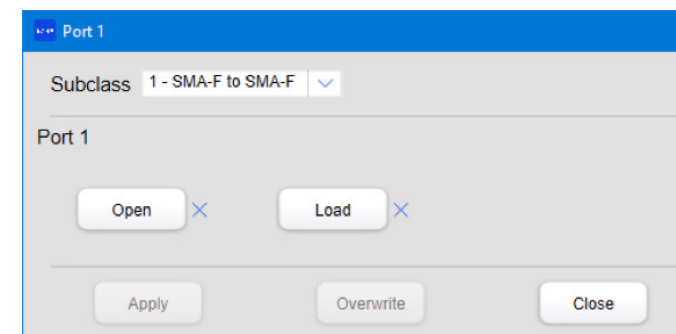
Figure 36: Open connection for response reflection calibration

To perform the Open / Short response calibration:

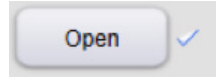
#### Caution:

- Ensure the bias-tee outputs are disabled to prevent damage to calibration standards

1. Select a calibration kit  
[Response](#) → [Cal](#) → [Cal Kit](#) → ...
2. Specify the Open or Short calibration type and the port for the measurement  
[Response](#) → [Cal](#) → [Calibrate](#) → [Response](#) → [Open | Short](#) → [Port 1 | Port 2](#)



3. Connect the Open or Short on the cable from the specified port using a torque wrench, as shown in figure 36
4. Select the correct subclass based on the input / output connectors of the DUT
5. Click the Open button in the calibration window to run the calibration sweep, a tick symbol will appear next to Open when complete



6. If an isolation calibration is to also be run, connect a Load standard on both the port 1 and port 2 cables using a torque wrench, as shown in figure 37



Figure 37: Load connection for response isolation calibration

7. Click the Load button on the calibration window to run the sweep, a tick will appear next to the button when complete
8. Click Apply and then Close to complete the process and apply the calibration coefficients to the measured data
9. Save the instrument and calibration state so it can be recalled later if needed (enter a filename and select the .cstate file type)

System → Save / Recall → Save

After the full calibration has been completed, it is possible to repeat the calibration measurement for an individual standard if needed. Follow the steps above but measure only the standard which needs to be updated, then click the Overwrite button to complete, instead of Apply.

#### SCPI

```

SYSTEM: BIAStee 0
SENSe: CORRection: COLlect:CKIT <number>
SENSe: CORRection: COEFFicient: METHod [:RESPonse]: OPEN <1|2>
| SENSe: CORRection: COEFFicient: METHod [:RESPonse]: SHORt <1|2>
SENSe: CORRection: COLlect [:ACQuire]: OPEN <1|2>
| SENSe: CORRection: COLlect [:ACQuire]: SHORt <1|2>
SENSe: CORRection: COEFFicient: SAVE
  
```

#### 4.2. Enhanced Response Calibration

The enhanced response process is a 2-port, 1-path calibration using all the SOLT standards. This calibration eliminates the directivity, source match, reflection tracking, transmission tracking and crosstalk errors.

An isolation calibration can optionally be performed to eliminate isolation errors.



Figure 38: Open / Short / Load connections for enhanced response calibration on port 1



Figure 39: Thru connection for enhanced response calibration

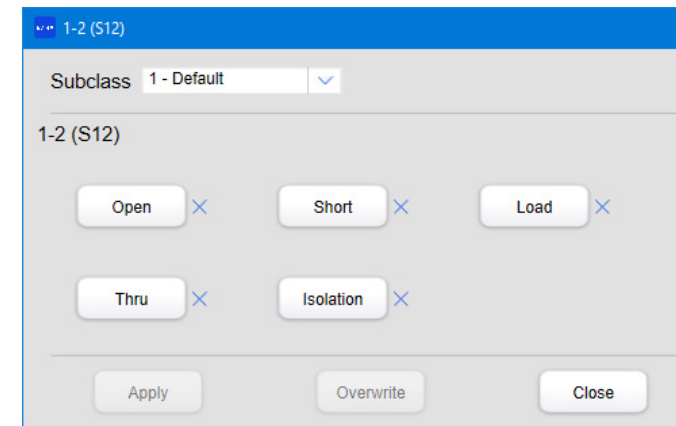


Figure 40: Load connections for enhanced response isolation calibration

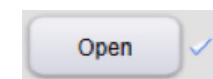
**Caution:**

- Ensure the bias-tee outputs are disabled to prevent damage to calibration standards

1. Select a calibration kit  
Response → Cal → Cal Kit → ...
2. Specify the Open or Short calibration type and the port for the measurement:
  - a. Port 2 as source, port 1 as response  
Response → Cal → Calibrate → Enhanced Response → 1-2 (S12)
  - b. Port 1 as source, port 2 as response  
Response → Cal → Calibrate → Enhanced Response → 2-1 (S21)



3. Connect the Open standard on the source port cable as shown in figure 38, using a torque wrench  
Response → Cal → Cal Kit → ...
4. Click the Open button in the calibration window to run the calibration sweep, a tick symbol will appear next to Open when complete



5. Repeat for the Short and Load standards
6. Connect the Thru between the port 1 and port 2 test cables using a torque wrench, as shown in figure 39
7. Click the Thru button in the calibration window to run the calibration sweep, a tick symbol will appear next to Thru when complete
8. If an isolation calibration is to also to be run, connect a Load standard on both the port 1 and port 2 cables using a torque wrench, as shown in figure 40

9. Click the Isolation button on the calibration window to run the sweep, a tick will appear next to the button when complete
10. Click Apply and the Close to complete the process and apply the calibration coefficients to the measured data
11. Save the instrument and calibration state so it can be recalled later if needed (enter a filename and select the .cstate file type)  
[System](#) → [Save / Recall](#) → [Save](#)

After the full calibration has been completed, it is possible to repeat the calibration measurement for an individual standard if needed. Follow the steps above but measure only the standard which needs to be updated, then click the Overwrite button to complete, instead of Apply.

