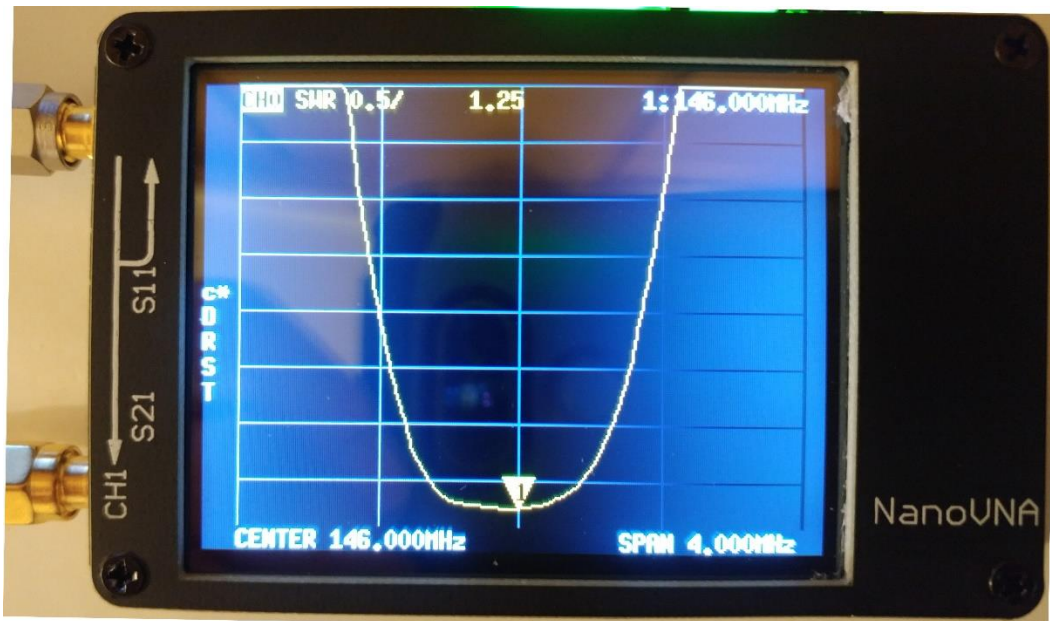# NanoVNA

Vector Network Analyzer

User Guide

WA5OKO 01/14/2020

VNA's provide very accurate measurements because of their ability to be calibrated for a particular frequency range. This article was written to help amateur radio operators who are not familiar with the operation and calibration of the NanoVNA.

Multifunction Switch   PWR LED   PWR SW   BAT LED   Type C USB Port.
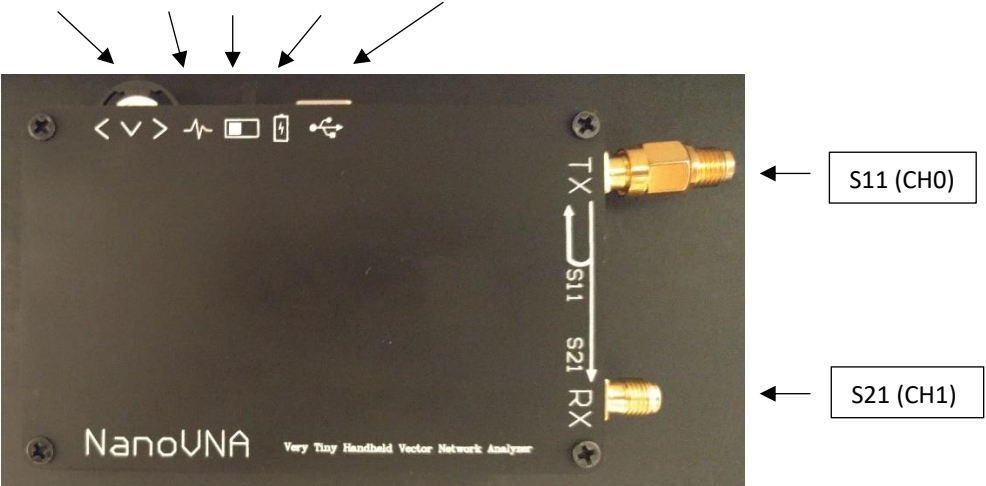
VNA Back

Multifunction Switch – Pushing down on the switch brings up the touchscreen menu and rotating the switch will select the menu function.

Power LED – This is a green that comes when the power switch is turned ON.

Power Switch – Turns VNA ON and OFF. Note: The power LED stays ON for about 40 seconds it goes out.

Battery LED – Blinks when charging and stops blinking went battery is charged. If the USB cable is plugged into a 5V power source, it charge even if the power switch is off.

