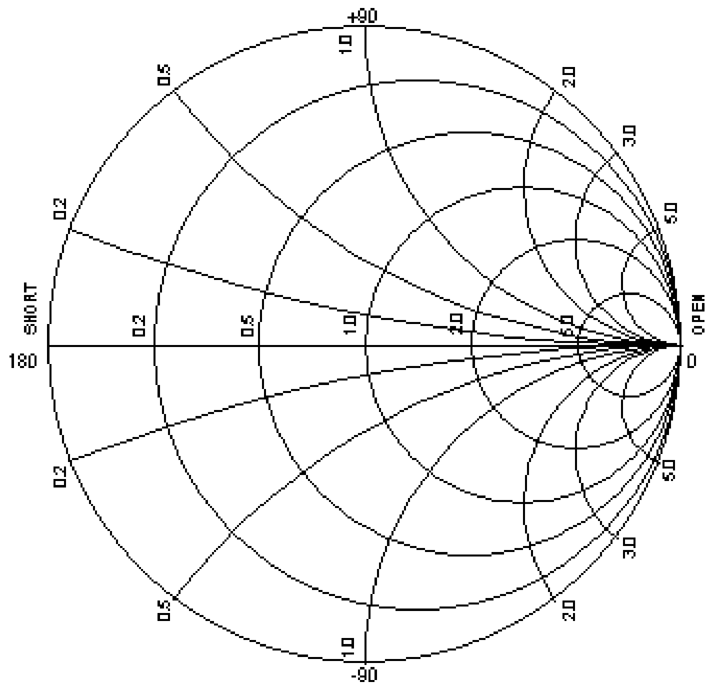
NanoVNA V2 Plus
PC Interface
INSTALLATION and USERS MANUAL



December 4, 2020 – March 21, 2021

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1. What's new

The software for the V2+ series of VNAs has now been ported to support the original NanoVNA.

With the various combinations of hardware, firmware and operating systems, it made no sense to release software for the first generation of hardware. You may wonder why release it now. There are a few reasons. First, my software has had a year to mature. While my expectations were that the new V2+ would exceed the performance of the original NanoVNA, it fell short. The design completely overlooked the need to perform narrow band measurements. While the software supported automated measurements of quartz crystals, the hardware/firmware design prevented its use.

Additionally, there have been ongoing efforts to create other software for the NanoVNAs. I have not been following their development but understand these programs have been largely adopted by the radio community. My software was not written for this group. It was designed as an engineering tool for the RF experimenter. Having other software available should help reduce the effort required to support this package.

If you are reading this, you know some time was spent documenting the software. Now that we have something in place, adding details where the two programs deviate should take minimal effort.

Lastly, people like your self kept asking for it.

From my own experience with the original NanoVNA, finding a stable version of firmware was always an issue. Many people were making changes to the firmware and releasing these into the public domain. As a consequence, there seemed to be a focus on features that added no value when running headless. In some cases it actually made the firmware less robust. To this day, I am running some very old firmware that has a fair number of problems. Even when running standalone, it is prone to lockups (requiring a power cycle), the screen will leave artifacts from a previous sweep, and maneuvering the NanoVNA's menus can cause the software to hang.

Those wanting to use this software with the original NanoVNA need to be aware that the poor quality of firmware and cloned hardware may cause a lot of wasted time. You're on your own.

Good luck

2. Documentation Update Log

Page Nos.	Amendment	SW Support	Doc Rev	Date
All	Draft	0.10	0.04	December 5, 2020
All	Add crystal measurements and segmented sweeps	0.10	0.05	December 6, 2020
All	Add TDR, Touchstone and filter sections	0.10	0.06	December 7, 2020
All	Add calibration interpolation	0.10	0.07	December 10, 2020
All	Add offset loss to calibration Update points when loading previous calibration Change all frequencies to Hz and use SI units Use standard units for RLC Normalize all memories Record normalized data if selected Use common terms, Start, Stop, Port 1 & 2 Add details regarding the transfer relay	0.10	0.08	December 11, 2020- January 9, 2021
All	Corrections from review	0.10	0.09	January 22, 2022
All	Include specific details for the original NanoVNA Correct scaling problem with Xtal C0 measurement. Problem was not discovered in the V2+ until after porting to the original NanoVNA.	1.00	0.10	March 13, 2021
All	Grammar corrections	1.00	0.11	March 21, 2021

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4. Scope

In this document, I will refer to both the NanoVNA Version 2 Plus and Version 2 Plus 4 as the V2+. As far as the software is concerned, the products are the same.

This software is loosely based on a program I had wrote for my HP8754A, which still requires a copy of Windows XP to run. After receiving the original NanoVNA, the software was rewritten to support it while running Windows 10. It was then used as a basis for my other vintage VNAs. The real benefit is that the software has the same look and feel for all of my analyzers and it allows me to automate various experiments.

Upon receiving the V2+ and being unsuccessful with the standard software supplied with it, it made sense to support it as well. I have no need to support multiple analyzers with one software package.

This software supports the measuring and sorting of your collection of crystals in order to design your next filter. I had hoped that the new V2+ would out perform the original NanoVNA in every way but found it wasn't up to the task of measuring narrow band devices. To mitigate this problem, the software was ported over to support the original NanoVNA hardware.

There are a few undocumented differences between the V2+ and V2+4 that were discovered during the development of this software. The primary difference is that the V2+ appears to lockup during long data collections and requires being power cycled to recover. This wasn't seen with the V2+4.

The author is not an amateur radio or citizens band hobbyist. Because the software was written for my own personal use, there are many features that may be lacking or have not been completed. This is most likely due to my lack of having a use for them. Some parts of the software may be doing something totally different than what a typical user may expect. I change the software often depending on the tests I am trying to run.

This software can be viewed as an engineering tool at best. Its primary use was to extend the author's understanding of V2+. It was never intended to be used as a general tool for radio hobbyist to tune their antennas. The software is fairly buggy and not very robust. Even under normal conditions, expect to run into several problems if attempting to use this software. It's a very poor choice for the beginner.

This manual assumes the reader is PC literate and has some basic understanding of how a VNA works. It is not a learner's guide on using a VNA and offers no assistance into solving basic computer related problems.

The software is continually being developed. You may find some screen shots and features change throughout this document as a result.

5. Basic Architecture

The software was written in LabView, which is a graphical programming language. LabView was developed for automating tests and is well suited for this type of application. LabView allows creating highly parallel programs which you can take advantage of with this software.

At the top level, the software has three threads. The lowest thread does nothing more than request data from the V2+, reads data from the communications port, performs a checksum and places the valid data into a queue. The queue is fairly deep and can handle any system delays that could possibility occur with the next thread.

The second thread waits for a valid entry in the queue. It pulls the entry and checks its index. The index is nothing more than the current sample's position in the sweep. If we are sweeping from 1.0 to 1MHz, the first sample has an index of 0. The second is 1 and so on. This thread then builds up an entire data set for one sweep. Once the full data set is available, it then applies any coefficients to the data and filters it. The data is then passed onto the main thread.

The third thread is the main program which is responsible for plotting the data to the screen, recording data to disk and making measurements. It also handles any user requests, for example, changing the start frequency.

Many of the subroutines are also processed in parallel. If you view the software in the task manager, there may be several threads running at a time.

With the release of 1.0, there are now two separate programs, one supporting the original NanoVNA's command set, the other for the V2+. A common code base is now being used. The top level architecture and communications interface are different between the two programs. The remainder of the software is common. This should help with future development.

When running the two programs, there are a few differences. This manual provides some added details regarding them.

6. Applicable Documents

The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed.

NUMBER	TITLE/AUTHOR
1EZ43_0E	T-Check Accuracy Test for Vector Network Analyzers using a Tee-junction / Rohde&Schwarz
	Measurement of Electronic Component Impedance Using A Vector Network Analyzer / Copper Mountain Technologies
ED-11192A	Terminiation SMA ANNE-50+ Mini-Circuits

7. Definition of Terms and Acronyms

Acronym	Definition
BW	Band Width
Cal	Calibration
CW	Continuous Wave
Dec	Decade
FIFO	First In First Out
FWHH	Full Width Half Height
HPAK	Hewlett Packard Agilent Keysight
IntpCal	Interpolate Calibration
PCB	Printed Circuit Board
Ref	Reference
SOLT	Short Open Load Thru (through)
Xfer	Transfer
Xtal	Crystal

8. Feature Summery

The following features are supported

Supports Agilent's standard coefficients
Performs interpolation of calibration
Generic support for add-on transfer relays
Supports external up/down conversion
Supports linear stage for TDR experiments
Support for both the NanoVNA V2+ and V2+4
Limited support for the original NanoVNA
Requires LabView 2011 runtime engine
Tested with Windows 10 (may run on OS's as early as XP)

9. Installation

Depending on what features you want to use and what peripherals are attached to your NanoVNA V2+, you may need to install additional drivers. The software will include an installer which contains the runtime engine only. No drivers will be included beyond NIVISA.

As of version 1.0 there are now two separate programs; one supports the original NanoVNA and the other supports the new V2+. The installer, runtime engine and VISA drivers will no longer be included. You may download these directly from NI, or just install the original release of the V2+ software. Once these are installed, copy the executable files to your directory.

9.1 Before you begin

You will want to have all the drivers installed and make sure your PC is seeing the device before getting started. The software was tested using both the recommended Cypress as well as MicroSoft's included drivers. No differences in their performance was noted.

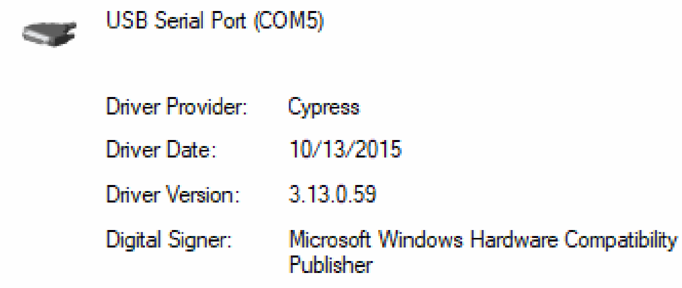


Figure 1

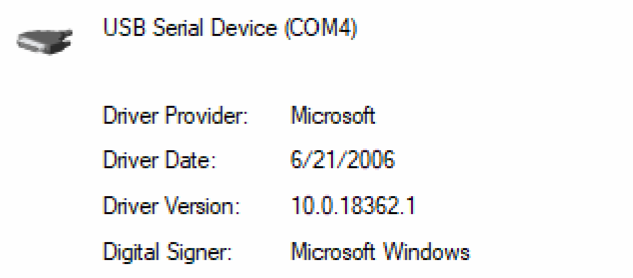


Figure 2

10. Button Quick Reference

The software contains quick tips. Move the mouse over the button to see a description.

Figure 3

11. Getting Started

For some of this section, the included cables, modified calibration standards and a low cost set of attenuators available from various sources will be used. The one I used is we will be using is shown in figure 4.

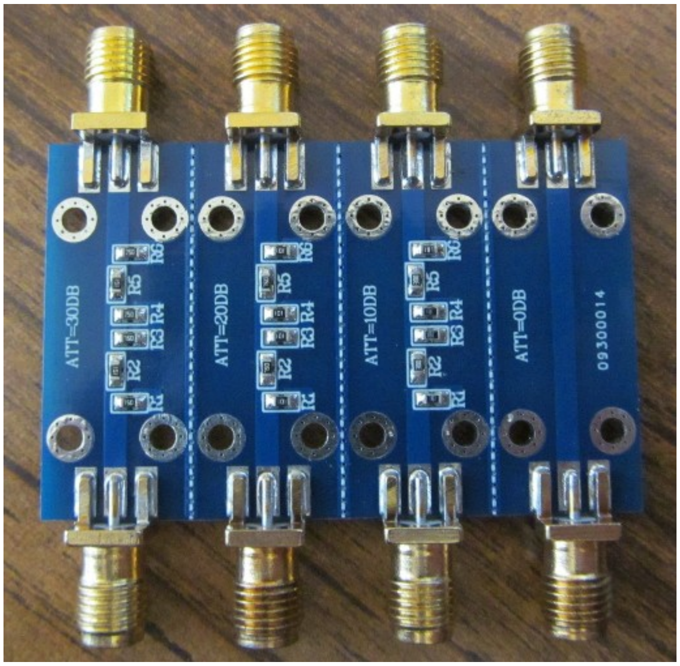


Figure 4

Features:
1.Special usage: This is a DC 4.0GHz RF Radio Frequency Fixed Attenuator.
2.The board layout is reasonable: beautiful, little current sound.
3.Uses the high quality material: stable and reliable performance.
4.Portable design: easy to install.
5.Good quality:durable to use.

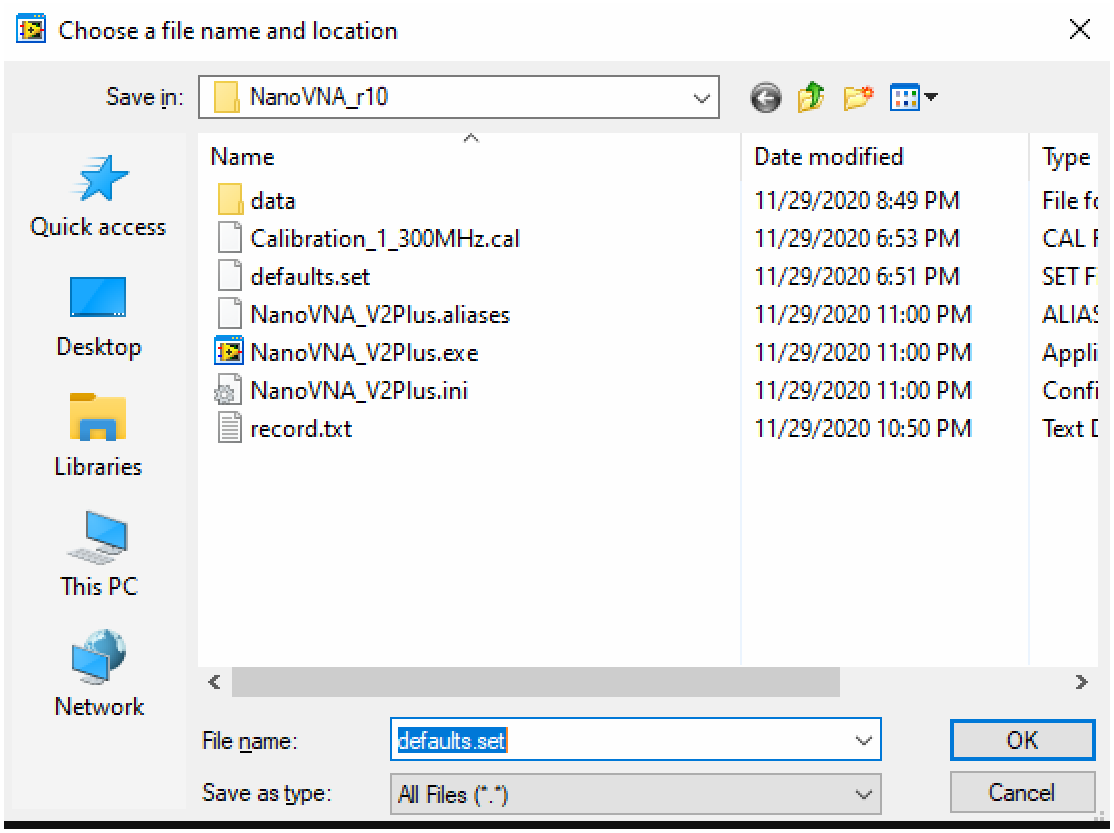
Descriptions:
1.The is a DC 4.0GHz RF Radio Frequency Fixed Attenuator Maximum power 23dBm SMA Double Female Head 0dB 10dB 20dB 30dB.
2.Compact design, easy to install.

Specifications:
Color:Green
Frequency range: DC-4.0GHz
Maximum power: 23dBm (200mW)
Standing wave ratio: 1.20
System impedance: 50
RF : SMA double female head (Outer screw inner hole)
Attenuation:

Direct: 0dB (reference)
Level 1: 10 0.8 dB
Level 2: 20 1.1 dB
Level 3: 30 1.5dB

11.1 Software Defaults

When starting the software, it will prompt you for a file that contains the default settings.



This file is not ASCII readable. It contains information about serial port settings, units, calibration standards and available peripherals. If you don't have a default setup, select cancel and the software will load with its default values.

Once the software has loaded you will be presented with the main menu (Figure 5). At this time, the software has not made any attempt to connect to the V2+ or any of the peripherals. If you do not yet have a properly configured default file, you will need to create one before attempting to do anything else with the software.

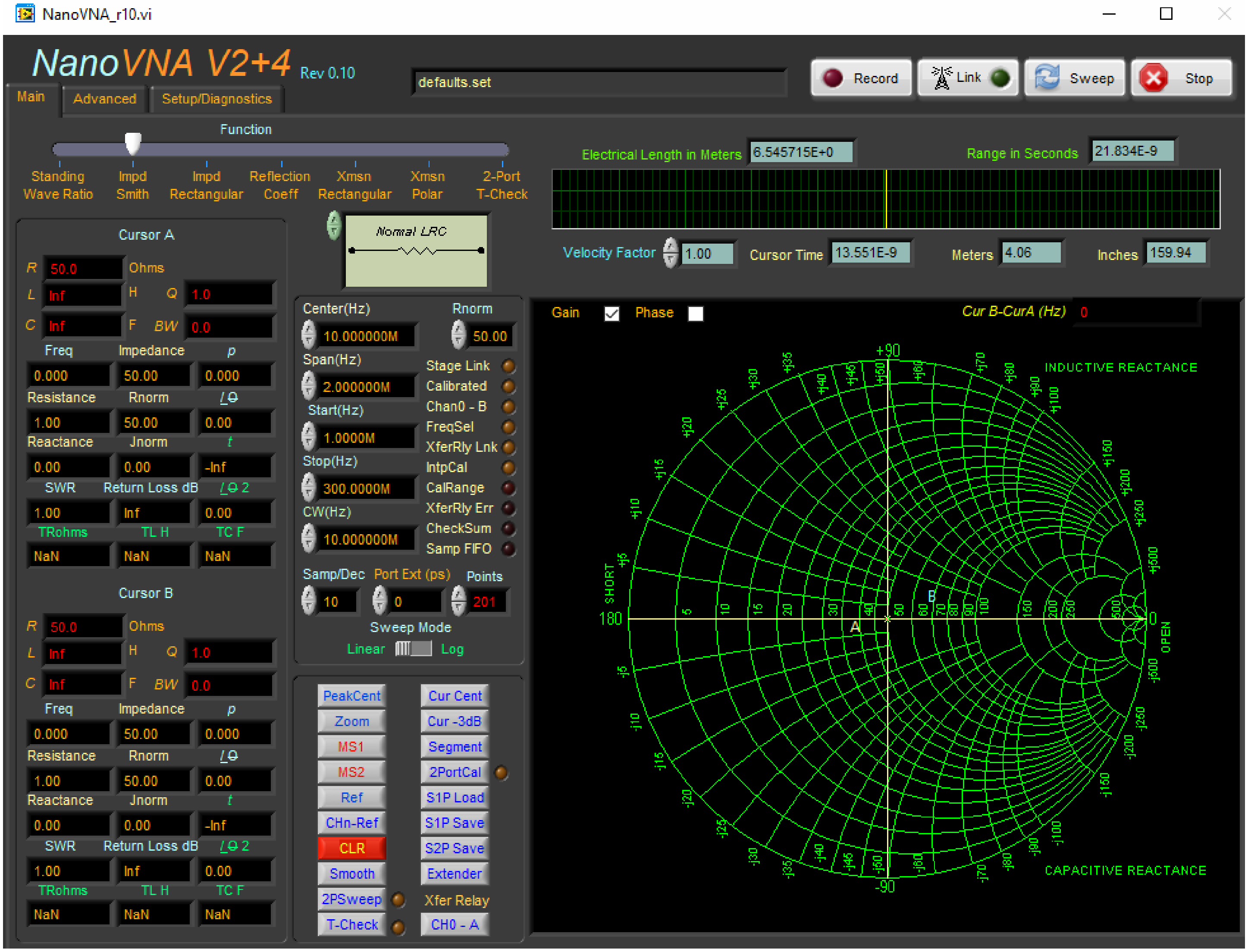


Figure 5

Looking at the main menu for the original NanoVNA (Figure 6), you can see the software is very similar. While both VNAs use the same physical layer to communicate, the original NanoVNA uses a different software layer. This goes beyond the command set. Rather than try and support multiple VNAs with a single application, the author made a clean cut of it. For the most part, these two programs drive the same.

NanoVNA Rev 1.00
Main
Advanced
Setup/Diagnostics
sweep stop 300000000
Record
Link
Sweep
Stop
Function
Standing Wave Ratio
Impd Smith
Impd Rectangular
Reflection Coeff
Xmsn Rectangular
Xmsn Polar
2-Port T-Check
Electrical Length in Meters
Range in Seconds
Normal LRC
Velocity Factor 0.78
Cursor Time
Meters
Inches 2
Cursor A
R 133.3 Ohms
L 176.74n H Q 0.0
C 9.38p F BW 2260557.8
Freq Impedance ρ
123.590M 137.24 0.481
Resistance Rnorm
2.67 133.27 -11.34
Reactance Jnorm
-0.66 -32.77 -84.037
SWR Return Loss dB
2.85 6.36 -101.14
TRohms TL H TC F
307.581k 2.05m 809.07a
Cursor B
R 127.3 Ohms
L 130.91n H Q 0.0
C 7.33p F BW 2764390.1
Freq Impedance ρ
162.460M 133.63 0.480
Resistance Rnorm
2.55 127.34 -14.77
Reactance Jnorm
-0.81 -40.50 -84.474
SWR Return Loss dB
2.85 6.38 -96.24
TRohms TL H TC F
181.904k 1.64m 585.31a
Center(Hz) 3.686452M
Rnorm 50.00
Span(Hz) 500.000000
Start(Hz) 1.0000M
Stop(Hz) 300.0000M
CW(Hz) 10.000000M
Stage Link
Calibrated
Chan0 - B
FreqSel
XferRly Lnk
IntpCal
CalRange
XferRly Err
CH1 Active
Chan1 Sel
Samp/Dec Port Ext (ps) Points
10 0.00 101
Sweep Mode
Linear Log
PeakCent
Cur Cent
Zoom
Cur -3dB
MS1
Segment
MS2
2PortCal
Ref
S1P Load
CHn-Ref
S1P Save
CLR
S2P Save
Smooth
Extender
2PSweep
Xfer Relay
T-Check
CH0 - A
Gain
Phase
Cur B-CurA (Hz) 38.87M
INDUCTIVE REACTANCE
CAPACITIVE REACTANCE
SHORT
OPEN
+90
-90
180
0

Figure 6

11.2 Selecting the Communication Port

You will now need to setup the software. Start by selecting the Setup/Diagnostics tab (Figure 7).

Figure 7

In the upper right, select the communications port for the V2+. The BAUD rate for this device will have no effect on the transaction rates and can be ignored.

11.3 Selecting Calibration Standards

A quick word on using calibration standards. If you are familiar with HP, Agilent and Keysight (HPAK) analyzers, you may find the format familiar. This is by design. At this time the Loss and Delay coefficients for both the Load and Thru are ignored. You may also notice the software supports a port extension setting on the main page.

For the calibration standards, I suggest leaving the custom ideal standard selected. If you have characterized your standards against a known set, you may enter the data into the calibration standards tables. Scroll through the available standards with the up\down arrows. The set currently displayed is the one being used. You may create a new standard, adding as many as you like, or modify an existing set. You may also copy/paste/insert and delete standards. The entire database of standards is stored into the default file. Again, you may have more than one default file as well.

The V2+ was designed to work above 3GHz but it seems to have a fair amount of leakage (or cross coupling) between ports 1&2. Using the leakage terms can introduce noise into the reading and is normally ignored. However, it seems that without accounting for these terms with the V2+, the errors above 3GHz make the unit useless. You may manually enable these by selecting Leakage Terms. This setting is stored into the default file.

Once you have everything the way you like it, just select the SaveSetup and the software will prompt you for a file name. Use the default and select OK.

Keep in mind that you can change all of the settings at any time. You do not have to save them in order for them to take effect.

11.4 Linking to the Device

When the V2+ is powered on, the LCD will show the previous configuration.

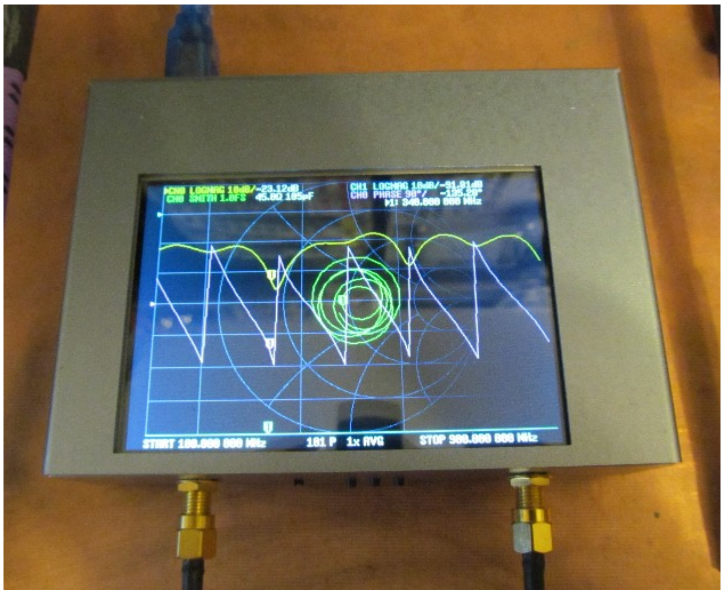


Figure 8

With the proper serial ports selected and known working, return to the main page and select Link. If the software locates the V2+, the link LED will turn green and information about the VNA will be displayed in the status bar (top center of screen, see Figure 9).

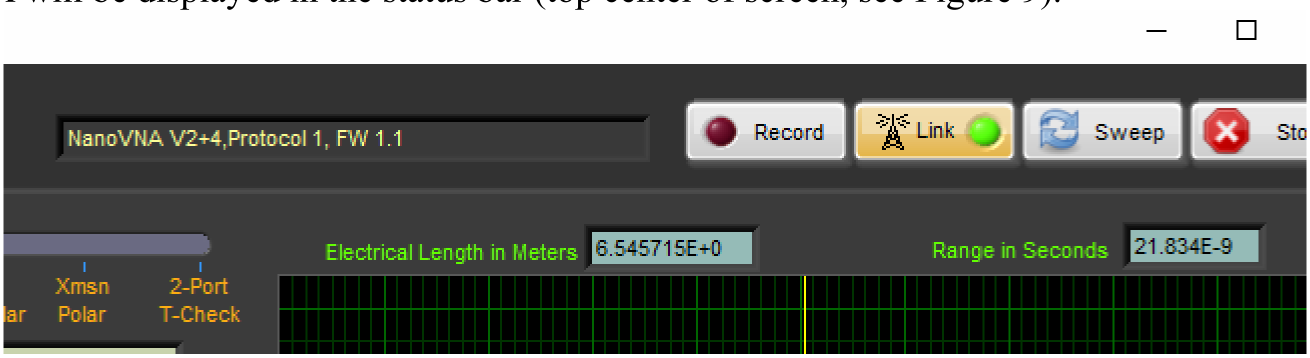


Figure 9

The Nano will display USB MODE (Figure 10). There is absolutely no use for the display when using the V2+ with the PC. As a matter of fact, the author has performed tests with the LCD completely removed, using only the main PCB.