#### SCPI

```
:SYSTem: BIAStee 0
SENSe: CORRection: COLLect:CKIT <number>
SENSe: CORRection: COEFFicient: METHod: ERESponse <1,2|2,1>
SENSe: CORRection: COLLect [:ACQuire]: OPEN <1|2>
SENSe: CORRection: COLLect [:ACQuire]: SHORt <1|2>
SENSe:CORRection: COLLect [:ACQuire]: LOAD <1|2>
SENSe: CORRection: COLLect [:ACQuire]: THRU <1,2|2,1>
SENSe: CORRection: COLLect [:ACQuire]: ISOLation <1,2|2,1>
SENSe: CORRection: COEFFicient: SAVE
```

### 4.3. One Port Calibration

1-port calibration is performed to measure single terminal DUTs such as antennas, only the Short, Open, and Load standards are needed from the SOLT kit. Figure 41 shows the calibration measurement setup with the eVNA, SOLT standards and accessory cables. Including the cables and accessories in the calibration enables the reference plane to be set at the DUT connector.



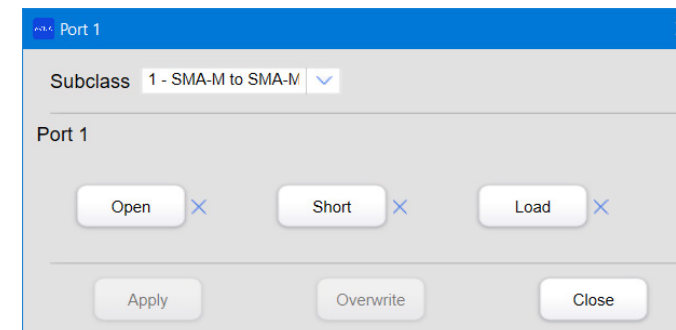
Figure 41: Measurement setup for 1-port calibration

To perform the 1-port calibration:

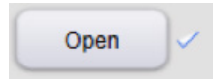
#### Caution:

- Ensure the bias-tee outputs are disabled to prevent damage to calibration standards

1. Select a calibration kit  
[Response](#) → [Cal](#) → [Cal Kit](#) → ...
2. Specify the 1-port SOL calibration type and the port for the measurement:  
[Response](#) → [Cal](#) → [Calibrate](#) → [1-port SOL](#) → [Port 1](#) | [Port 2](#)



3. Connect the Open standard on the source port cable as shown in figure 41, using a torque wrench
4. Click the Open button in the calibration window to run the calibration sweep, a tick symbol will appear next to Open when complete



5. Repeat for the Short and Load standards
6. Click Apply and then Close to complete the process and apply the calibration coefficients to the measured data
7. Save the instrument and calibration state so it can be recalled later if needed (enter a filename and select the .cstate file type)

[System](#) → [Save / Recall](#) → [Save](#)

After the full calibration has been completed, it is possible to repeat the calibration measurement for an individual standard if needed. Follow the steps above but measure only the standard which needs to be updated, then click the Overwrite button to complete, instead of Apply.

#### SCPI

```
:SYSTem: BIAStee 0
SENSe: CORRection: COLlect: CKIT <number>
SENSe: CORRection: COEFFicient: METHod: SOLT 1
SENSe: CORRection: COEFFicient: METHod: SOLT: NPORTS 1
SENSe: CORRection: COEFFicient: METHod: SOLT: PORTS <1|2>
SENSe: CORRection: COEFFicient: METHod: SOLT1 <1,2>
SENSe: CORRection: COLlect [:ACquire]: OPEN <1|2>
SENSe: CORRection: COLlect [:ACquire]: SHORt <1|2>
SENSe: CORRection: COLlect [:ACquire]: LOAD <1|2>
SENSe: CORRection: COEFFicient: SAVE
```

#### 4.4. Two Port Calibration

The full 2-port calibration is the recommended approach where best accuracy is required, although it is the most time consuming. It requires the full SOLT calibration kit and the user must select the proper accessories based on the connector types of the DUT, considering whether it is an insertable (with connectors of opposite genders) or non-insertable (with connectors of the same gender) device. An example of the measurement connections to perform a 2-port calibration is shown in figure 42 & 43.