USB Port – This is a USB class "C" connector, which is bipolar, so if you order a longer cable, make sure it has the correct type of connector

Trace Setting

You can have 4 traces running at the same time, using the touchscreen main menu, turn off all of the traces except Trace 0. Holding the key will turn the trace off.
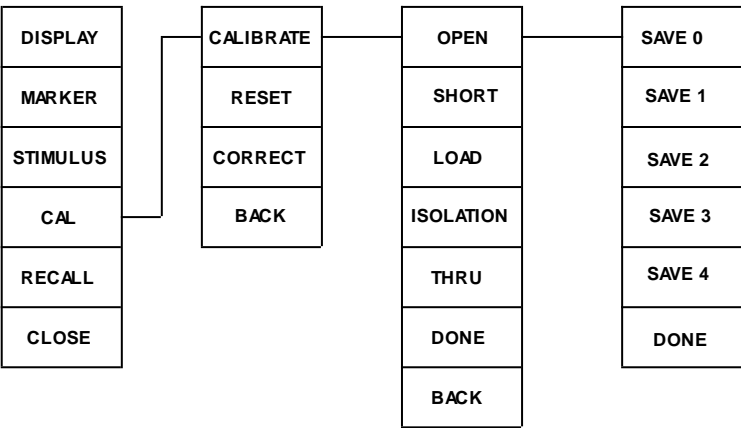
MAIN MENU
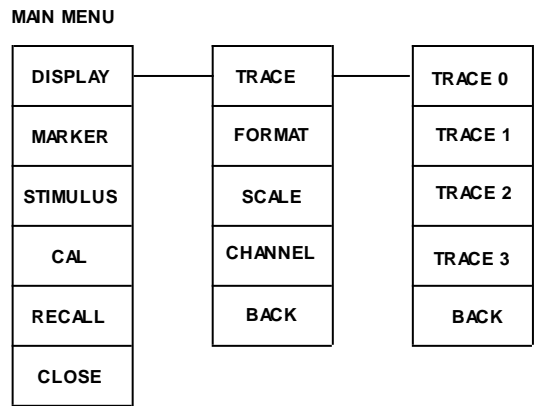
Frequency Setting

Before performing the calibration procedure, the frequency range needs to be set. When you touch the Start key, the first screen will appear, then touch the bottom right hand corner of the numbers bar and the second screen will appear. I was measuring the 2M band, using the number pad, touch 144, M and x1 to set the Start frequency. Touch the Stop frequency key and enter 148 MHz Stop frequency, then touch Back key.

MAIN MENU

DISPLAY	START
MARKER	STOP
STIMULUS	CENTER
CAL	SPAN
RECALL	CW FREQ
CLOSE	PAUSE SWEEP
	BACK

Calibration Procedure

Now that you have entered frequency range, it's time to calibrate the unit. Calibration is accomplished by applying an (OSLT) open, short and 50 ohm load to the CH0 (S11) connector, plus connecting jumper cable between the two VNA connectors for the THRU calibration. Using the touchscreen main menu:

DISPLAY	CALIBRATE	OPEN	SAVE 0
MARKER	RESET	SHORT	SAVE 1
STIMULUS	CORRECT	LOAD	SAVE 2
CAL	BACK	ISOLATION	SAVE 3
RECALL		THRU	SAVE 4
CLOSE		DONE	DONE
		BACK	

Using the calibration connectors from the calibration kit, install the Open connector on the Channel 0 (S11) connector and momentarily touch the Open menu key. Repeat this step with the Short and Load. If you are only going make S11 measurements, touch the Done key and save the calibration to one of the Save numbers and touch the Done key. If you are going to perform a S11 & S21 measurements, you must also perform the Thru calibration, install a jumper cable between the S11 & S21 ports and touch the Thru key. Touch the Done key, then select a Save number and touch the Done key. Note: You skipped the Isolation calibration. This requires that both connectors be terminated with a 50 ohm load and only one is supplied with the VNA. I've made many tests with and without performing Isolation calibration step and have seen no accuracy difference.
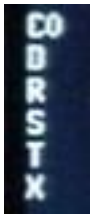
The Calibration Status is always shown on the left side of the display screen. C0: indicates that I'm using the 0 saved calibration table. D: Directivity. R: Reflection Tracking, S: Source Match. T: Transmission Tracking. X: for Isolation. In this case, I perform the Isolation calibration. You can store 5 calibration tables for each of the amateur frequency bands and use the Main Menu RECALL to select when calibration is needed. Note: If you see a C*, the calibration is missing.

