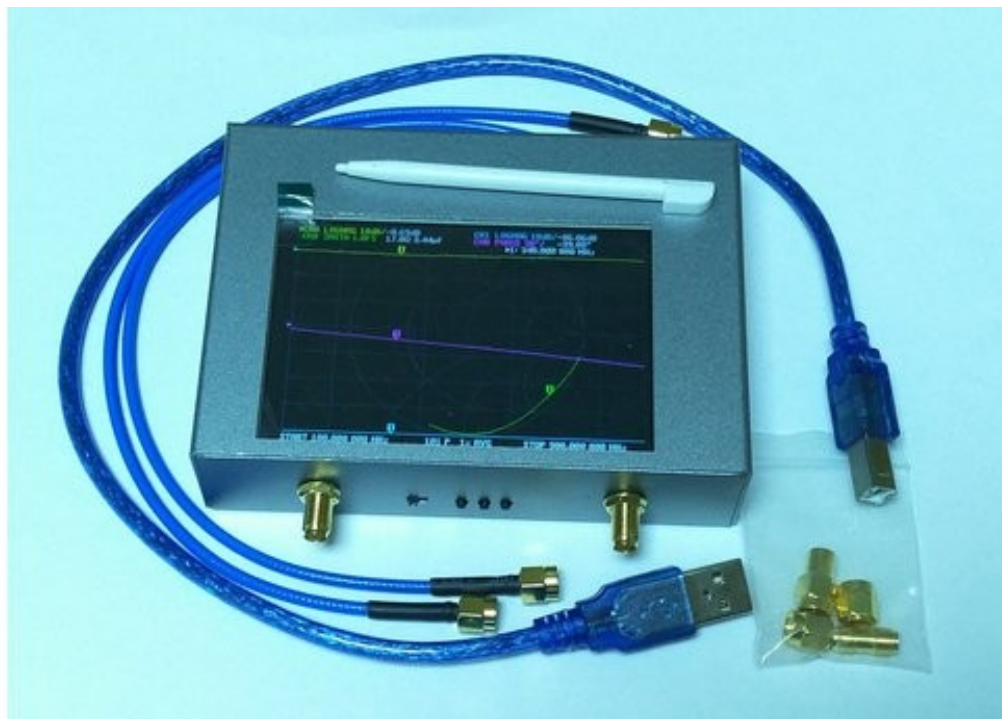# THE MISSING MANUAL

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FOR THE

NanoVNA V2 PLUS4 v2.4

Manual Version 0.562

Contents

INTRODUCTION

Unless otherwise noted, any reference to "**Nano**", or "**NanoVNA**" in this manual refers specifically to a NanoVNA V2 PLUS4 v2.4 with F/W version git-20201013-32077fd. "**VNA**" refers to a generic VNA.

The goal of this document is to help beginners learn about and operate this amazing instrument, the NanoVNA V2 PLUS4 ver. 2.4, as rapidly, efficiently, and accurately as possible. I believe there are many errors and misconceptions written into other documentation along with missing basic information that makes it a real challenge to get there, not to mention the fact that none of them are specific to this version and leave a lot to interpolate for a beginner.

This is not an application manual. Its goal is to explain what the Nano functions are, what they do, and how to implement them.

Specifically, I am using a **NanoVNA V2 PLUS4 v2.4 with F/W version git-20201013-32077fd** to write and verify this document. If you are comparing it to any other version, I am sure there will be differences. It is a little amazing how much has changed between V2.2, 2.3 & 2.4, let alone V1 to V2.

I was motivated to do this because I am frustrated trying to figure out how my Nano works with the info that is currently available. If I write it down, I learn. If it is written, others can learn. Please do not expect this to be perfect. I am only a new user, not the designer/developer.

MANUAL CONVENTIONS

1. In most NanoVNA documentation there are 2 definitions for "ACTIVE" Active and Visible. To eliminate that confusion, in this manual "VISIBLE", means a trace or marker can be seen on the display. There can be 4 visible traces and 4 visible markers. "ACTIVE" refers to the reference trace or marker. There is only one of those. You can only make parameter changes to an active trace or marker. Sometimes data will be reference to the active trace or marker.

2. For all menu instructions in this document, ≡ means "open the main menu". To open the main menu, tap anyplace on the screen, EXCEPT on a marker, or press the center button. To use the buttons for menu selection, the left button moves up, the right button moves down, and the center button executes the selection. If you roll off the menu it returns to the previous menu.

3. ► means tap: **MI** = **M**enu **I**tem: **[n]** refers to a figure: **(n)** refers to an index as in **SAVE (n)**

4. All operating instructions will be described relative to stylus use (preferred method until you lose the stylus). If you wish to use the buttons, read the button instructions (2) and apply them.

Note: that when you tap the screen to close a menu, tapping again will bring you back to where you were and not to the main menu. Some instructions do not have a "≡" because they continue a previous instruction. If you are not coming from there you will have to add those steps, or vice-versa.

WHAT IS A VECTOR NETWORK ANALYZER?

A Vector Network Analyzer (VNA) is an instrument that displays network parameters of electrical entities – a Device Under Test (DUT). A DUT can be a single component like a capacitor or inductor, a device like a LPF, HPF or BPF, or an antenna system from transmitter to radiating device. As I have discovered, the DUT can be a large number of other things. There are literally tons of applications. Refer to the Appendix for some links to many.

It performs this analysis with just two measurements, amplitude and phase. By transmitting a signal of a specific known frequency and amplitude and measuring the amplitude and phase change of the signal returning from the DUT and/or passing thru the DUT.

These parameters are famously known as "S" (Scatter) parameters and are designated

$$\mathbf{S_{11}, S_{21}, S_{12}, S_{22}}$$

The 1st subscript is where the signal is measured. The 2nd subscript is where the signal is applied.

So, $\mathbf{S_{21}}$ is measured at port 2 with the signal applied to port 1. That would be a TRANSMISSON characteristic – port 1 to port 2. $\mathbf{S_{11}}$ would be a REFLECTION characteristic since it is reading both parameters at the same port. Ports on the NanoVNA are also referred to as **CH**annels, **CH0** for port 1 and **CH1** for port 2. Since the NanoVNA only transmits a signal from port 1, it cannot do $\mathbf{S_{12}}$, or $\mathbf{S_{22}}$ measurements ….. without a little help. Simply reverse the connections to the DUT. This may create a small error mostly because you are moving things around, but if you were concerned about that you would have that $30,000 VNA.

The ONLY signals a VNA measures are amplitude and phase. With this information, and its knowledge of the frequency it is generating at 0 phase, the VNA calculates relevant S parameters for that DUT. Once calculated, it outputs those parameters in an easily human readable form. In the case of the NanoVNA, that form is by graphic display and raw numbers.

When measuring one port devices, such as an antenna or individual components, the VNA transmits a signal of known magnitude and frequency from its CH0 port into the DUT and measures the magnitude and phase of the reflected signal from the DUT on the same port.

When measuring two port devices, e.g., BPF, HPF, or LPF, the VNA transmits a signal of known magnitude and frequency from its CH0 port into the DUT and measures the magnitude and phase of the signal passing through the DUT to the CH1 port. Reflected signals from the DUT are also measured on CH0.

Any data, other than amplitude or phase is calculated. Calibration is important for any frequency or band of frequencies being used because the VNA's parameters contributes to the result and must be zeroed out by the calibration.

Obviously, a $30,000 VNA would be much more accurate with more capabilities than a NanoVNA, but for its intended use, the NanoVNA beats the price and can be quite accurate if used properly.

(That's a very simplistic explanation but enough to get us started).

WHAT CAN YOU DO WITH A VNA?

Most people who purchase a Nano have a few specific projects they want to use it on. The more you learn about a VNA, the more you realize your imagination can go wild. The only limitation is the frequency range. Audio parameters can be characterized with the right VNA – not a Nano.

This site is a gold mine of ideas with 71 application notes. Some of them are referenced below. But I would finish reading/studying this manual before diving into that information. Here is a small taste.

Measure:

Complex gain of active and passive circuits
Complex impedance and admittance of active and passive devices
Swept S-parameters of electronic circuits and filters
Group delay characteristics
Input Impedance and Filter Stability

Analyze:

Traditional and Non-Invasive Stability Measurement
Stability of control circuits such as DC/DC converters in power supplies
Parasitics of passive components and circuit boards
Power-plane impedance for optimum decoupling
Reflection coefficient and return loss of filters, antennas or amplifiers
Ultrasonic and piezo electric devices
Resonance frequency and Q-factor of RFID tags, NFC tags, antennas, and crystals

And don't forget the world library of YouTube. I found tons of info there also.

WHAT IS IN THE BOX

Depending on where you purchased it, the NanoVNA V2 PLUS4 v2.4 comes with a 4-piece calibration set - open, short, load, & thru, two male-male SMA cables, a USB2-B to USB2-A cable, female-female SMA adapter, and a stylus to operate the touch screen menu and markers.

MODEL INFORMATION

Ninety percent of this document likely applies to the V2.3 2.8" screen version as well, but I do not have one and cannot verify that. A lot has changed thru the various models, so if you have one of those it would be better to refer to a more targeted document. The screenshots in this document come from my Nano or other documents when applicable. Given the options available with this Nano, it shouldn't be a surprise if a screenshot does not exactly match yours of the same vintage. So, you may find screenshot that are not exactly like yours if you are looking at something other than what is being discussed in that screen.