Figure 42: Open, Short & Load must be connected in turn on ports 1 & 2

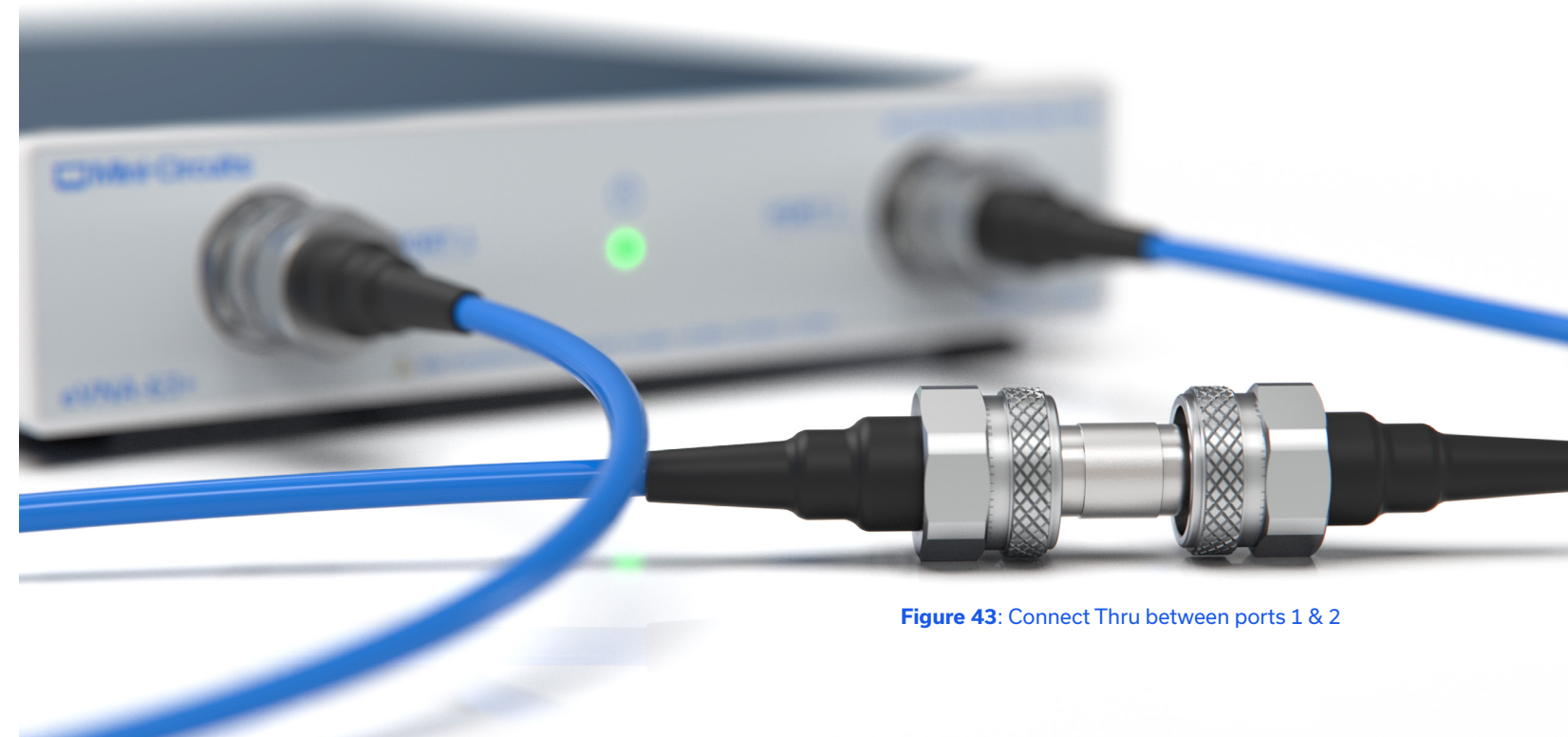


Figure 43: Connect Thru between ports 1 & 2

To perform the 2-port calibration:

**Caution:**

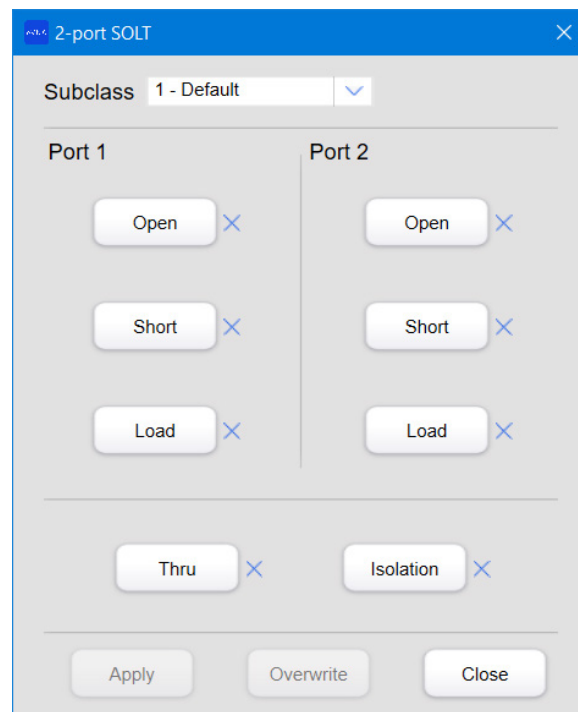
- Ensure the bias-tee outputs are disabled to prevent damage to calibration standards

1. Select a calibration kit

[Response](#) → [Cal](#) → [Cal Kit](#) → ...

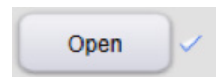
2. Specify the 2-port SOLT calibration type:

[Response](#) → [Cal](#) → [Calibrate](#) → [2-port SOLT](#)



3. Connect the Open standard on the port 1 cable as shown in figure 42, using a torque wrench

4. Click the Port 1 - Open button in the calibration window to run the calibration sweep, a tick symbol will appear next to Open when complete



5. Repeat for the Short and Load standards on port 1

6. Repeat the process for all 3 standards (Open, Short and Load) on port 2

7. Connect the Thru standard between the cables on port 1 and 2 using a torque wrench, as shown in figure 43

8. Click the Thru button in the calibration window to run the calibration sweep, a tick symbol will appear next to Thru when complete

9. Connect Loads on both the port 1 and port 2 cables using a torque wrench, as shown in figure 42

10. Click the Isolation button in the calibration window to run the calibration sweep, a tick symbol will appear next to Isolation when complete

11. Click Apply and then Close to complete the process and apply the calibration coefficients to the measured data

12. Save the instrument and calibration state so it can be recalled later if needed (enter a filename and select the .cstate file type)

[System](#) → [Save / Recall](#) → [Save](#)

After the full calibration has been completed, it is possible to repeat the calibration measurement for an individual standard if needed. Follow the steps above but measure only the standard which needs to be updated, then click the Overwrite button to complete, instead of Apply.