Measurement Type

This VNA is a 2 port instrument, which is capable of making S11 and S21 measurrments. S11 is a reflective measurement, where the RF energy is transmitted into a device and reflected energy is compared to the forward energy. An antennas SWR measurement is a good example of a S11 measurement. Measuring insertion loss of a length of coaxial cable is a example of S21 measurment, where the transmitted output level is compaired to the level received by the receiver. If you look at the VNA's back cover, the S11 port is marked as TX and the S21 is idenified as a TX port.
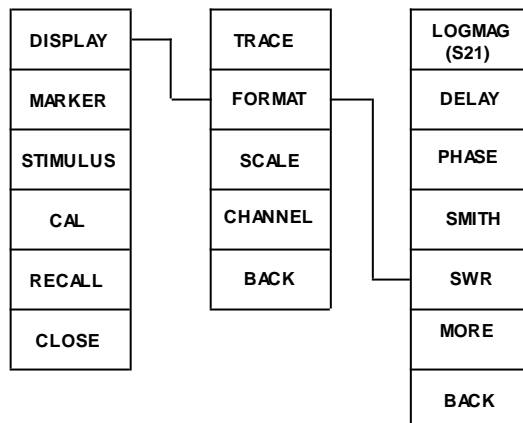
This Sample shows the SWR is 1.25:1

S11	S21
SWR	Isertion Loss
Phase	Grain
Return Loss (RL)	Polar Plots
Impedance (Z)	Group Delay
Smith Chart	
Quality Factor	
R+jX	
Serial C	
Serial	

Selecting Test Mode

MAIN MENU

| DISPLAY		TRACE		LOGMAG (S21)
MARKER		FORMAT		DELAY
STIMULUS		SCALE		PHASE
CAL		CHANNEL		SMITH
RECALL		BACK		SWR
CLOSE				MORE
				BACK

One of the drawbacks of using of using the touchscreen to operate the VNA, there's a limited number of test measurements available. The good news is, all of the S11 & S21 test modes show in the table above can be measured when this VNA is operated by your computer.

Interfacing the VNA with your computer will be covered later in this article.

The picture on the next page shows the insertion loss (S21) of a Helical Resonator Filter tuned for 146 MHz. Note that the measurement channel was changed from CH 0 to CH1.
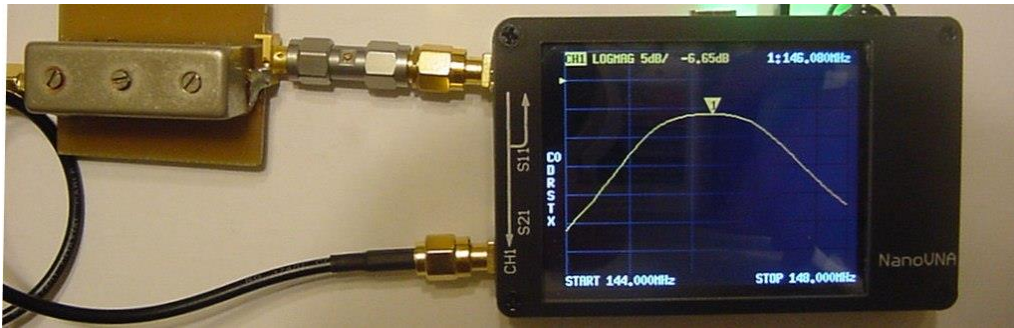
This picture shows that the filters Insertion Loss was 6.65 dB at 146 MHz's.
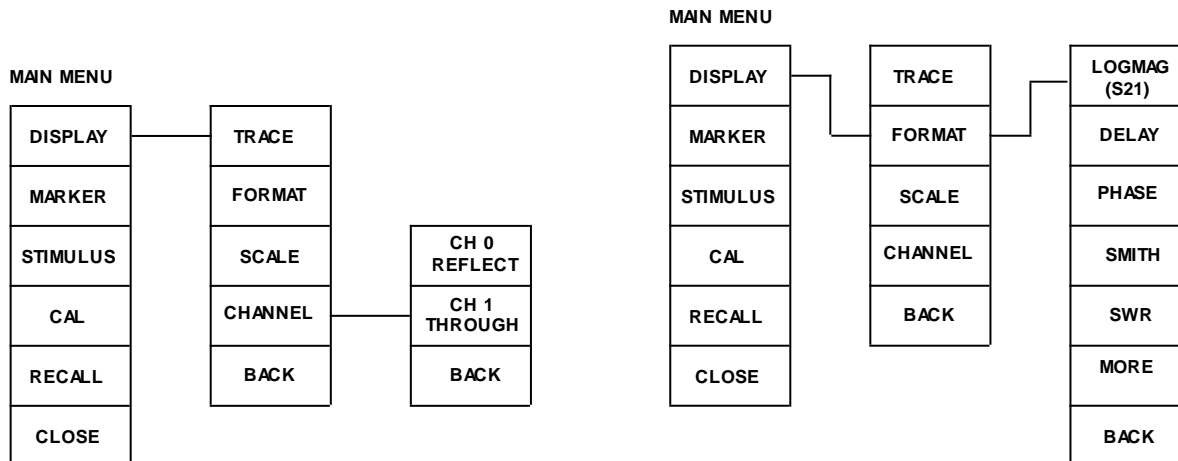
VNA Output Level

This VNA uses SMA connectors because this type of connector maintains a constant 50 ohms into the GHz frequency range. It also provides an excellent transition from the printed circuit board's planer surface to the coaxial connection.