The major difference with different models will be the capabilities of the device. The NanoVNA V2 PLUS4 ver 2.4 is currently the most advanced (IMHO, read expensive). Refer to the SPECIFICATIONS in the Appendix. To compare specifications to other versions, visit the referenced user websites in the SUPPORT section.

BEFORE YOU START

There are a couple of things you may want to consider before you start playing with your new NanoVNA.

1. The SMA connectors will take some wear and tear. You may want to add a Male-Female SMA adapter to each. It will be a lot easier changing those, than replacing the PCB connectors. However, if you need to, that should not be too difficult. There is a teardown in the Appendix.

2. The screen is like any other portable screen and you may want to add a screen protector. For reference, the size of the protector should be 59mm x 92mm. You can go slightly larger up to 61mm x 94mm but that does not buy you anything. Do not go smaller. The screen protector I used came from AliExpress and had cutting guides on it.

3. Various adapters and cables to be able to handle devices with N, F, BNC, RPSMA, etc. in male/female forms. These are cheaply available direct from China (AliExpress) or pricier from AMZ or eBay. An extra set of calibration standards might also come in handy if for nothing else than when you lose one.

4. A factory calibration is stored in **SAVE 0**. That is what boots up. I do not know what the quality of their standards are but it might be interesting to compare. (Now I think of it). The first thing I would do NOW, if I had a new one, is to do a CALIBRATE and a **SAVE 1**. Then VERIFY my calibration, **Recall 0** and verify again. The difference is your standards vs theirs. Document it. It may help in the future to get better accuracy using **Edelay**.

5. You might also want put some color on that stylus so it isn't lost on white paper.
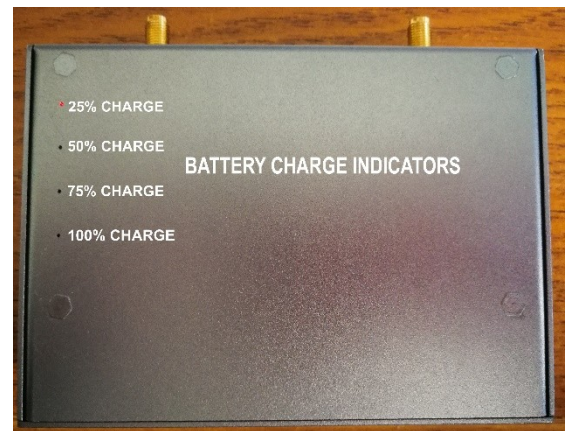
MEET THE NANOVNA V2 PLUS4 VER 2.4

Figure 2   photoshopped labels
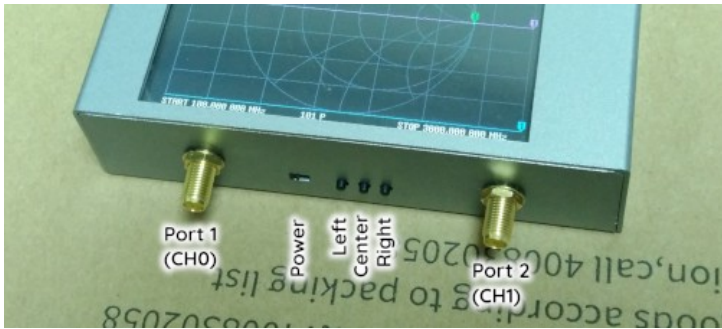
The "TOP" of the Nano [1] has the controls and ports. The "Bottom" [2] has the **USB2-B** port.

"Top" & "Bottom" depend on which way the screen is

Figure 1   photoshopped labels

flipped. Mine is connectors up with the **FLIP SCREEN** checkbox checked.

On the back of the Nano [3], you will see 4 tiny holes which provide visibility to the 4 battery charge level LEDs. Look closely and you will see this picture shows the **25% CHARGE** LED lit (red).

POWER switch turns the NanoVNA **ON**/off. After switching off, the battery LEDs stays lit for approx. 30 seconds. This is normal. It may be doing a computer type shutdown?

Figure 3   photoshopped labels

BUTTONS function in selecting and executing menu commands and moving markers.

Press the **center** button to open the main menu or to execute a selected menu command

Press the **right** (down) or **left** (up) button to select a menu item

Press the **right** or **left** button to move selected marker set along the trace on the screen.

  NOTE: The button only moves the ACTIVE marker.

CH0 – the reflection port, also known as port 1

CH1 – the thru port, also known as port 2

USB2-B port is used to charge the battery and communicate with a PC. The type B is used because it is the most rugged USB connector, and type C speed or power is not needed.

BATTERY CHARGE INDICATORS – These are the battery fuel gauge. The one closest to the CH1 port connector is the lowest charge level indicating ≤ 25%. When charging, each one flashes while it is being charged to that level. It then stays lit and the next one starts flashing. When it is fully charged all 4 LEDs will be lit. The Nano will shut down when the battery voltage reaches approx. 3.1V (my measurement, YMMV).

Refer to the Appendix for breakdown views of the Nano.

HOW DOES THE NanoVNA OUTPUT MEASUREMENT RESULTS?

The NanoVNA draws the measurement result on the screen as a graph (trace) of the measured quantity versus frequency and/or on the Smith Chart.

The trace that NanoVNA draws on the screen is similar to the graph that we could draw by hand on a piece of paper. Take SWR measurement as an example. How do we do that by hand? With a transmitter and SWR meter! We measure the SWR at regular points, e.g., at every 20 kHz in the frequency range of interest, enter the measured values onto the graph paper [4] and connect all data points to get a graph. In Figure 9, SWR was measured in the frequency range from 3500 to 3800 kHz, in regular frequency intervals of 20 kHz.

On the drawn graph, we see the SWR of our antenna on the whole band at first glance. For example, if we are interested in SWR at a frequency of 3570 kHz, we draw a vertical line from the 3570 kHz label on the X-axis to the graph. From this point of intersection, we draw a horizontal line to the Y-axis and read the SWR from the Y-axis.
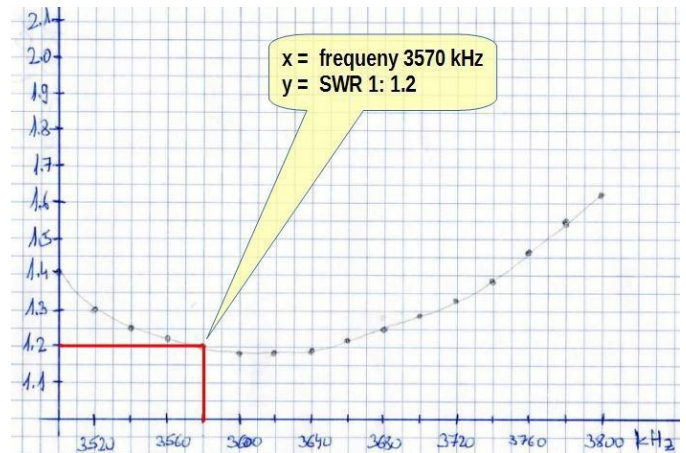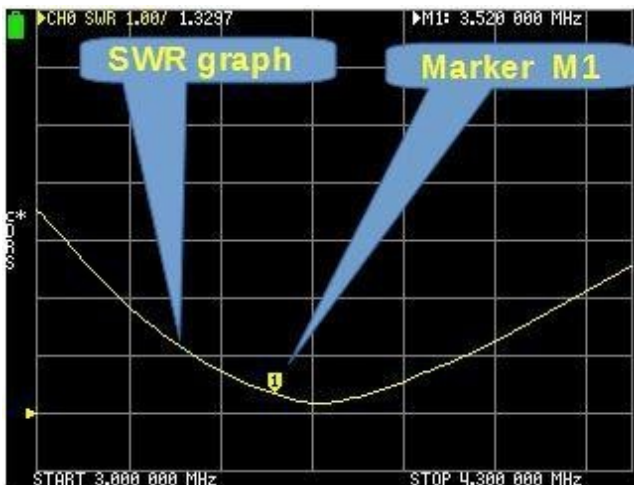

Figure 4

The above procedure took some time, no probably a lot of time. It was also more prone to failure as our antenna system was powered. A NanoVNA can produce a similar graph on the

screen [5] in a second. On the NanoVNA, we program the traces, set up the frequencies, calibrate the Nano, and connect the antenna. The rest is the NanoVNA's job. All that is left is to read the results.

We have computerized our paper graph and made it more precise and accurate. We do not have to interpolate the answer.

We are also seeing just the small portion of interest of the graph instead of the whole graph, so we can get a more precise answer. The

marker position on the trace indicates the frequency and the SWR calculation is revealed numerically at the top of the screen [5] & [6]. Bonus! We can configure up to 4 variables to be displayed at the same time with the same data in a heartbeat. Well, maybe a little longer than that.
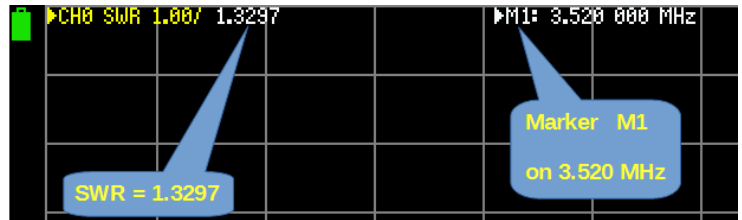
The Nano will also interface with PC programs for increased capabilities. See Appendix for more.

INITIALIZATION

INSERTING A BATTERY

You may have received your Nano with or without a battery. To insert or remove the battery, remove the 2 screws from each side and lift the top off. Pick the battery out of its holder and/or insert a battery into the holder. The holder has polarity marked but you need to look for it. There are also markings on the PCB. Reverse the process to seal it back up.