**SCPI**

```
:SYSTem: BIAStee 0
SENSe: CORRection: COLLeCt:CKIT <number>
SENSe: CORRection: COEFFicient: METHod: SOLT 2
SENSe: CORRection: COEFFicient: METHod: SOLT: NPORTS 2
SENSe: CORRection: COEFFicient: METHod: SOLT: PORTS <1,2|2,1>
SENSe: CORRection: COLLeCt [:ACQuire]: OPEN <1|2>
SENSe: CORRection: COLLeCt [:ACQuire]: SHORt <1|2>
SENSe: CORRection: COLLeCt [:ACQuire]: LOAD <1|2>
SENSe: CORRection: COLLeCt [:ACQuire]: OPEN <2|1>
SENSe: CORRection: COLLeCt [:ACQuire]: SHORt <2|1>
SENSe: CORRection: COLLeCt [:ACQuire]:LOAD <2|1>
SENSe: CORRection: COLLeCt [:ACQuire]: THRU <1,2|2,1>
SENSe: CORRection: COLLeCt [:ACQuire]: ISOLation <1,2|2,1>
SENSe: CORRection: COEFFicient: SAVE
```

## 5.Optimizing Calibration Conditions

There are a number of simple settings which can be applied to improve the accuracy of calibration measurements, typically at the expense of measurement speed:

Reduce the IF bandwidth:

[Response](#) → [Avg](#) → [IF Bandwidth](#)

IF Bandwidth  kHz

Enable averaging during the calibration measurements to minimize random errors:

3. Specify the number of sweeps over which measurements should be averaged:

[Response](#) → [Avg](#) → [Factor](#)

Factor

4. Toggle averaging mode on:

[Response](#) → [Avg](#) → [Averaging](#)

Power Level  dBm

## 6. Calibration Verification

### 6.1. Smith Chart Analysis

The Smith chart plot can be used to verify the quality of an Open / Short / Load calibration measurement. Before performing the calibration measurements, set the trace format to Smith chart and the measurement to  $S_{11}$ . The closer to the center of the Smith chart the frequency trace is, the closer matched to the  $50\Omega$  characteristic impedance. Figure 44 shows the Smith chart plots for the Short, Open and Load standards. All standards should appear close to the x-axis with the Short on the left-hand edge at  $0\Omega$ , the Load on the center at  $50\Omega$  and the Open on the right-hand edge at infinite impedance. Since the calibration standards are not ideal, a resistive arc will typically appear for the Short and a capacitive arc for the Open.

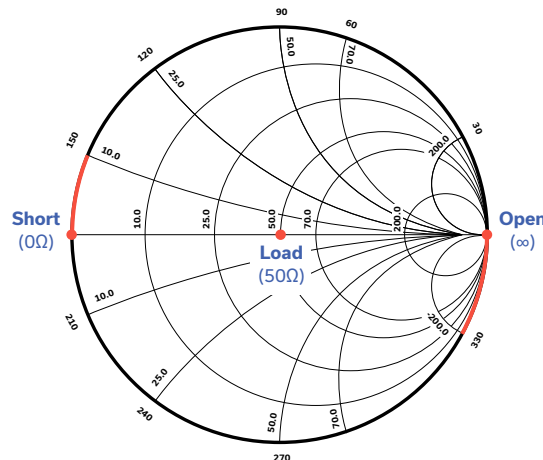


Figure 44: Smith chart representation of Short, Open & Load standards

### 6.2. Golden DUT

One method for verifying whether the last VNA calibration is valid is through the use of a golden DUT. The DUT can be any reliable 2 port device, such as a band pass filter. After a full calibration, the golden DUT can be characterized to obtain and save a reference set of measurement data. To re-confirm the accuracy of the VNA and calibration later, the golden DUT can be measured again and the data compared to the original saved data. Any differences in the data tend to indicate drift errors which have appeared over time since the last calibration, or deviations in the test setup.

## 7. Additional Calibration Options

### 7.1. Power Calibration

The eVNA supports power calibration of ports 1 and 2 independently with an external power meter. The settings can be found under:

[Response](#) → [Cal](#) → [More](#) → [Power Calibration](#) → [Port n](#) → ...

### 7.2. Receiver Calibration

A receiver calibration can be performed on ports 1 and 2 for measurements requiring an accurate output power level. The settings are under:

[Response](#) → [Cal](#) → [More](#) → [Receiver Calibration](#) → ...

### 7.3. Cal Trig Source

External or software trigger synchronisation can be enabled for calibration measurements by setting the calibration trigger source to "System". In this mode the calibration measurements will respond to the trigger setting defined for measurements. In "Internal" trigger mode, calibration measurements do not wait for an external trigger input.

To toggle between "System" and "Internal" trigger calibration modes:

[Response](#) → [Cal](#) → [More](#) → [Cal Trig Source](#)



# E - Measure

## 1. Measurement Process Flow

Figure 45 presents the measurement data process flow diagram for the eVNA. This summarizes the steps taken automatically by the eVNA from measurement to display and is a means to understanding where each level of data correction and manipulation is applied.