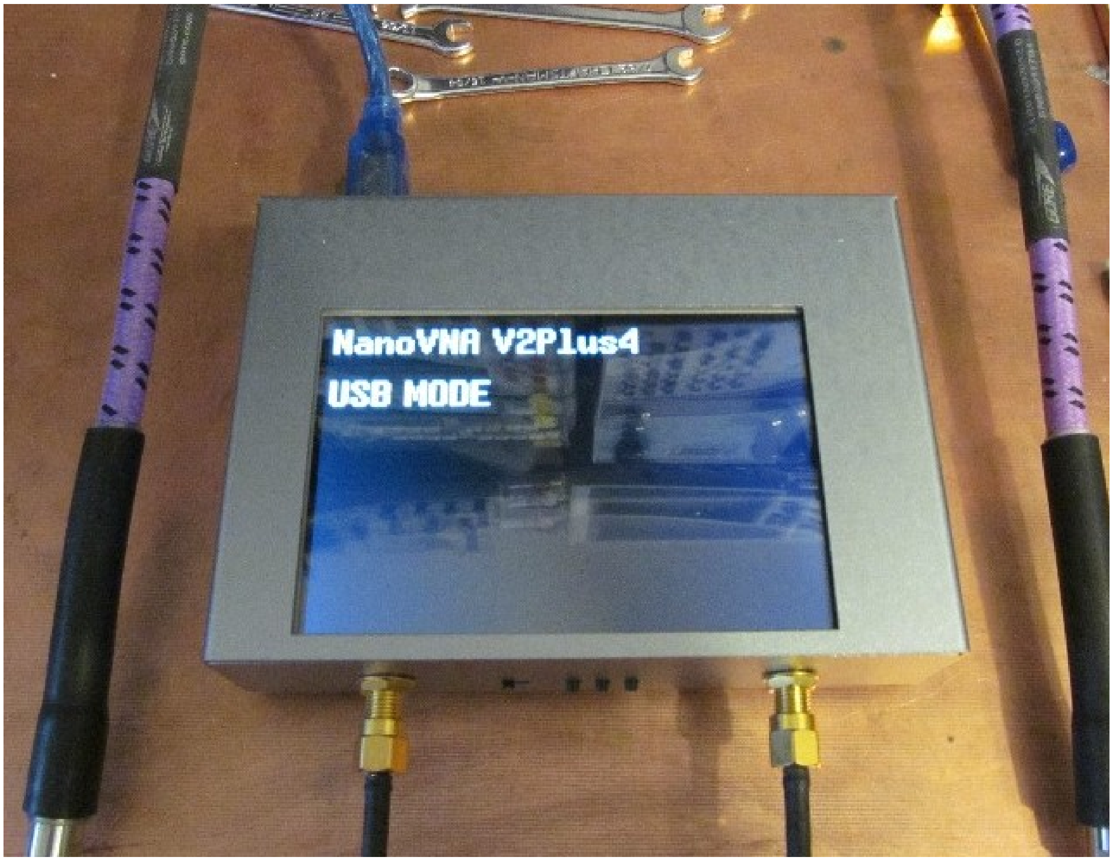


Figure 10

11.5 Displaying Data

The software will default to a center frequency of 10MHz with a 2MHz span and 201 data points (Frequency spectrum shown in Figure 11). The V2+ was programmed with these defaults when the connection was made. The V2+ is actually sweeping at this time. Select the Sweep button and the software will begin collecting data from the V2+.

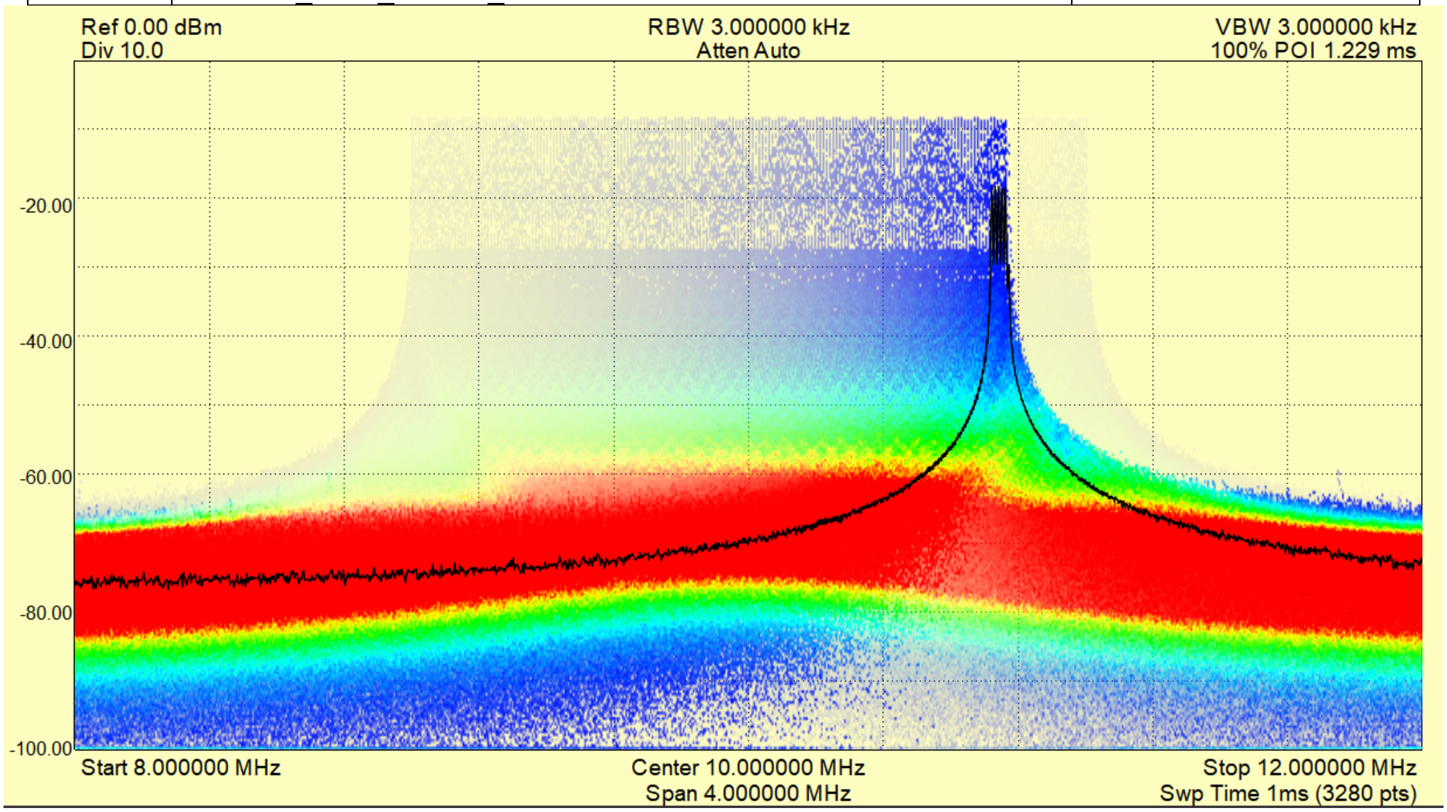


Figure 11

11.6 Normalization Example

The graph shown in Figure 12 depicts a 10dB attenuator which has been attached between Port 1&2. You can see that S11 shows very close to 50 ohms without performing any calibration.

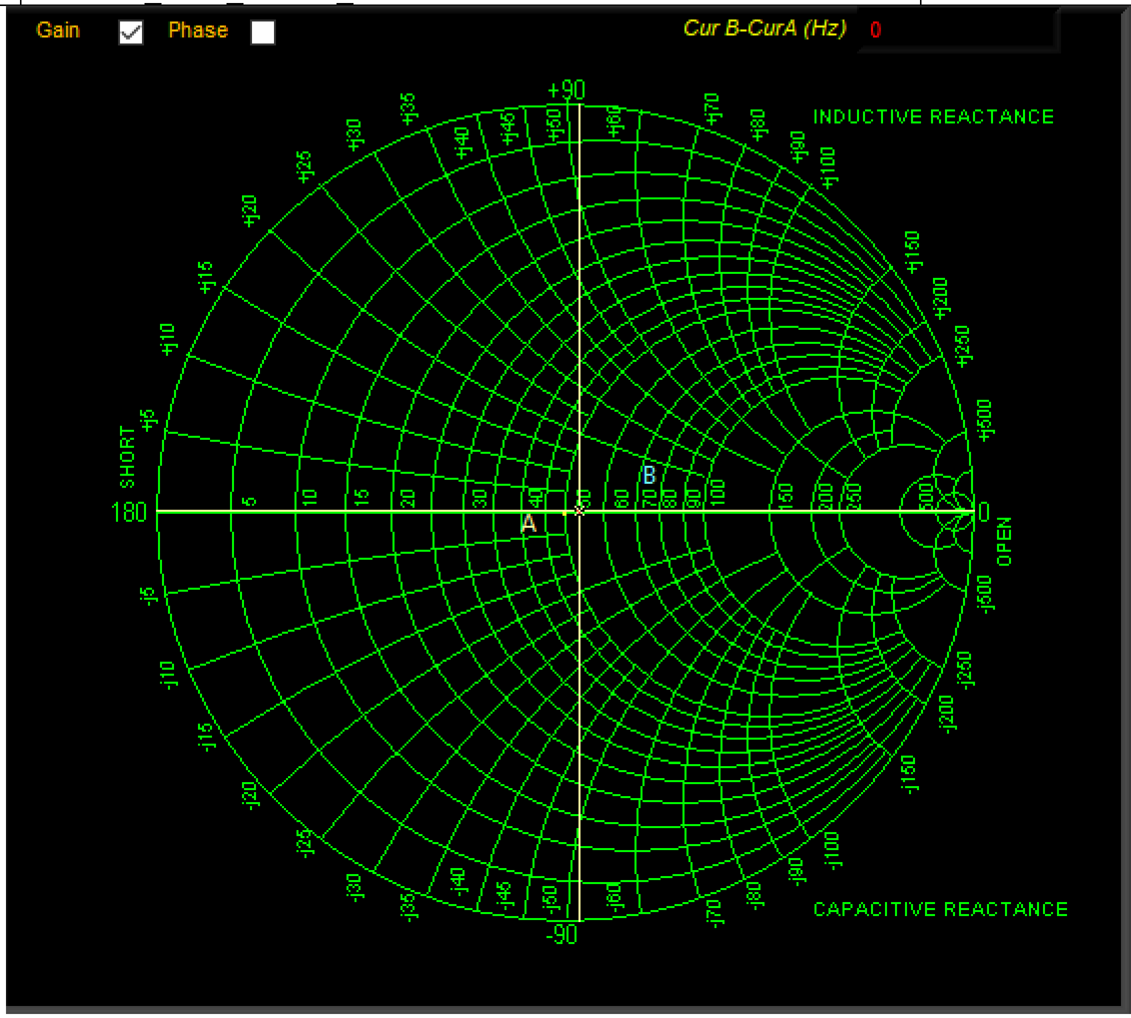
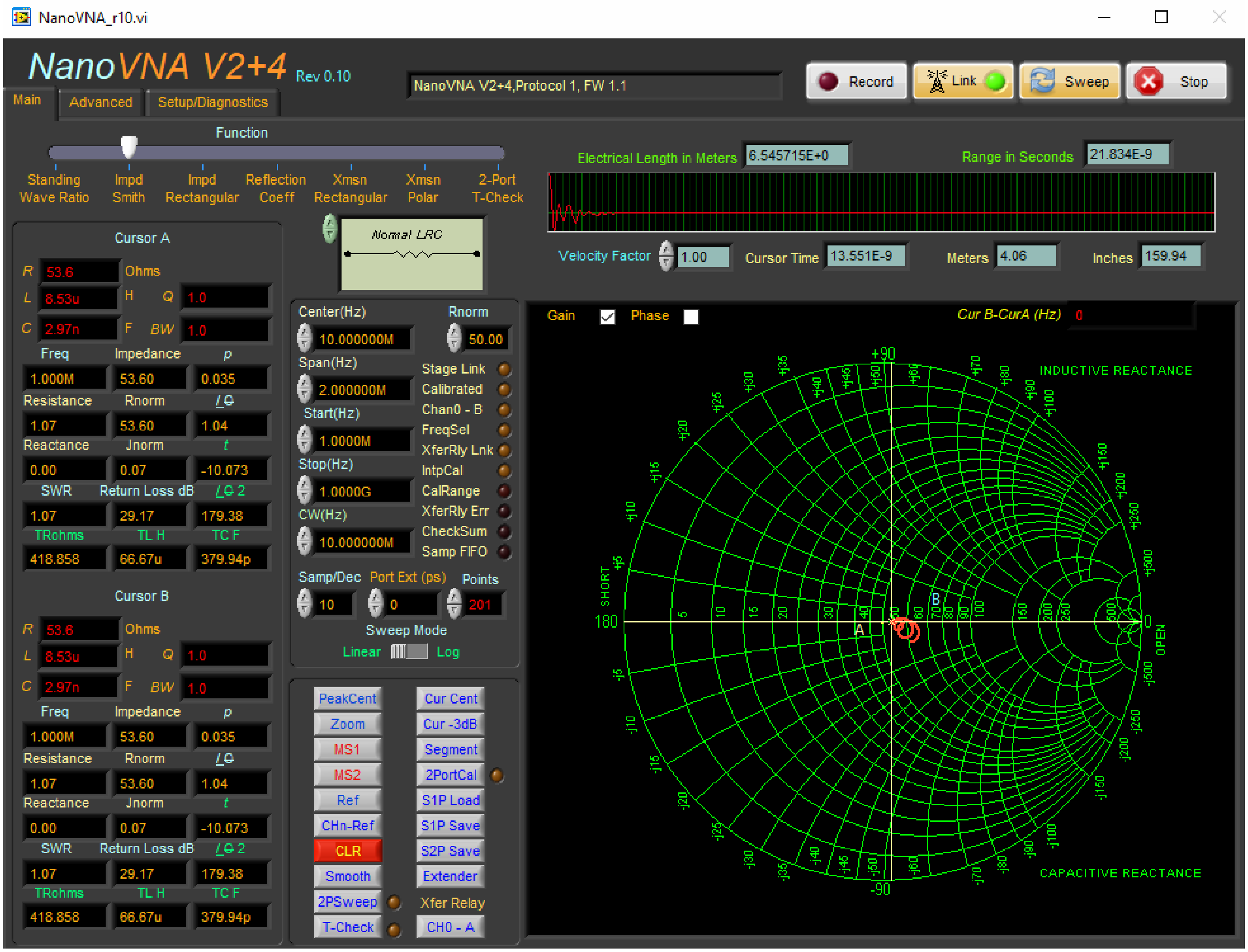


Figure 12

Now change the Stop frequency to 1GHz. The software understands SI units as well as exponents. All of the following are interpreted as 1GHz:

1000000000
1000000k
1000M
1G
1e9
1000e6

… and so on. Units are displayed in SI format. You can now see that the attenuator no longer appears to behave as a 50 ohm load (Figure 13).



NanoVNA_r10.vi
NanoVNA V2+4
Rev 0.10
Main
Advanced
Setup/Diagnostics
NanoVNA V2+4,Protocol 1, FW 1.1
Record
Link
Sweep
Stop
Function
Standing Wave Ratio
Impd Smith
Impd Rectangular
Reflection Coeff
Xmsn Rectangular
Xmsn Polar
2-Port T-Check
Normal LRC
Electrical Length in Meters
6.545715E+0
Range in Seconds
21.834E-9
Velocity Factor
1.00
Cursor Time
13.551E-9
Meters
4.06
Inches
159.94
Cursor A
Cursor B
Center(Hz)
10.000000M
Rnorm
50.00
Span(Hz)
2.000000M
Start(Hz)
1.0000M
Stop(Hz)
1.0000G
CW(Hz)
10.000000M
Stage Link
Calibrated
Chan0 - B
FreqSel
XferRly Lnk
IntpCal
CalRange
XferRly Err
CheckSum
Samp FIFO
Samp/Dec
Port Ext (ps)
Points
10
0
201
Sweep Mode
Linear
Log
PeakCent
Zoom
MS1
MS2
Ref
CHn-Ref
CLR
Smooth
2PSweep
T-Check
Cur Cent
Cur -3dB
Segment
2PortCal
S1P Load
S1P Save
S2P Save
Extender
Xfer Relay
CH0 - A
Gain
Phase
Cur B-CurA (Hz)
INDUCTIVE REACTANCE
CAPACITIVE REACTANCE
SHORT
OPEN

Figure 13

Select the transmission function Xmsn Rectangular. The attenuator is within 1.5dB again, keeping in mind no calibration has been performed. When the V2+ is being controlled by USB, all of the data is raw. No internal coefficients are being applied.

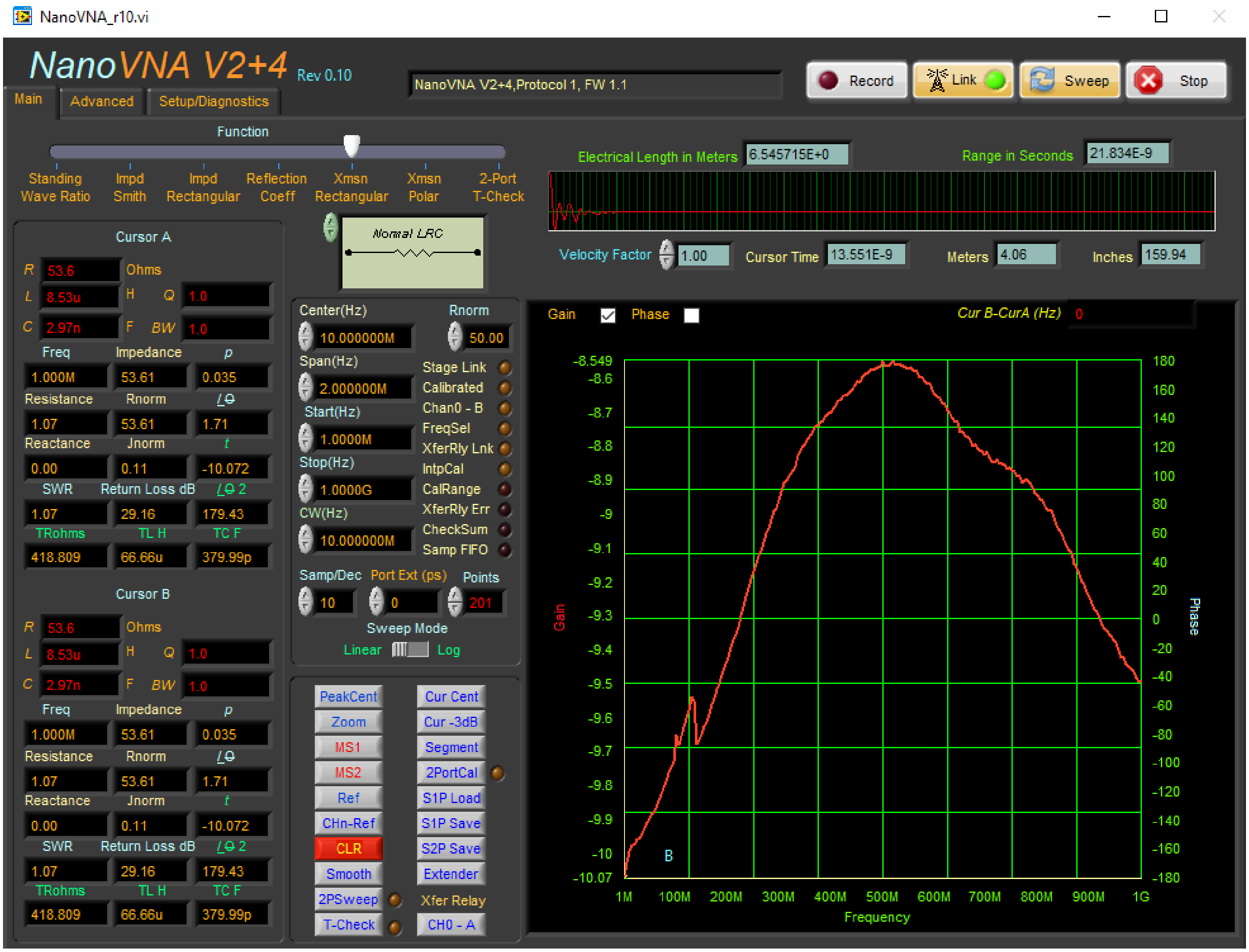


Figure 14

You can get a better idea of what this attenuator looks like simply by normalizing the data. Performing a full calibration or selecting standards is not necessary.

The first thing to do is replace the attenuator with a thru (Figure 15).

Figure 15

This would normally be 0dB but as shown, the measurement is roughly 1.3 dB higher than expected (Figure 16).

Figure 16

Select the Ref button which will temporarily store the swept data as a reference. Next select the CHn-Ref. This will cause the software to use this reference to normalize all further readings to zero. With the thru still inserted, the software now displays very close to 0dB +/-0.02dB (Figure 17).

Figure 17

Reinserting the 10dB attenuator, you can now see the software displays within 0.5dB over the entire swept range.

Figure 18

As was mentioned earlier, the V2+ exhibits a fair amount of cross talk and normalization may not always yield good results. To demonstrate this, start by changing the Stop frequency to 4GHz. Next change the start frequency to 2.5GHz. Next, deselect the Phase checkbox in the upper left corner of the graph. Now deselect the CHn-Ref to turn off the normalization and reinstall the thru.

As you can see rather than 0dB, the V2+ is displaying from -2 to -5dB (Figure 19). The waveform should be very stable.

Figure 19

As before, select the Ref followed by CHn-Ref to once again normalize the data. As shown, the data is now within +/-0.1dB over the entire 1.5GHz range (Figure 20).

Figure 20

Now install the 30dB attenuator section. You may notice that the V2+ displays something other than 30dB (Figure 21).

Figure 21

Just how much of that error is from the low cost attenuator? The cost of this set was in the order of $5. As a comparison, an 18GHz, 30dB attenuator from Midwest Microwave is shown below (Figure 22).

The data for this part looks much better. However, above 3GHz the error greatly increases.

Figure 22

To further demonstrate these errors, the thru was reinstalled and the VNA was programmed to sweep from 2.5 to 4.4GHz. The number of data points was changed from 201 to 401. A new reference was then stored. The thru was then replaced with an 18GHz, 30dB attenuator from Midwest Microwave (Figure 23).

Figure 23

Is the attenuator really this poor, or is it the V2+? Midwest isn't known for making poor products and I would expect better performance from the V2+. So what's going on? As mentioned, normalization may not always work very well.

11.7 The V2+ SOLT Standards

It's time to try and calibrate the V2+. Although I purchased the V2+ and the V2+4 with cables and standards, there are a few problems with them. The short's center conductor is locked and will turn as the nut is tightened. The thru standard doesn't have a flat. There is no way to hold it securely with your ignition wrench while you torque it.

Figure 24

The bigger problem is the return loss of the load is not very good. The following compares the load supplied with my original Nano against the two included with my V2+ VNAs, along with two Mini-Circuits ANNE-50+ terminators. Also shown as a reference, the Keysight 85033 standard load. (No standards were harmed during these measurements!!)

We can see the loads supplied with my two V2+ VNAs have a very similar performance and offer a much improved return loss over the standard that was supplied with my original Nano. However when compared with the Mini-Circuits ANNE's that were hand selected, they were not as good (Figure 25).

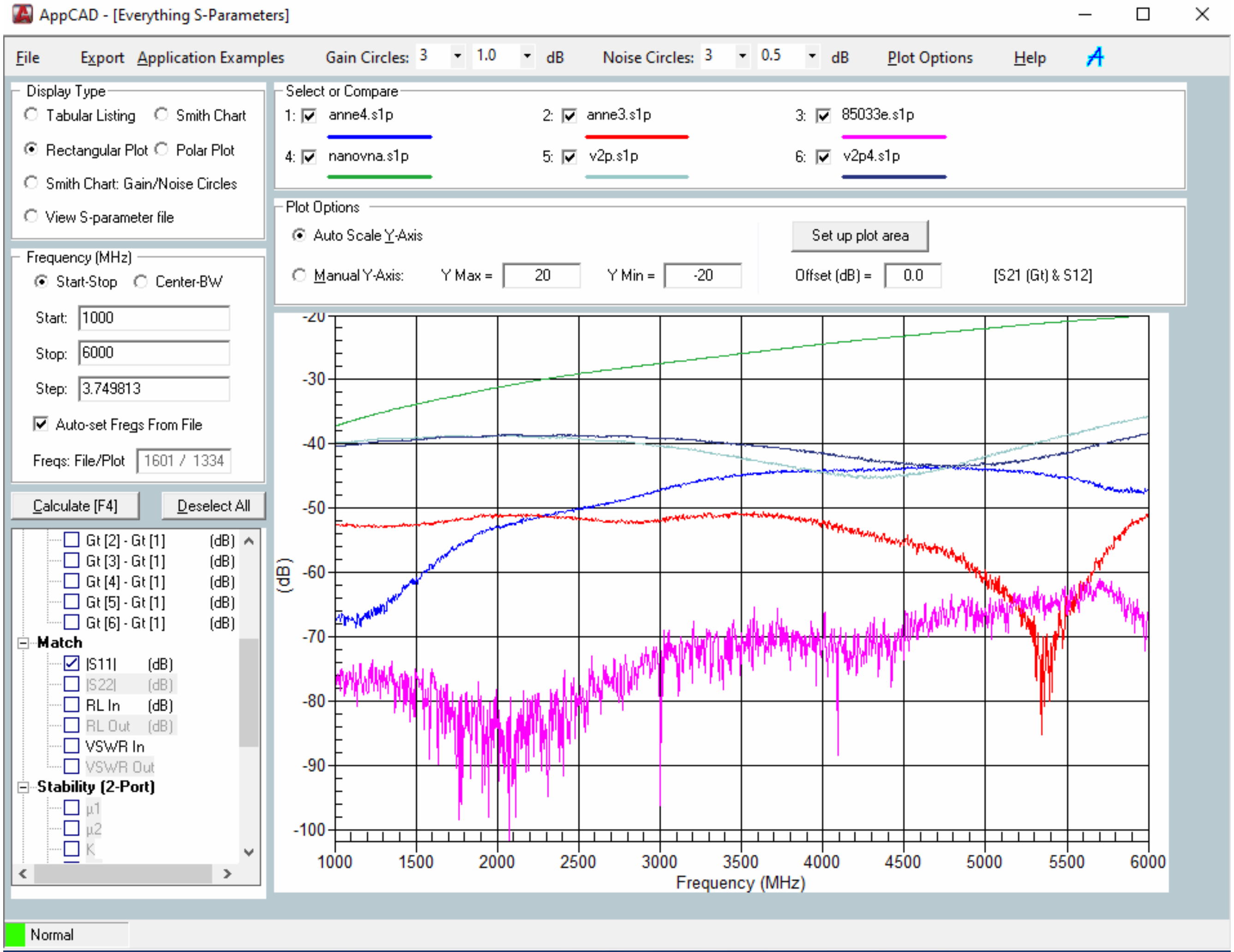


Figure 25

These two Mini-Circuit ANNE's are from a batch of seven that I purchased and sorted based on their return loss. The two shown are the best out of the group. ANNE #3 is what I use as my standard for my lab experiments. For the V2+, the original load was swapped out for ANNE #4.

Shown are some of my homemade standards using various SMT resistors for experimenting up to a GHz (Figure 26).

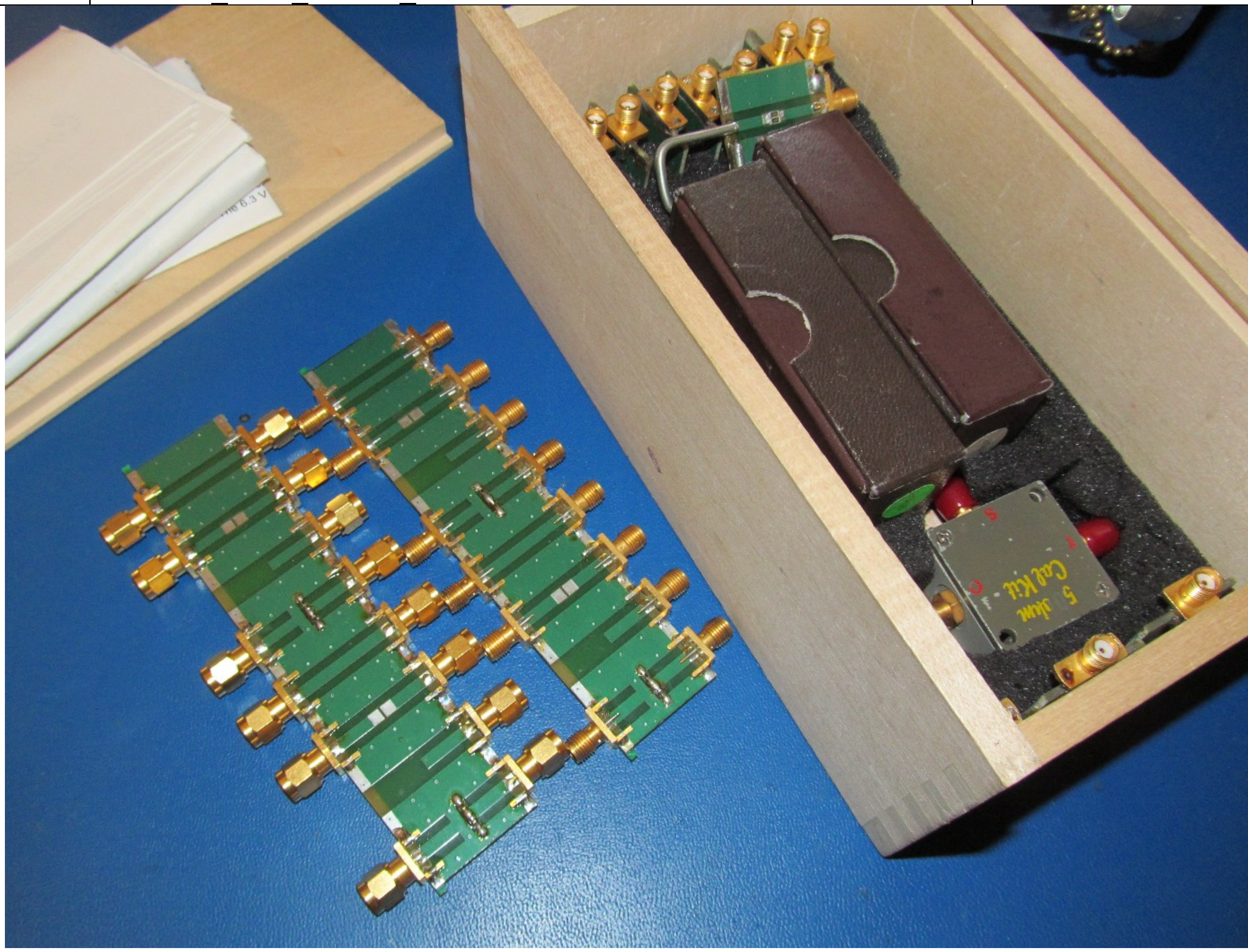


Figure 26

Attempting to make a decent load for 3GHz, good luck with that! I have attempted to make standard's for use above 1.5GHz in the past and the only thing I have accomplished is wasting time.