To adapt the VNA's SMA connectors to a SO-239, N type and BNC connectors, you need to purchase these adapters. The other adapter is a Male SMA to Female SMA. SMA's ware out and it's easier to replace the adapter than the VNA connector.
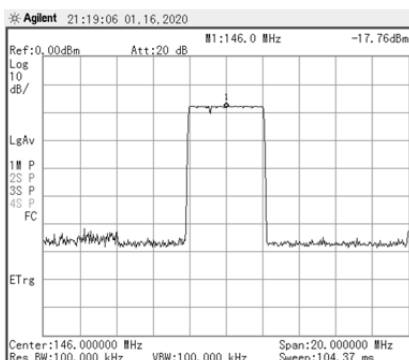

A receiver input impedance can be difficult to measure. Most VNA's output level is 0 dBm are more and could damage the receivers input stage. My MFJ-259B antenna analyzer output is 8 dBm. For repeater duplexers, the receiver's impedance must match the duplexer's 50 ohm impedance. I measured the NonoVNA's sweep output level at 146 MHz's and the level was -17.76 dBm. This is a safe level for any receiver, so the NanoVNA can be used to measure a receiver's input (Z).

Computer Interface
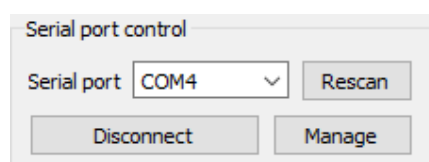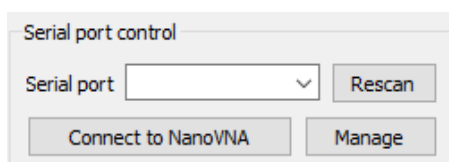
I'm using a free software program developed by HexAndFlex, but there's several programs on the web which I have not tried. https://hexandflex.com/2019/09/15/getting-started-with-the-nanovna-part-3-pc-software/
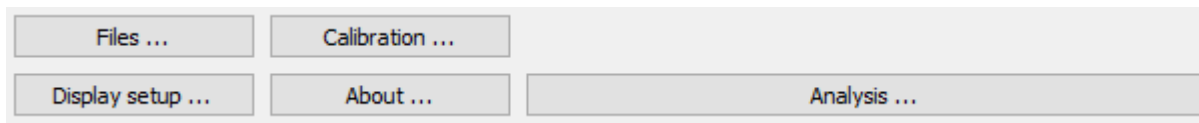
You need to calibrate the VNA and set the frequency range before connecting the VNA to the computer. The computer will transfer this information to the program.
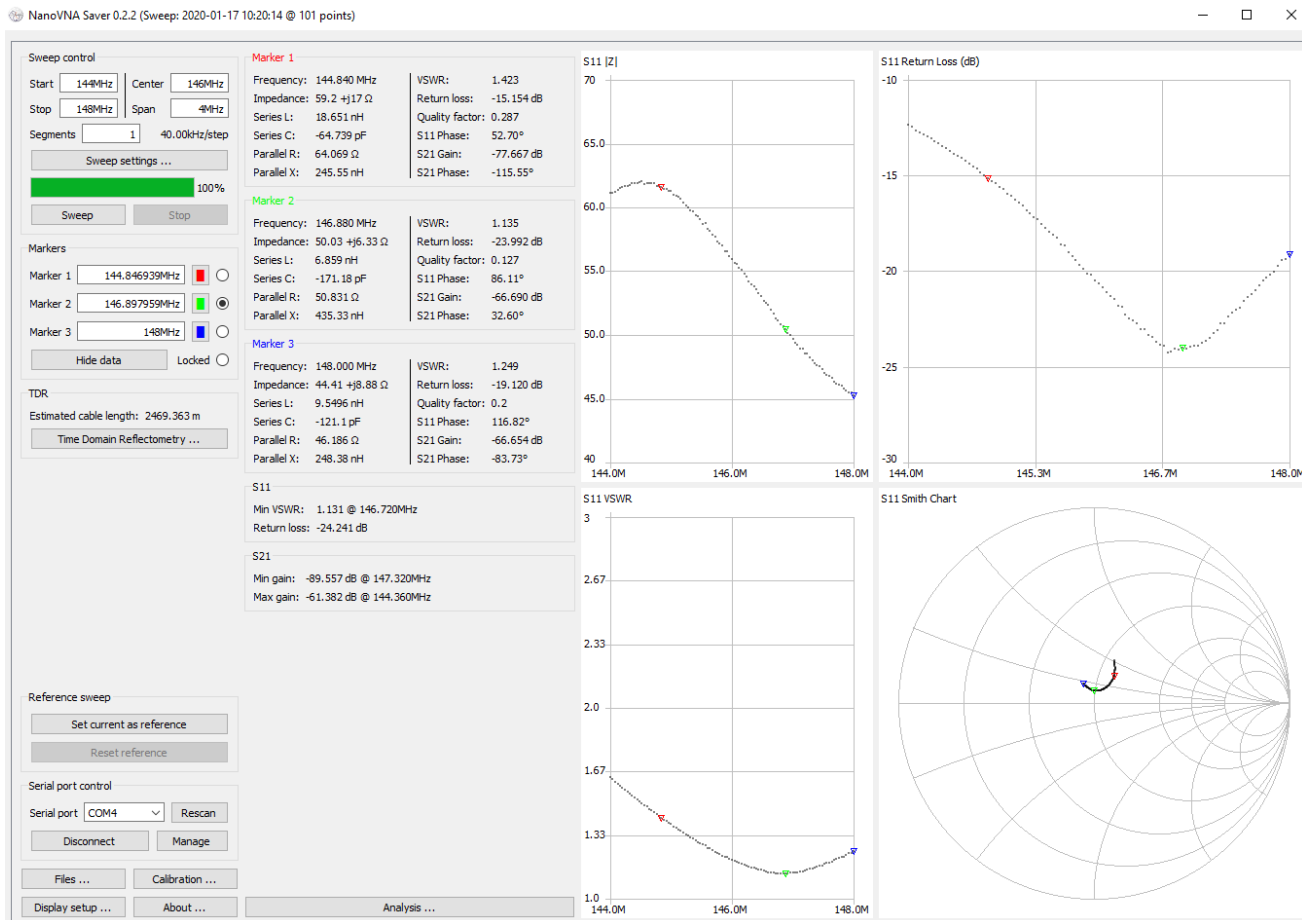
The programs main screen picture is too small to read on this page size, so I will snip various sections of this screen for illustration purposes.