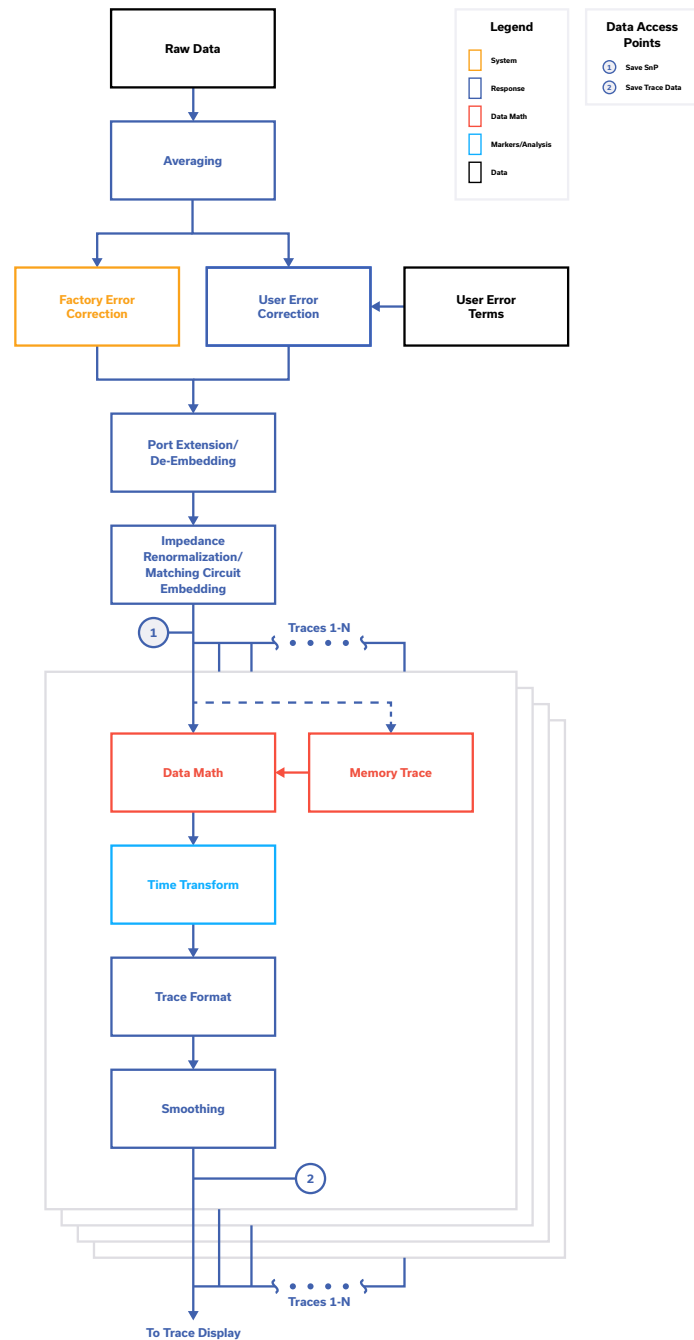


Figure 45: Data process flow diagram for eVNA measurements

## 2. Measurement Examples:

Several examples in this section will be used to present the procedure for typical active and passive device measurements. The Calibration section of this guide should be followed to calibrate for the test setups in advance of the measurements.

### 2.1. One Port Device Measurement (Antenna Example)

The measurement of a 2.4 GHz WiFi antenna will be used as an example of a passive 1-port device measurement.

#### Prepare

Define the measurement data required and familiarize yourself with the relevant eVNA settings. Based on the expected characteristics of the DUT, consider the required sweep frequency range, power level and number of measurement points required.

1. Return the eVNA-63+ to its default state:  
System → Preset → OK
2. Set the frequency sweep parameters as required:  
Stimulus → Start → 500 kHz  
Stimulus → Stop → 6000 MHz
3. Set the sweep power level:  
Stimulus → Sweep Setup → Power Menu → Power Level → 0 dBm
4. Set the number of points to include in the frequency sweep:  
Stimulus → Sweep Setup → Points → 401
5. Set the IF bandwidth:  
Response → Avg → IF bandwidth → 100 kHz

#### SCPI

```
SYSTem: PRESet: MODE USER
SENSe: FREQuency: START 500000
SENSe: FREQuency: STOP 6000000000
SOURce: POWer 0
SENSe: SWEep: POINTs 401
```

## Practice

Select the appropriate cables and adapter based on the gender of the antenna connector.

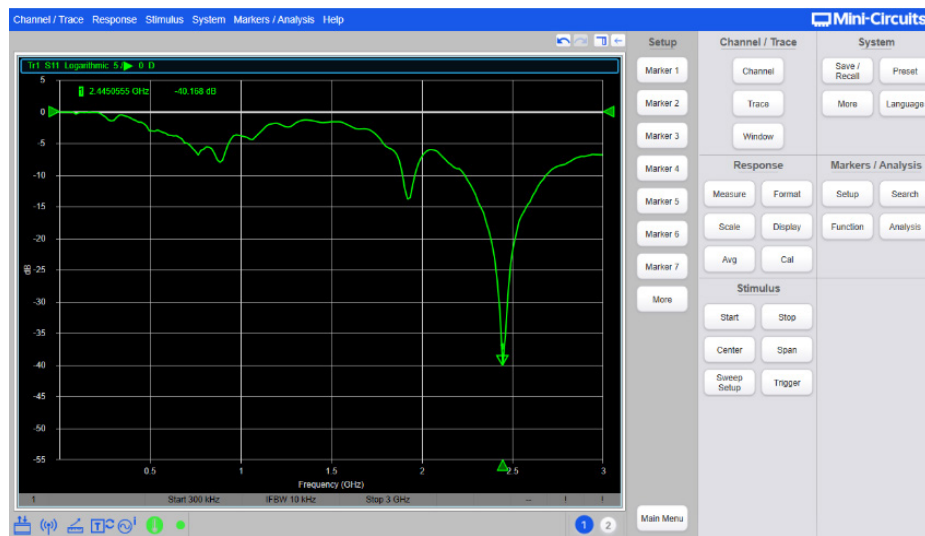
Allow the eVNA-63+ sufficient time to warm up.

## Calibrate

Carry out the calibration using the 1-port SOL method on port 1, with the correct calibration kit selected. Refer to section C-4.3 for details.

## Measure

1. Connect the DUT to the open end of the cable from port 1
2. Set the trace to display S11 (return loss):  
[Response](#) → [Measure](#) → [S11](#)
3. Add a marker to the trace:  
[Markers / Analysis](#) → [Setup](#) → [Marker 1](#)
4. Use the mouse cursor to drag marker 1 on the trace display to the lowest point on the S11 plot. This is the point where the antenna returns the least amount of energy to the source and therefore where it transmits the most power (resonance).



5. Scale the display to present the graph as clearly as possible

[Response](#) → [Scale](#) → [Autoscale All](#)

6. Save the data so that it can be recalled later

[System](#) → [Save / Recall](#) → [Save](#)

## 2.2. Pair of One Port Device Measurements (Dual Antenna Example)

The 1-port antenna measurement outlined above can be extended with a second 1-port antenna connected on port 2. S11 for both antennas can then be plotted simultaneously for comparison and analysis of any interaction between the 2 DUT.