An attempt was made at making a set of TRL standards using some RG401 semi-ridgid coax from Fairview Microwave, PN# FM-SR250ALTN-STR (Figure 27).

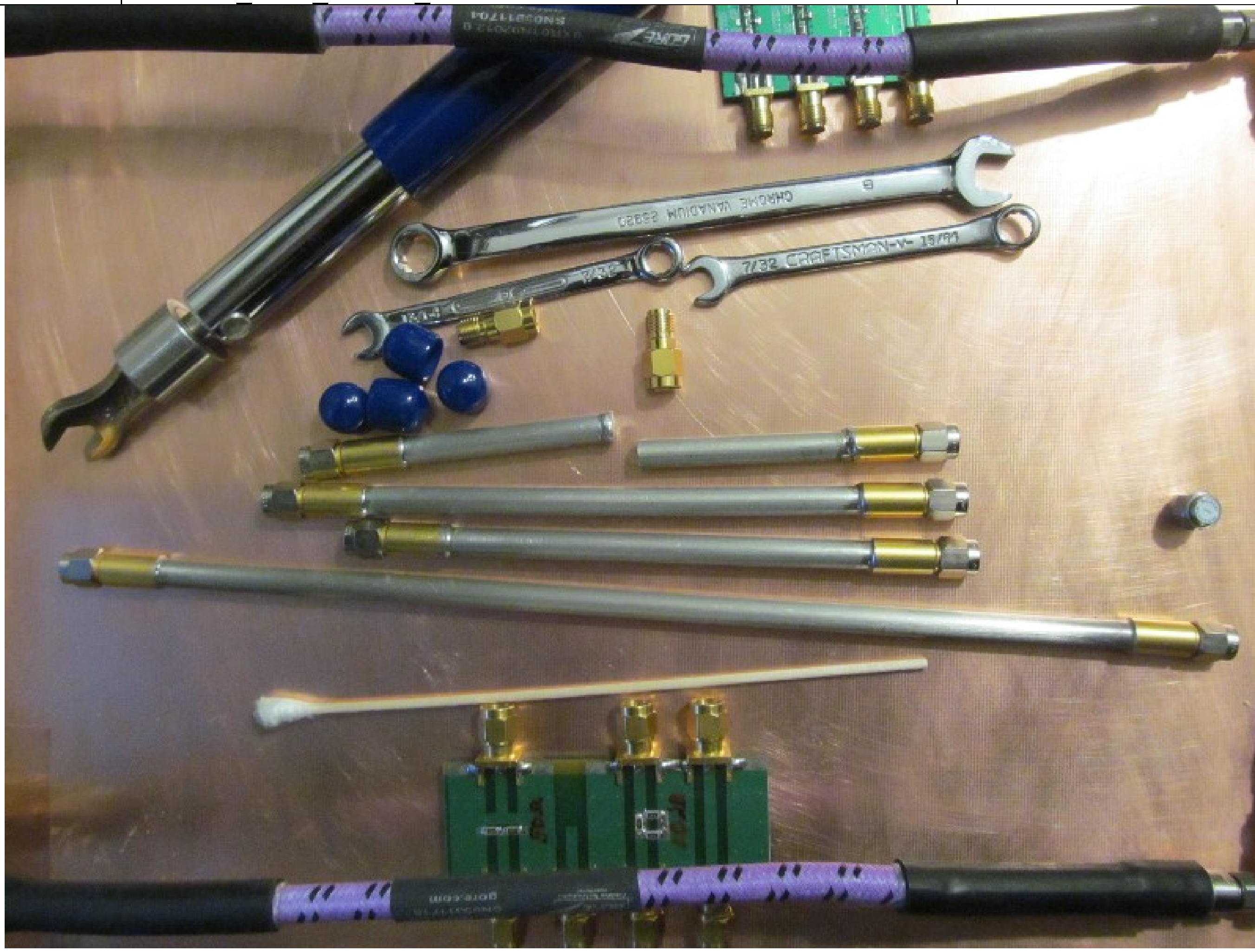


Figure 27

Figure 28 shows some of my homemade standards for experimenting in the GHz range. Toward the left are the N and SMA standards. These were characterized using a set of HPAK standards.

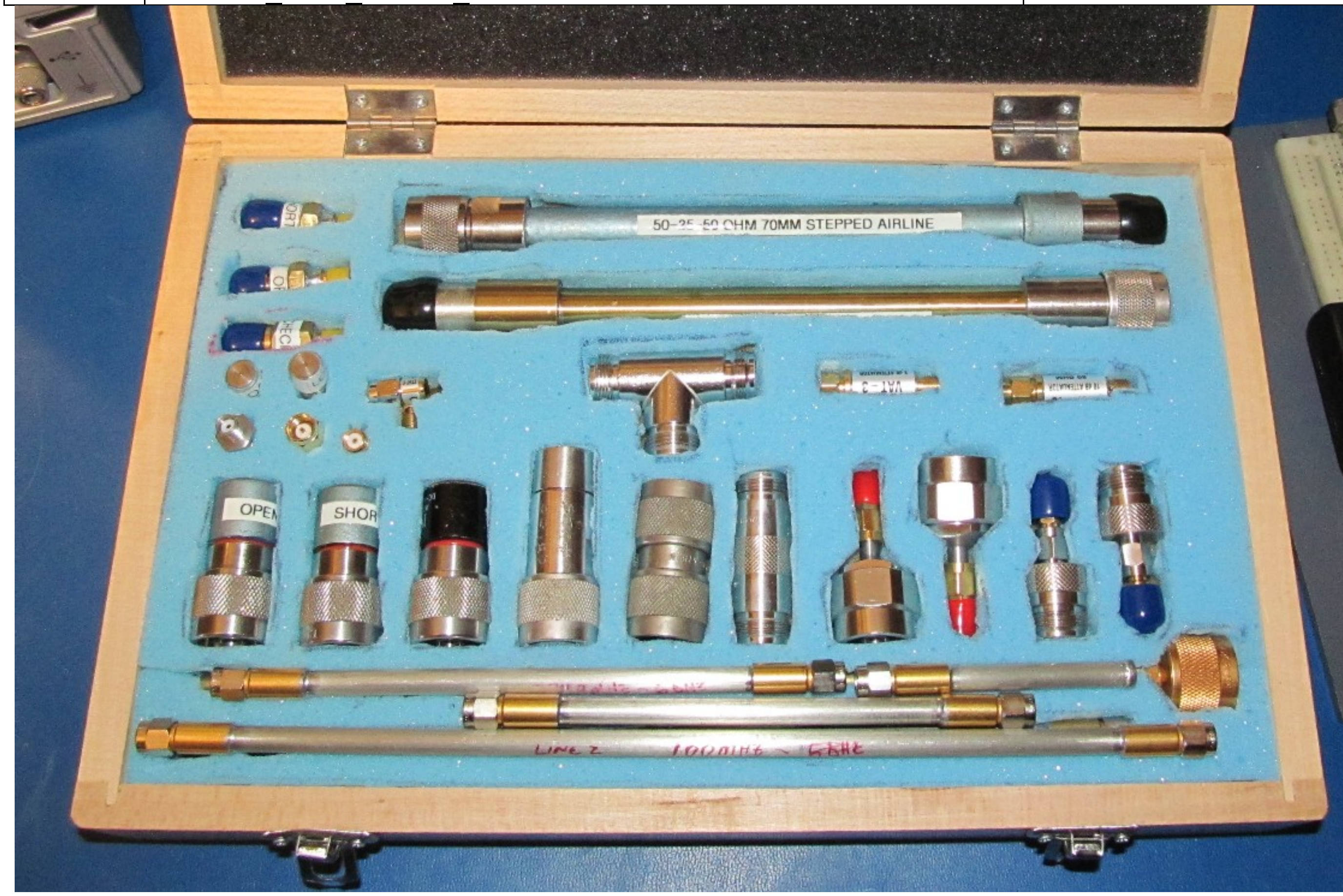
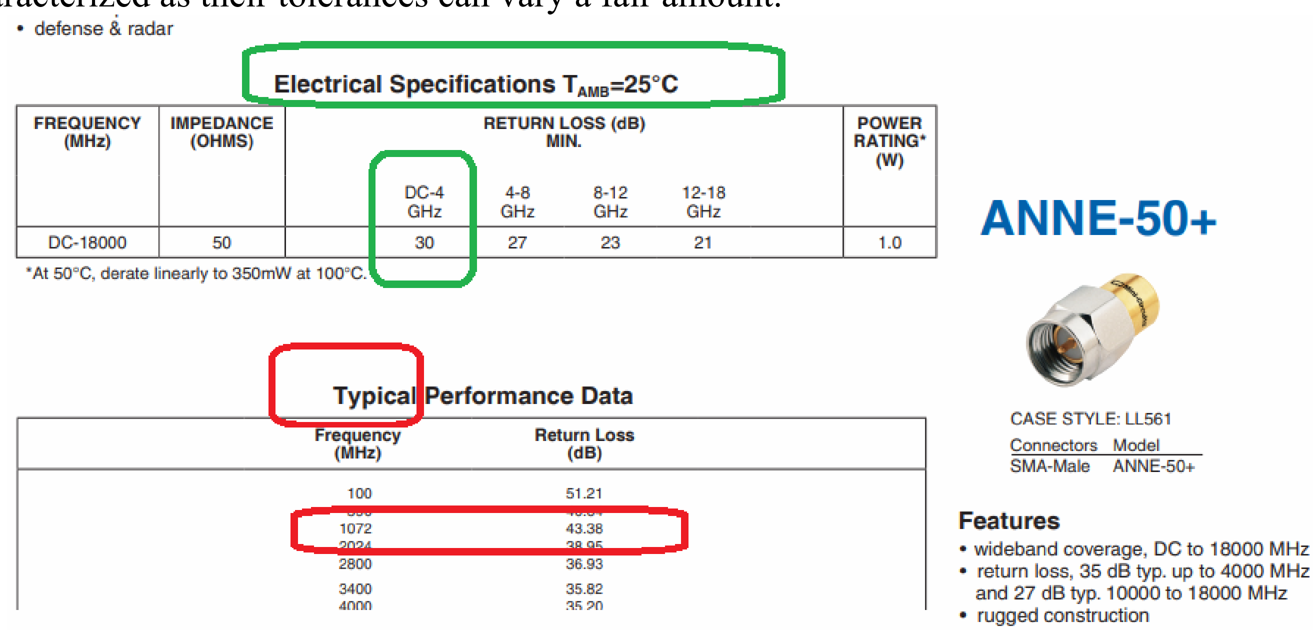


Figure 28

The N type were made from some old Narda terminators. Machining the parts for these took several attempts. The T-Check shown (upper left third down) was a improvement over the original PCB style and yields good results to around 2GHz.

Figure 29

Don't expect to go out and buy a new part from Mini-Circuits to replace yours. They need to be characterized as their tolerances can vary a fair amount.



• defense & radar

Electrical Specifications T_{AMB}=25°C

FREQUENCY (MHz)	IMPEDANCE (OHMS)	RETURN LOSS (dB) MIN.				POWER RATING* (W)
		DC-4 GHz	4-8 GHz	8-12 GHz	12-18 GHz	
DC-18000	50	30	27	23	21	1.0

*At 50°C, derate linearly to 350mW at 100°C.

ANNE-50+

CASE STYLE: LL561

Connectors	Model
SMA-Male	ANNE-50+

Typical Performance Data

Frequency (MHz)	Return Loss (dB)
100	51.21
1072	43.38
2024	38.95
2800	36.93
3400	35.82
4000	35.20

Features

- wideband coverage, DC to 18000 MHz
- return loss, 35 dB typ. up to 4000 MHz and 27 dB typ. 10000 to 18000 MHz
- rugged construction

Figure 30

Sorting the terminators is not trivial. Shown below is one of my vintage VNAs along with a set of HP standard's that were used to characterize my homemade N standards.

Figure 31

Another set of Agilent standards used to characterize my 3.5mm set.

Figure 32

Of course these standards were never used with the NanoVNA. They are a metrology grade and demand care.

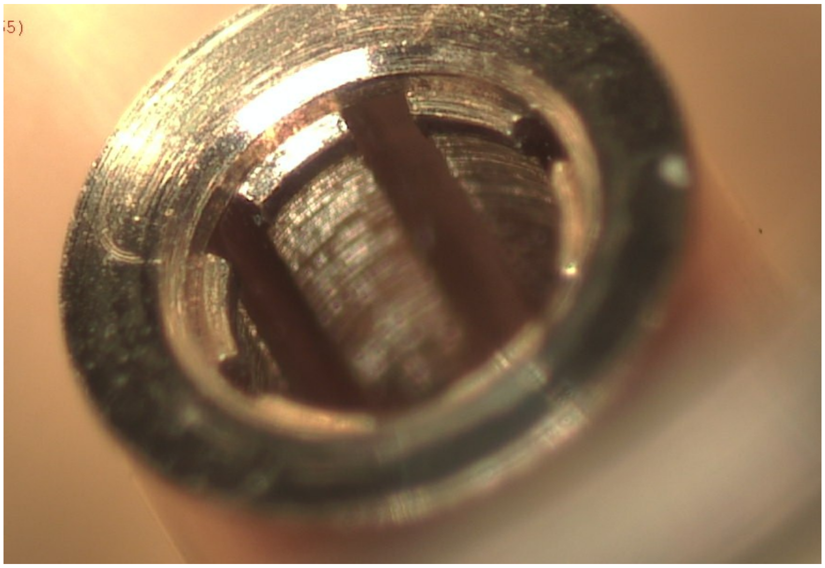


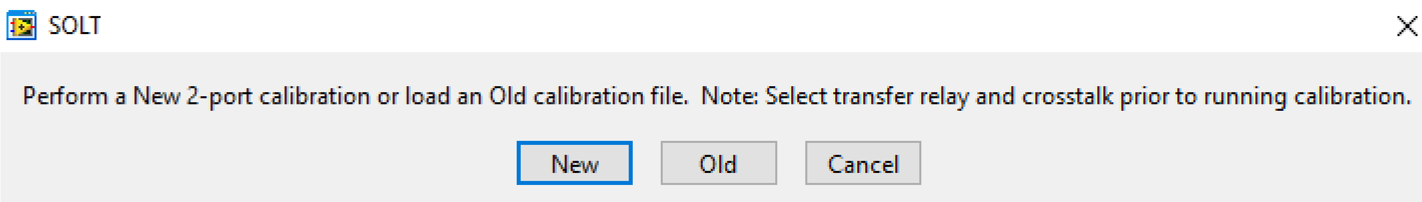
Figure 33

Shown is the new thru with a flat and ANNE included in my V2+ cal kit. On the far left it the original short. There was not enough of the center exposed to be able to hold it without twisting the center pin. I machined up a 5/16" nut from brass hex stock and soldered it to the back side (Figure 34 left). This allows a standard wrench to be used with it, a much needed improvement.

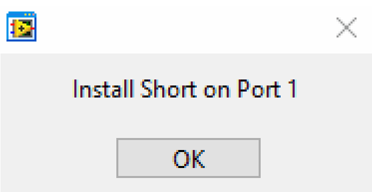
Figure 34

11.8 SOLT Calibration

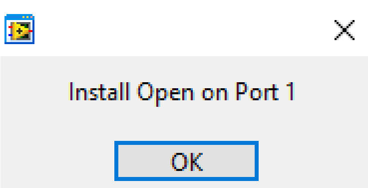
For this experiment, I used the included cables and modified calibration kit. Select CHn-Ref to disable the normalization. Next select the 2PortCal. You will be prompted to create a new calibration or load a previously saved one. You can have as many calibration files as you want. If you had a previously loaded calibration and you select Cancel, it will purge the current calibration.



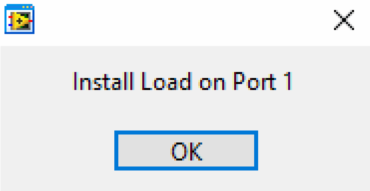
Select New. You will be prompted to insert the short on Port A (Port 1).



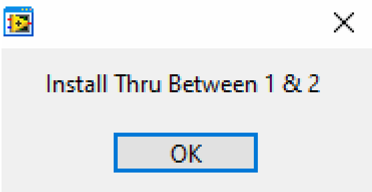
After you have it properly installed (cleaned, torqued…) go ahead and select OK. The software will not prompt you to install the Open standard.



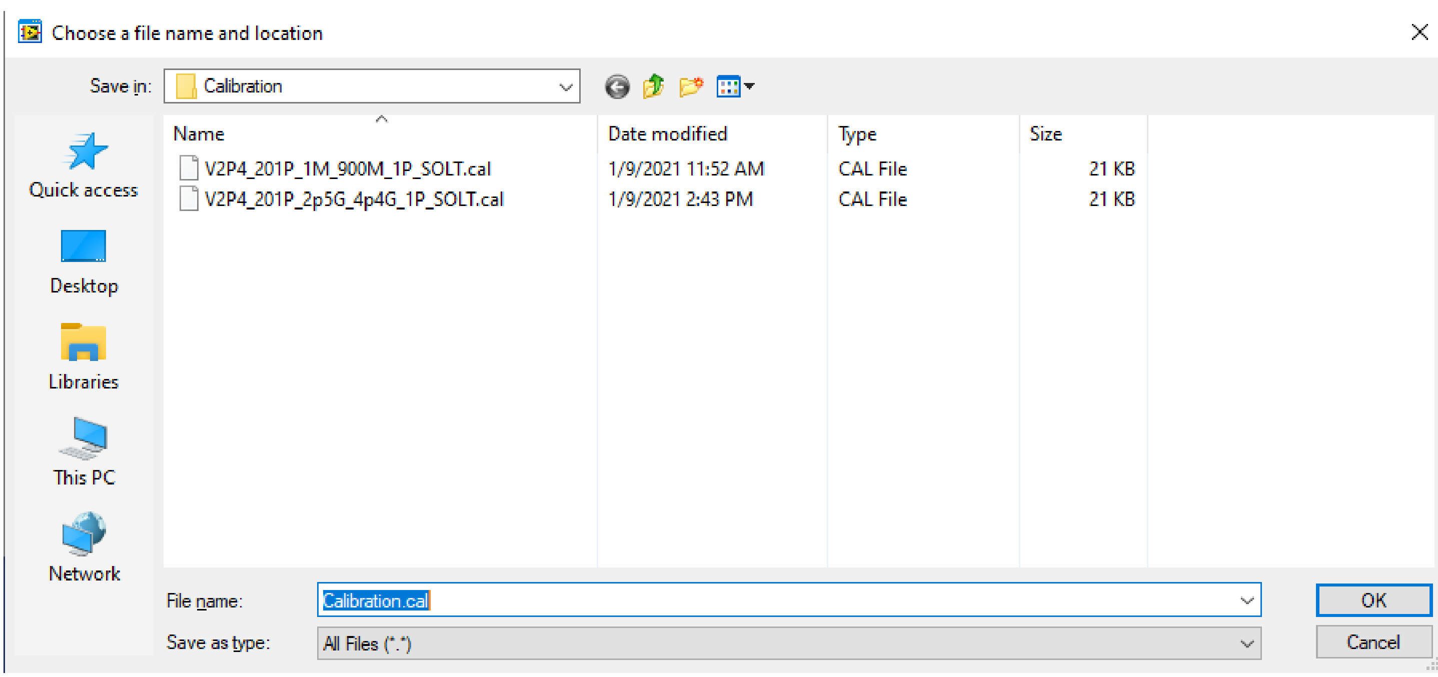
Replace the short with the open and select OK. The software will measure the crosstalk during this time and will then prompt you to install the load.



Again, select OK after installing. Now install the thru.



This software has the ability to control a transfer relay. If this option was enabled prior to selecting the calibration, you would be prompted to repeat this process for port B (2).   After collecting the data, the software will ask you where you would like to save this new calibration. It defaults to Calibration.cal. I like to use descriptive names. As shown, you can see I will include the start and stop frequencies in the file name. I also keep the calibration files in a separate directory.



Select OK. With the thru still installed, select the rectangular transmission function. The software now shows the V2+ is calibrated. As we can see, with no normalization the V2+ is now showing < 0.1 dB of error (Figure 35).

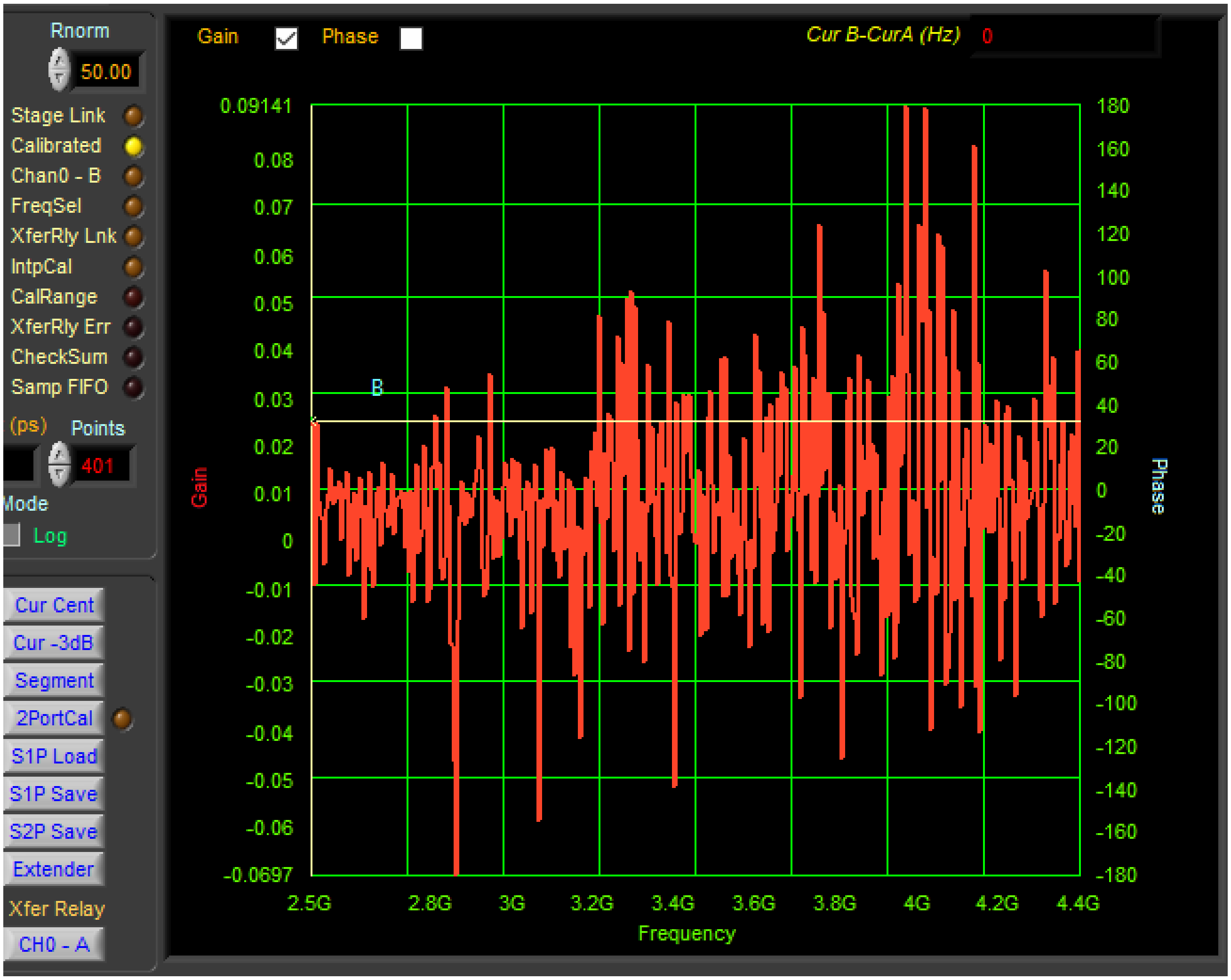


Figure 35

Next the Midwest Microwave 30dB attenuator was inserted. The data doesn't look very good but remember, I mentioned the problem with crosstalk at these higher frequencies (Figure 36).

Figure 36

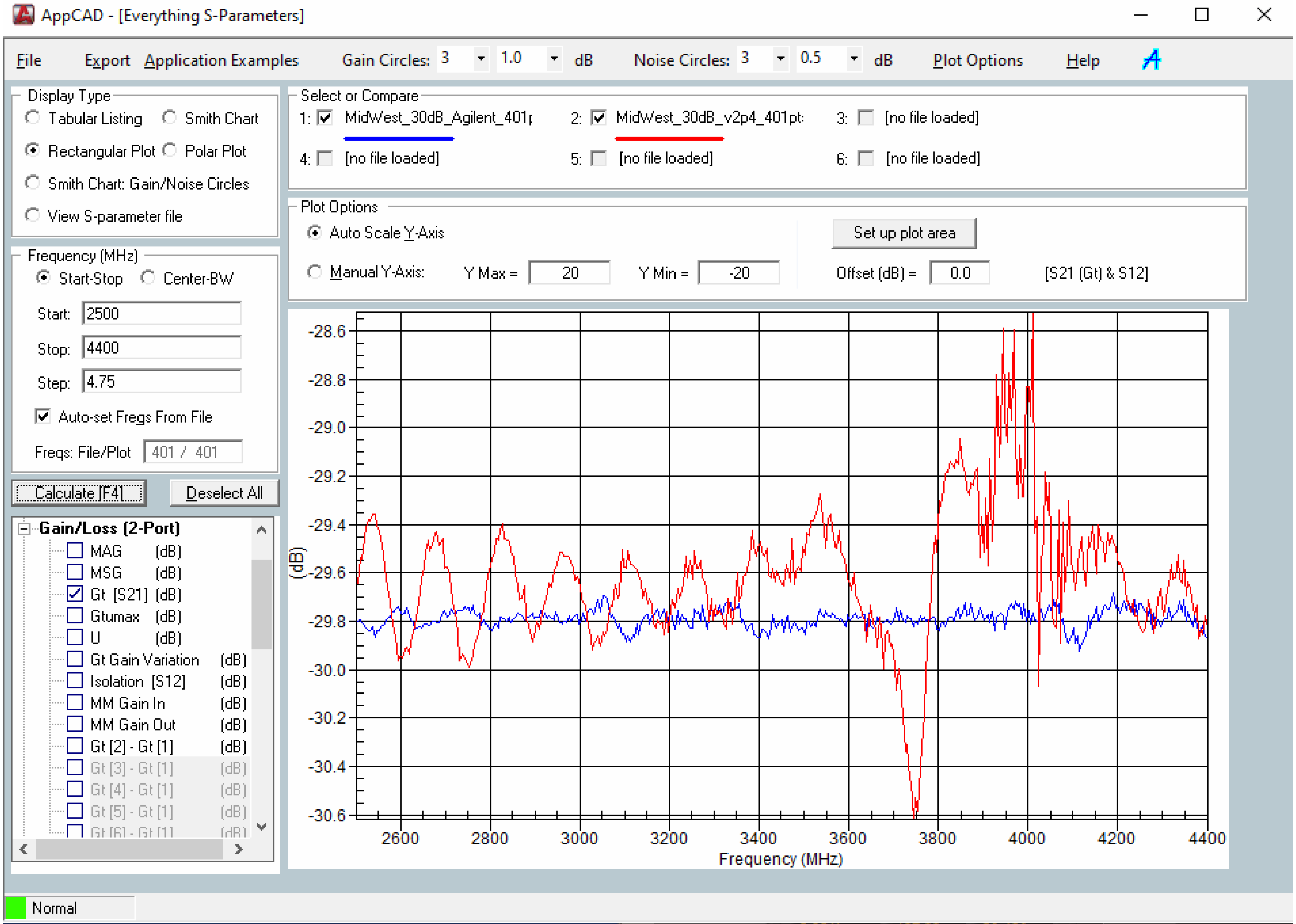
Before moving on, let's save this data to memory by selecting MS1. Select the Setup/Diagnostics menu and then select the Calibration Terms submenu. Now select the Leakage Terms checkbox (Figure 37).