When the program initially loads, you will need to select the "Connect to NanoVNA" box. My computer automatically connected to COM4 which was an open port. If the VNA doesn't connect, select the "Rescan" box. When you finish using the program select the "Disconnect" box.

Files …	Calibration …	
Display setup …	About …	Analysis …

Select the "Calibration" box and the screen below will appear.

Notice that the "Active Calibration" source is the NanoVNA which was previously calibrated. If you are going to use a different frequency range, you will need to create another calibration table. This program requires that you enter the Start and Stop frequencies and select the "Sweep" box each time you change VNA port termination during the SOLT calibration procedure. Save the calibration to your computer. You can save as many calibrations as needed and load the calibration needed for your particular test.

Select the "Display Setting" box and screen below will appear.

This screen allows you to choose how many display charts you desire and the type of measurement from the drop-down selection. In this case, I've chosen 4 charts and selected Impedance (Z), SWR, Return Loss and the Smith Chart. Note: I usually set the check the "Show Lines", change the "Sweep Color" to Black and "Second Sweep" to White.

The charts on the next page shows the test sweep results for the measurements I selected on the display setting. These tests show the test results of a 5/8 mobile antenna located on the roof of a car.
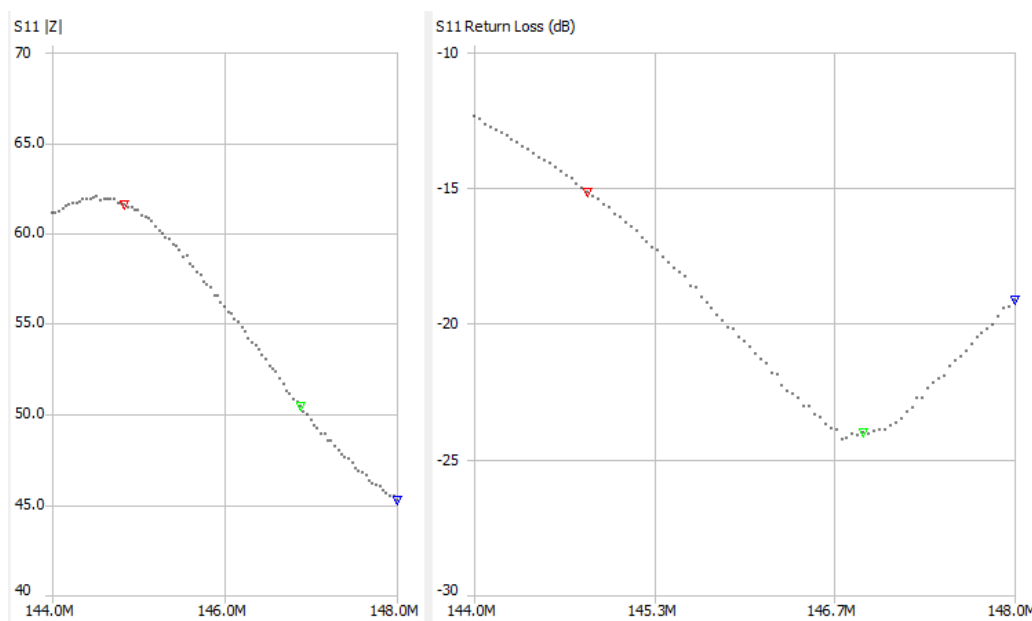
The start and stop frequencies include the complete 2M band. Looking at the Impedance (Z) chart, the impedance varied between 62 and 45 ohms. The RED marker shows the (Z) was 59.2 ohms. GREEN marker was 50.2 ohms and BLUE marker was 44.41 ohms. I set the RED marker on the Return Loss chart to -15 dB. Most antenna design engineers try to obtain RL of -15 dB because that equals to an SWR of about 1.5:1.