## Prepare

Complete the steps for the 1-port antenna example above

## Practice

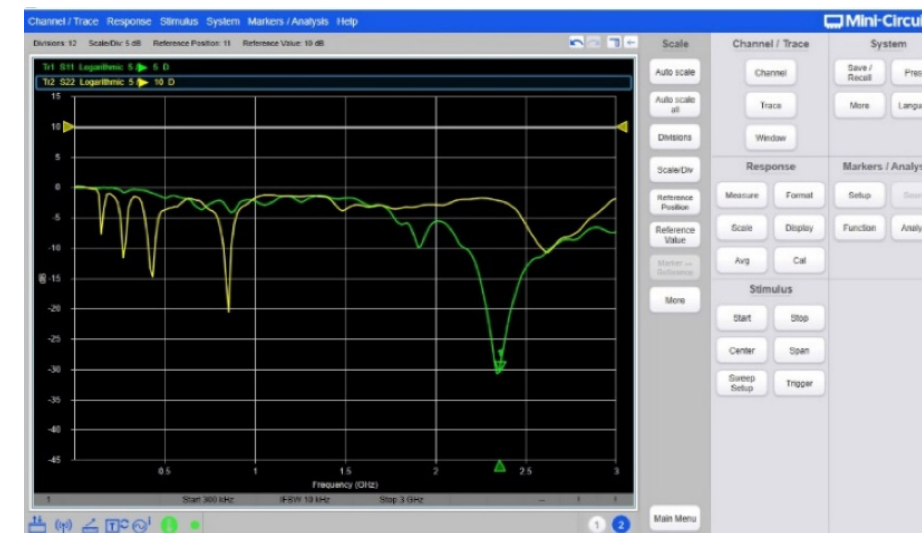
Select the appropriate cables and adapter based on the gender of the antenna connector.

## Calibrate

Repeat the calibration process for port 2, with a 1-port SOL calibration on port 2.

## Measure

1. With the first antenna already connected and displayed on port 1, connect the second antenna on port 2
2. Add an additional trace to the display  
[Channel / Trace](#) → [Trace](#) → [Num Traces](#) → [2](#)
3. Select trace 2 and display S22 (input return loss for the DUT on port 2)  
[Response](#) → [Measure](#) → [S22](#)
4. Scale the display  
[Response](#) → [Scale](#) → [Autoscale All](#)
5. Both traces should now be visible on the same graph display  
(trace 1 / S11 for the antenna on port 1 and trace 2 / S22 for the antenna on port 2)



### 2.3. Two Port Passive Device Measurement (Band Pass Filter Example)

The 1-port antenna measurement outlined above can be extended with a second 1-port antenna connected on port 2. S11 for both antennas can then be plotted simultaneously for comparison and analysis of any interaction between the 2 DUT.

#### Prepare

Define the measurement data required and familiarize yourself with the relevant eVNA settings. Based on the expected characteristics of the DUT, consider the required sweep frequency range, power level and number of measurement points required.

1. Return the eVNA-63+ to its default state:

[System](#) → [Preset](#) → [OK](#)

2. Set the frequency sweep parameters as required:

[Stimulus](#) → [Start](#) → [500 kHz](#)

[Stimulus](#) → [Stop](#) → [6000 MHz](#)

3. Set the sweep power level:

[Stimulus](#) → [Sweep Setup](#) → [Power Menu](#) → [Power Level](#) → [0 dBm](#)

4. Set the number of points to include in the frequency sweep:

[Stimulus](#) → [Sweep Setup](#) → [Points](#) → [201](#)

5. Set the IF bandwidth:

[Response](#) → [Avg](#) → [IF bandwidth](#) → [100 kHz](#)

#### SCPI

```
SYSTem: PRESet: MODE USER
SENSe: FREQuency: START 500000
SENSe:FREQuency: STOP 6000000000
SOURce: POWer 0
SENSe: SWEep: POINts 201
[IF bandwidth can't be set with SCPI]
```

#### Practice

Select the appropriate set of cables and adapters based on the gender of the band pass filter connectors. Allow the eVNA-63+ sufficient time to warm up.

#### Calibrate

Carry out the calibration using the 2-port SOLT method, with the correct calibration kit selected. Refer to section C-4.4 for details.

#### Measure

1. Connect the DUT into the RF test path using the same configuration of accessory cables and adapters used for the calibration
2. Set 2 traces to display S11 and S21 on the same graph:  
[Channel / Trace](#) → [Trace](#) → [Num Traces](#) → [2](#)
3. Trace 1 will default to S11, click trace 2 to make it active and then set it to display S21:  
[Response](#) → [Measure](#) → [S21](#)
4. Add a marker to the trace:  
[Markers / Analysis](#) → [Setup](#) → [Marker 1](#)
5. Set the marker to the center of the pass band response by specifying the frequency or using the peak search function:  
[Markers / Analysis](#) → [Search](#) → [Peak](#) → [Search Peak](#)
6. Display the filter bandwidth using the bandwidth search function:  
[Markers / Analysis](#) → [Search](#) → [Bandwidth](#)

The marker label will display the bandwidth, center frequency, lower and upper cut-off frequencies and the Q of the filter, as shown in Figure 46.