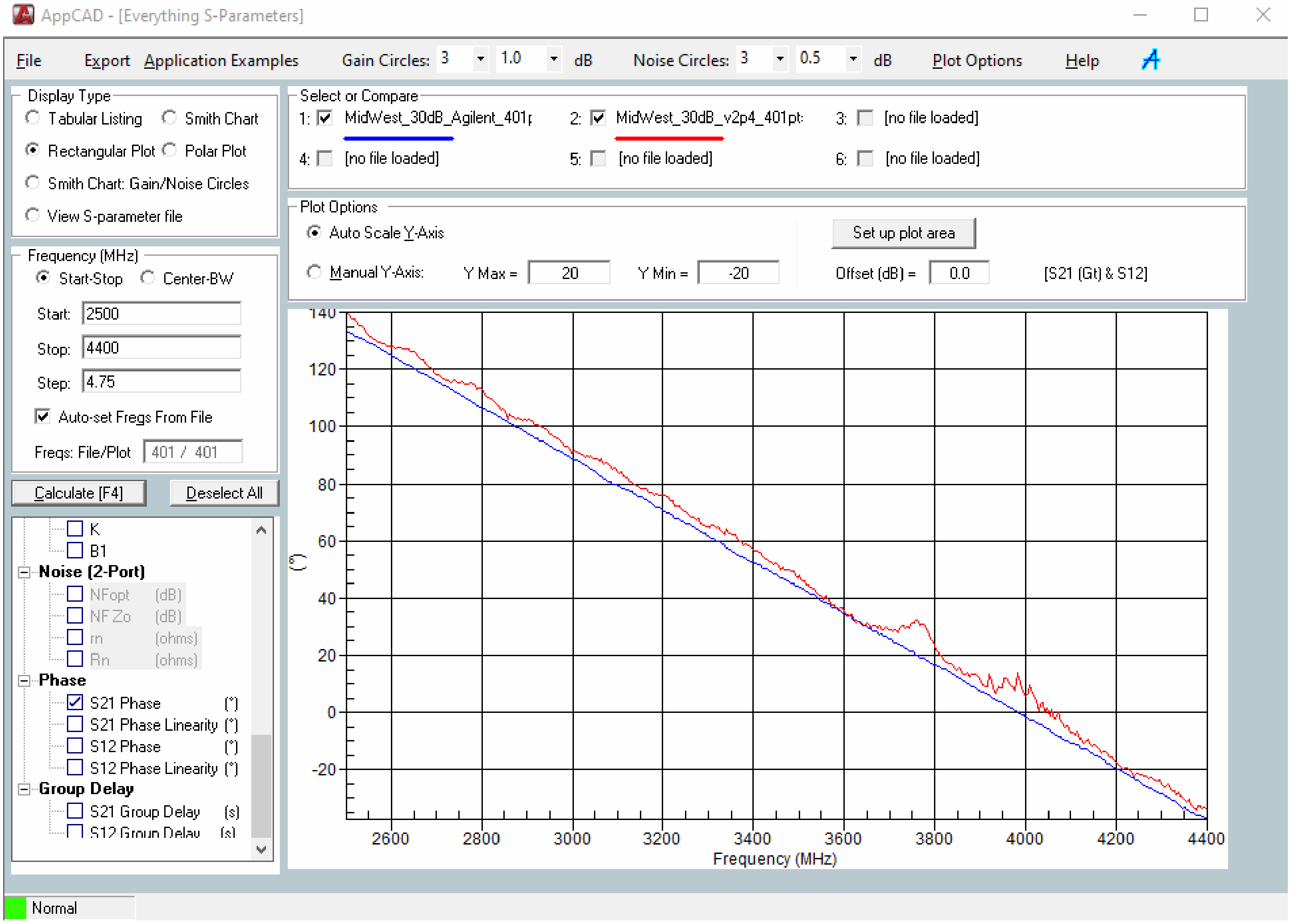
Figure 37

After you have selected Leakage Terms, return to the main menu. Notice the attenuator is now within 2dB all the way up to 4.4GHz (Figure 38).

Figure 38

Of course, you may be curious if this is correct or not, so here is the same attenuator shown on one of my old VNAs using my own homemade calibration kit.


AppCAD - [Everything S-Parameters]
File
Export
Application Examples
Gain Circles:
Noise Circles:
Plot Options
Help
Display Type
Tabular Listing
Smith Chart
Rectangular Plot
Polar Plot
Smith Chart: Gain/Noise Circles
View S-parameter file
Frequency (MHz)
Start-Stop
Center-BW
Start: 2500
Stop: 4400
Step: 4.75
Auto-set Freqs From File
Freqs: File/Plot 401 / 401
Calculate [F4]
Deselect All
Gain/Loss (2-Port)
MAG (dB)
MSG (dB)
Gt [S21] (dB)
Gtumax (dB)
U (dB)
Gt Gain Variation (dB)
Isolation [S12] (dB)
MM Gain In (dB)
MM Gain Out (dB)
Gt [2] - Gt [1] (dB)
Select or Compare
1: MidWest_30dB_Agilent_401p
2: MidWest_30dB_v2p4_401pt
3: [no file loaded]
4: [no file loaded]
5: [no file loaded]
6: [no file loaded]
Plot Options
Auto Scale Y-Axis
Set up plot area
Manual Y-Axis:
Y Max = 20
Y Min = -20
Offset (dB) = 0.0
[S21 (Gt) & S12]
(dB)
Frequency (MHz)
Normal



Now install the low cost 30dB attenuator. It's not much better but again, it's a $5 part and rated for 4GHz with a 1.5dB flatness. The author purchased two different versions of these low cost attenuators. One of them performed much closer to the claimed specification (Figure 39).

Figure 39

11.9 Interpolation

The software will now perform an interpolation of the calibration data if the frequency is changed rather that requiring a new calibration be performed. This is done automatically if the frequency bounds have changed by more than 20KHz. The new frequency range must be within the range that the unit was calibrated. If for example we set the start and stop frequencies to 1 and 300MHz, then perform a calibration. We can now change the start and stop to anything within that range. For example, we can change the start to 20MHz and you will not have to recalibrate. The software will activate the IntpCal indicator to let you know it is using interpolation (Figure 40).

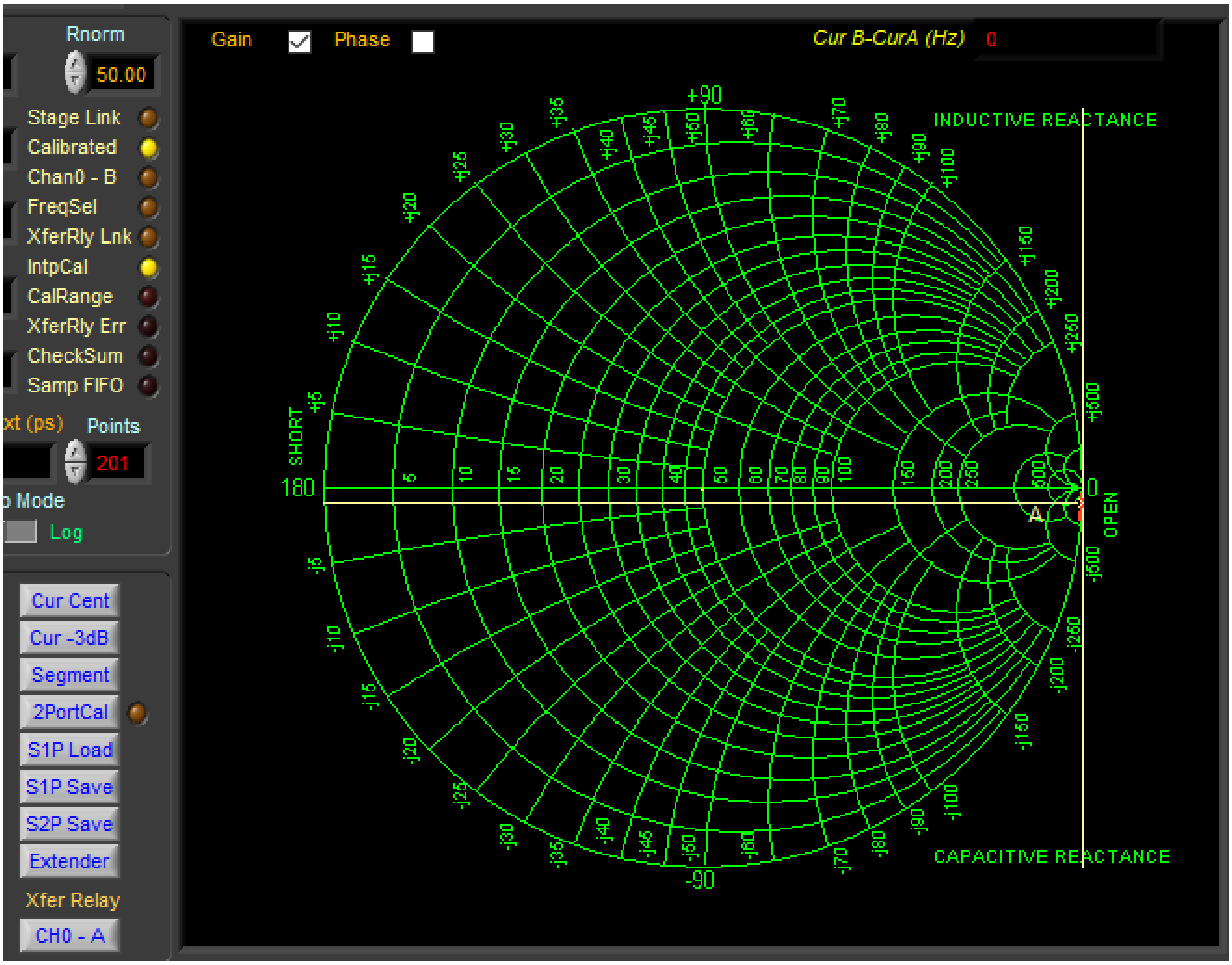
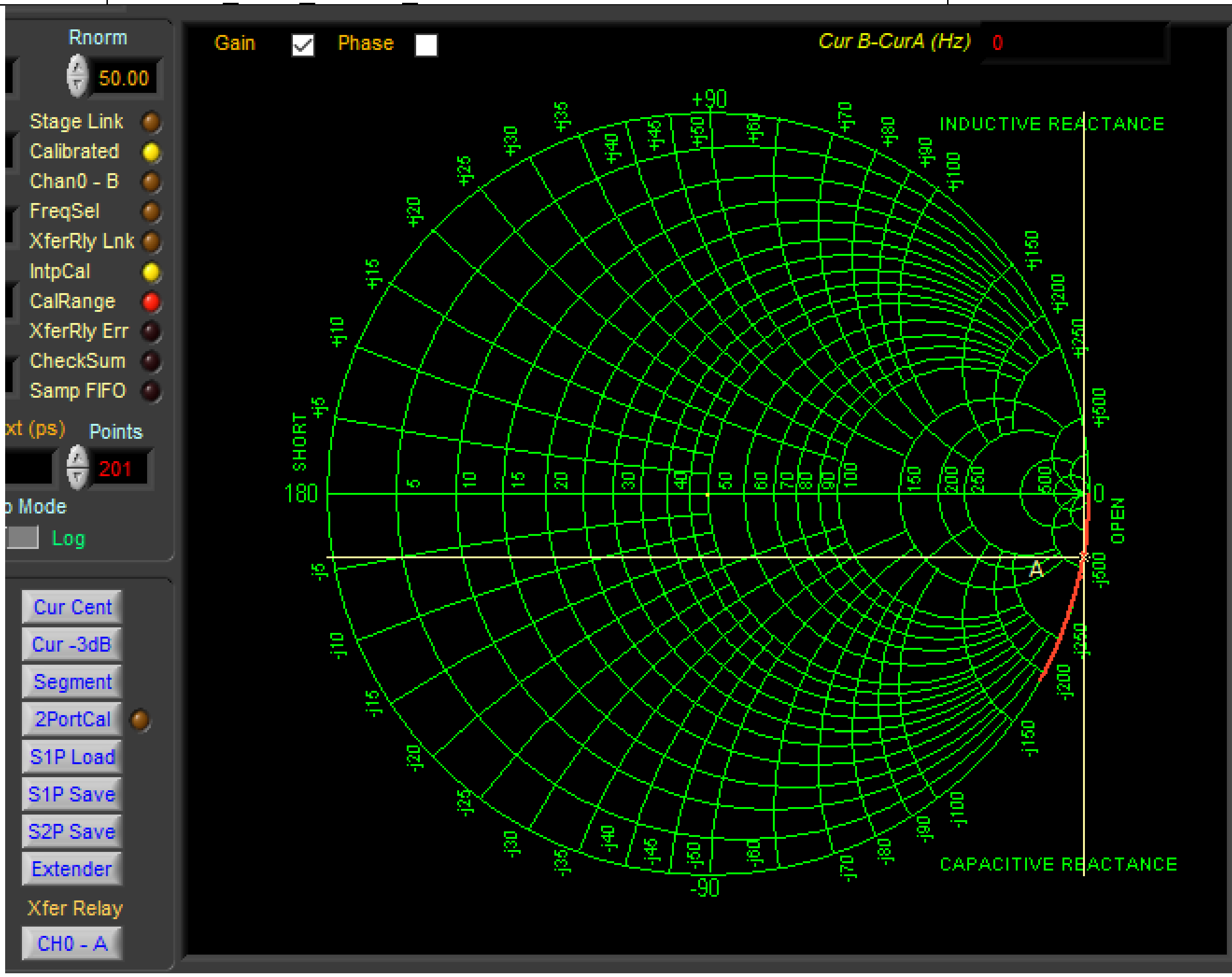


Figure 40

If you change the start to within 20KHz of the frequency the unit was calibrated, the IntpCal indicator will turn off along with interpolation. If you do go outside of the calibrated range, the software will activate the CalRange error as shown in Figure 41.



Rnorm
50.00
Stage Link
Calibrated
Chan0 - B
FreqSel
XferRly Lnk
IntpCal
CalRange
XferRly Err
CheckSum
Samp FIFO
xt (ps)
Points
201
p Mode
Log
Cur Cent
Cur -3dB
Segment
2PortCal
S1P Load
S1P Save
S2P Save
Extender
Xfer Relay
CH0 - A
Gain
Phase
Cur B-CurA (Hz)
0
+90
INDUCTIVE REACTANCE
SHORT
180
0
OPEN
A
-90
CAPACITIVE REACTANCE

Figure 41

12. Using Memories

The software has three memories that may be used to temporarily store and overlay waveforms. The Ref and CHn-Ref is a special memory that is used to normalize the data. MS1&2 have no math functional associated with them.

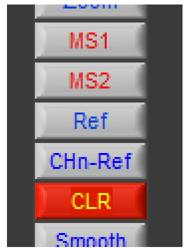


Figure 42

Store the current waveform by selecting one of the two buttons, MS1 or 2. The waveform will be immediately displayed. In the following two different waveforms have been saved.

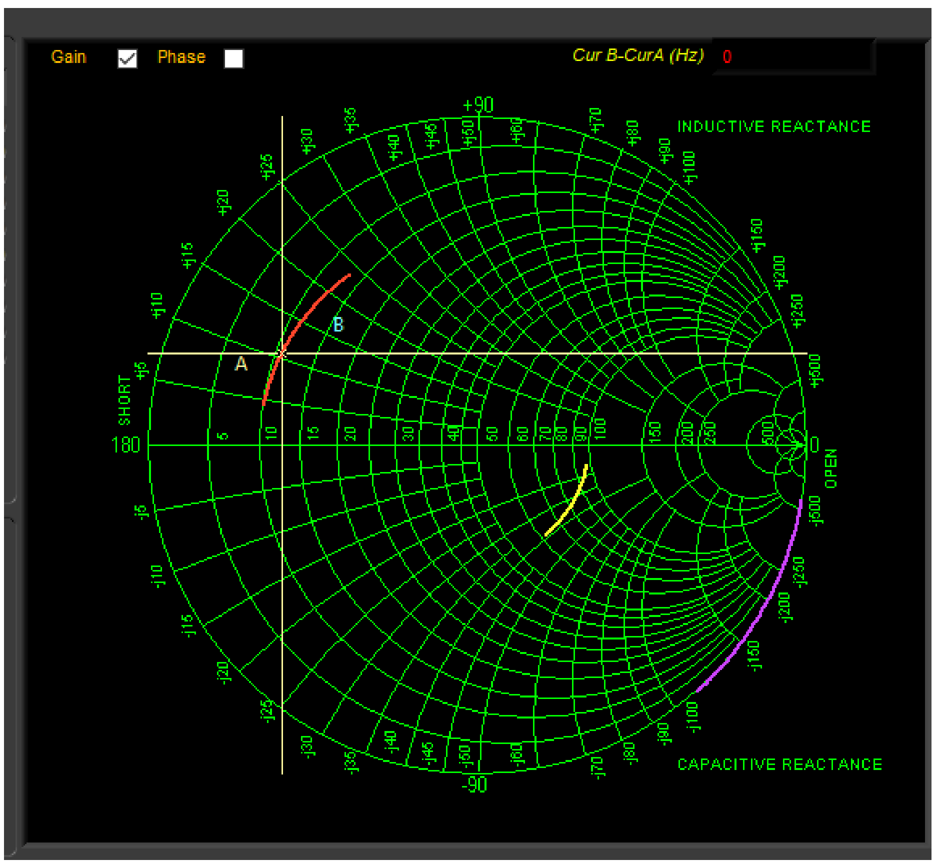


Figure 43

The memories will work for both polar and rectangular measurements. Here I have installed a manual step attenuator (Figure 44).

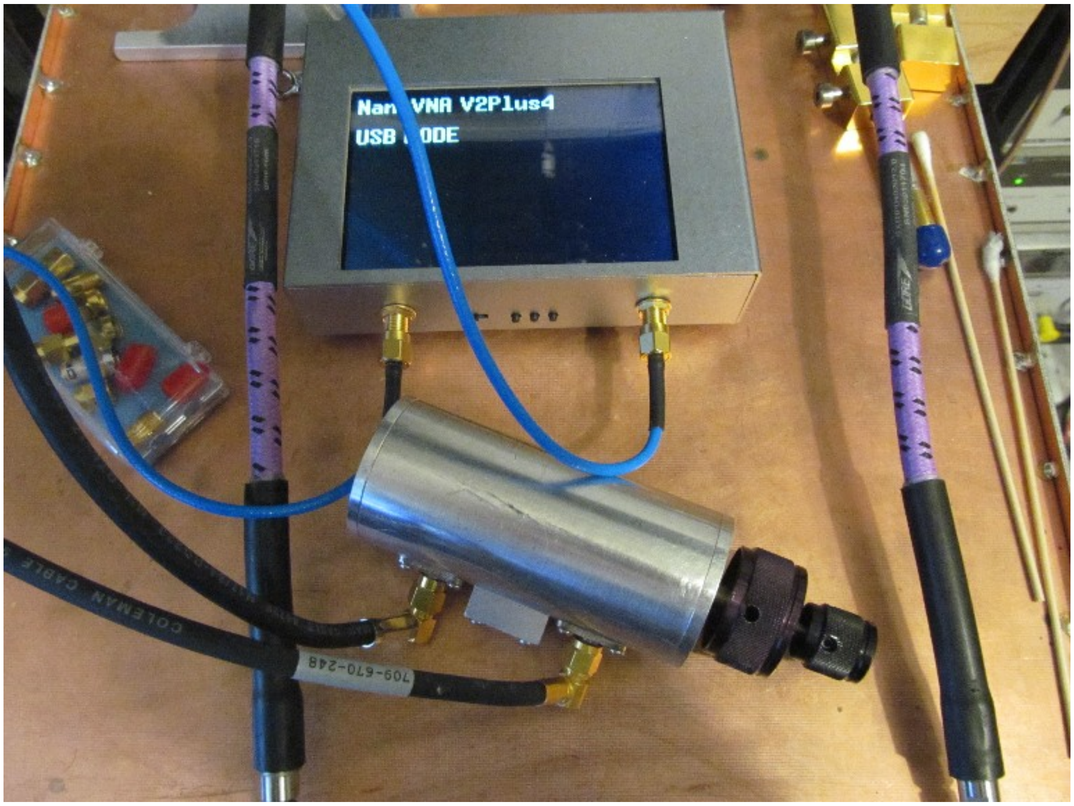


Figure 44

I have saved 0dB into Mem1 and 10dB into Mem2. The attenuator was then set to 20dB.

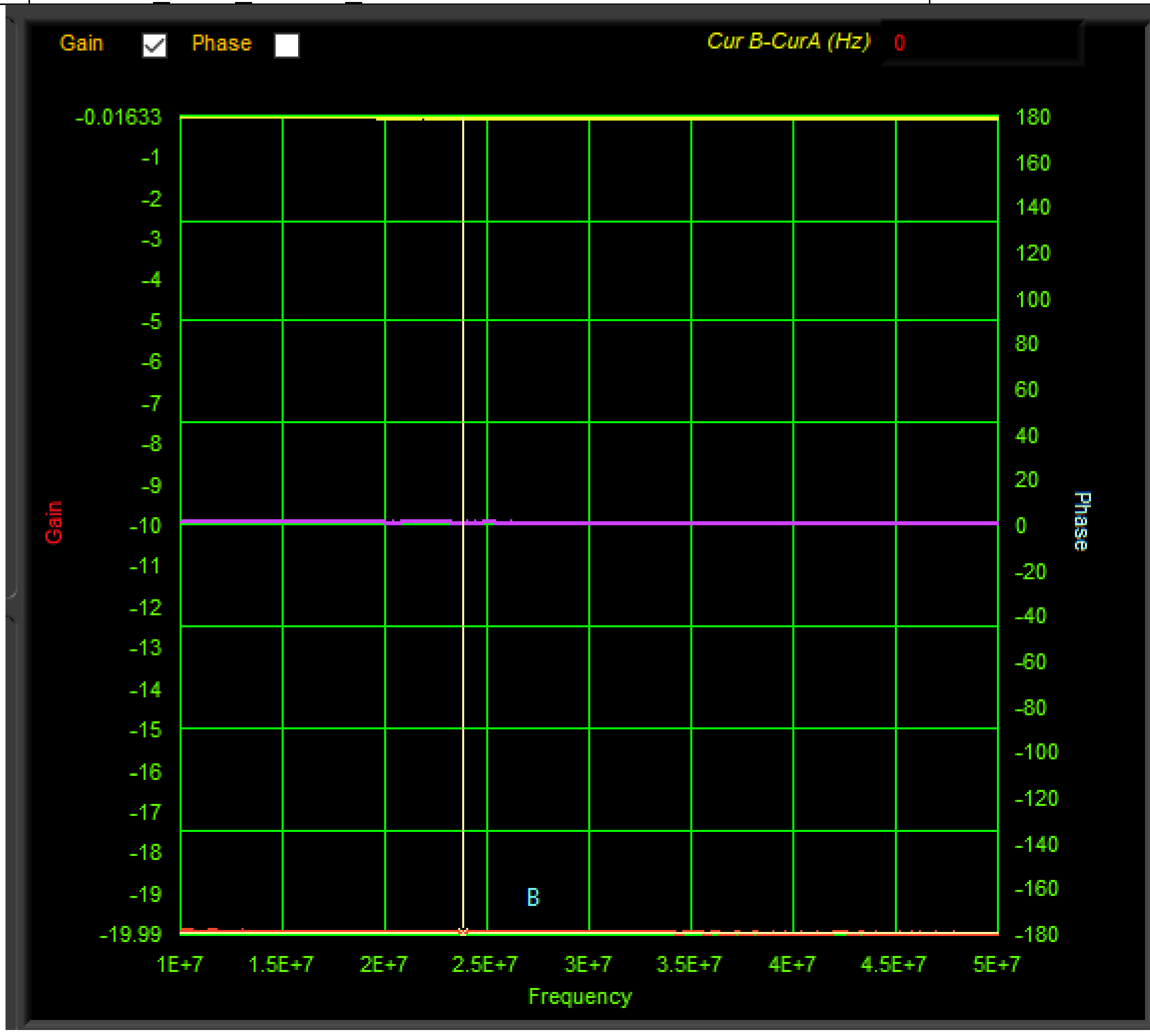

Gain
Phase
Cur B-CurA (Hz)
0
-0.01633
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
-16
-17
-18
-19
-19.99
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
Phase
B
1E+7
1.5E+7
2E+7
2.5E+7
3E+7
3.5E+7
4E+7
4.5E+7
5E+7
Frequency

Figure 45

If the Ref is selected, it will save 20dB as the reference. If CHn-Ref is selected, the software will apply the reference to the current sweep as well as the saved data in each memory.

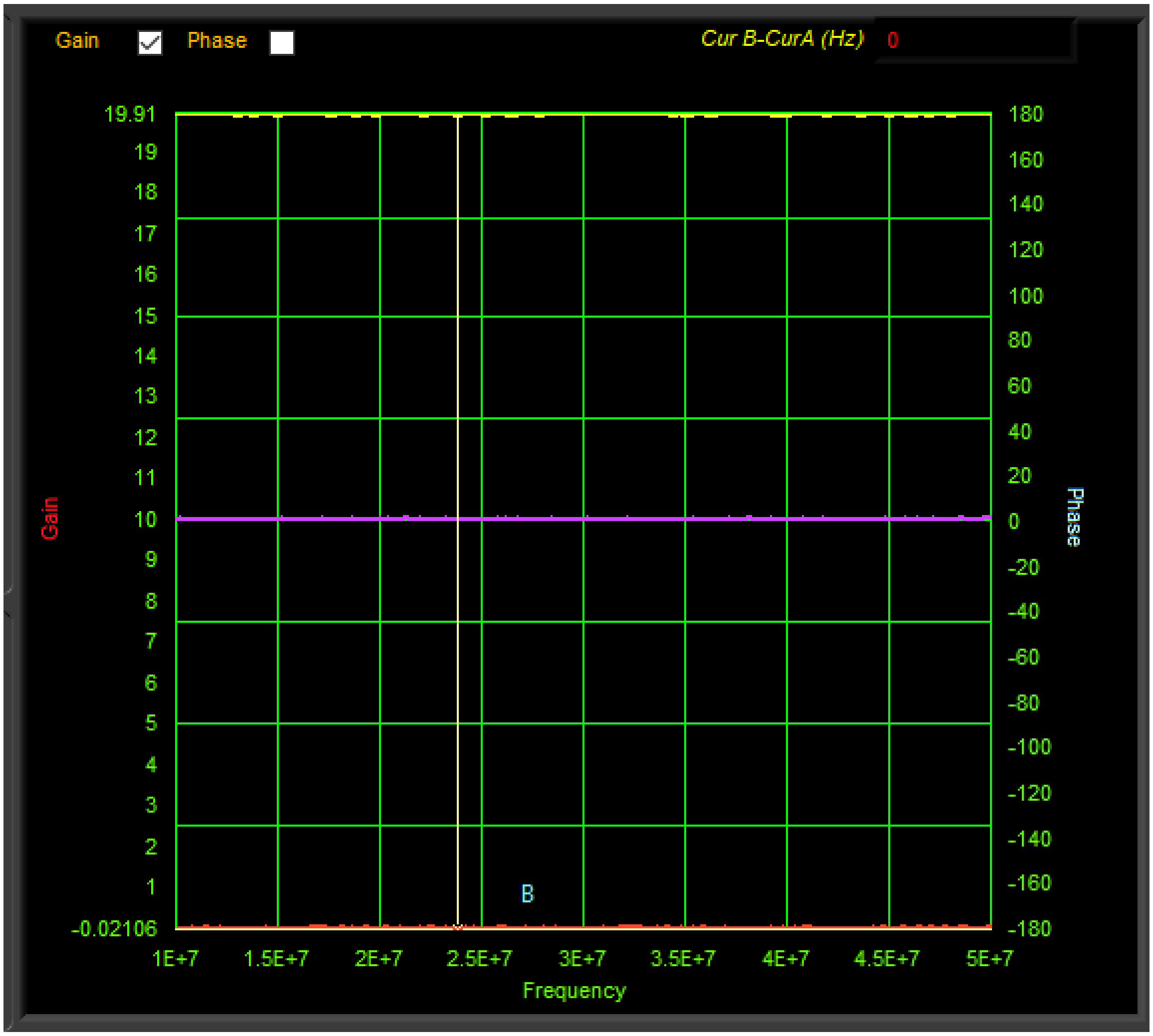


Figure 46

Selecting the clear button will erase all three memories and turn them off. You do not have to erase a memory before storing a new waveform. Pressing one of the memory keys will always overwrite the previously stored waveform.

13. Recording Multiple Sweeps to Disk

The software has the ability to record the swept data to disk. Once you have the VNA setup, select the Record button. You will be prompted to enter a filename.