WARNING: Observe polarity when inserting the battery.

CHARGING THE BATTERY

Plug the USB cable into the Nano and into a 5V charger.

TIP: A USB2 port will only provide 500mA. My unit runs @ 420mA typ. The spec is low. Therefore, to rapid charge the battery, use at least a 1.5A charger especially if Nano is on.

NOTE: The Nano will not power on, even with a fully charged battery inserted, until it is connected to an external power source. The reason for this is that the battery charging circuitry must initialize with the new battery and cannot do that without external power. You must do this each time you remove/replace the battery.

TIP: If the USB cable is unplugged while running, even with a fully charged battery, it will reboot.

When charging the battery, the NanoVNA can be off or on, assuming you have enough supply current.

SELECTING AND EXECUTING A MENU COMMAND

With STYLUS - To select and/or execute a command from the menu, tap the command MI with the stylus. The command briefly changes the background color and is executed.

With BUTTONS – Press center button to open menu. Use the left button to go down or the right button to go up. To execute the selected item, press the center button. If you roll over the top or bottom, the menu will be closed.

RESET FUNCTIONS

RESET – This clears the calibration data in memory only. The indicators on the side go out.

RESET ALL- This resets the above and returns all parameters to default settings.

TOUCH SCREEN CALIBRATION

TIP: This needs to be done AFTER you flip the screen, if that is your preference.

For proper stylus operation, the touch screen must be calibrated and the calibration should be stored in the NanoVNA memory, otherwise, you must to do it after each bootup.

1. Tap **CONFIG** on the MAIN menu [7] ≡ ►**CONFIG** If the touch screen is too far out of calibration, you may need to use the buttons to open the screen. After that it is all stylus.

2. Tap the **TOUCH CAL** MI on the CONFIG menu [8]. ►**TOUCH CAL**

3. On the TOUCH CAL screen [8], touch the upper left corner of the screen [9] with the stylus. Push the stylus into the very corner.

4. Now touch the lower right corner of the screen [10] with the stylus. Again, push the stylus into the very corner.

   TIP: If you studder/shake when doing this, the screen may lock up. Just reboot the Nano with the POWER switch and try again.

5. Tap TOUCH TEST, then touch the screen with your pointer and drag it around creating a continuous line [11]. Releasing contact returns to the previous screen.

NOTE: The probe and trace should be dead on in the center regardless of where you touched. The trace will start leading the pointer as you move toward the edges if you did not touch the very corner of the screen. If you did, the pointer and trace will match all the way around. **THEREFORE, you must go to the edges for full verification.**

6. ►**SAVE** after calibration [8]. This calibration mostly affects the process of moving markers on the screen because of their size and does not save programming configurations.

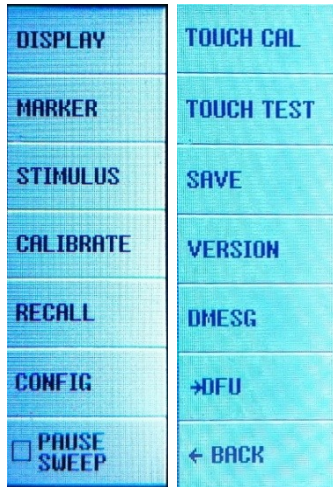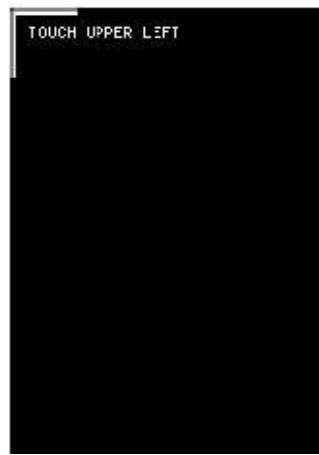**NOTE:** This calibration must be repeated any time the F/W is updated.
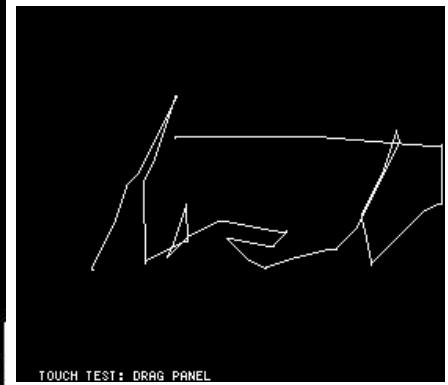
Figure 7

Figure 8

Figure 9

Figure 10

Figure 11

FLIP DISPLAY

The second thing you want to do is to set the orientation of the display. The default orientation is with the SMA connectors and controls on the bottom. If you like that, proceed to the next topic. If not, this is your first menu exercise.

Turn the Nano on and the orient the display upright. With your stylus, tap the screen any place EXCEPT on a marker (≡). The menu [12] will open up on the left. Tap (►) **DISPLAY**, then tap (►) **FLIP DISPLAY**.

In the future, the above will be written using the shorthand:

   ≡ ►**DISPLAY** ►**FLIP DISPLAY**

A check will be placed in the box [13], and the display will flip over rendering the menu on the other side and upside down. Rotate the Nano 180° and you are done. Save this with the following;

   ►←**BACK** ►**CONFIG** ►**SAVE**

PLEASE NOTE: When you flip the screen **CH0** will be on the right.

SAVING and MOVING CONFIGURATIONS

There are 2 **SAVE** functions;

 A **SAVE** for system configuration, which is the **TOUCH CAL** and **FLIP DISPLAY** data. These two items must be saved after being configured, or they will reset on power up. They should be verified after reinstalling a battery and redone and resaved if necessary.

A **SAVE (n)** for up to 7 test configurations. This saves BOTH your test configurations, and the calibration data generated by the Nano for that configuration.

Figure 12

Figure 13
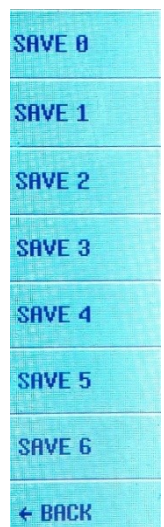
These settings are only stored in RAM. You know what that means. Avoid the agony of delete by saving to non-volatile memory. You can use it as an intermediate save during configuration. The key is to use the same location for each save of the same test configuration. Sometimes you will forget.

The save step will only be shown after a calibration is completed. If you wish to perform one during configuration, these are the steps from the display.

≡ ►CALIBRATE ►SAVE ►SAVE (n)
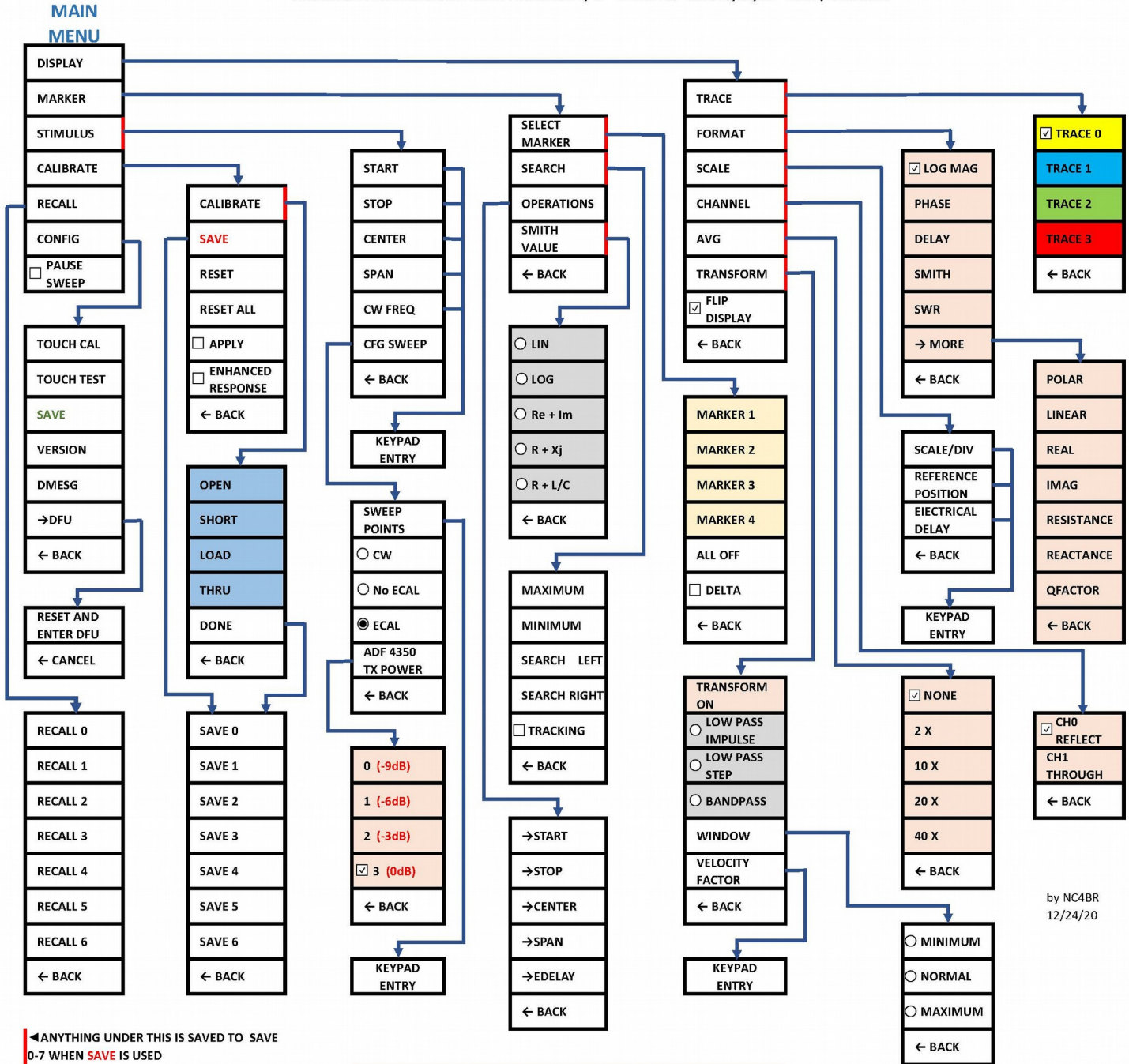
To move a configuration from one slot to another:

≡ ►RECALL ►RECALL (n) ►≡ ►CALIBRATE ►SAVE ►SAVE (n)

MENU MAP

This is the NanoVNA operating system. Memorize it and you got it. You will get the hang of it with a little persistence. Most of these are repeated in the text where appropriate.