Marker 1

Frequency:	144.840 MHz	VSWR:	1.423
Impedance:	59.2 +j17 Ω	Return loss:	-15.154 dB
Series L:	18.651 nH	Quality factor:	0.287
Series C:	-64.739 pF	S11 Phase:	52.70°
Parallel R:	64.069 Ω	S21 Gain:	-77.667 dB
Parallel X:	245.55 nH	S21 Phase:	-115.55°

Marker 2

Frequency:	146.880 MHz	VSWR:	1.135
Impedance:	50.03 +j6.33 Ω	Return loss:	-23.992 dB
Series L:	6.859 nH	Quality factor:	0.127
Series C:	-171.18 pF	S11 Phase:	86.11°
Parallel R:	50.831 Ω	S21 Gain:	-66.690 dB
Parallel X:	435.33 nH	S21 Phase:	32.60°

Marker 3

Frequency:	148.000 MHz	VSWR:	1.249
Impedance:	44.41 +j8.88 Ω	Return loss:	-19.120 dB
Series L:	9.5496 nH	Quality factor:	0.2
Series C:	-121.1 pF	S11 Phase:	116.82°
Parallel R:	46.186 Ω	S21 Gain:	-66.654 dB
Parallel X:	248.38 nH	S21 Phase:	-83.73°
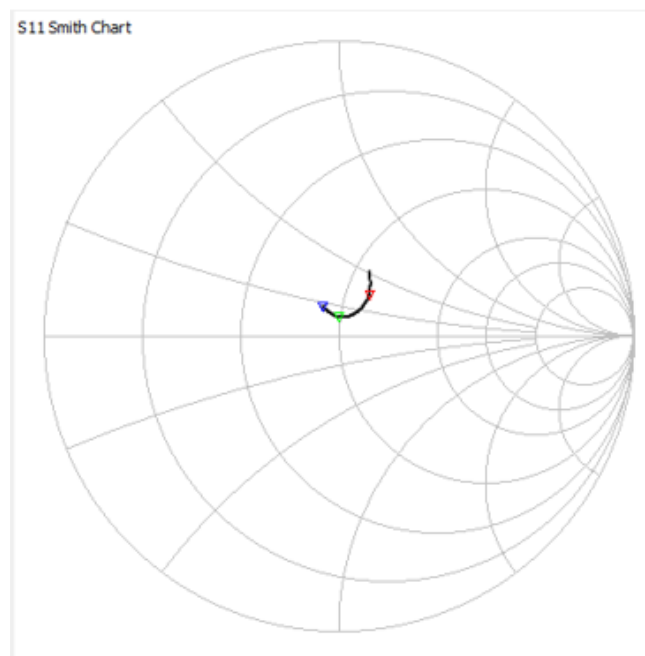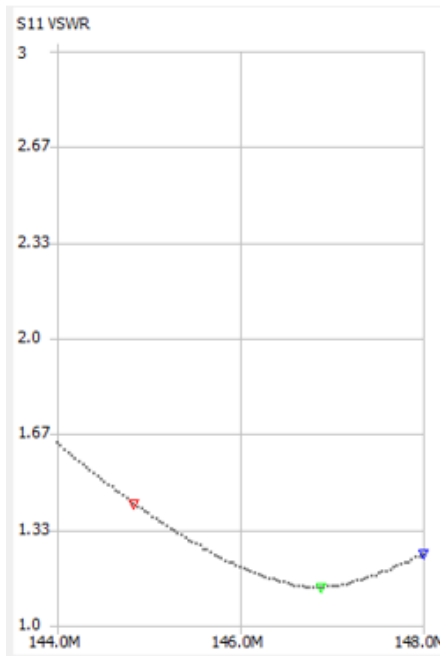
The marker data on the previous page also applies to these two charts. The Smith Chart used in this program does not include any line information and that's ok if you are familiar with these charts. The following is a short lesson about Smith Charts.
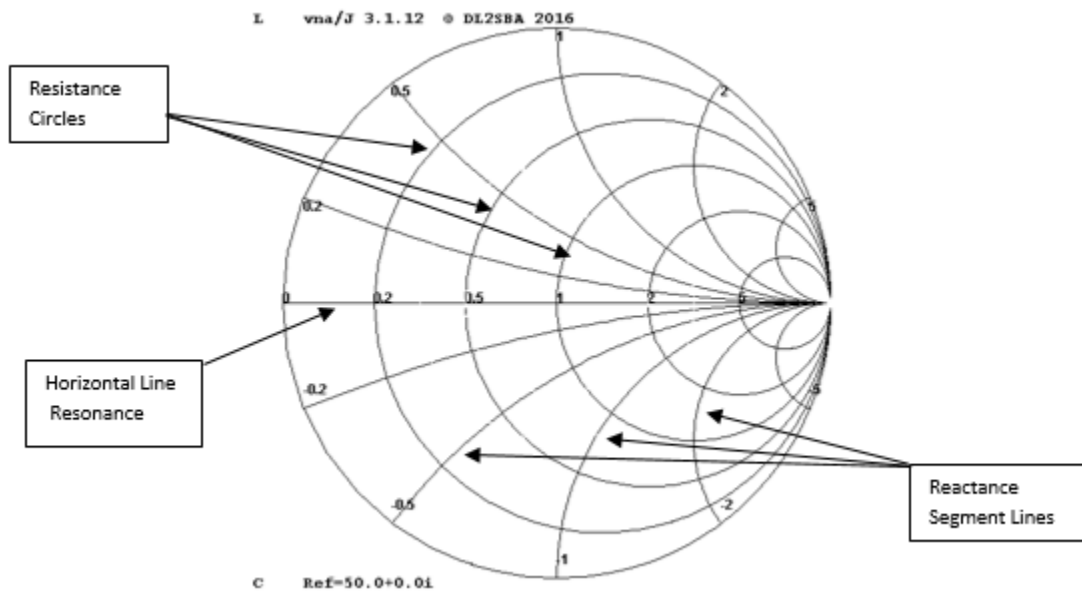
There's only one horizonal line and it's the resonant frequency line, where the trace crosses this line identifies the antennas resonant frequency. This line is also none as the pure resistance line, because at this point there's no inductance or capacitance in the ohms value. The circles represent resistance, but the ohms value above the horizontal line includes inductance and below capacitance is included. The chart on the next page shows the resistance value of each circle. The center circle is always 50 ohms.