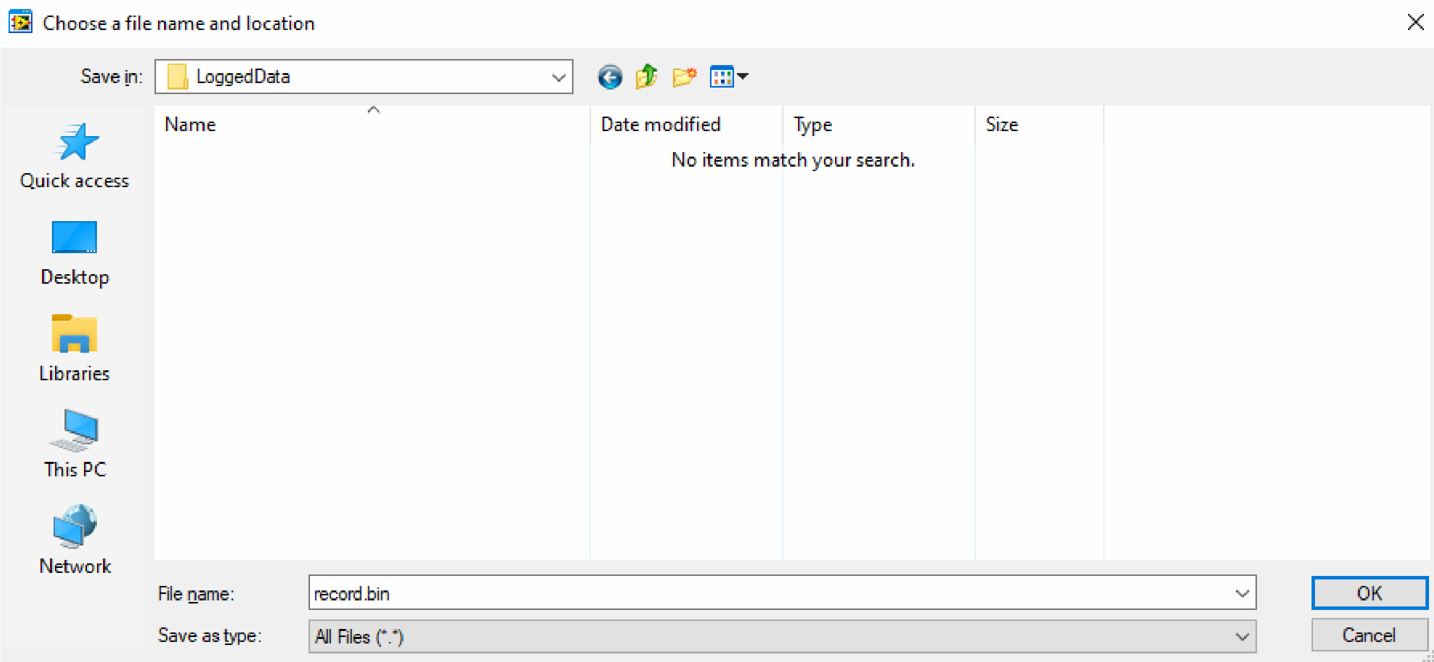


Figure 47

The software will immediately begin recording all of the corrected S-parameters. Selecting standards, performing a calibration, changing the port extension, using normalize and enabling filters will all have an effect on the recorded data.

The author has found the V2+ (not the +4 model) to be very unreliable when running for extended times. The NanoVNA itself appears to lockup and will require a power cycle to clear it. The +4 model does not appear to have this problem. You need to be aware of this if you are attempting to run a long term study.

Figure 48

Once you have finished recording your data, just select Record again to stop the collection.

13.1 Post Processing

Selecting the Advanced tab followed by the Surface tab will bring up the following menu.

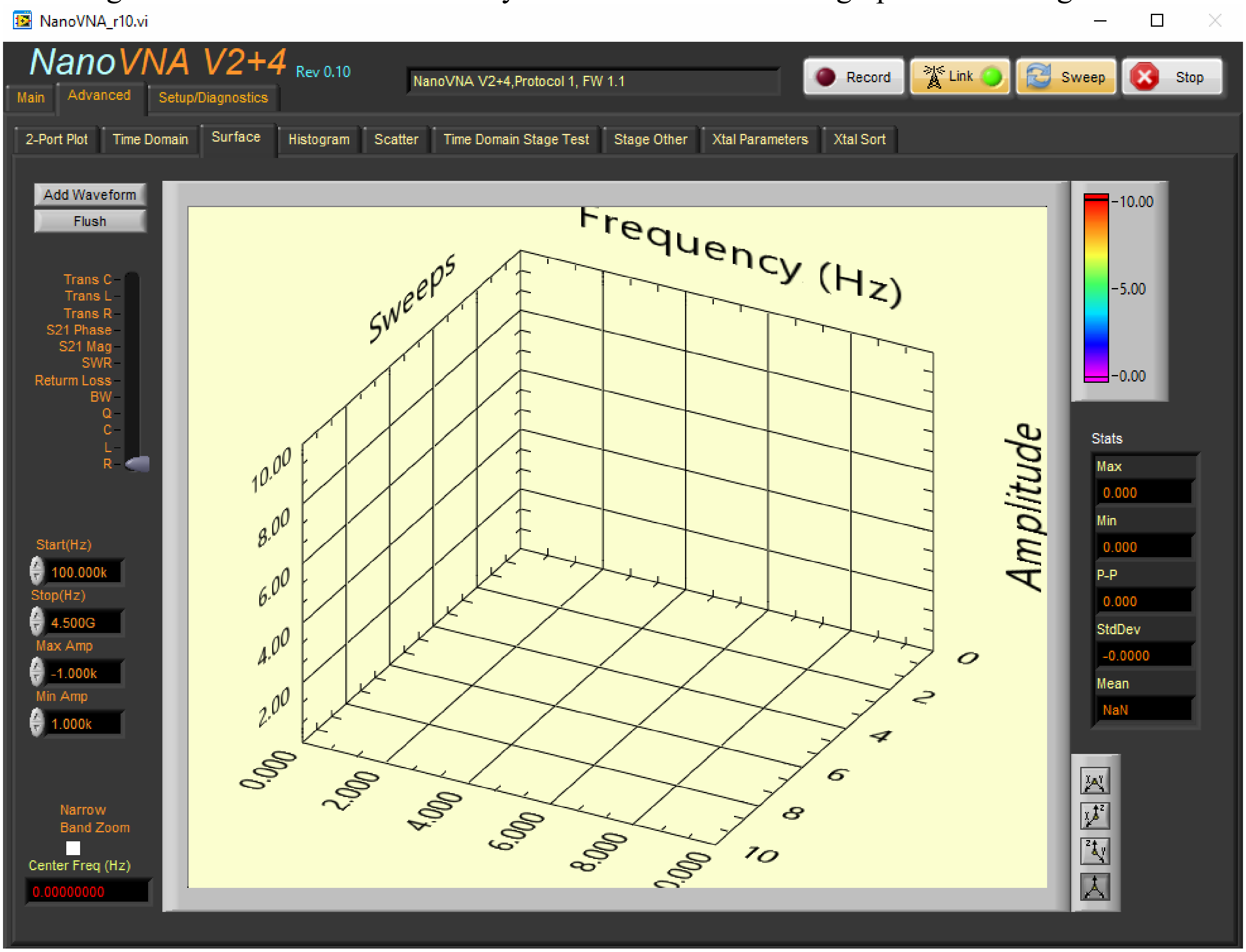


Figure 49

You may now select your file by selecting Add Waveform. You will be prompted for a file name. Note there is now a file named record.txt which is the file just created.

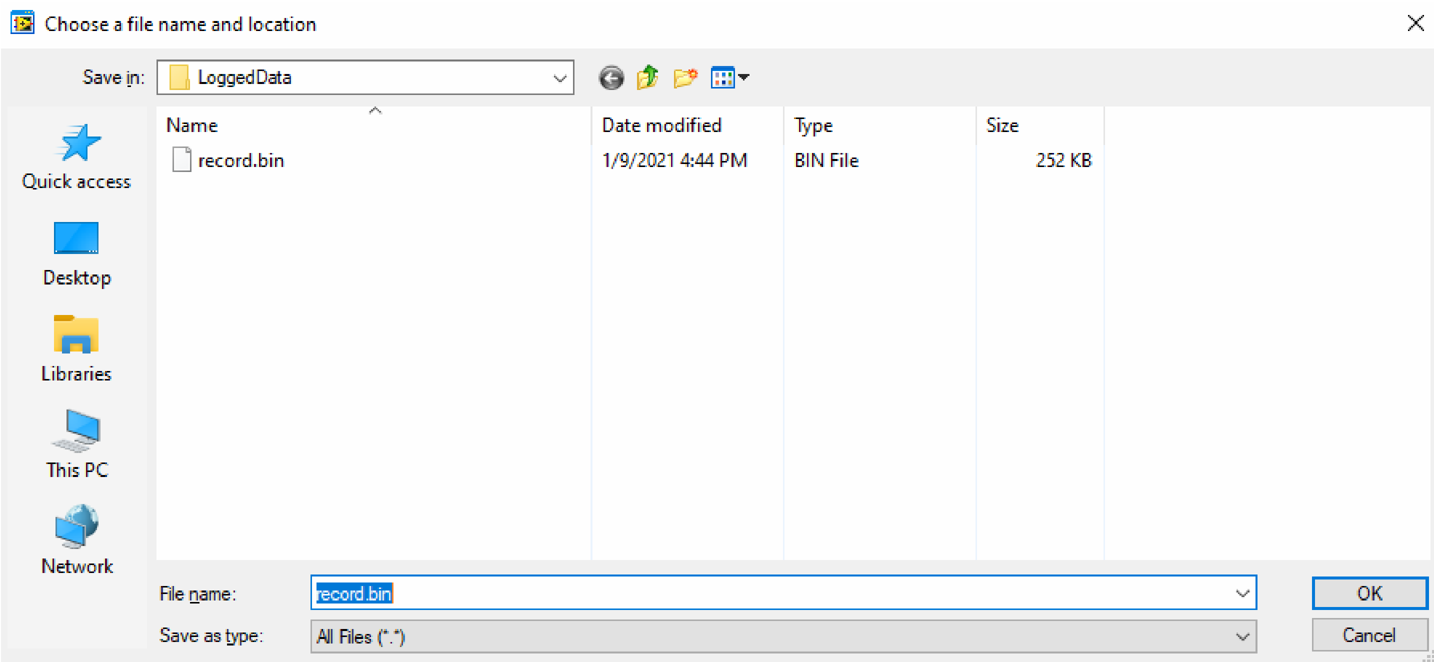


Figure 50

Once the file has been loaded, you may use the slider on the left to select the parameter you would like to view.

IMPORTANT!!!!

This file is not ASCII formatted! The default names were changed to .bin to reflect being a binary file. Currently, Touchstone is the only ASCII formatted file type supported for swept data.

Selecting Flush will purge the memory.

In some cases you will want to view very narrow band data. The Narrow Band Zoom feature allows rescaling the graph around the center frequency. You may also use the Start, Stop, Max and Min amplitudes to change the displayed range of the graph.

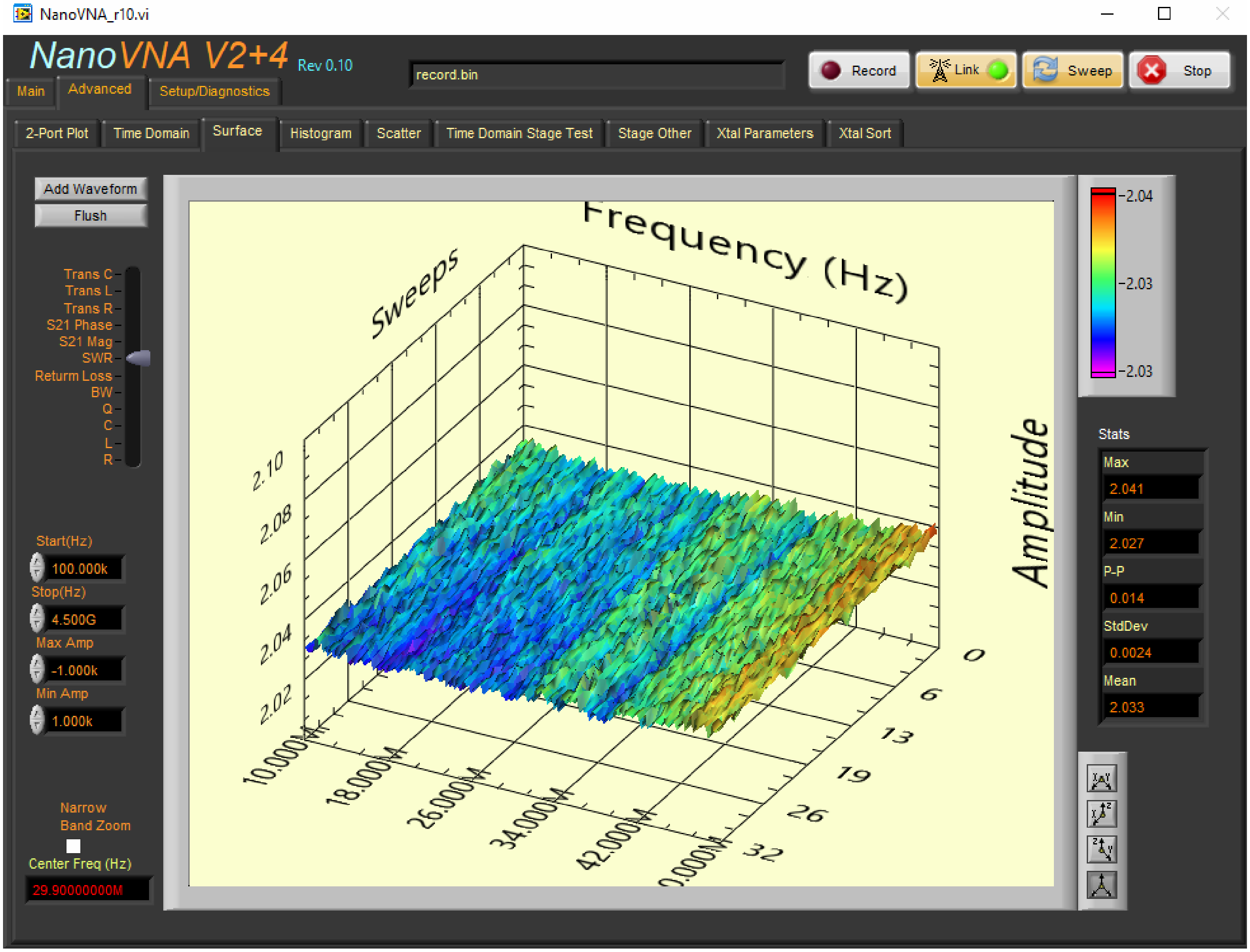


Figure 51

13.2 Histograms and Scattering Diagrams

You may also display the histogram for the selected data.


NanoVNA_r10.vi
NanoVNA V2+4
Rev 0.10
Main
Advanced
Setup/Diagnostics
record.bin
Record
Link
Sweep
Stop
2-Port Plot
Time Domain
Surface
Histogram
Scatter
Time Domain Stage Test
Stage Other
Xtal Parameters
Xtal Sort
Probability Samp
100
Samples
Measured Value
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
2.026
2.028
2.03
2.032
2.034
2.036
2.038
2.04
2.042

Figure 52

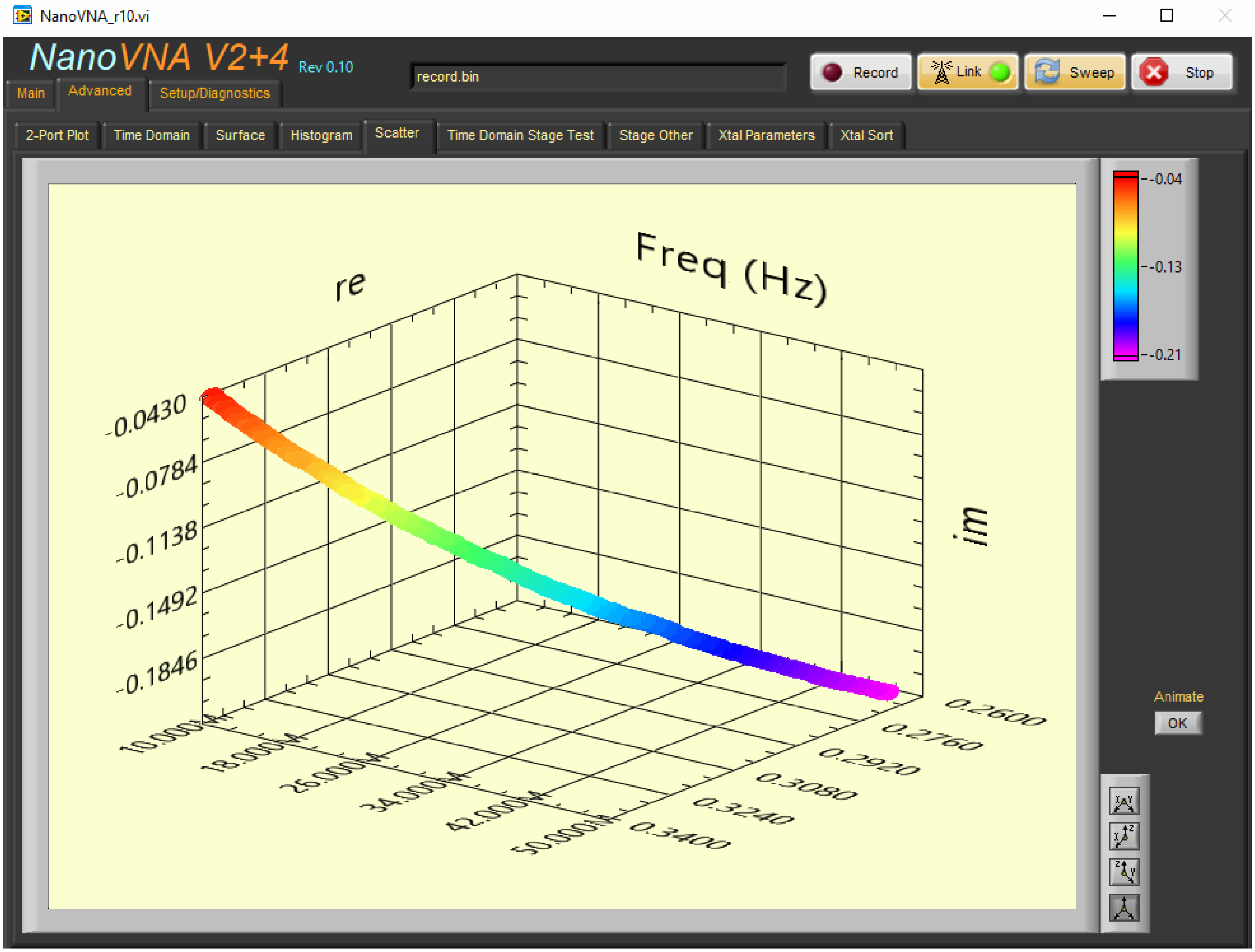


Figure 53

14. Narrow Band Measurements

&$#&%$#%^!!!!!!!!!!!!!!

While the original NanoVNA did a very nice job making narrow band measurements, sadly the V2+ is not able to make these same measurements. The various features have been included but do not expect them to provide any useful data.

14.1 Segmented Sweeps

Segmented sweep was originally added to the NanoVNA software to provide a means of creating high resolution Touchstone files that could be used to generate SPICE models. The original NanoVNA supported a fixed 101 data points for a given sweep range. Segmented sweeps provided a way to work around this limitation. The resolution was really only limited by how long the user wanted to wait and the hardware's minimum step size.

The V2+'s firmware supports more than enough data to make these measurements without the need for segmentation.

14.1.1 Linear / Log Sweep

When using segments, you may select either linear or logarithmic sweeps. Linear is fairly straight forward. For log sweeps, the software computes the step size for each segment based on the samples per decade. While not a true log sweep in the sense, it does allow collecting a higher number of data points for lower frequencies.

14.1.2 Setting up the Segmented Mode

Assuming you are running a linear sweep, set Fspan to the frequency range of each segment. The step size is the span divided by the number of data points selected.

Next, set the start (Fmin) and stop (Fmax) to the range of frequencies you would like to sweep.

IMPORTANT!!!!

There is an order to selecting the data. The software will always program the V2+ to the last setting you made. If you change Fcenter, the software will use the center and span to calculate the new range. If you change Fmin, the software will use the min (start) and max (stop) to calculate the range. If you were to program the min and max first, then change the span, the V2+'s start and stop would change.
Also, changing the number of points will cause the software to recalculate the sweep range based on the min (start) and max (stop).

Using the defaults, the software will start by sweeping from 1MHz to 3MHz, with 201 data points. It will then continue to the next segment.

By attaching a 12MHz 5 pole LP filter, you can see that the resolution in the lower frequencies is poor. I have changed the span from 2MHz to 50MHz.

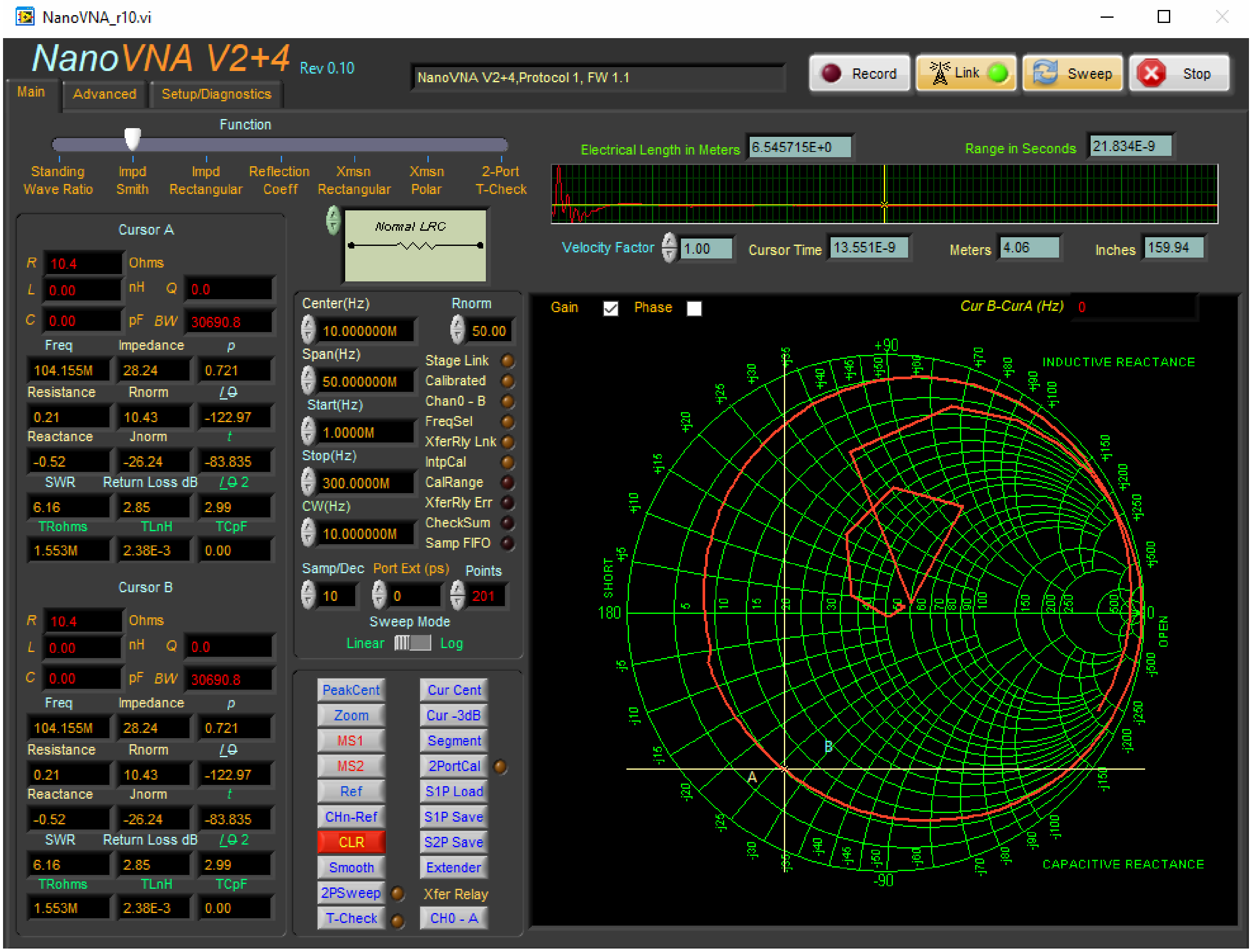


Figure 54

Selecting Segment, and increasing from 201 points to 1005 points allows for more detail.

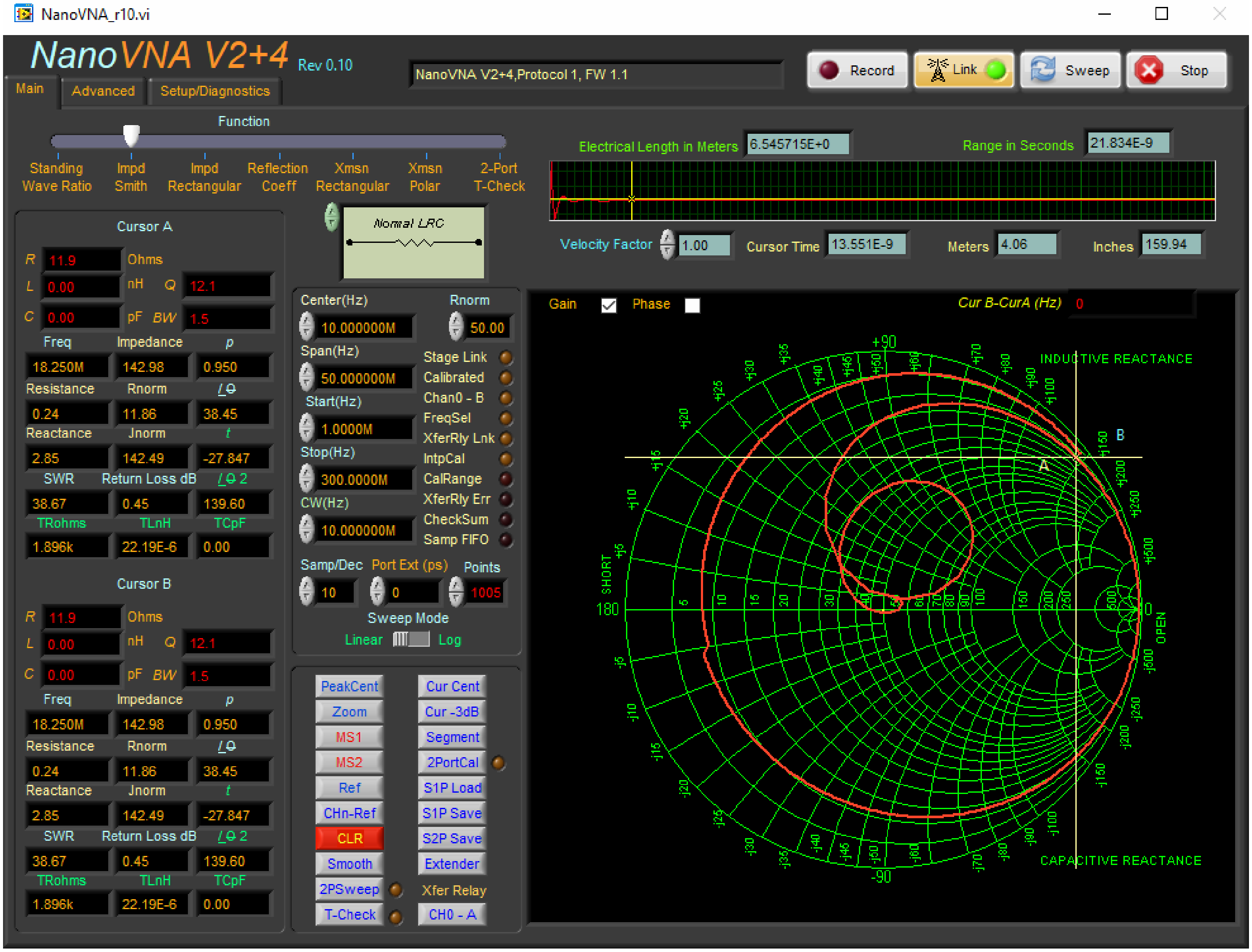
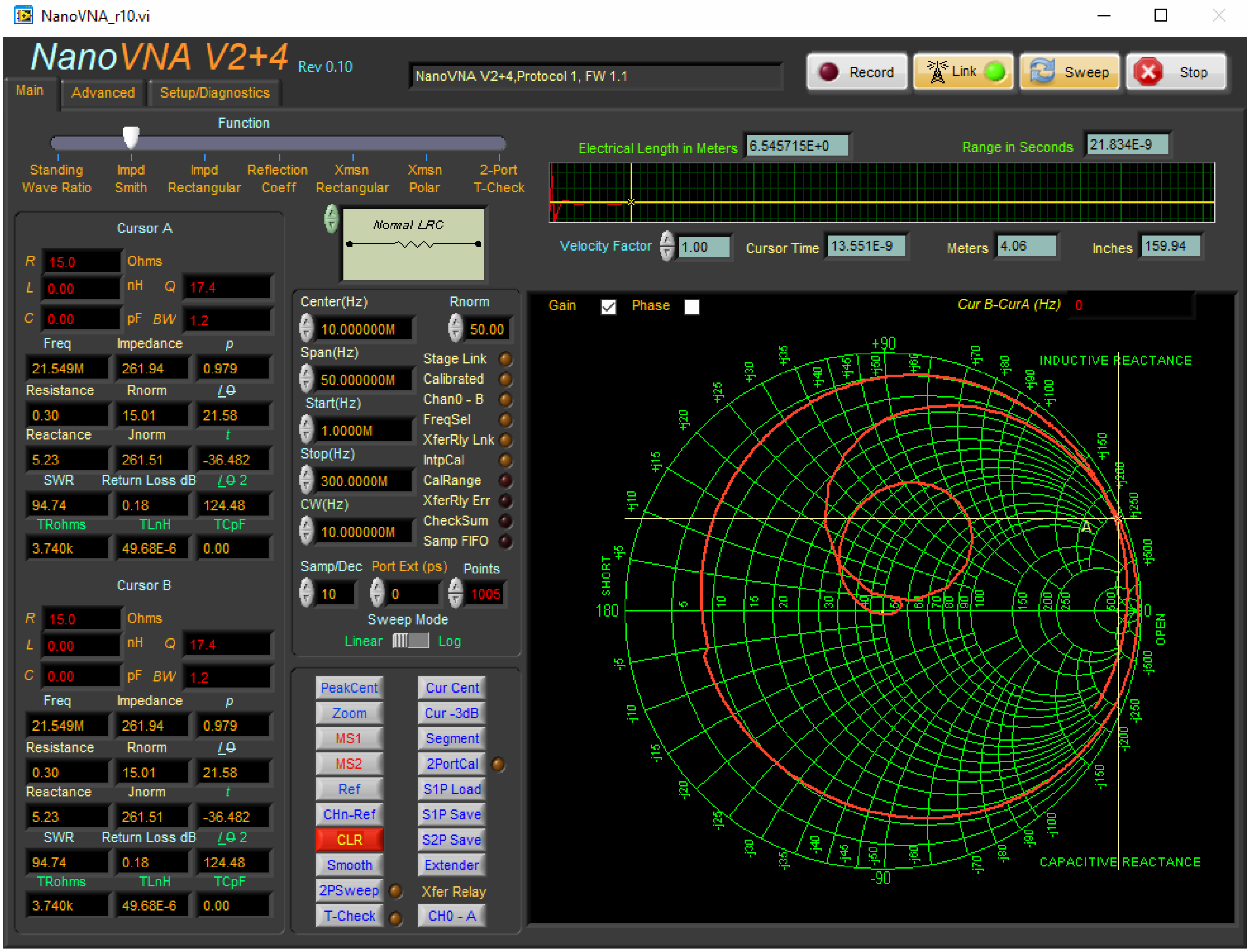


Figure 55

The software currently supports up to 1600 data points. Changing the number of points to 1005 the V2+ will send the same amount of data with a normal sweep.