MENU MAP FOR NANOVNA V2 PLUS4 V2.4 WITH 10/13/20 F/W
THIS IS FOR THE ABOVE UNIT WITH THE LISTED F/W   >>Rev 1.0   date 12/24/20   Merry Christmas

MAIN MENU

- DISPLAY
- MARKER
- STIMULUS
- CALIBRATE
- RECALL
- CONFIG
- ☐ PAUSE SWEEP

- TOUCH CAL
- TOUCH TEST
- SAVE
- VERSION
- DMESG
- →DFU
- ← BACK

- RESET AND ENTER DFU
- ← CANCEL

- RECALL 0
- RECALL 1
- RECALL 2
- RECALL 3
- RECALL 4
- RECALL 5
- RECALL 6
- ← BACK

CALIBRATE
- SAVE
- RESET
- RESET ALL
- ☐ APPLY
- ☐ ENHANCED RESPONSE
- ← BACK

- OPEN
- SHORT
- LOAD
- THRU
- DONE
- ← BACK

- SAVE 0
- SAVE 1
- SAVE 2
- SAVE 3
- SAVE 4
- SAVE 5
- SAVE 6
- ← BACK

- START
- STOP
- CENTER
- SPAN
- CW FREQ
- CFG SWEEP
- ← BACK

- KEYPAD ENTRY

SWEEP POINTS
- ○ CW
- ○ No ECAL
- ◉ ECAL
- ADF 4350 TX POWER
- ← BACK

- 0 (-9dB)
- 1 (-6dB)
- 2 (-3dB)
- ☑ 3 (0dB)
- ← BACK

- KEYPAD ENTRY

SELECT MARKER
- SEARCH
- OPERATIONS
- SMITH VALUE
- ← BACK

- ○ LIN
- ○ LOG
- ○ Re + Im
- ○ R + Xj
- ○ R + L/C
- ← BACK

- MAXIMUM
- MINIMUM
- SEARCH LEFT
- SEARCH RIGHT
- ☐ TRACKING
- ← BACK

- →START
- →STOP
- →CENTER
- →SPAN
- →EDELAY
- ← BACK

TRACE
- FORMAT
- SCALE
- CHANNEL
- AVG
- TRANSFORM
- ☑ FLIP DISPLAY
- ← BACK

- MARKER 1
- MARKER 2
- MARKER 3
- MARKER 4
- ALL OFF
- ☐ DELTA
- ← BACK

TRANSFORM ON
- ○ LOW PASS IMPULSE
- ○ LOW PASS STEP
- ○ BANDPASS
- WINDOW
- VELOCITY FACTOR
- ← BACK

- KEYPAD ENTRY

- ☑ LOG MAG
- PHASE
- DELAY
- SMITH
- SWR
- → MORE
- ← BACK

- SCALE/DIV
- REFERENCE POSITION
- ElECTRICAL DELAY
- ← BACK

- KEYPAD ENTRY

- ☑ NONE
- 2 X
- 10 X
- 20 X
- 40 X
- ← BACK

- ○ MINIMUM
- ○ NORMAL
- ○ MAXIMUM
- ← BACK

- ☑ TRACE 0
- TRACE 1
- TRACE 2
- TRACE 3
- ← BACK

- POLAR
- LINEAR
- REAL
- IMAG
- RESISTANCE
- REACTANCE
- QFACTOR
- ← BACK

- ☑ CH0 REFLECT
- CH1 THROUGH
- ← BACK

by NC4BR
12/24/20

◄ ANYTHING UNDER THIS IS SAVED TO SAVE 0-7 WHEN SAVE IS USED
☑ FLIP DISPLAY = CONNECTORS ON TOP
☑ WHEN SELECTED, ALL CAN BE SELECTED
CHECKBOX APPEARS WHEN DONE

HAS CHECKBOX WHEN ACTIVE, ONLY ONE CAN BE SELECTED
BUTTON, ONLY ONE CAN BE & IS REQUIRED TO BE SELECTED
SAVE saves CONFIG changes; SAVE saves calibration & parameters

SETTING UP TO PERFORM A TEST

Configuring the NanoVNA for a test is easy. The hard part is figuring out what you want to measure and what data you want to see.

Here are your options for this Nano:

- 12 variations of trace format including Smith Chart. But there are only 4 traces
- 5 variations for Smith Chart data format.
- 9 different trace positions, but number 8 is essentially useless. (not an error)
- 4 markers
- 4 power levels
- 3 variations of sweep
- Up to 199 (2-201) sweep points
- 5 averaging options
- 7 options for Transforms for Time Domain Reflectometry (TDR)
- Tracking and Delta

Go for it! ……………… Seriously, for demo boards and newbie tests, you need not be concerned with most of those options. You will probably be at the intermediate level by the time you have a need.

Let's start by programming the traces. OH, BTW, there is also 7 memory slots.

CONFIGURING TRACE

A **trace** is your window to the parameters of the DUT. You get nothing with no visible traces. You get garbage without configuring the traces.

≡ ►**DISPLAY** to open the **DISPLAY** menu [14].

The Nano can have 4 visible traces 0-3, but only one can be active at a time. An active trace is also visible, but a visible trace may not be active. An invisible trace is neither active or visible.

You can only activate visible traces. >> The Nano handles this, so be happy.

You can only configure active traces. >> **YOU** must be aware of this or you will program the wrong trace. Been there, done that, many times!

THEREFORE, for each trace that you want to configure you must start by making it or ensuring that it is ACTIVE.

Figure 14

TRACE   [15]

►**TRACE** - The trace status menu [15] will display four colors of traces. Tap a **TRACE (n)** MI until it cycles to the active state with a checked checkbox. There are only 3 options available; visible, active, or not visible/not active. The cycle repeats with 2 options. For Trace 0; (there are no gray traces on the menu here)

►**TRACE 0** ► ⊠**Trace 0** ► **Trace 0** ► ⊠**Trace 0** ► ⊠**Trace 2**

To make a different Trace active tap it as shown above. Trace 0 will stay visible but Trace 1 will become active. Play with it till you get the hang of it.

Figure 15

When Trace 0 is active, you may then proceed through the following items to configure it.

If a trace is visible, its MI will be yellow (Y) = T0, blue (B) = T1, green (G) = T2, or magenta (M) = T3. If it is gray it is not visible on the screen or active. All of them can be gray.

If a **Trace (n)** is active, its MI will have a checked box inside. Only one **Trace (n)** will be active at a time. The Nano is in control here.

From the beginning: ≡ ►**DISPLAY** ►**TRACE**

FORMAT   [16 & 17]

You assigned each trace a format. The format is the type of data that the trace will display on the screen, such as SWR, reactance, resistance, etc. The assigned format will have a checked box in its MI.

►**FORMAT** ►<select one of 12> 5 visible [16], ►→**MORE** for 7 more options [17].

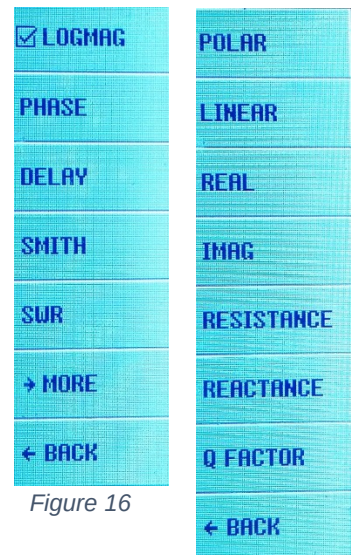From the beginning: ≡ ►**DISPLAY** ►**FORMAT** + ►→**MORE**

SCALE   [14]

Almost there! The Nano display is divided into 8 horizontal sections.

Figure 16

Figure 17

SCALE/DIV [18]

SCALE/DIV [18] defines the number of units of measure per division or section.

≡ ► **DISPLAY** ► **SCALE** ►**SCALE/DIV** ► keyboard entry ►x1 or ◄ to cancel

Simple keypad. Numbers "**0-9**", " ◄ ", and "**x1**". " ◄ " erases the last entry until there are no more, then returns; "**x1**" returns with entered number even none.
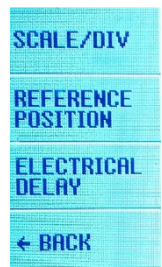
Figure18

REFERENCE POSITION   [18]

The trace reference position [18] is one of the horizontal lines on the screen and represents zero value for that function. There are 9 horizontal lines. The bottom line is #0, and the top line is #8. However, selecting #8 presents some visibility issues. The reference position of the corresponding trace is indicated by a colored coordinated ► at the left edge of the trace.