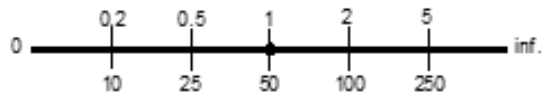
The curved segments of the Smith Chart represent reactance (X), which also measured in ohms. The reactance values above horizonal line are inductive and capacitive below the line. The chart below shows the reactive value of each segment.
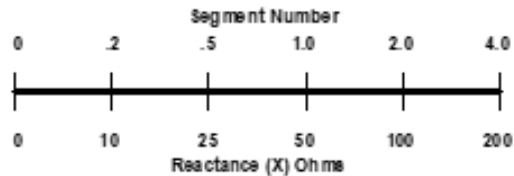
Look at programs S11 Smith Chart, the 5/8 mobile antenna is a non-resonance antenna, so the trace never crossed the horizonal resonant line. The trace is all above the horizonal line, so it is primarily inductive and any small value of capacitance that shows up in marker data is result of other measurements. The Green marker shows that trace crossed the 50-ohm circle at 146.88 MHz's. If you like designing your on antennas, Smith Charts are a great tool!

If the program does not transfer the frequency information from the NanoVNA, you will need to manually type them in the Start and Stop boxes. There's no way to signify if its Hz or MHz, so you must enter the complete number.

Markers

Once you have selected a Marker and entered a frequency, you can use your mouse the move the Marker to any location. If You have more than one Marker on the screen, you must select the Marker you want to move

VNA Accuracy

The accuracy of VNA depends on things and I don't expect a $45 instrument to be as accurate as a $20,000 VNA. There's a simple test I use to determine just how accurate your VNA might be. Choose a frequency range that you want test. You can use this test to confirm that your calibration was successful.