As shown in Figure 56 when compared with Figure 55, the only difference between the segmented and the normal sweep modes is the sweep time for the normal mode is roughly 4.4 seconds (Figure 57).



NanoVNA_r10.vi
NanoVNA V2+4
Rev 0.10
Main
Advanced
Setup/Diagnostics
NanoVNA V2+4,Protocol 1, FW 1.1
Record
Link
Sweep
Stop
Function
Standing Wave Ratio
Impd Smith
Impd Rectangular
Reflection Coeff
Xmsn Rectangular
Xmsn Polar
2-Port T-Check
Electrical Length in Meters
6.545715E+0
Range in Seconds
21.834E-9
Velocity Factor
1.00
Cursor Time
13.551E-9
Meters
4.06
Inches
159.94
Cursor A
R 15.0 Ohms
L 0.00 nH Q 17.4
C 0.00 pF BW 1.2
Freq Impedance ρ
21.549M 261.94 0.979
Resistance Rnorm ∠Θ
0.30 15.01 21.58
Reactance Jnorm t
5.23 261.51 -36.482
SWR Return Loss dB ∠Θ 2
94.74 0.18 124.48
TRohms TLnH TCpF
3.740k 49.68E-6 0.00
Cursor B
R 15.0 Ohms
L 0.00 nH Q 17.4
C 0.00 pF BW 1.2
Freq Impedance ρ
21.549M 261.94 0.979
Resistance Rnorm ∠Θ
0.30 15.01 21.58
Reactance Jnorm t
5.23 261.51 -36.482
SWR Return Loss dB ∠Θ 2
94.74 0.18 124.48
TRohms TLnH TCpF
3.740k 49.68E-6 0.00
Normal LRC
Center(Hz) 10.000000M
Rnorm 50.00
Span(Hz) 50.000000M
Start(Hz) 1.0000M
Stop(Hz) 300.0000M
CW(Hz) 10.000000M
Stage Link
Calibrated
Chan0 - B
FreqSel
XferRly Lnk
IntpCal
CalRange
XferRly Err
CheckSum
Samp FIFO
Samp/Dec Port Ext (ps) Points
10 0 1005
Sweep Mode
Linear Log
PeakCent
Cur Cent
Zoom
Cur -3dB
MS1
Segment
MS2
2PortCal
Ref
S1P Load
CHn-Ref
S1P Save
CLR
S2P Save
Smooth
Extender
2PSweep
Xfer Relay
T-Check
CH0 - A
Gain
Phase
Cur B-CurA (Hz)
0
INDUCTIVE REACTANCE
CAPACITIVE REACTANCE
SHORT
OPEN
180
+90
-90

Figure 56

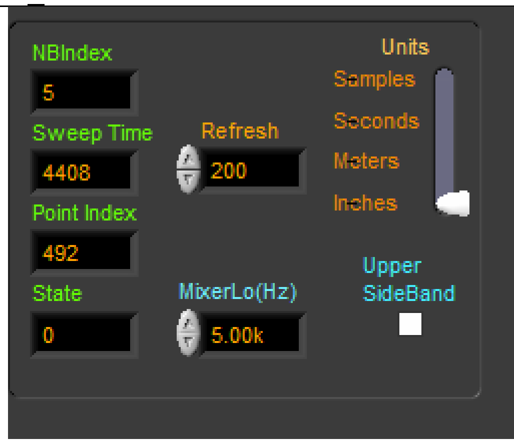


Figure 57

14.2 Measuring Crystals

While the original NanoVNA made these measurements fairly accurately compared with the author's other VNAs and various test equipment, the V2+ lacks the ability to perform any narrowband measurements. This section of the document has been included only to provide details explaining (showing) how the software works. Do not expect to make use of these specific modes unless an improved V2+ that is software compatible with the current versions is released. To mitigate this problem, I suggest the original NanoVNA be procured.

The following table from CopperMountain shows the equations for the three types of impedance measurements. For these measurements, we will be looking at the crystals series impedance.

1	$Z_0 \cdot \frac{1+S_{11}}{1-S_{11}}$	$\Delta Z^{\max} = \frac{2Z_0 \cdot \lvert \Delta S_{11}^{\max} \rvert}{\lvert 1-S_{11} \rvert^2}$, $\lvert \Delta S_{11}^{\max} \rvert = \lvert D \rvert + \lvert R-1 \rvert \cdot \lvert S_{11} \rvert + \lvert M \rvert \cdot \lvert S_{11} \rvert^2$	2.5 Ohm to 1 kOhm
2	$\frac{Z_0}{2} \cdot \frac{S_{21}}{1-S_{21}}$	$\Delta Z^{\max} = \frac{Z_0 \cdot \lvert \Delta S_{21}^{\max} \rvert}{2 \cdot \lvert 1-S_{21} \rvert^2}$, $\lvert \Delta S_{21}^{\max} \rvert = (\lvert T-1 \rvert + \lvert M \rvert + \lvert L \rvert) \cdot \lvert S_{21} \rvert + \lvert X \rvert$	1 mOhm to 100 Ohm
3	$2Z_0 \cdot \frac{1-S_{21}}{S_{21}}$	$\Delta Z_3^{\max} = \frac{2Z_0 \cdot \lvert \Delta S_{21}^{\max} \rvert}{\lvert S_{21} \rvert^2}$, $\lvert \Delta S_{21}^{\max} \rvert = \lvert T-1 \rvert \cdot \lvert S_{21} \rvert + \lvert X \rvert$	8 Ohm to 100 kOhm

Figure 58

14.3 Test Fixture

To make these measurements, a custom test fixture was created. This is nothing more than two 3dB attenuators and two five-turn bifilar transformers wound with Teflon wire. I used some cores I had on hand. These are toroids with a 12.7mm dia, 6.35mm height and a 2.4mm thickness. I suspect these were made by TDK or Fair-Rite. This fixture works fairly well for measuring crystals in the range of 2-30MHz.

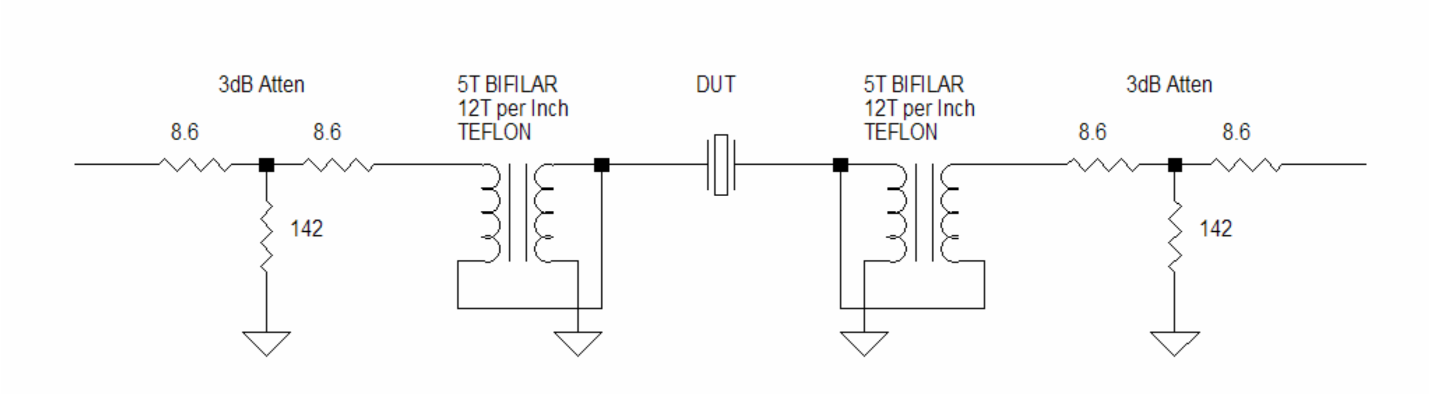


Figure 59

The standards along with the fixture are shown below. The copper block and connector is just a heatsink for soldering these.

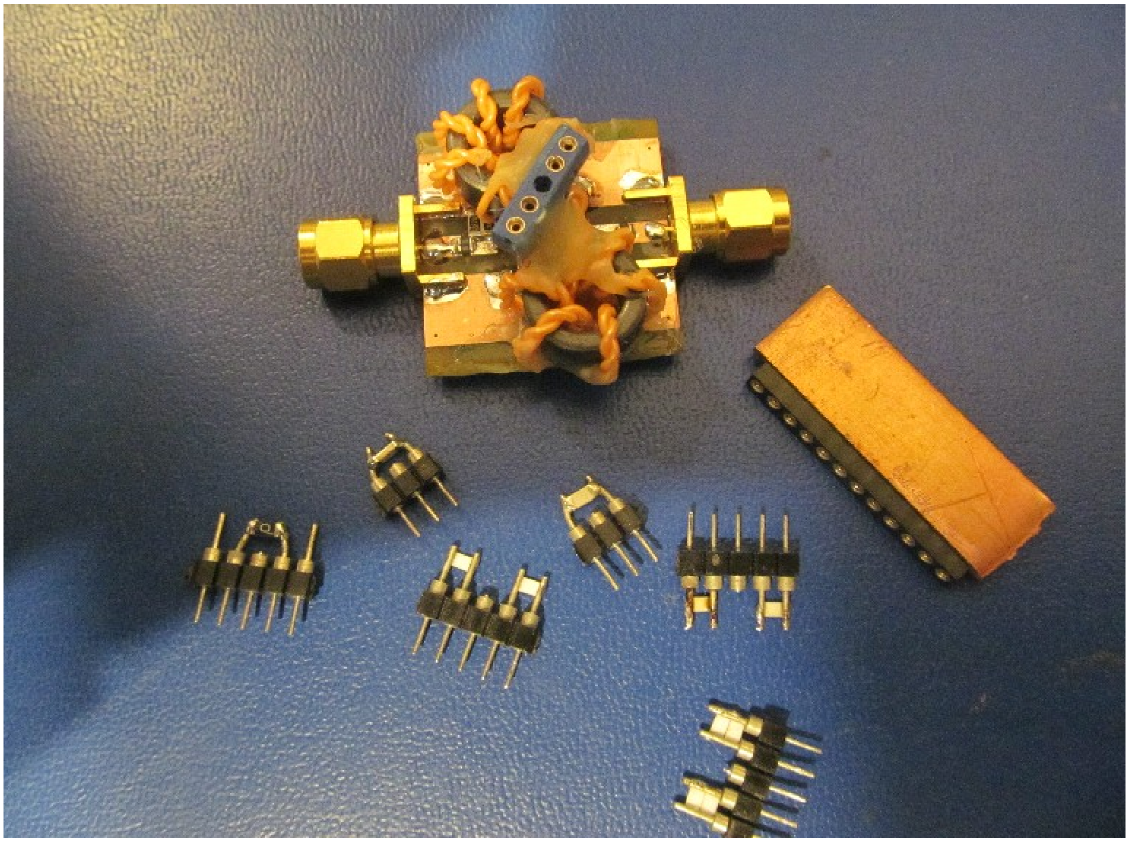


Figure 60

14.4 Example of Measuring a Crystal

The basic steps when characterizing quartz crystals is as follows:

Insert fixture
Set the Center frequency to roughly the value of the Xtal and set the span to 1MHz
Install short standard into Xtal socket
Select Ref, followed by CHn-Ref (Should now measure 0dB)
Remove short and insert Xtal to test
Select Zoom. The software will try and zoom into the peak and set the span to 500Hz
Select Advanced, Xtal Parameters
Make sure that the Fixture type is set to 4:1 (unchecked)
Select CO Cap and wait for TrC measurement to complete
Right mouse click on the center graph and select Clear data
Wait for the crystal to become temperature stable
Fill out the Serial number, Brand and Model of the device
Select Save Data (This will write one record to the file you select)
Replace the crystal and repeat steps 10-13 for each crystal to characterize.

Note that no calibration is required as normalization is used.

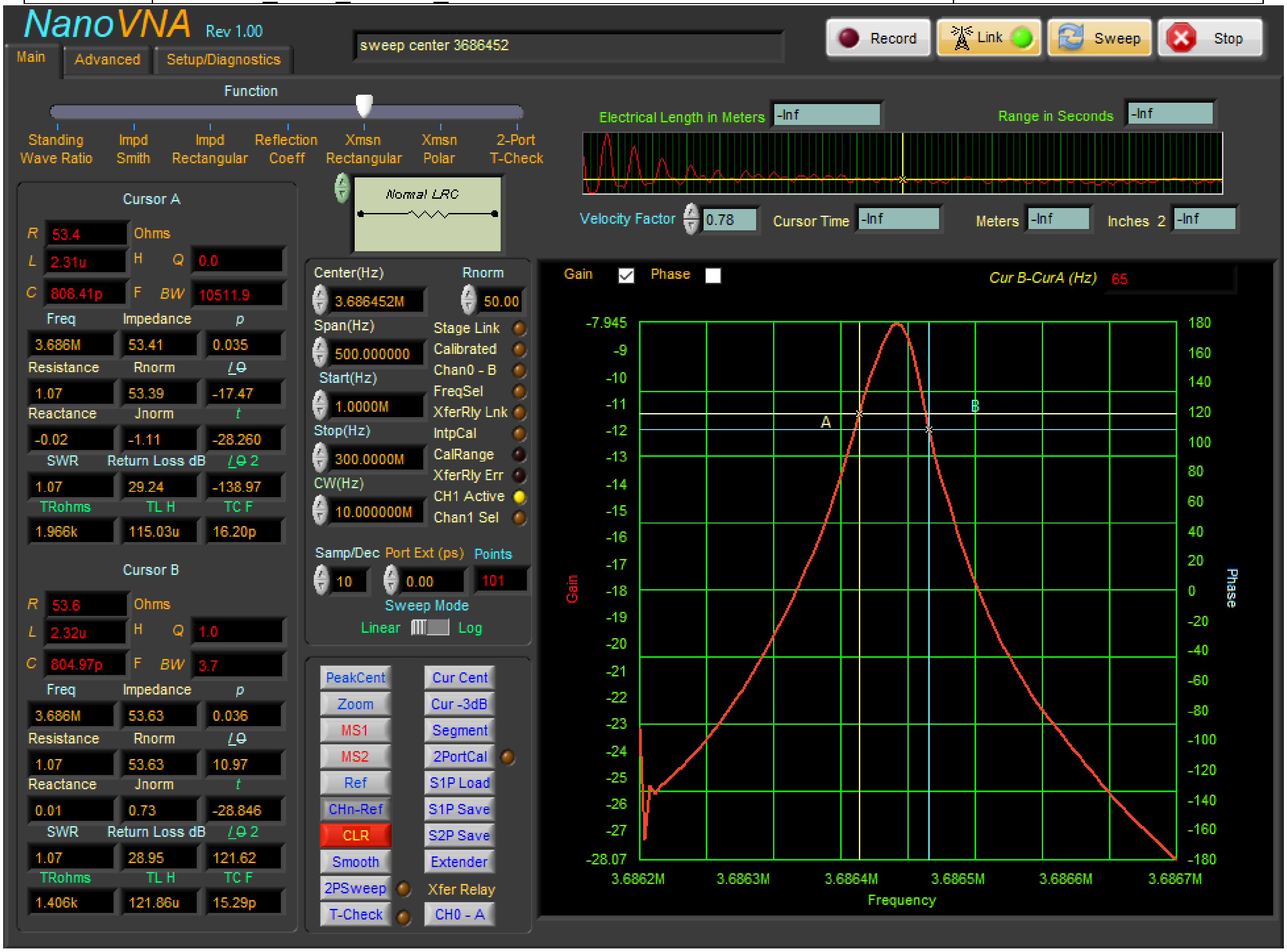
For this example I used a 3.6864MHz crystal from Fox, series 0368S. Start by installing the fixture and a short in place of a crystal. Set the function to Xmsn Rectangular. Set the center frequencies to 3.7MHz (roughly in the center of the crystals you plan to characterize).

When using the original NanoVNA, you should not use the internal calibration for any measurements. Rather you can reset the calibration from the Nano's menu and then store that to settings 0. When the unit is powered up, it will always be cleared. Of course the software does not care if the Nano is calibrated or not and it does support loading the internal calibrations for those who need this feature. Again, think engineering tool.

Notice without the calibration, the original NanoVNA will display roughly 17dB.

Figure 61

Select the Ref button to store this as your reference. Now select CHn-Ref. The software will now display 0dB. Next install the crystal you want to characterize and select Zoom. The software will automatically zoom into the peak and center it. Once finished, you can set the cursors to the 3dB points by selecting Cur-3dB.



NanoVNA Rev 1.00
Main
Advanced
Setup/Diagnostics
sweep center 3686452
Record
Link
Sweep
Stop
Function
Standing Wave Ratio
Impd Smith
Impd Rectangular
Reflection Coeff
Xmsn Rectangular
Xmsn Polar
2-Port T-Check
Normal LRC
Electrical Length in Meters
Range in Seconds
Velocity Factor 0.78
Cursor Time
Meters
Inches 2
Cursor A
Cursor B
Center(Hz) 3.686452M
Rnorm 50.00
Span(Hz) 500.000000
Start(Hz) 1.0000M
Stop(Hz) 300.0000M
CW(Hz) 10.000000M
Stage Link
Calibrated
Chan0 - B
FreqSel
XferRly Lnk
IntpCal
CalRange
XferRly Err
CH1 Active
Chan1 Sel
Samp/Dec Port Ext (ps) Points
Sweep Mode
Linear Log
PeakCent
Zoom
MS1
MS2
Ref
CHn-Ref
CLR
Smooth
2PSweep
T-Check
Cur Cent
Cur -3dB
Segment
2PortCal
S1P Load
S1P Save
S2P Save
Extender
Xfer Relay
CH0 - A
Gain
Phase
Cur B-CurA (Hz) 65
Frequency

Figure 62

If using the V2+, when adjusting the start and stop frequencies (or span) to zoom into this area, you begin to see a problem. Normally, you would expect this to be a very smooth curve but the limitation of the V2+ is already causing problems.

Figure 63

Notice the steps in the V2+'s data as we continue to zoom into the peak.

Figure 64

For a reference: Figure 65 shows the same model/brand crystal and test fixture attached to one of my old network analyzers. The original NanoVNA compares closely to the results obtained with this instrument.

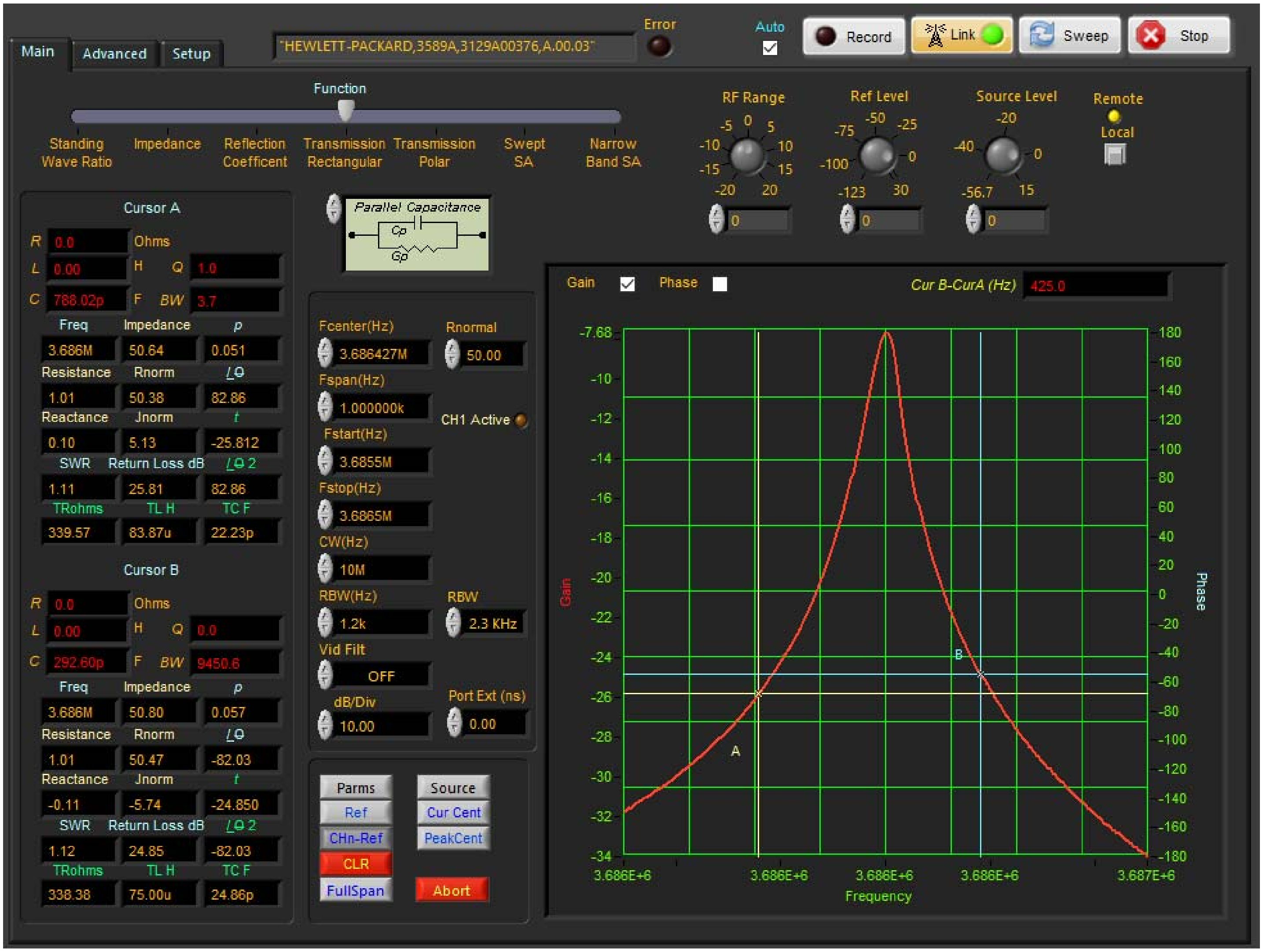


Figure 65

Next select the Advanced tab followed by Xtal Parameters. If you right click on the center graph, you can select clear data. Allow the temperature to stabilize. This may take more than a minute depending on your procedure.

We can see this by monitoring the Series Frequency. I suggest not handling the crystals with your hands to avoid the effects of your body temperature. The NanoVNA is more than sensitive enough to detect very small changes in the crystal. As the part starts to become stable you will see a peak in the histogram.

Figure 66

Once the crystal is stable, selecting the C0 button will cause the software to automatically make this measurement. As noted, I have built up various standard for this fixture. One standard has a 5.6, 10 and 100pF capacitors. These are placed in the fixture rather than the crystals to validate the setup.

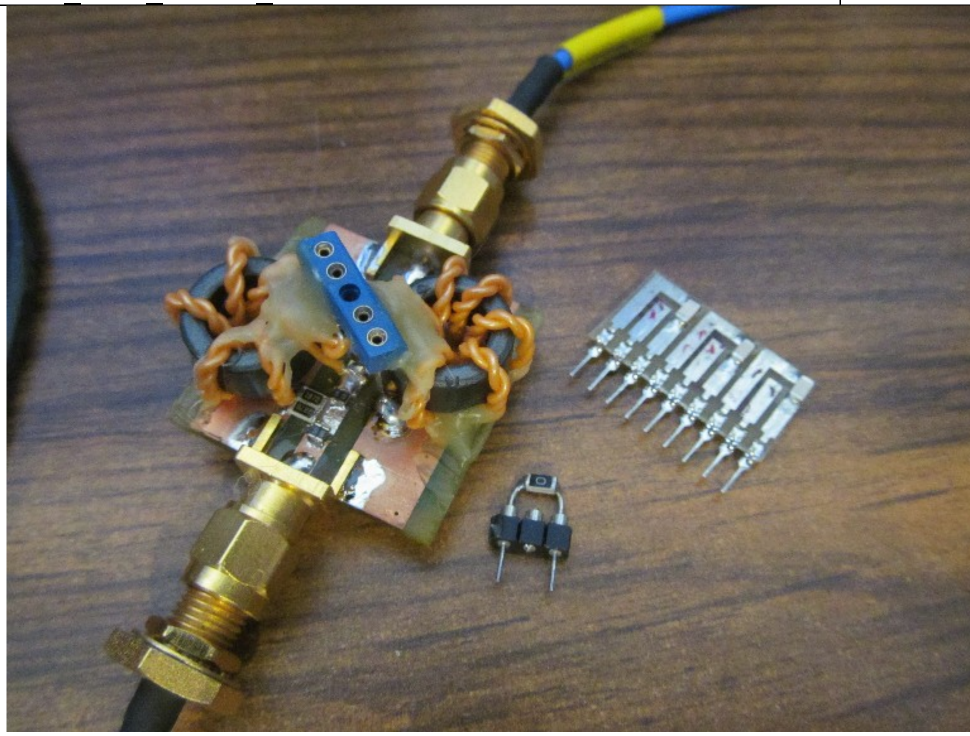


Figure 67

As you can see, the NanoVNA has calculated a value of 4.159pF for C0. Note the dip in the frequency. The software reprograms the VNA to 1MHz to make this measurement.   Currently this is fixed. Obviously this assumes you are not testing crystals with a resonance near 1MHz.