To set the reference position:

≡ ►**DISPLAY** ►**SCALE** ►**REFERENCE POSITION** ►< enter 0-8> ►**x1**

Again, a simple keyboard. 8 is not recommended. Try it and see why.

ELECTRICAL DELAY [18]

Better known as PORT EXTENSION in VNA circles since it is actually the process of extending the point of measurement (the port) electrically to the DUT. This allows you to eliminate and apparatus needed to get to the "heart" of the DUT, like cables and connectors that can't be included when calibrating. A good explanation of that is here @ 40:15.

For entry, in addition to "**0-9**", "**&**", "**.**", the keypad has "**n**", "**p**" and "**–**" (instead of x1). "**n**" = nanofarad, "**p**" = picofarad and "**–**" is to subtract the value instead of add it.

CHANNEL [19]

The Nano has two ports, known as **CH0** and **CH1** or Port 1 and Port 2.

Open the **CHANNEL** menu [19] and select a measurement port for the active trace.

≡ ►**DISPLAY** ►**CHANNEL** ►**CH0 REFLECT** or **CH1 THROUGH** >> the selected item will become checked.
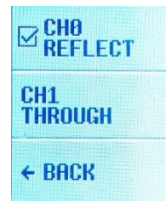
Figure19

AVG [20]

This option allows you to average the number of scans used to calculate values for each sweep.

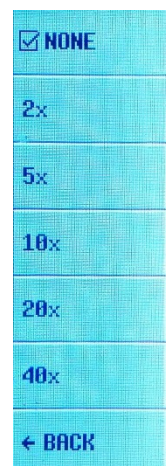≡ ►**DISPLAY** ►**AVG** ►<select one>

Figure 20

TIME DOMAIN OPERATION

The NanoVNA V2 can simulate time domain reflectometry by transforming frequency domain data. I am sure this will take some extra-curricula reading.

≡ ►DISPLAY ►TRANSFORM ►TRANSFORM ON to convert measured data to the time domain.

If **TRANSFORM ON** is enabled (checked box), the measurement data is immediately converted to the time domain and displayed. The relationship between the time domain and the frequency domain is as follows.

1. Increasing the maximum frequency increases the time resolution

2. The shorter the measurement frequency interval (i.e., the lower the maximum frequency), the longer the maximum time length

Figure 21

3. For this reason, the maximum time length and time resolution are in a trade-off relationship. In other words, the time length is the distance.

4. If you want to increase the maximum measurement distance, you need to lower the frequency spacing (frequency span / sweep points).

5. If you want to measure the distance accurately, you need to increase the frequency span.

TIP: Use a lower frequency to measure a longer length and a higher frequency to measure a shorter length and adjust accordingly for accurate results.

TIME DOMAIN BANDPASS [21]

In bandpass mode, you can simulate the DUT response to an impulse signal [22].

NOTE: The trace format can be set to LINEAR, LOGMAG or SWR.

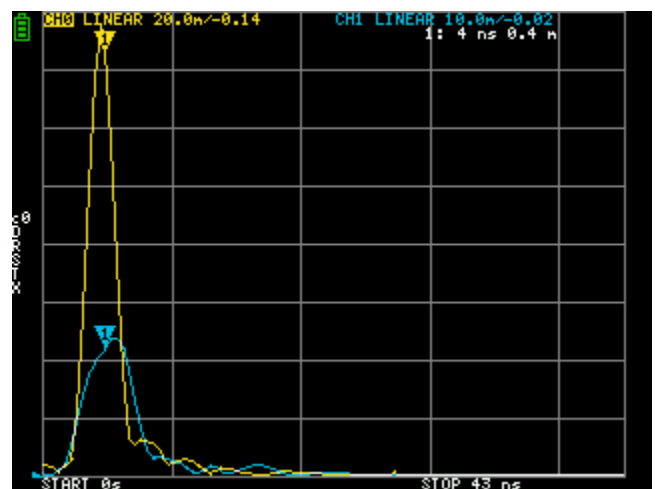This is an example of the impulse response of a bandpass filter.

Figure 22

TIME DOMAIN LOW PASS IMPULSE [21]

In low-pass mode, you can simulate TDR. In low-pass mode, the start frequency must be set to 50 kHz, and the stop frequency must be set according to the distance to be measured.

The trace format can be set to REAL.

Examples of Impulse response in open state and impulse response in short state are shown below. [23 & 24]
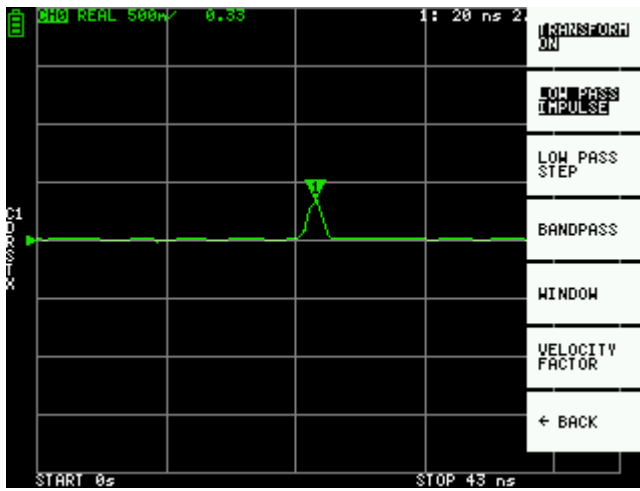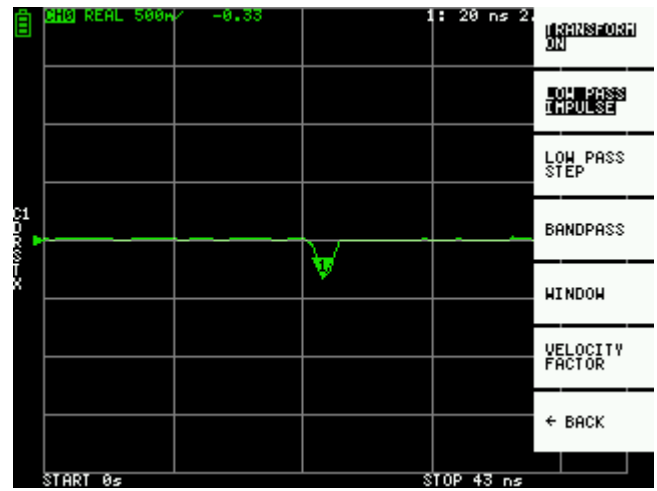
Open

Figure 23

Short

Figure 24

TIME DOMAIN LOW PASS STEP [21]

The trace format can be set to REAL. Example measurements of Step response are [25→30].
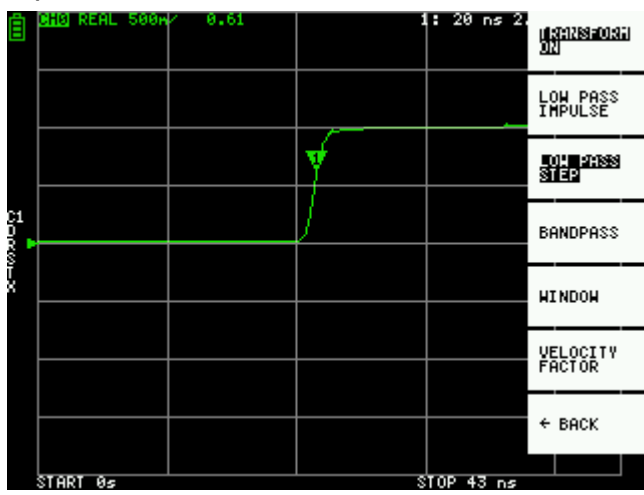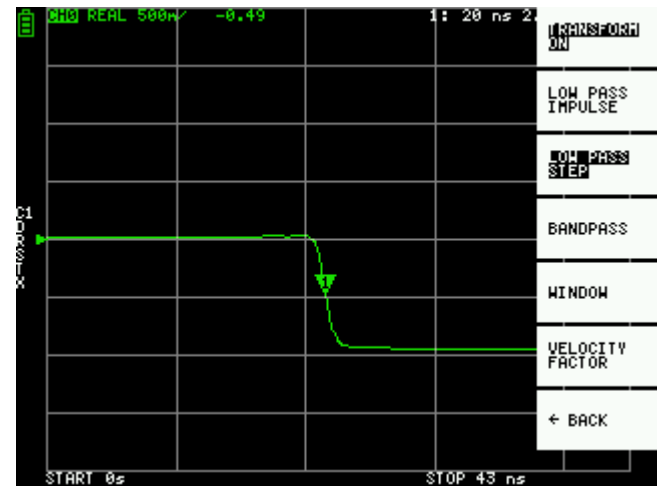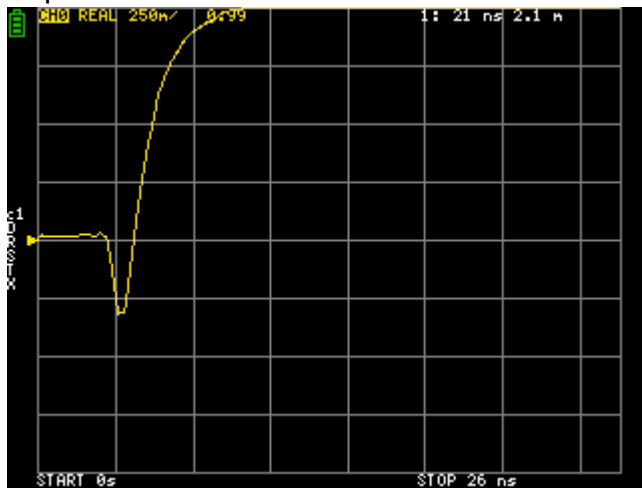
Open