    Test Procedure

1. Calibrate the VNA using menu touchscreen.

2. Connect the NanoVNA to your computer and start the VNA program.
3. Go to Calibration screen and make sure the program is using the VNA as the calibration source.
4. From the Display Setting screen, choose only the Smith Chart measurement.
5. Attach the 50 ohm load to the CH0 (TX) connector.
6. Select the "Sweep" button on the program menu and allow it to complete the sweep.
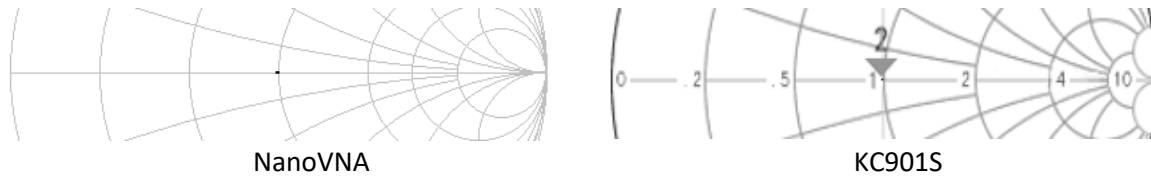
NanoVNA   KC901S

The NanoVNA and KC901S are terminated with 50-ohm loads that are pure resistance, no inductive or capacitive characteristics. Both VNA's show the trace point to be on horizontal resistive line and on the 50-ohm circle.

7. The 50-ohm load was removed and the connectors were shorted.

 Both VNA's show that a short trace was on the 0-ohm circle, but the NanoVNA shows there is a small amount of capacitance. The same short was used when VNA's were calibrated, so this error was caused by circuitry.

8. The short was removed and connector were terminated with an open.
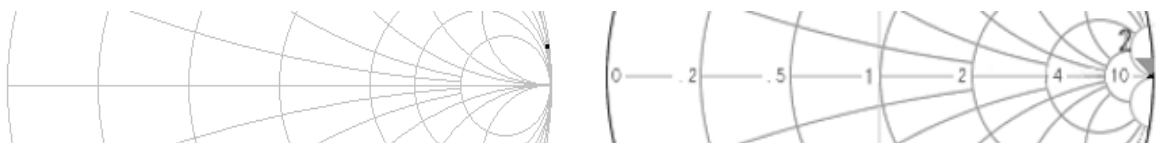
Again, both traces are on the high resistance circle, but in this case, the NanoVNA showed to have a small amount of inductance.

These tests were performed at a 2M frequency. I compared the NanoVNA to a high dollar VNA, and I'm surprised at how accurate this $45 VNA is.

End of Test

Summary

This VNA is more accurate than a lot of instruments I've used. I replaced the 50-ohm calibration load that was included with the VNA I received, it measured 52.3 ohms. Checking a receivers input impedance can damage the receivers input stage if an antenna analyzer or VNA's output is too high. The NanoVN's output is only -17.7 dBm which is a safe level for this measurement. I have not used the computer program for very long and still learning some of its quirks. I'm using version 2.2. You need to use touchscreen stylus pin with a sharp point to navigate the menu on this VNA, especially if your fingers are large.   I've included AE5CE Menu Structure Map is on the last page.

NanoVNA Menu Structure Map

START 50.000 kHz   STOP 900.000 000 MHz

nanoVNA
GEN111.TAOBAO.COM

If calibration is available, the CAL status will be displayed. Otherwise, it is hidden. C * is in the state where an unsaved calibration is applied (it disappears from memory when the power is turned off).
C0 to C4 indicates that the saved calibration values are applied to one of the save locations. Saved or Unsaved will change when calibration data is properly saved. The letters below C indicate that the following error terms have been applied. D: Directivity, R: Reflection Tracking, S: Source Match, T: Transmission Tracking and X: Isolation

Menu items:

HOME MENU: DISPLAY, MARKER, STIMULUS, CAL, RECALL/SAVE, CLOSE

RECALL: RECALL 0, RECALL 1, RECALL 2, RECALL 3, RECALL 4, BACK

SAVE: SAVE 0, SAVE 1, SAVE 2, SAVE 3, SAVE 4, BACK

DISPLAY: TRACE, FORMAT, SCALE, CHANNEL, BACK

TRACE: TRACE 0, TRACE 1, TRACE 2, TRACE 3, BACK

FORMAT: LOG MAG, PHASE, DELAY, SMITH, SWR, MORE, BACK
MORE: POLAR, LINEAR, BACK

SCALE: SCALE/DIV, REFERENCE POSITION, ELECTRICAL DELAY, BACK — NUMERIC KEYPAD

CHANNEL: CH0 REFLECT, CH1 THROUGH, BACK

MARKER: SELECT MARKER, START, STOP, CENTER, SPAN, BACK
SELECT MARKER: MARKER 1, MARKER 2, MARKER 3, MARKER 4, ALL OFF, BACK — NUMERIC KEYPAD

STIMULUS: START, STOP, CENTER, SPAN, CW FREQ, PAUSE SWEEP, BACK — NUMERIC KEYPAD

CAL: CALIBRATE, RESET, CORRECT, BACK
CALIBRATE: OPEN, SHORT, LOAD, ISOLATION, THRU, DONE, BACK
DONE: SAVE 0, SAVE 1, SAVE 2, SAVE 3, SAVE 4, BACK

By: AE5CZ
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