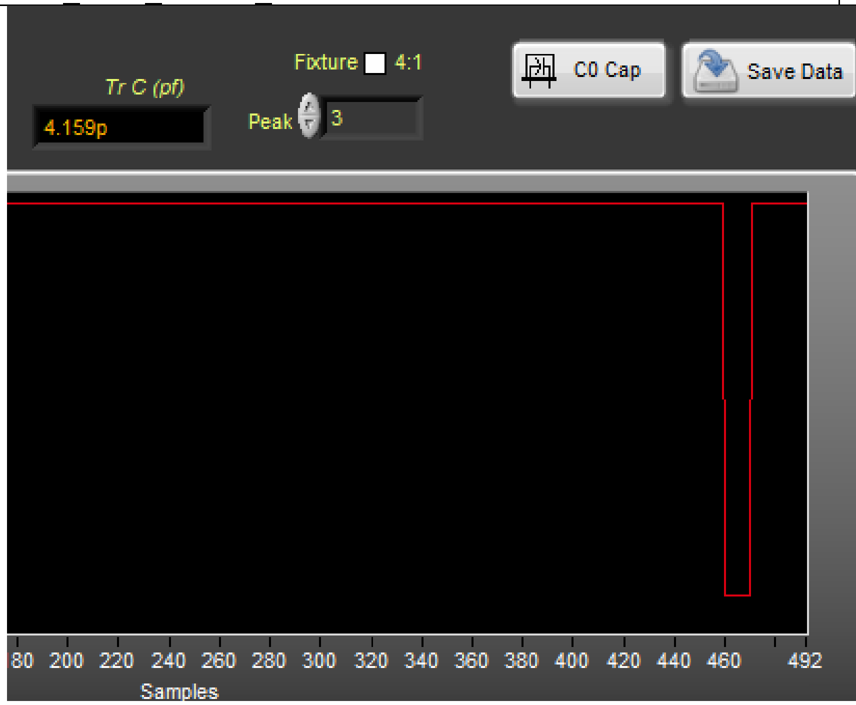


Figure 68

A simple RLC meter can also be used to validate the results. 70fF, close enough….

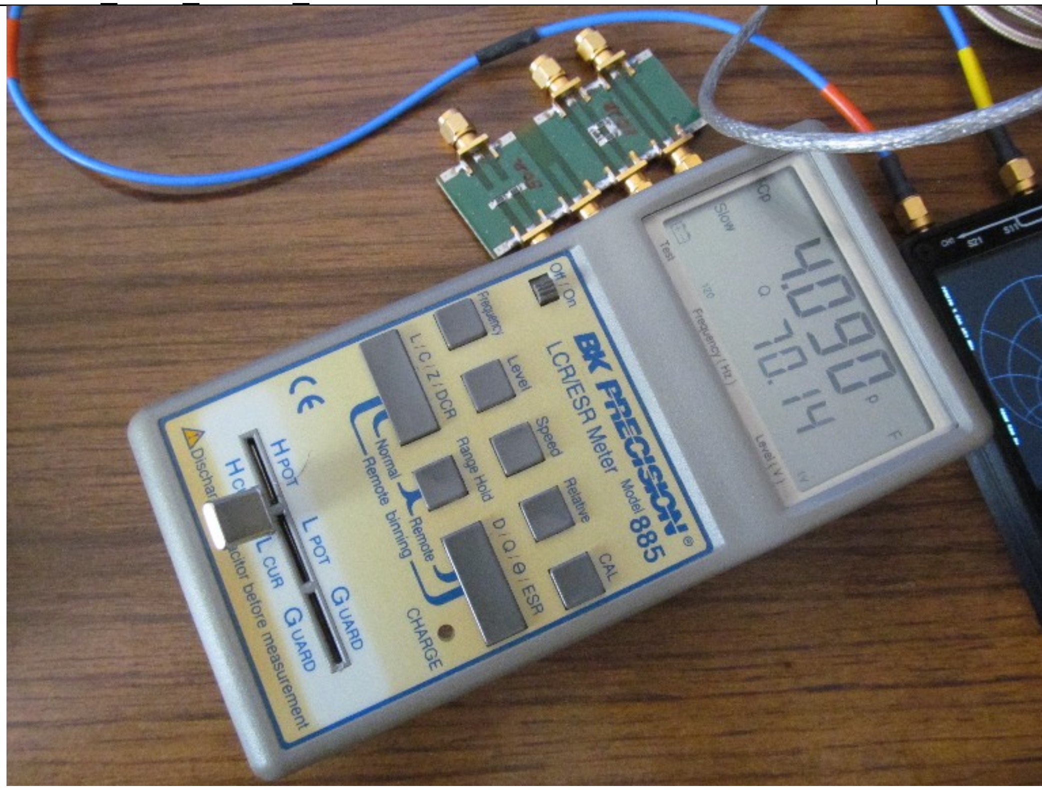


Figure 69

You may now clear the series frequency graph. Allowing the system to run, you will get a feel for the noise.

The software has made all the measurements and you can enter a serial number, brand and model that will be stored with the data.

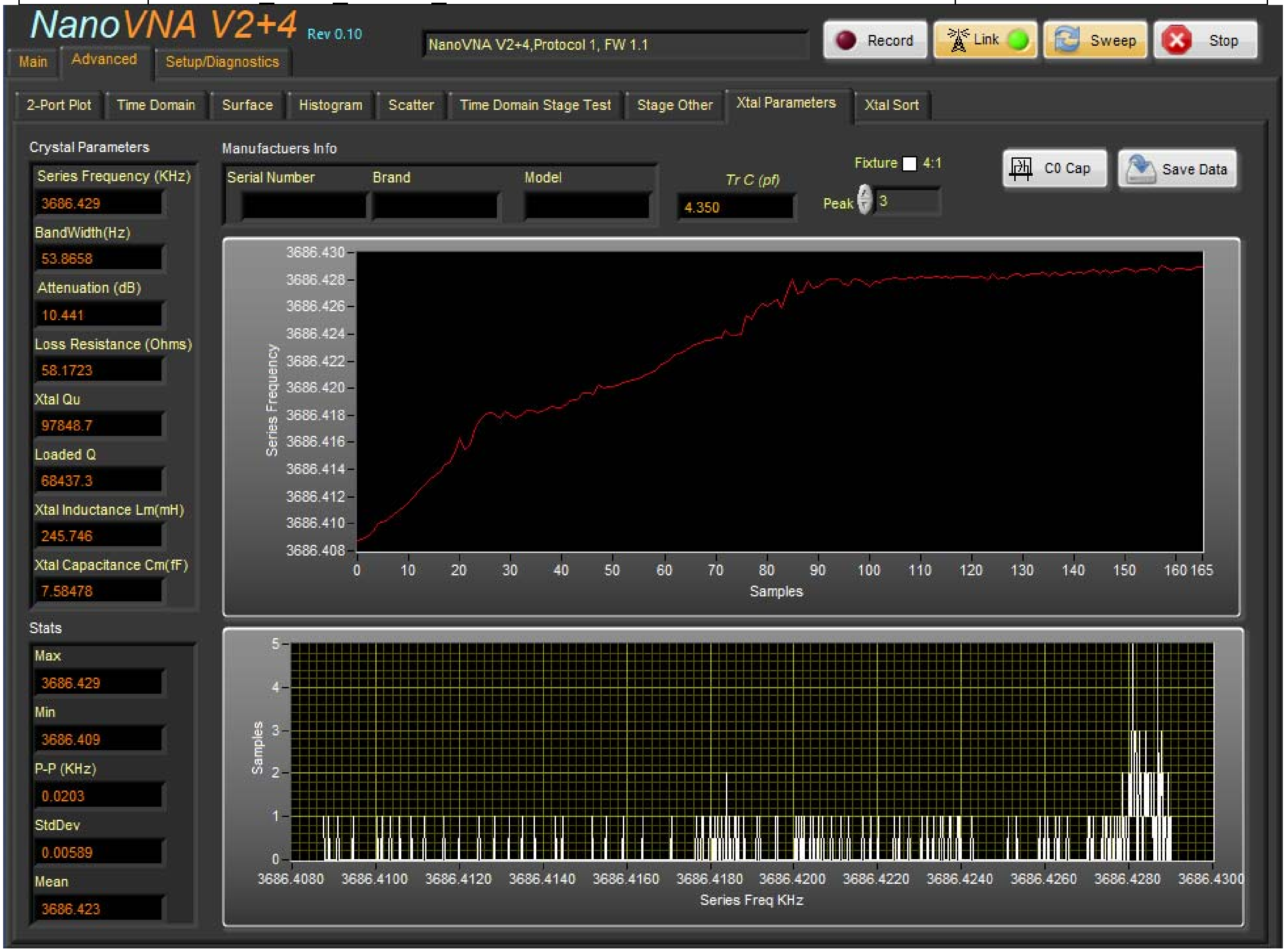


Figure 70

Select Save Data and you will be prompted for a file name. It’s best to name the file with a meaningful description.

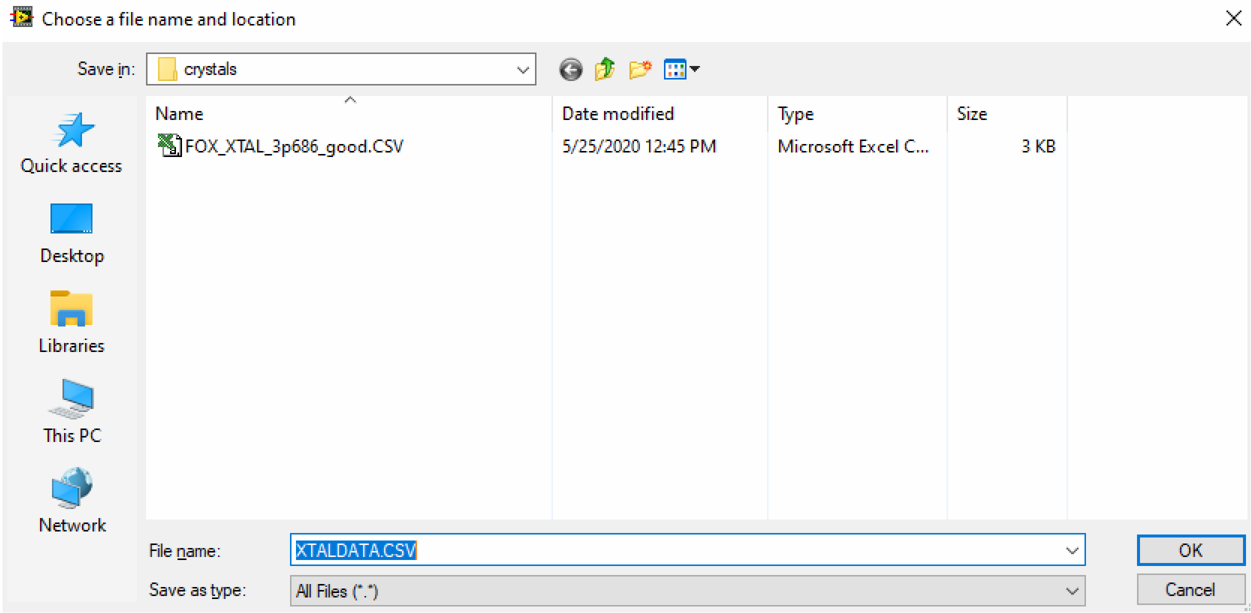


Figure 71

Selecting Xtal Sort tab will allow you to sort the data you have collected. Select the SortData button and you will be asked to select the file name to sort. For this example, I used data collected from the original NanoVNA.

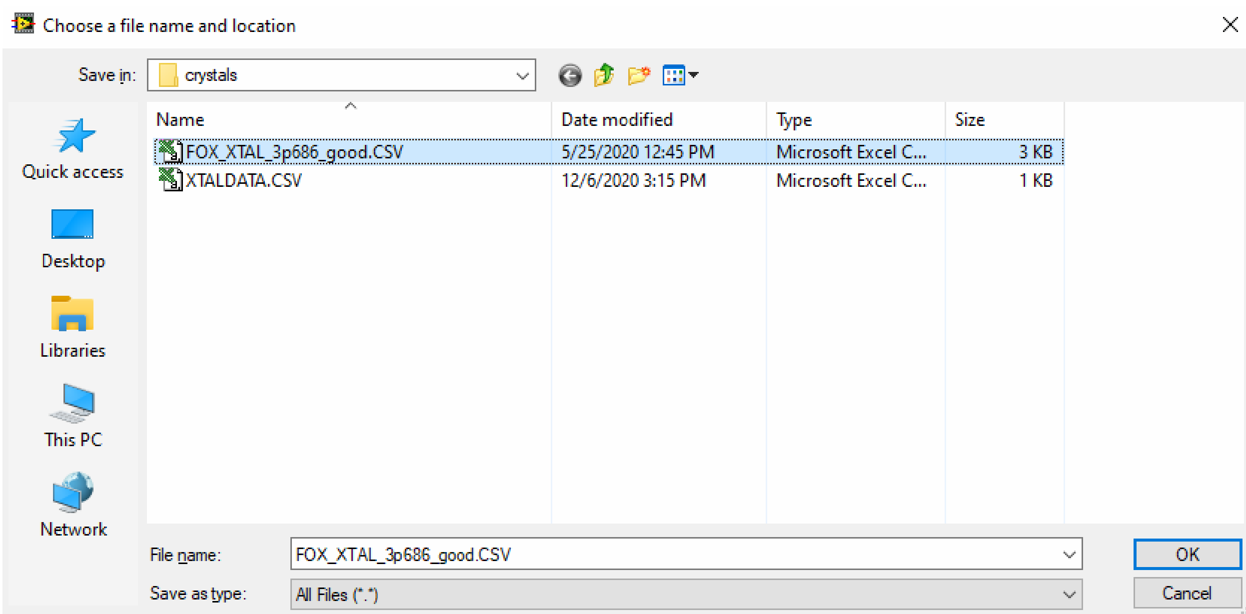
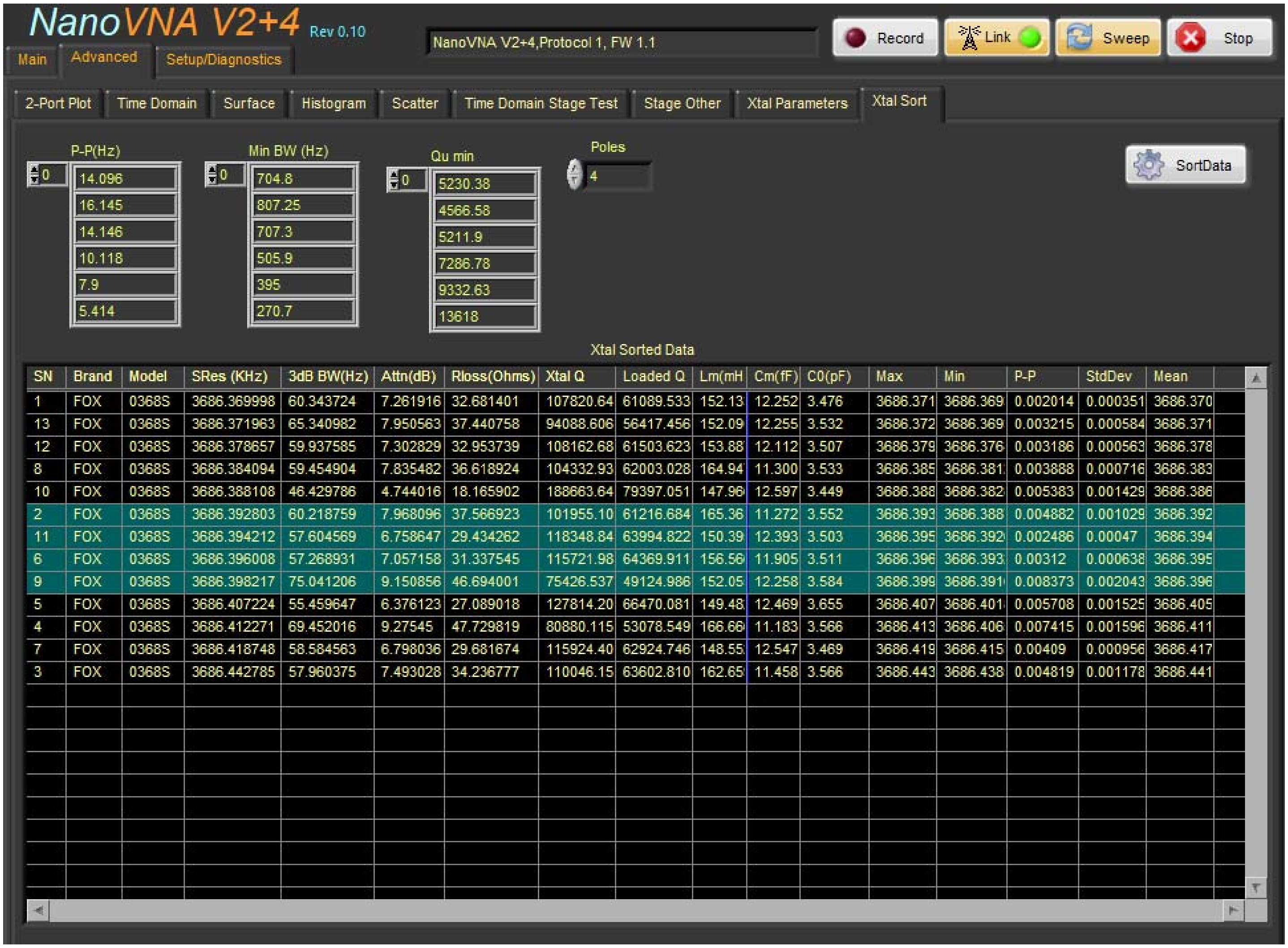


Figure 72

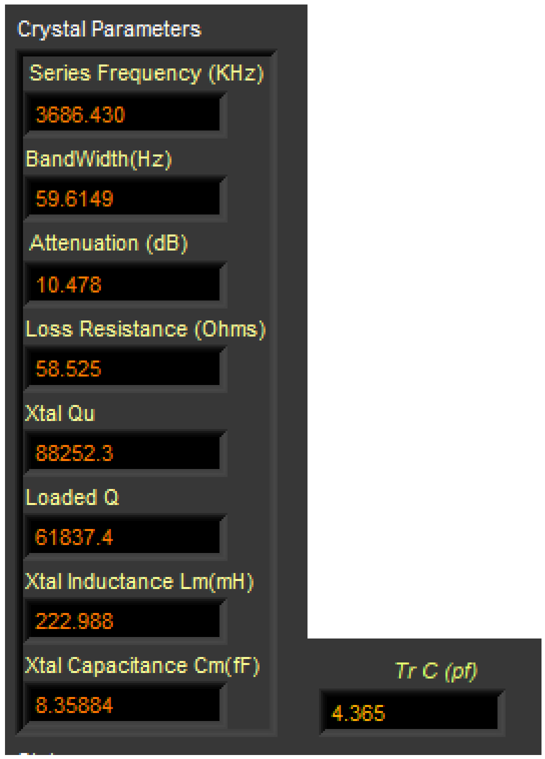
The crystal data will be presented in table format. You may then select the number of poles for the filter you are designing and the software will highlight the closest match.



SN	Brand	Model	SRes (KHz)	3dB BW(Hz)	Attn(dB)	Rloss(Ohms)	Xtal Q	Loaded Q	Lm(mH	Cm(fF)	C0(pF)	Max	Min	P-P	StdDev	Mean
1	FOX	0368S	3686.369998	60.343724	7.261916	32.681401	107820.64	61089.533	152.13	12.252	3.476	3686.371	3686.369	0.002014	0.000351	3686.370
13	FOX	0368S	3686.371963	65.340982	7.950563	37.440758	94088.606	56417.456	152.09	12.255	3.532	3686.372	3686.369	0.003215	0.000584	3686.371
12	FOX	0368S	3686.378657	59.937585	7.302829	32.953739	108162.68	61503.623	153.88	12.112	3.507	3686.379	3686.376	0.003186	0.000563	3686.378
8	FOX	0368S	3686.384094	59.454904	7.835482	36.618924	104332.93	62003.028	164.94	11.300	3.533	3686.385	3686.381	0.003888	0.000716	3686.383
10	FOX	0368S	3686.388108	46.429786	4.744016	18.165902	188663.64	79397.051	147.96	12.597	3.449	3686.388	3686.382	0.005383	0.001429	3686.386
2	FOX	0368S	3686.392803	60.218759	7.968096	37.566923	101955.10	61216.684	165.36	11.272	3.552	3686.393	3686.388	0.004882	0.001029	3686.392
11	FOX	0368S	3686.394212	57.604569	6.758647	29.434262	118348.84	63994.822	150.39	12.393	3.503	3686.395	3686.392	0.002486	0.00047	3686.394
6	FOX	0368S	3686.396008	57.268931	7.057158	31.337545	115721.98	64369.911	156.56	11.905	3.511	3686.396	3686.393	0.00312	0.000638	3686.395
9	FOX	0368S	3686.398217	75.041206	9.150856	46.694001	75426.537	49124.986	152.05	12.258	3.584	3686.399	3686.391	0.008373	0.002043	3686.396
5	FOX	0368S	3686.407224	55.459647	6.376123	27.089018	127814.20	66470.081	149.48	12.469	3.655	3686.407	3686.401	0.005708	0.001525	3686.405
4	FOX	0368S	3686.412271	69.452016	9.27545	47.729819	80880.115	53078.549	166.66	11.183	3.566	3686.413	3686.406	0.007415	0.001596	3686.411
7	FOX	0368S	3686.418748	58.584563	6.798036	29.681674	115924.40	62924.746	148.55	12.547	3.469	3686.419	3686.415	0.00409	0.000956	3686.417
3	FOX	0368S	3686.442785	57.960375	7.493028	34.236777	110046.15	63602.810	162.65	11.458	3.566	3686.443	3686.438	0.004819	0.001178	3686.441

Figure 73

When this data is compared with that we just measured, the series frequency and bandwidth are good, the attenuation is about 3dB off. The measured loss resistance is more than 20 ohms high. Lm, Cm and C0 are not even close. The author owns a few old VNAs that are more than capable of making this measurement and the data collected with the original Nano is very close to what I get with the other systems, using the same test jig.



SN	Brand	Model	SRes (KHz)	3dB BW(Hz)	Attn(dB)	Rloss(Ohms)	Xtal Q	Loaded Q	Lm(mH	Cm(fF)	C0(pF)
1	FOX	0368S	3686.369998	60.343724	7.261916	32.681401	107820.64	61089.533	152.13	12.252	3.476
13	FOX	0368S	3686.371963	65.340982	7.950563	37.440758	94088.606	56417.456	152.09	12.255	3.532
12	FOX	0368S	3686.378657	59.937585	7.302829	32.953739	108162.68	61503.623	153.88	12.112	3.507
8	FOX	0368S	3686.384094	59.454904	7.835482	36.618924	104332.93	62003.028	164.94	11.300	3.533
10	FOX	0368S	3686.388108	46.429786	4.744016	18.165902	188663.64	79397.051	147.96	12.597	3.449
2	FOX	0368S	3686.392803	60.218759	7.968096	37.566923	101955.10	61216.684	165.36	11.272	3.552
11	FOX	0368S	3686.394212	57.604569	6.758647	29.434262	118348.84	63994.822	150.39	12.393	3.503
6	FOX	0368S	3686.396008	57.268931	7.057158	31.337545	115721.98	64369.911	156.56	11.905	3.511
9	FOX	0368S	3686.398217	75.041206	9.150856	46.694001	75426.537	49124.986	152.05	12.258	3.584
5	FOX	0368S	3686.407224	55.459647	6.376123	27.089018	127814.20	66470.081	149.48	12.469	3.655
4	FOX	0368S	3686.412271	69.452016	9.27545	47.729819	80880.115	53078.549	166.66	11.183	3.566
7	FOX	0368S	3686.418748	58.584563	6.798036	29.681674	115924.40	62924.746	148.55	12.547	3.469
3	FOX	0368S	3686.442785	57.960375	7.493028	34.236777	110046.15	63602.810	162.65	11.458	3.566

Figure 74

So while it may be interesting for some to play with this feature, it really offers no value at this time.

15. Filtering the Swept Data

The software includes a filter which acts on the corrected data before it is processed by the main loop. The same filter is used for all of the S-parameters. The filter is enabled by selecting the Smooth button.

16. Touchstone Files

Touchstone format is an industry standard, allowing you to compare data from various test equipment. I use AppCad's built-in viewer for this. I also use it with SPICE as a way to create models for RF circuits.

The software supports both single and two port formats. If you select a 2-port file and you do not have a transfer relay installed, the software will replicate the same data for both ports. This still may be useful for comparing data.

One thing I should mention is that AppCad requires the same number of points in all the Touchstone files. If you plan to use this tool, make sure your NanoVNA is configured the same as your other equipment.

17. Time Domain Measurements

Shown below is a home made Beatty standard made from an old microwave air line attenuator and some brass tubing. The step is 70mm long.

Figure 75

The Beatty standard is placed between ports 1 &2. The frequency range is set from 50KHz to 4GHz. For this example, the instrument has not been calibrated.

The time domain data can be seen towards the upper right. The first negative going peak is the first discontinuity caused from the Beatty standard's step in the brass tubing thickness. The second positive peak is where the tubing necks back down to 50 ohms. The distance between these two peaks is the length of your standard.

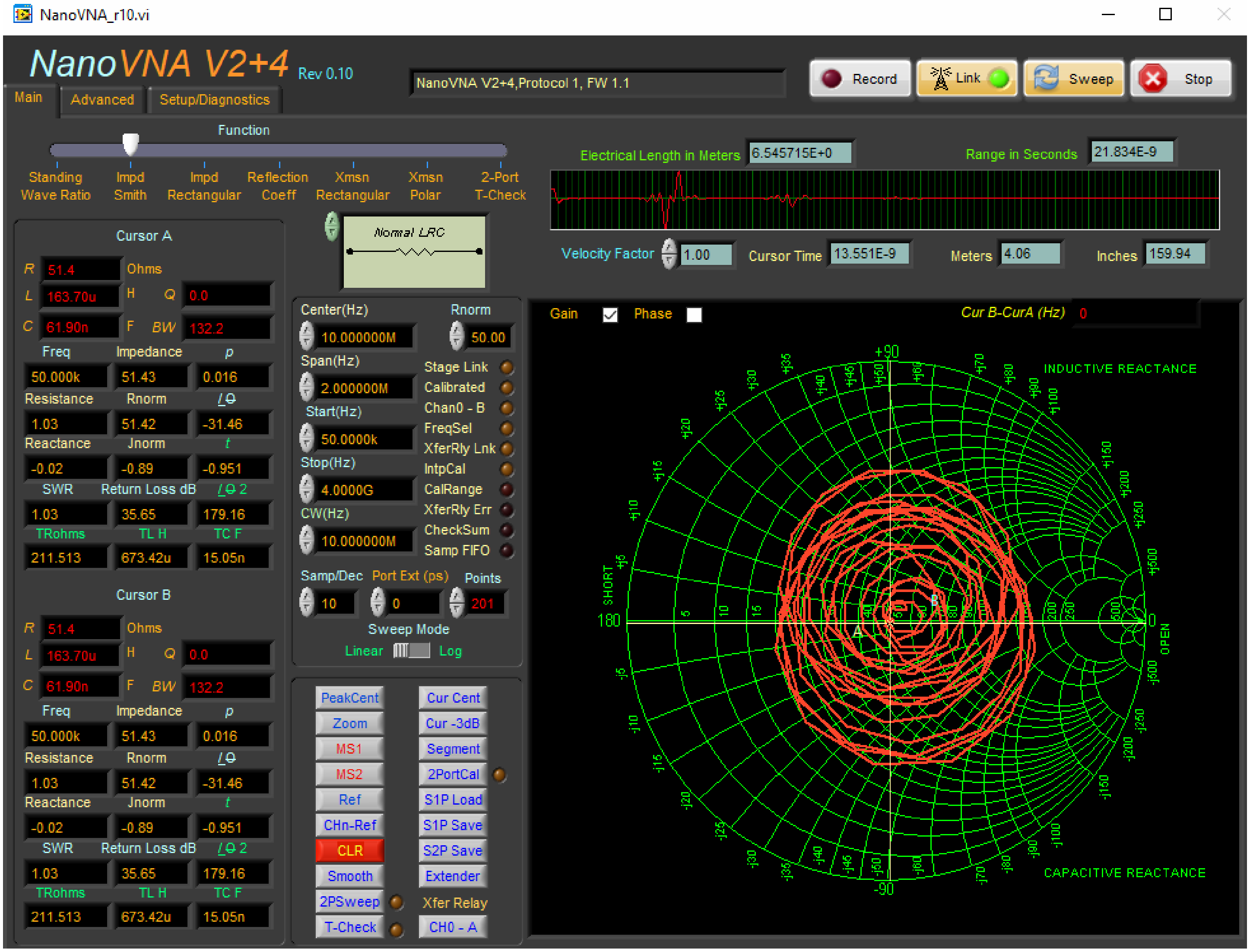


Figure 76

While this view is fine for longer cable measurements, you can select the Advanced tab followed by Time Domain which will provide an easier to read graph.