Figure 25

Short

Figure 26

Capacitive Short
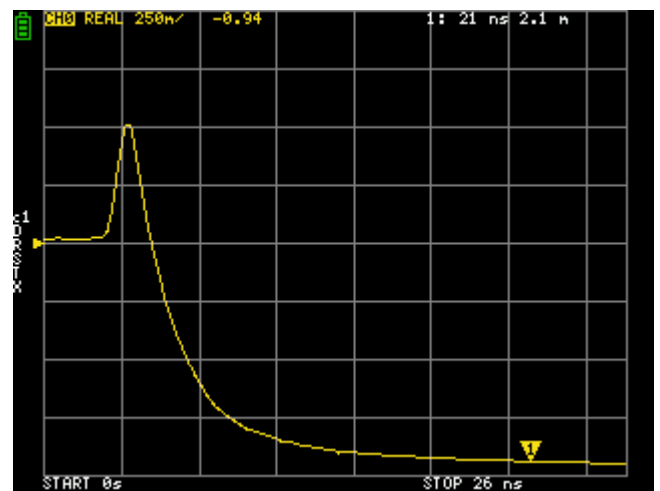

Figure 27

Inductive Short

Figure 28

Capacitive Discontinuity (C In Parallel)
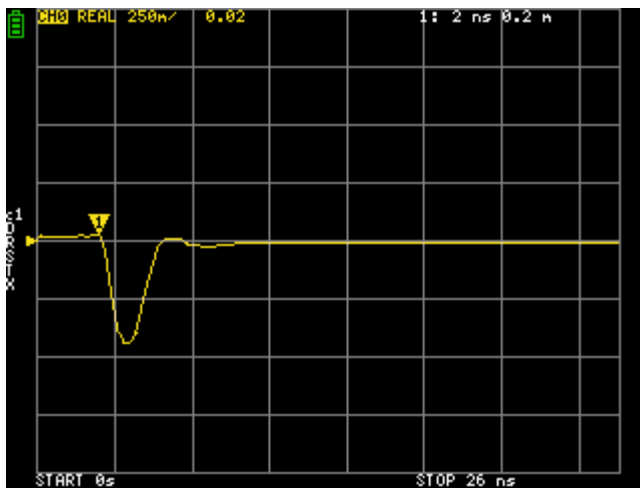
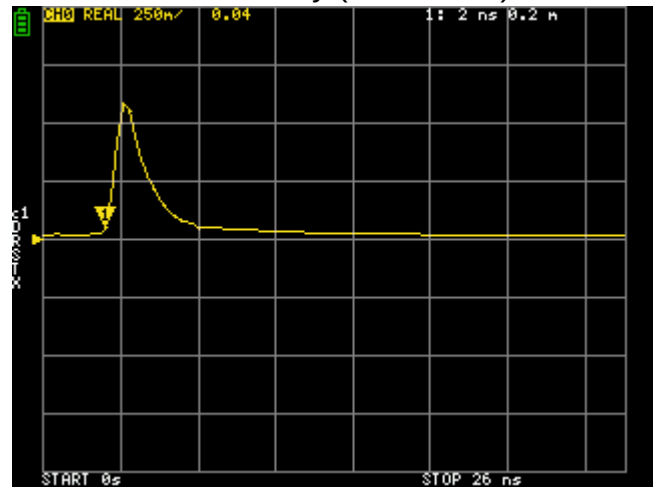Inductive Discontinuity (L In Series)

Figure 29

Figure 30

TIME DOMAIN WINDOW   [32]

The range that can be measured is a finite number, and there is a minimum frequency and a maximum frequency. A window can be used to smooth out this discontinuous measurement data and reduce ringing. A great explanation is <u>here</u>. Wikipedia comes through again.

There are three levels of windowing [31]

MAXIMUM   equivalent to Kaiser window β = 13; provides the highest resolution

NORMAL   equivalent to Kaiser window β = 6; is in the middle.

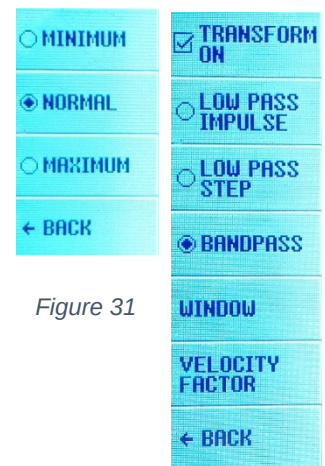MINIMUM   rectangular window; provides the highest dynamic range

Figure 31

Figure 32

VELOCITY FACTOR [33]

The transmission speed of electromagnetic waves in the cable varies depending on the material. The ratio to the transmission speed of electromagnetic waves in vacuum is called the Velocity Factor. This is always stated in the cable specifications.

In the time domain, the displayed time can be converted into distance. The wavelength shortening ratio used for distance display can be set with

≡ ►**DISPLAY** ►**TRANSFORM** ►**VELOCITY FACTOR.**

For example, if you measure the TDR of a cable with a wavelength reduction rate of 67%, specify 67 for the VELOCITY FACTOR. (Do not use a decimal point).
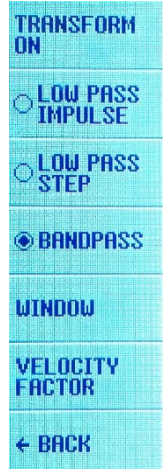
Figure 33

MARKERS

Marker operation involves turning markers on/off and moving them to provide more meaningful presentation of the results of your test. Marker status is saved when you save your configuration but most of this is classified as operational and not configuration since it affects HOW you see things, not WHAT you see.

As with traces, you can only make parameter changes to an active marker. The active marker is also the one the others are referenced to when comparisons are made.

One way to use a marker is to touch and drag it with your stylus. When you do this it also makes it the active marker. You will use this method to position the marker at any spot on one of the traces and read the parameters at that point from your marker info display.

If you are searching for a minimum or maximum point on a trace it is best to use the **SEARCH** function.

SELECT MARKER   [24]

≡ ►**MARKER** ► **SELECT MARKER** ►<turn on/off up to 4 markers> [24]

Read this slowly. You will definitely have to play with this a while.

If there are no markers on, there will be no trace data at the top of the display. A marker defines the measurement point.

A marker must be on to be visible. The process of turning a marker on is to tap the marker MI putting a checked box into its MI. When you tap the first marker, trace data is turned on but the marker is not active. When you turn a 2nd marker on, trace data changes to marker data and the marker is designated by ► **M(n)**<data> **i**ndicating that it is active. The checkbox, unlike traces, ONLY means it is visible. Tapping another marker MI or its icon makes it the new ACTIVE marker and visible if it was not already. The marker data shows the marker ID as **M(n)** and its frequency position.

Figure 34

To turn a marker off, tap its MI once if it is active or twice if it is not. The 1st tap makes it active.

Tapping an ACTIVE marker MI turns it off and the top data returns to trace data as long as at least one other marker is on.

To return to a screen with trace data, you must turn an active marker off before closing or backing out of the menu. If you try to turn an inactive marker off it will become active first then go off (2 taps).
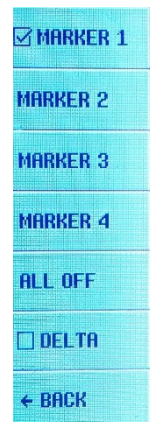
Figure 35

DELTA

►☒ **DELTA**   [35]

Tapping DELTA checks the box and changes the marker display information to show the frequency difference (Δ) between the ACTIVE marker and other visible markers. Tap a different marker MI, making it active, for different DELTAs.

►**M1 6.540000MHz**   **M2 Δ-0.040000MHz**
M2 Δ0.060000MHz

SEARCH [34]

≡ ►**MARKER ► SEARCH ►**

The functions under [23] **SEARCH** allow you to use the Nano to automatically find minimums and maximums with the <u>active</u> marker on the <u>active</u> trace. The **SEARCH** menu [24] has 4 search functions [36]:

MINIMUM	Tap to move the marker to the minimum point of the trace.
MAXIMUM	Tap to move the marker to the maximum point of the trace.
SEARCH ←LEFT	Tap to move the marker left to the next peak of the trace.
SEARCH →RIGHT	Tap to move the marker right to the next peak of the trace.

Figure 36

TRACKING	Causes the marker to follow the highest peak of the trace.

Sometimes markers will get buried behind other markers. You can usually drag them out by touching another one and dragging out the other. If they are following the same thing as the other marker it will just snap back when you let go.

OPERATIONS – [34]

≡ ►**MARKER** ►**OPERATIONS** ►

You can set the frequency range from this menu as follows [37]:

►**START** - Sets the start frequency to the active marker's frequency.

►**STOP** - Sets the stop frequency to the active marker's frequency.

►**CENTER** - Sets the frequency of the active marker to be the center frequency.

Figure 37

►**SPAN** - Sets the absolute frequency span to the last two active markers.
You need to have any two markers (M1-M4) enabled for the Span button to work. If only one marker is displayed, nothing happens.

EDELAY displays Edelay value at top and changes with each tap???