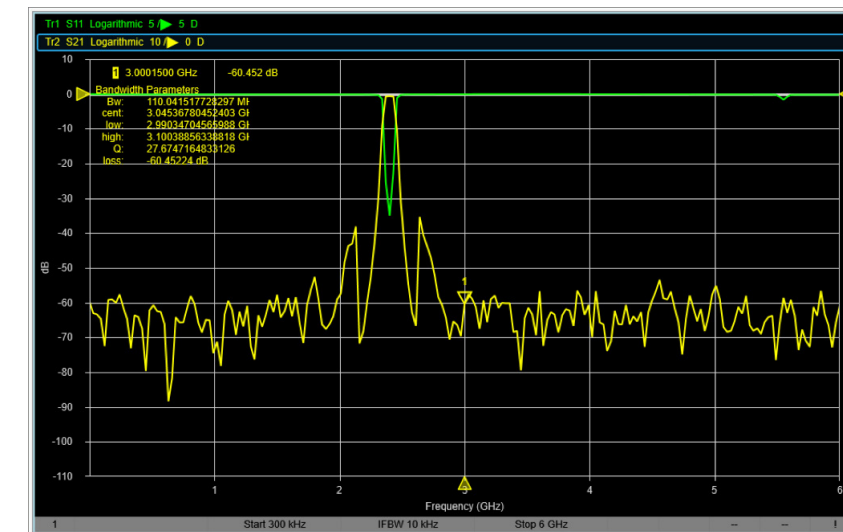


Figure 46: Measured band pass filter S21 response

### 3. De-Embedding Measurement Data

De-embedding is the process of removing the contribution of a test fixture from the measured DUT results, the goal is to move the reference plane as close to the edge of the DUT as possible. This capability can be used to remove the phase length / loss of fixed coaxial cables, microstrip lines, or test fixtures from a DUT measurement. Figure 47 shows a possible application for this principle, where the calibration was performed with the configuration on the right but later in the setup an additional cable is required between the DUT and eVNA instrument.

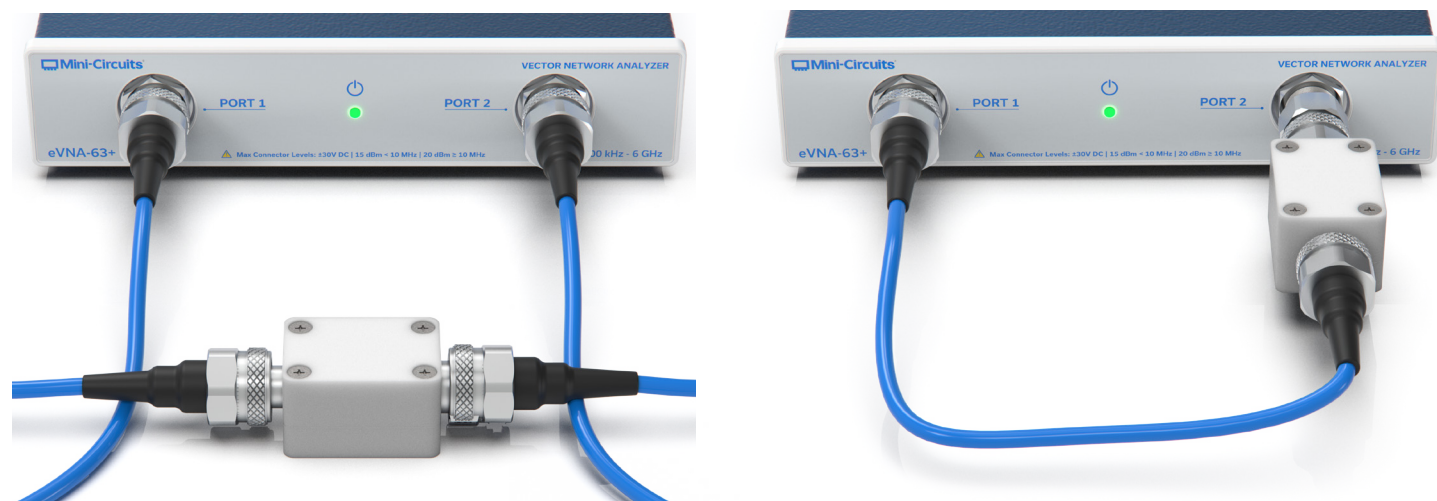


Figure 47: Typical 2-port DUT measurement setup

The eVNA supports 3 possible methods of de-embedding, the details of which are covered in the respective sections of this guide.

1. Port extension
2. Time domain gating
3. Modify the calibration kit

#### 3.1 Port Extension

Port extension allows the reference plane to be moved from the calibration plane to the DUT edges by adjusting for time delay and loss in the test fixturing.

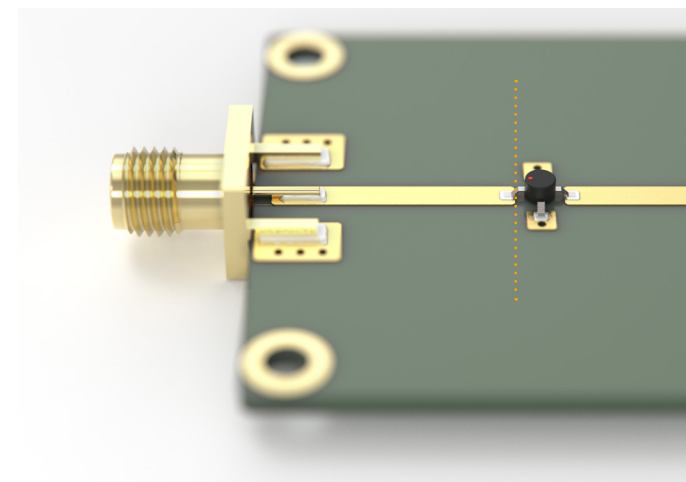


Figure 48: Desired reference plane location at the DUT input, mounted on an evaluation board