SMITH VALUE [34]

This sets all the marker's data to SMITH CHART values of the selected format.
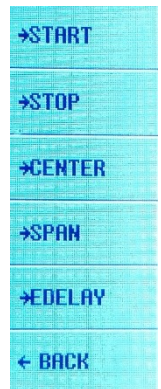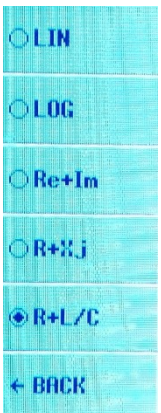
≡ ►**MARKER** ►**SMITH VALUE** ►<select format> [38]

Figure 38

STIMULUS

Stimulus is the signal the Nano generates for the test where it takes the measurements of amplitude and phase. You can specify it as **START/STOP**, **CENTER/ SPAN**, or select a single frequency **CW FREQ**. Tapping any one brings up the Frequency Keypad.

The keypad has added **G**, **M**, & **k** for **G**Hz, **M**Hz, & **k**Hz. Tapping any one will return with the value. These are multipliers x1,000,000,000, x1,000,000, & x1,000 written shorter in a more intuitive form.

Figure 26

TIP: Tapping **x1** will enter 10kHz regardless of any other numbers entered.

TIP: Minimum entry is 10k but that is below what is speced?

Tap ◄ to erase and/or cancel during entering a number on any of the following:

START/STOP entry [27]:

≡ ► **DISPLAY** ► **STIMULUS** ► **START** ► <enter frequency> ► **G, M, k** ► **x1**

≡ ► **DISPLAY** ► **STIMULUS** ► **STOP** ► <enter frequency> ► **G, M, k** ► **x1**

CENTER/SPAN entry [27]:

≡ ► **STIMULUS** ► **CENTER** ► <enter frequency> ► **G, M, k** ► **x1**

≡ ► **STIMULUS** ► **SPAN** ► <enter frequency> ► **G, M, k** ► **x1**

Figure 27

=> a **CENTER** of 100M and a **SPAN** of 30M will sweep from 85M to 115M.

CW FREQ entry [27]:

≡ ► **STIMULUS** ► **CW FREQ** ► <enter frequency> ► **G, M, k** ► **x1**
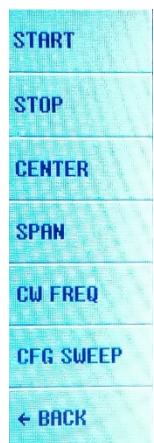
CFG SWEEP [27]

SWEEP POINTS [28]

Sweep points are the number of frequencies measured in one sweep.

▶**SWEEP POINTS** <select the number of sweep points [28] you want 2-201>

Default = 101 - lower = faster sweep, higher = more resolution

CW normally the signal on output is switched on and off (when off it is switched to internal load ECAL) if you want to use the device as a signal generator, on/off is not good ... in CW mode ECAL is off and you the set CW for stimulus

No ECAL

Figure 28

ECAL default and normally not changed. Refer to ECAL definition for more info.

ADF4350 TX POWER

TX POWER [29] is for special cases and normally can be left at default = 3.

▶**ADF 4350 TX POWER** ▶<select one> ▶←**BACK** ▶←**BACK** ▶←**BACK**

Figure 29

That's it for the STIMULUS FREQUENCY. Now go to CALIBRATION or you can skip that if you are just playing. If you want to save your work do it here [29a]
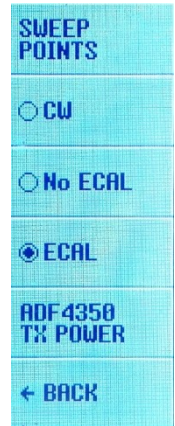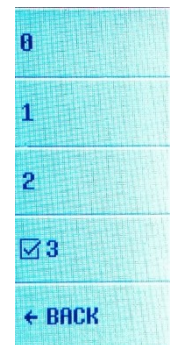
≡ ▶**CALIBRATE** ▶**SAVE** ▶**SAVE (n)**

Figure 29a

CALIBRATION

The proper NanoVNA calibration is absolutely crucial for accurate measurements.

Reality Check…..

Now that I have said that let me tell you that there is ONE assumption that puts a "fly in the ointment". **The calibration standards supplied with this instrument are PERECT**. NOT. They are cheap and they are not characterized. You can upgrade to better ones, and some are even reasonable. The question is, what accuracy do you need? And can you get that accuracy from the Nano? Maybe the Nano can benefit from $15-$50. Units. But $300-$600 units, IMHO, would be a total waste of money.

Make me a 1µh inductor. How close will you get to perfect? Put it into a box. How much will it change and will you tweak that change out of it? Not unless you are in a $100M lab designing that $30,000 VNA will that be an issue. OK, we are back to reality.

WHAT YOU NEED TO CALIBRATE YOUR NANO

Calibrate the NanoVNA with the calibration standards that came with the device: OPEN, SHORT, 50Ω, SMA to SMA

SMA to SMA connector

Figure 31

50 ohm

SHORT

OPEN

adapter and Cables.

Figure 30

The cal parts are not marked, but if you look at them it becomes obvious. I put some red (short) and black (open) Sharpie ink in the groove at the top. The cables have an SMA male connectors on each end. The SHORT has a pin in the center of the business end. The OPEN has no pin in it. The 50Ω terminator is the taller one with a male connector. The SMS to SMA is the only one left.

Figure 32

OH, and that funny looking cable you have already met doing a battery charge.

The most important one of course it the stick, aaah, STYLUS.

Technically, all you need to do for configuration to calibrate your NanoVNA is to set the STIMULUS. All the other settings simply tell the NanoVNA what to do when a DUT is connected. When you instruct it to calibrate, it knows what to do. It has already been programmed into it.

However, that would make the workflow more cumbersome, so we set it all up FIRST, then calibrate it. This INCLUDES connecting all the cables and adapters needed to finally connect your DUT.

Now if you do not have the required adapters to accomplish this your results are going to be questionable. If it is an important measurement you may want to wait till that boat from China arrives. If you are just playing or practicing, what the heck!
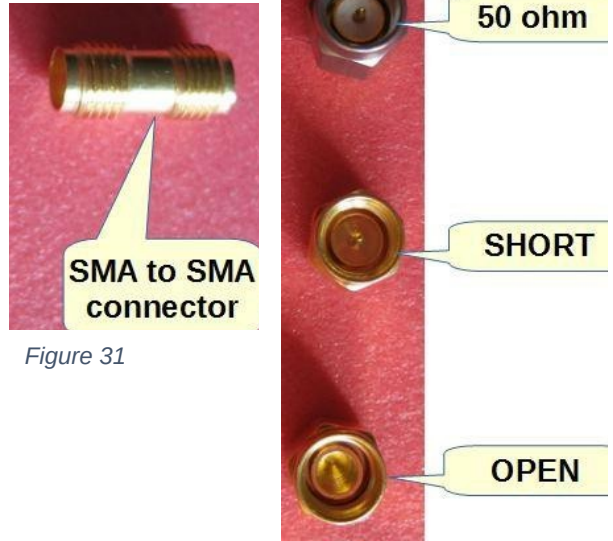
OK, what does CALIBRATION do? It zeros out all the garbage up to the point of connection to the DUT, or NORMALIZES (remember that word) the test fixture. This way, what you are reading for results are the properties of the DUT and not your test fixtures.

To get to this point, you have come a long way. You purchased and waited weeks for your NanoVNA to arrive. You unboxed and initialized your NanoVNA and charged it up. That was easy, huh? You found this manual and waded thru it soaking up every detain. You found some simple DUT you could use for a your first non-destructive (hopefully) test. You decided what you wanted to know about your DUT. You secured all the adapters needed to connect it. You stumbled back thru this manual to setup the NanoVNA for the test till you were finally told to come here.

So, let's get started. All of this is common to both an SOL and an SOLT calibration except the part where I tell you that it is not.

CALIBRATE

Power up your NanoVNA. RECALL the configuration you want to use. You did save it, right?

≡ ►RECALL ►RECALL (n) ► ←BACK

or create another one. Then

≡ ►CALIBRATE ►RESET ►CALIBRATE

Secure the **OPEN** standard to the **CH0** port

►**OPEN** and wait for the checked box. An "**O"** appears on the left edge

Remove the **OPEN** and secure the **SHORT** to the **CH0** port

►**SHORT** and wait again. An "**S"** appears above the "**O"** on the left side

Remove the SHORT and secure the **50Ω LOAD** to the **CH0** port

►**LOAD** and wait again. An "**L"** appears below the "**O"** on the left side

At this point you have an "**SOL"** calibration. All this waiting is getting you tired, right? Well, you are done and can tap **DONE,** UNLESS this is a 2-port test and you need to do the T part.

Remove the LOAD and secure the both ends to the cable assembly – one to CH0 and one to CH1. OH, you probably already have the cable ends connected thru the SMA-to-SMA adapter, right? If not, do that.

TIP: (advanced) The cable assembly is for the purpose of connecting to the DUT. If the DUT has its own cables attached you should attempt to equalize them. You can do this, depending on what accuracy you are trying to achieve, by measuring them and adding an Edelay, matching the thru cable or a combination. This is beyond this manual, but I wanted to make you aware of it.

►**THRU** and wait. A "**T**" appears below the "**L**" on the left side

At this point you have an "**SOLT**" calibration. NOW, tap **DONE**.

This will take you to the **SAVE** menu. Select the appropriate locations and all your parameters and cal data will be saved there. A **C(n)** (n=0-6) appears above the **SOLT** on the left side indicating it was saved to **C(n)**.

TIP: The factory calibration is/was stored in Slot 0. There is nothing magic about it except that is what is loaded at boot. If you want to keep it do not press SAVE 0. If you want this to be your boot configuration, **SAVE 0**.

Reboot the NanoVNA.

.

.