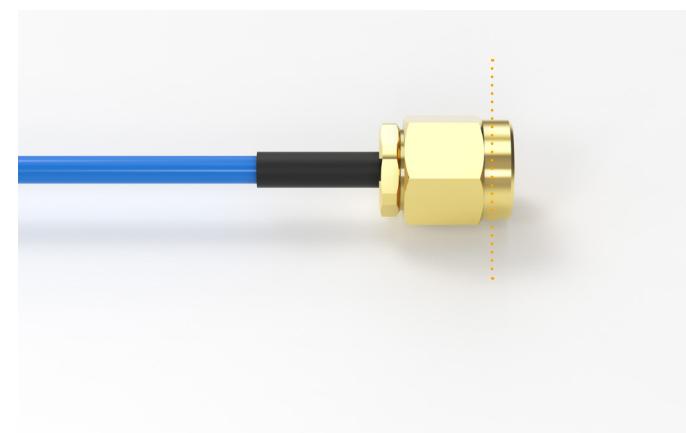
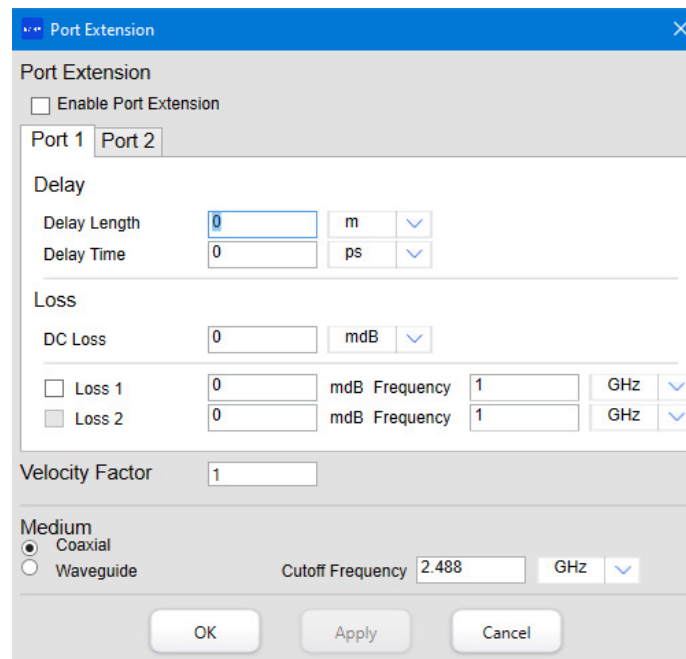


Figure 49: Desired reference plane location at the output of the VNA cable

Figure 48 presents a common application for port extension where characterization of a DUT mounted on a test fixture is required. After calibration, the reference plane for the eVNA is at the connector edges as shown in figure 49. The DUT is mounted on the test fixture after the SMA launch connector and a section of microstrip (middle of image). To measure S11 of the DUT itself, the input section of the fixture needs to be de-embedded by moving the reference plane from the test cable connector, to the DUT input lead. Using port extensions, it is not required to perform the difficult task of creating a separate test fixture without the DUT as a reference measurement. The electrical characteristics of the fixture can be de-embedded from the measurement mathematically.

1. Open the port extension settings window  
[Response](#) → [Cal](#) → [Port Extension](#)



2. Check the "Enable port extension" option
3. Specify the electrical delay time required. If delay length is known instead, enter this and the software will automatically calculate and suggest the equivalent delay time value. Delay time must be between -10 and +10 seconds.
4. Specify the loss for the test fixture / substrate at DC and 1 to 2 other frequencies if known. An equation is applied to extrapolate loss across the sweep range.
5. Adjust the velocity factor for the medium as required (table 10 summarizes some typical values)
6. The media type can also be set between coaxial and waveguide (the cut-off frequency must be specified for waveguide)
7. Repeat for port 2 if required
8. Click Apply and OK to update the measured data

Dielectric	Velocity Factor
Light in a vacuum	1.0
Air line	1.0
Polyethylene	0.66
Foamed polyethylene	0.82

Table 10: Typical dielectrics and their velocity factors

### 3.2. Time Domain Gating

Time domain gating is another feature of the eVNA which allows the user to de-embed test fixtures from the measured data. Data can be mathematically transformed into the time domain and a particular portion (based on the electrical length) "gated" from the data. On converting back to the frequency domain, the effect of the gated section is removed from the data. The gate type can be defined in terms of a notch or bandpass characteristic

### 3.3. Modify the Cal Kit

The ability to modify calibration kit provides a simplistic method to remove the effect of the test set-up from DUT measurements. Calibration kits can be defined to include the effects of adapters, coaxial cables, connectors, and other components in the test path. Refer to section C-3.5 for details on how to modify the cal kit standards.

#### Note:

- It is recommended to clearly label cal kits which have been modified in this way, to avoid inadvertent use in other measurements where the "de-embedded" items are not included.

## 4. Optimizing Measurement Speed vs Measurement Performance

There are a number of VNA settings which can be altered to optimize the measurement, typically as a trade-off between measurement speed and measurement accuracy.

### 4.1. Number of Sweep Points

Reducing the number of points in the sweep will reduce the sweep time. If the typical characteristic of the DUT is known then it may be possible to optimize the number of points by using a segmented sweep. The sweep for a band pass filter measurement for example, could be configured to have more points in the transition regions where a large variation in data is expected, with fewer points in the pass band and far into the stop band.

### 4.2. Turn off Display Update

Where fastest speed is critical and the measurement does not need to be viewed live, the display update can be turned off and the trace will pause at its last value. Measurement operations continue in the background and the display update can be re-enabled again

when needed. This feature is particularly applicable where the measurement is automated via the eVNA API.

#### 4.3. Use a Single Source

Using both sources for eVNA measurements will double the sweep time due to internal source switching. Limiting the measurements to those from a single source (for example S11 and S21 only) therefore allows a faster sweep time.

#### 4.4. IF Bandwidth

IF bandwidth can be adjusted to suit the highest measurement priority. Narrower bandwidths reduce the effect of random noise on the measurement, improving measurement accuracy. Wider bandwidths allow a faster measurement speed but at the expense of measurement accuracy.

#### 4.5. Data Averaging

Data averaging can be enabled to improve measurement accuracy. Each data point is calculated as an average across a set number of sweeps, therefore minimizing the effect of any random noise fluctuations on the data. The trade-off is against measurement speed as multiple sweeps need to be performed for each measurement.

#### 4.6. Sweep Power Level

Increasing the power level of the sweep has the effect of increasing the signal to noise ratio (SNR) of the sweep, improving overall measurement accuracy.

#### Caution:

- Review the power ratings of all devices connected in the test path before selecting an output power level