TIP: If you want to recreate the factory configuration do a **RESET ALL**, then **RESET** for good measure, then **CALIBRATE** and **SAVE 0**. The only thing you can't recreate from the factory is their standards.

TIP: If you want to keep **SAVE 0** for prosperity, or until you run out of slots, Just

≡ ►**RECALL 0**, then ►**SAVE (n)** to another location

TIP: You don't even have to save anything, just leave the NanoVNA on. I guess you can call that **SAVE 7 volatile**.

Remember, before any calibration we have to **RESET** the existing calibration. After the reset we see that the calibration indicators on the left side have gone away. Only then we can proceed with the calibration.

TIP: RESET clears the previous calibration data **in memory** so that calibration corrections are not applied to measurements taken for the calibration. Otherwise, you will end up with biased bias data. None of the configuration parameters like the markers & traces are changed either in the slots or in memory,

RESET ALL = resets configuration with defaults. Among them are:

START = 100MHz, STOP = 900 MHz, 101 P, 1x AVG, ECAL, TX POWER = 3, Markers = 1, TRANSFORM = off, TRANSFORM = BANDPASS, Window = NORMAL, Apply = off, Enhanced Response = off

Not changed are: TRACE, DELTA, & TRACKING.

☐**APPLY**   This turns calibration off if you uncheck it. Formerly = CORRECTION

☐**ENHANCED RESPONSE**   This makes the input circuity more sensitive to view lower-level
                      artifacts, It also increases the noise level. When this is checked an "**E**"
                      appears under the "**T**"

VERIFY THE CALIBRATION

It is wise to check that the calibration has been done well, like my steaks; Well done is not done well. This is where a little knowledge of SMITH CHARTS will come in handy.

What do you know, or at least believe? A SHORT = 0R + j0. An OPEN = ∞R + j∞ and 50Ω LOAD = 50R + j0.

Where are those values on a SMITH CHART? …………. Did you cheat and look already?

∞ is at the point where all those circles touch or where the largest circle touches the zero line.

0 is the total opposite of ∞ so it is on the left where the largest circle touches the zero line. The zero line being the one thru the center or the diameter line.

The hard part is that **50Ω LOAD**. Remember NORMALIZE? Where is the center of the SMITH CHART? It is where the 3rd circle meets the zero line, or the center of the largest circle.

THAT = 1 on a SMITH CHART. Since we calibrated with a 50Ω LOAD, a correct calibration will place that load mark at 1 or 50Ω. Basically, we are making it a 50Ω SMITH CHART.

TIP: You can make it into a 75Ω, 100Ω, anything you want with the right load. That point will always represent the value of the load used. This is why calibration works. Whatever values the NanoVNA sees during calibration it sets those points to 1 by using those values to bias what it reads while testing. So, your cal standards must appear at those points unless something went VERY wrong. That is also why those standards are so important.

If you did not select one of the traces to be a Smith Chart already, temporarily change a trace to Smith Chart.

TIP: If you have to do this and you did not SAVE your CALIBRATION, you may mess things up. Do a **SAVE (n)** first.

≡ ►DISPLAY ►TRACE ►<activate a trace> ►←BACK ►FORMAT ►SMITH

TIP: Depending on what other parameters were previously set for that trace, you may need to change a few other things to get a precise reading. If the SCALE/DIV is set too high there will not be enough resolution to get a precise reading. Other settings may also affect the precision you see.
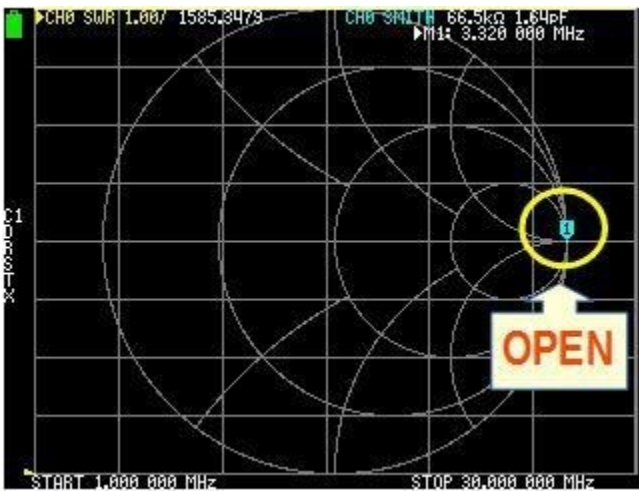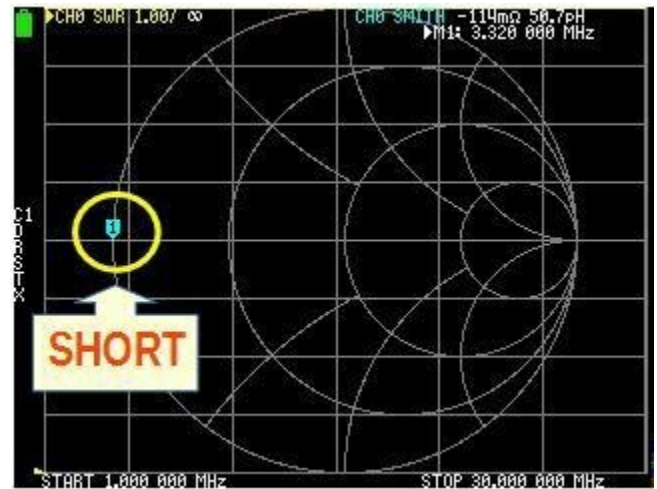
TIP: DO NOT save your change. Once you are done verifying, RECALL your saved location.

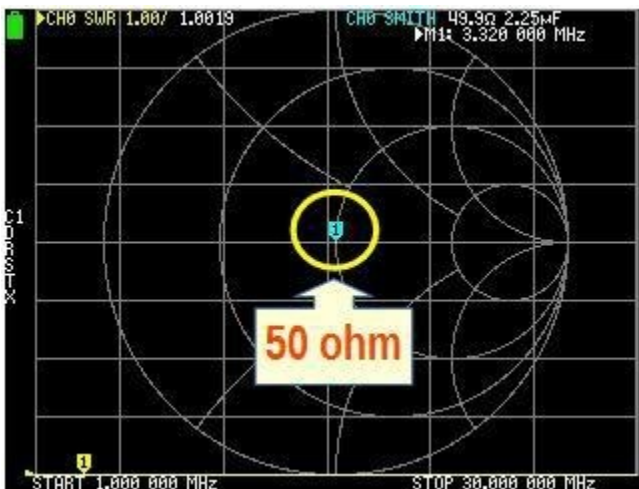Connect the OPEN calibration standard. The

marker on the Smith Chart should be all the way to the right. [33].

Figure 33

Connect the SHORT calibration standard. The marker on the Smith Chart will be all the way to the left and the resistance will be in the mΩ range. Can you understand why it isn't 0.0 ±n? [34]

Figure 34

Connect the 50Ω load calibration standard. The marker will be at the center of the Smith Chart. The value will be to 50Ω ±0.1Ω even if your standard is not 50Ω. Why is this? [36]

If the standards are defective, this will not tell you that. You would need to use a different set to verify.

Figure 35

FIRMWARE

The much of the NanoVNA's capabilities are determined by the installed firmware. The screenshots in this document were taken mostly from my NanoVNA V2 PLUS4 ver 2.4 with F/W version git-20201013-32077fd. If you are comfortable with operating your NanoVNA and updating the firmware, visit the support sites to keep up to date with the latest F/W. Just keep in mind that an update may change the relevance of some of this information.

NOTE: Firmware releases aren't always ready for primetime as demonstrated recently where an update was pulled because of a serious flaw in a new feature. So, my recommendation to not be

an early adopter and give it enough time for a good workout by the masses.

Please remember, the touch screen calibration should be done after every firmware upgrade.

OPERATIONAL TIPS

ON STIMULUS

You have programmed the Stimulus frequency for your test. Now that you know more, here is something else to think about.

If you set the frequency range from 3 to 30 MHz, the unit will generate a signal in increments of about 134.32835 kHz (27000 kHz / 201 steps). In other words, it takes a measurement at every 134 kHz, which may not be accurate enough for you.

To improve the precision of the measurement, you need to narrow the frequency range and thus get less Hz between points. Depending on how much you change this, you may need to recalibrate for the best accuracy. If you are after speed, use less steps for a given frequency range.

If you are looking for parameters around a frequency, like for a filter, you would do better with a CENTER/SPAN setup assuming you have a good idea what the center frequency is. It is easier to change if you need to widen or narrow it.

ON SCALE/DIV

It is possible to purposely set the scale/div to 0. It is also possible to do it accidentally. If you have a flat line for a parameter, check your scale first.

A DISPLAY MAP

This is a screen shot of the BPF on the RF Demo Kit. The Markers are not tagged. Is it one or 4 markers?

Value ——————————————
Scale ——————————————
Format ——————————————
Channel 0——————————————
Active Trace——————————————

Trace on CH1

▶CH0 LOGMAG 1dB/ −2.45dB
 CH0 SMITH 1.0FS 11.4Ω 633pF
CH1 LOGMAG 10dB/−35.24dB
CH0 PHASE 90°/ −101.90°
▶1: 6.400 000 MHz

Marker Freq.
Marker #
Active Marker

Saved @ Save 1
Short Cal Done
Open Cal Done
Load Cal Done
Thru Cal Done
Blue Trace
Baseline Marker

C1
S
O
L
T

CENTER 6.500 000 MHz   101 P 1x AVG   SPAN 2.000 000 MHz

Center Freq.
Set Frequency
Points/Sweep

Frequency Set
Span Freq.
Averaged