The software will calculate the FWHH automatically. We can see it is displaying 2.74. Under Setup, the units are set to inches. 70mm is 2.75" Changing to the Setup/Diagnostics, change the units from Inches to Meters. The FWHH becomes 69.5mm.

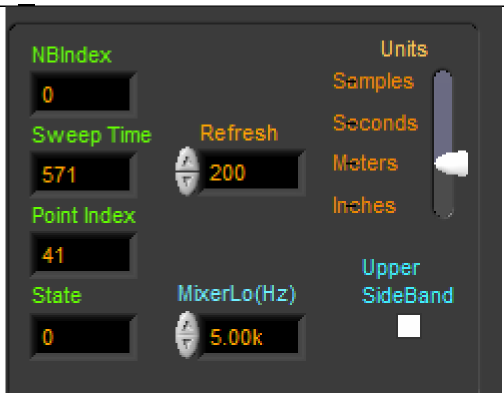

NBIndex
0
Sweep Time
571
Point Index
41
State
0
Refresh
200
MixerLo(Hz)
5.00k
Units
Samples
Seconds
Meters
Inches
Upper
SideBand

Figure 77

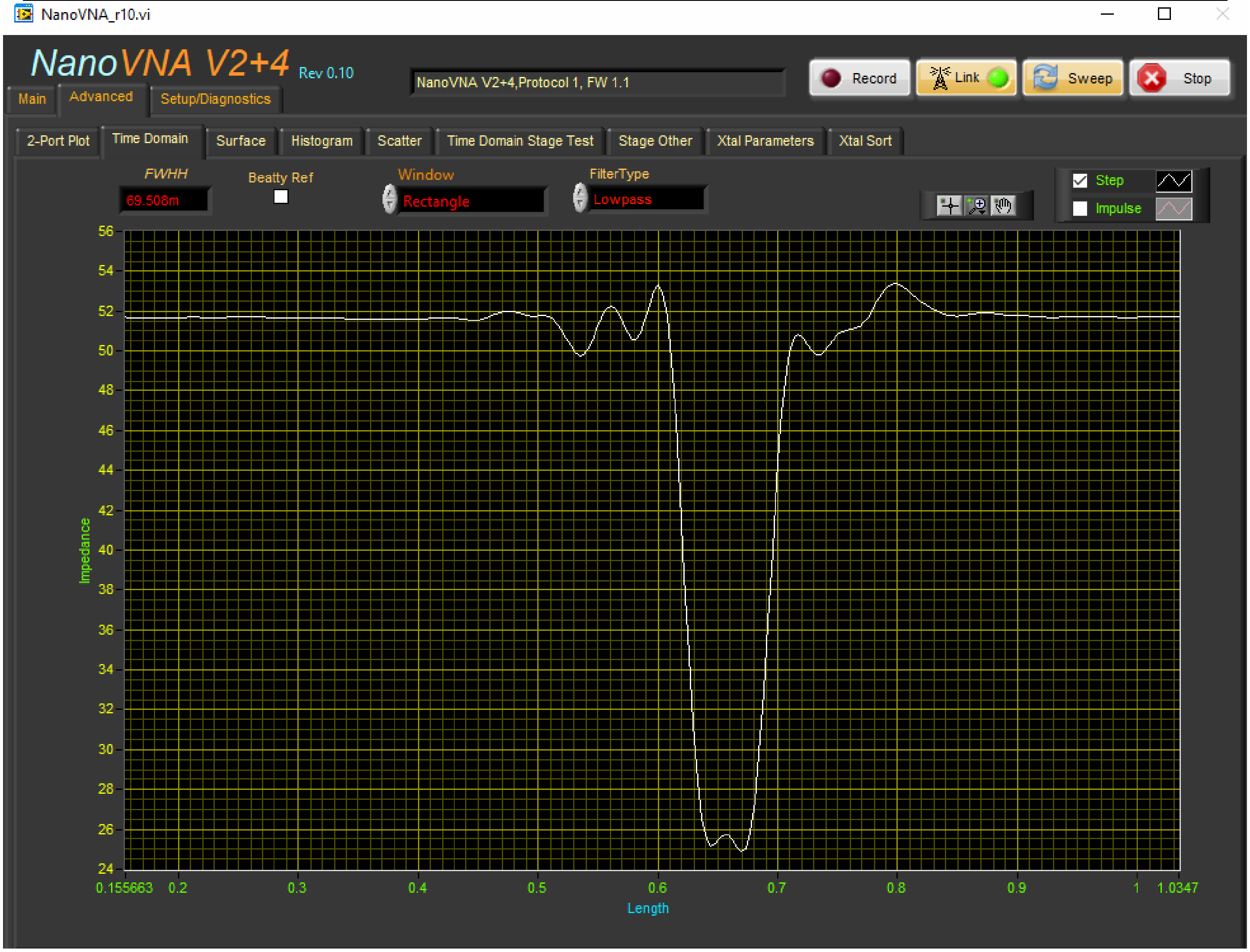


Figure 78

17.1 Linear Stage

The software supports a linear stage, or slide. This is a ball screw driven from a stepper motor. The software supports the M-Drive series motors using a standard communications port.

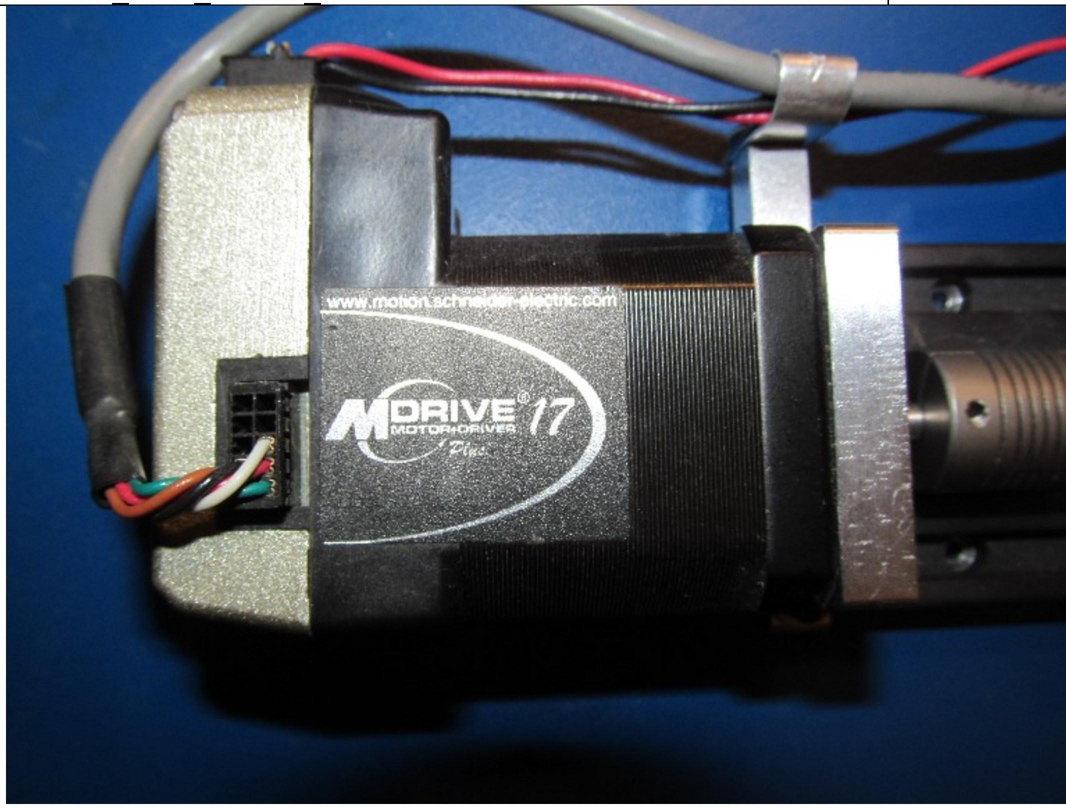


Figure 79

You will need to select the correct communications port and select the Stage checkbox to enable use of the slide. There is also a separate tab to set the motor parameters.

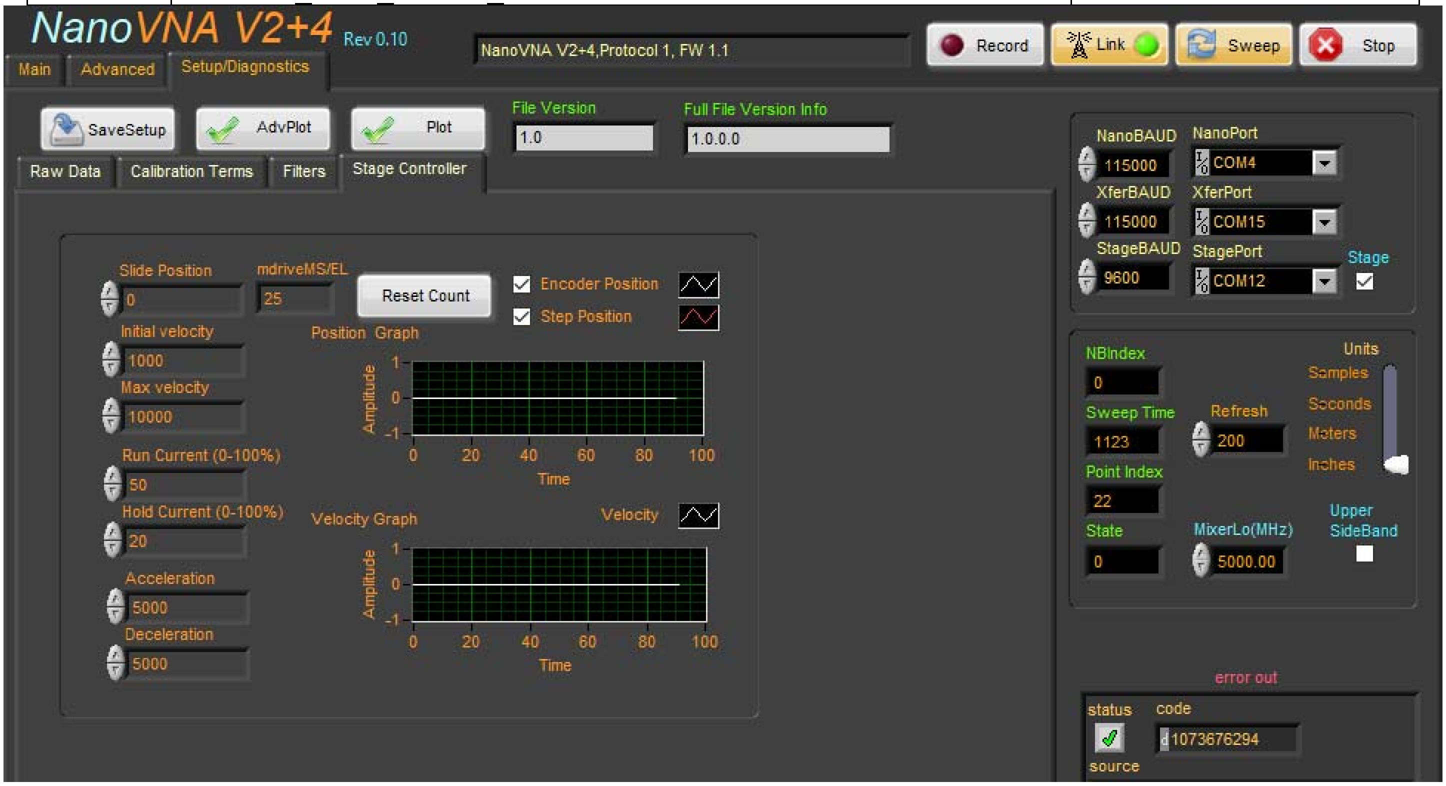


Figure 80

Attached to the slide is a homemade section of airline made from brass tubing. This setup allows you to change the length of the transmission line fairly precisely.

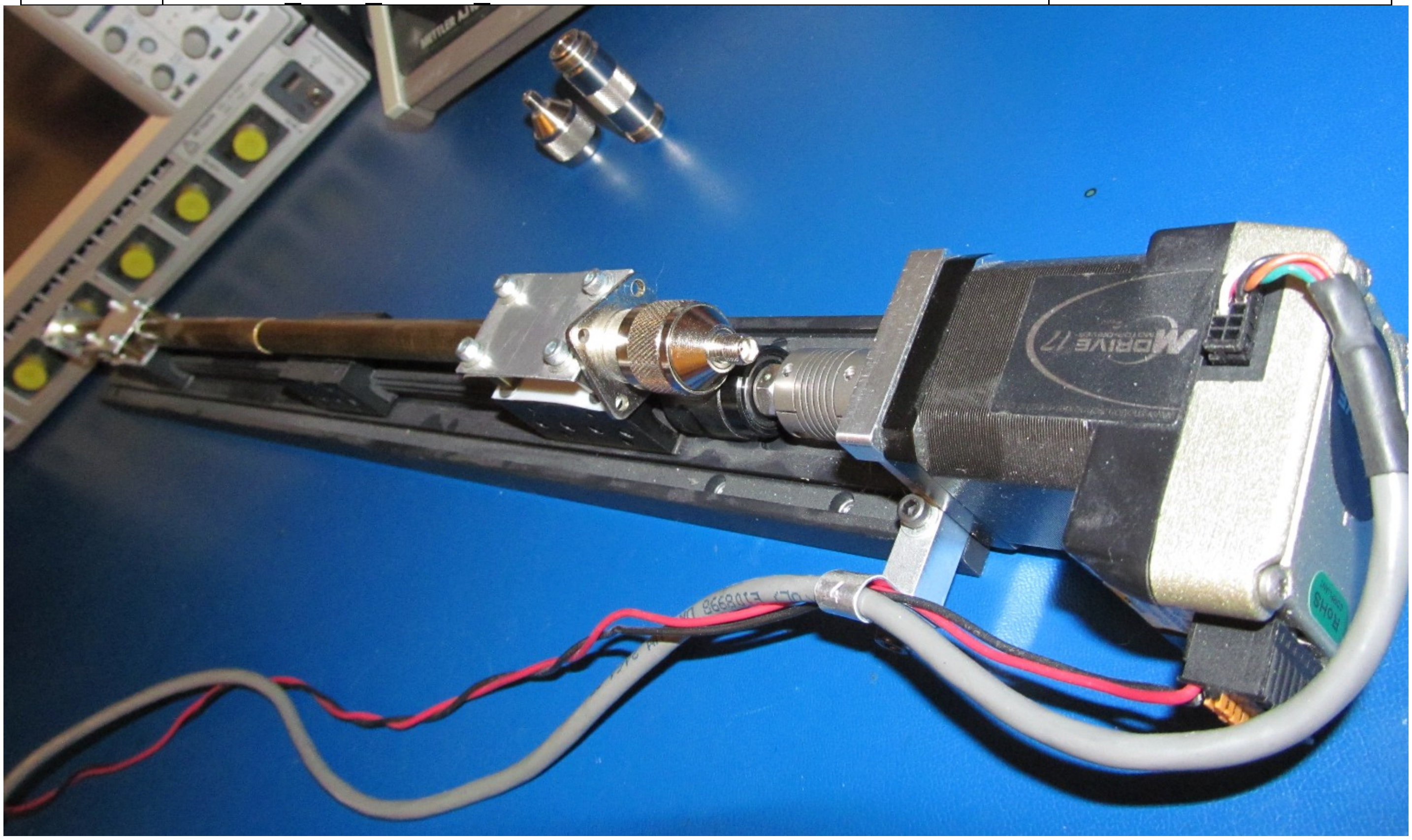


Figure 81

Shown below, the slide is attached to the V2+.   One end of the coax is left open.

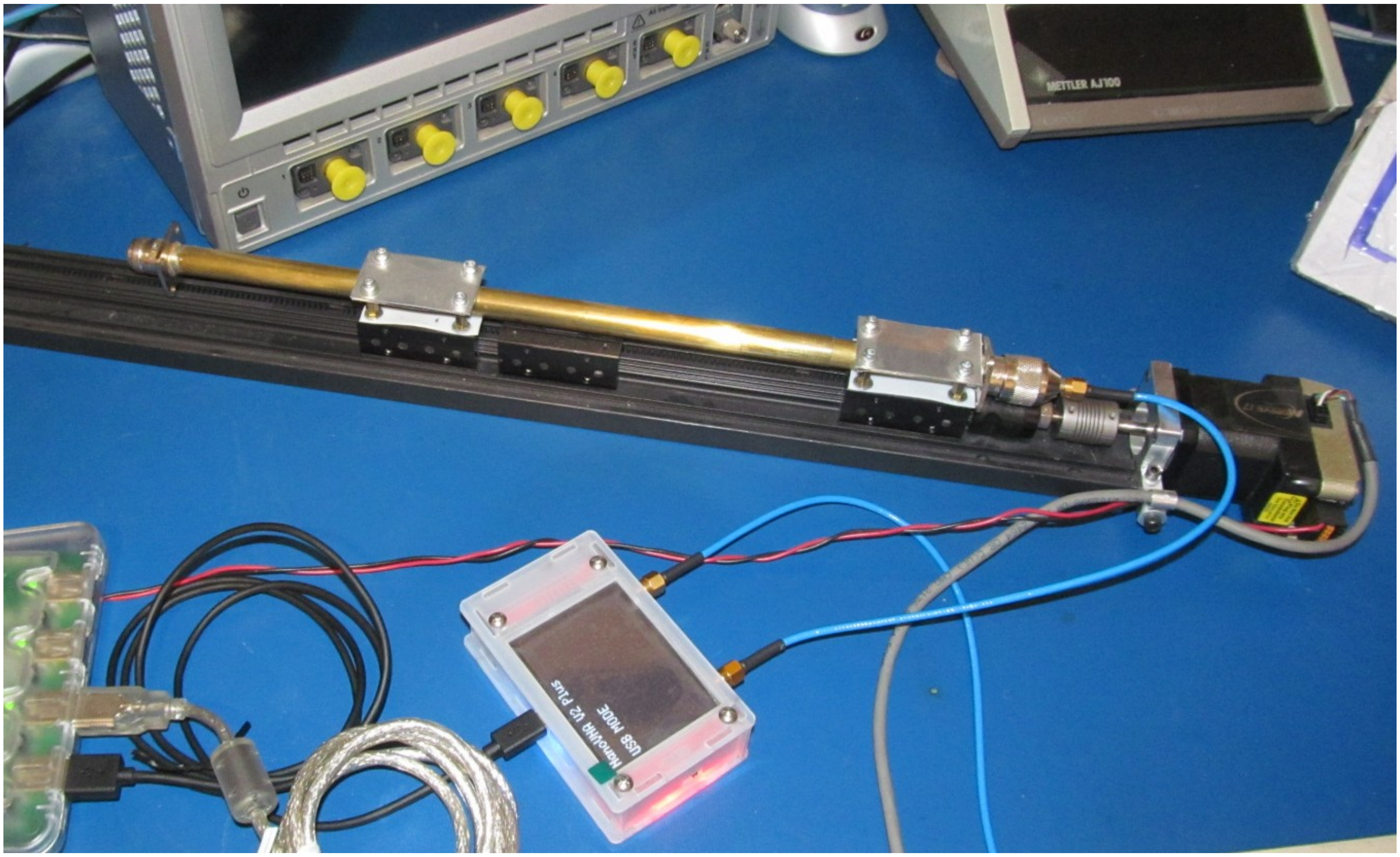


Figure 82

To run a sweep using the stage, select the Advanced tab followed by Time Domain Stage Test. Towards the upper left, you may set the number of steps per unit length.   My slide will travel 0.100” with 2048 steps. As shown, we are moving the slide 200 unit lengths of 0.025” each. The average step size the V2+ measured was 0.0249”.   There is a bit of noise. Looking at the center histogram, you can see the noise has a somewhat Gaussian shape. It’s very possible this is a limitation of the stage using the homemade airline.

Figure 83

18. Integrating a Transfer Relay

The software supports adding an external transfer relay. The author has attempted to construct some low cost units based on GaAs and relay technologies for experimenting with the NanoVNA. Their performance was very poor.

Figure 84

Note that there are 6 ports total on the two homemade transfer relays. These provide bias-Ts for each of the two ports.

The left most relay is an old Transco device. It was designed for operation to 18GHz and is well suited for this task.

The software really doesn't care what type of transfer relay is attached. It uses a common USB – TTL adapter from FTDI. The RTS signal is used to select the state of the relay and the CTS is used to monitor it's status. The communications port is selected in the Setup/Diagnostics page using the XferPort. Again, the BAUD rate has no effect. The selected port is saved as part of the defaults. Shown is the FTDI cable attached to the Transco controller.

Figure 85

18.1 Manually Controlling the Transfer Relay

With the correct communications port selected, the next time Link is selected, the software will check for the presence of the port. There is no other check beyond it finding a valid port number.   If found the XferRly Lnk indicator (found on the main page), will become active.

You can manually change the state of the relay by selecting the CH0-A switch on the front panel. Once selected, the Chan0-B indicator will become active. If the relay does not change states, the XferRly Err indicator will become active.

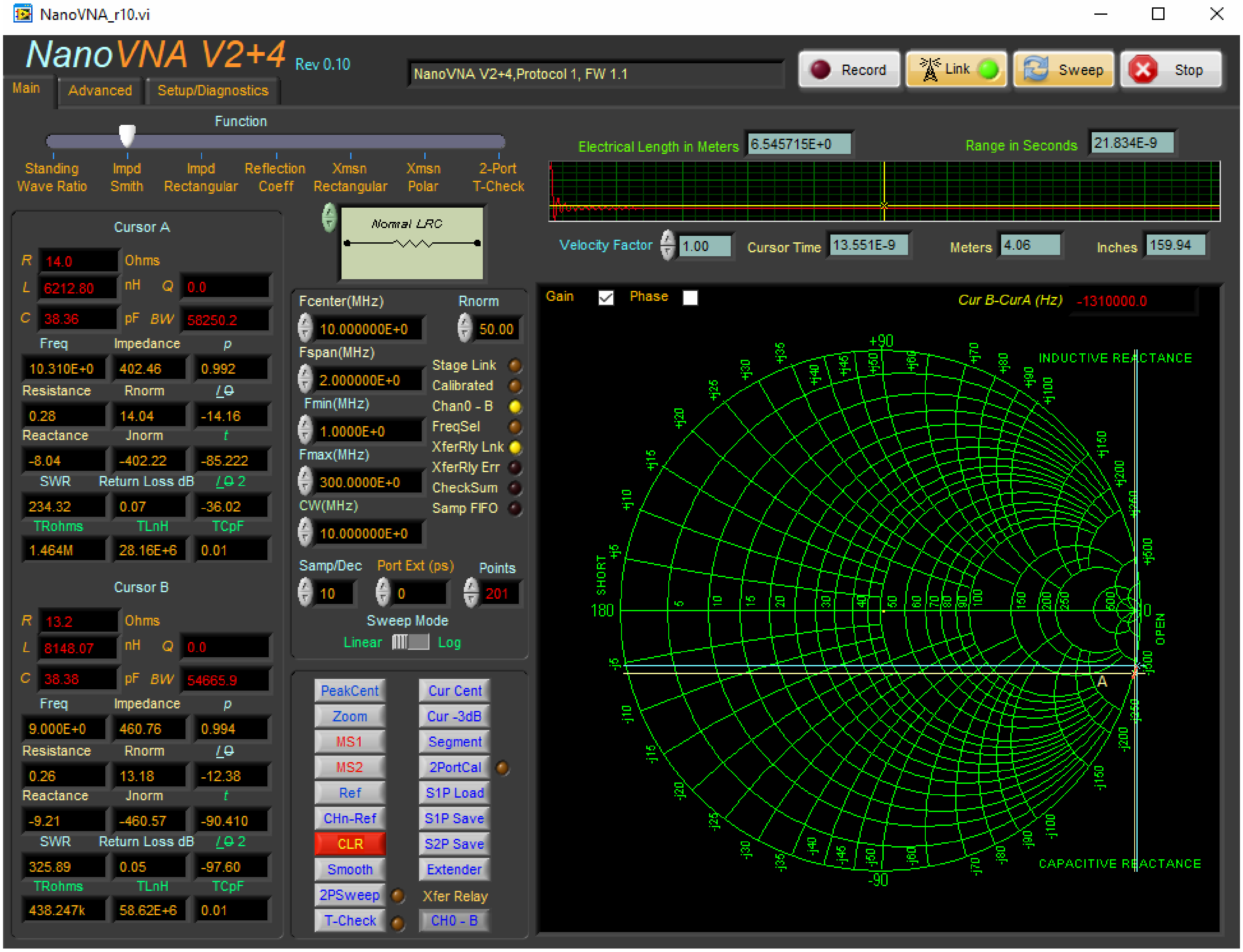


Figure 86

18.2 Full 2-Port Calibration

Once the transfer relay is inserted, selecting a 2PortCal will now walk you through a full 2-Port calibration. You will be prompted to insert the SOL standards on each port rather than just Port1.

Once calibrated, you should see very little difference measuring between the two ports. In the following a parallel LC circuit was installed first on Port1. The data was stored into MS1 and then the circuit was moved to Port2. Notice the two are basically identical.

Figure 87

18.3 T-Check Testing 2 port calibration

The software supports using a T-Check as a means to ensure the calibration is valid. The T-Check is nothing more than a T with the stub terminated. For this example I'm using some homemade standards and T-Check to help remove any errors due to the fixtures. This is very doable at these low frequencies.

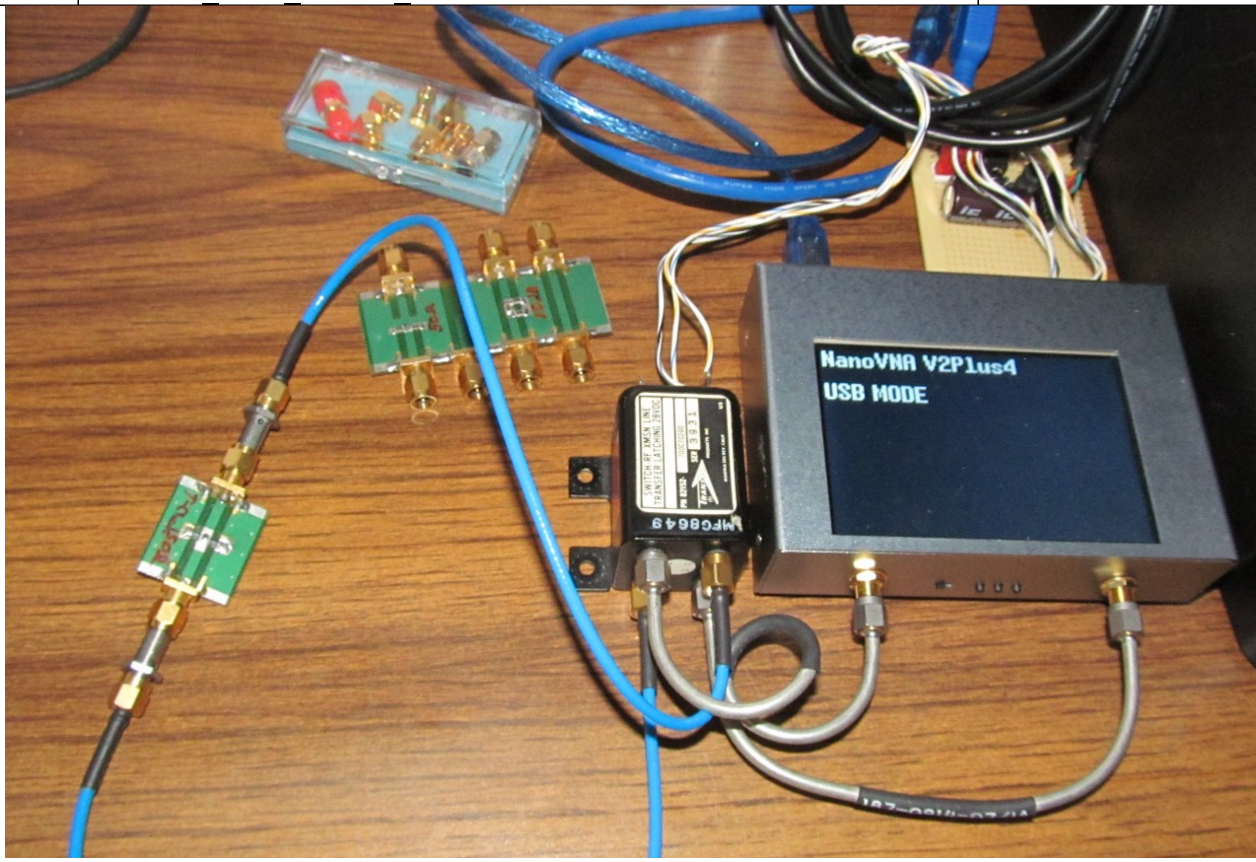


Figure 88

Once installed, you should see something close to 25 ohms as seen here. Again saving a channel and then changing the state of the transfer relay should show very little difference.

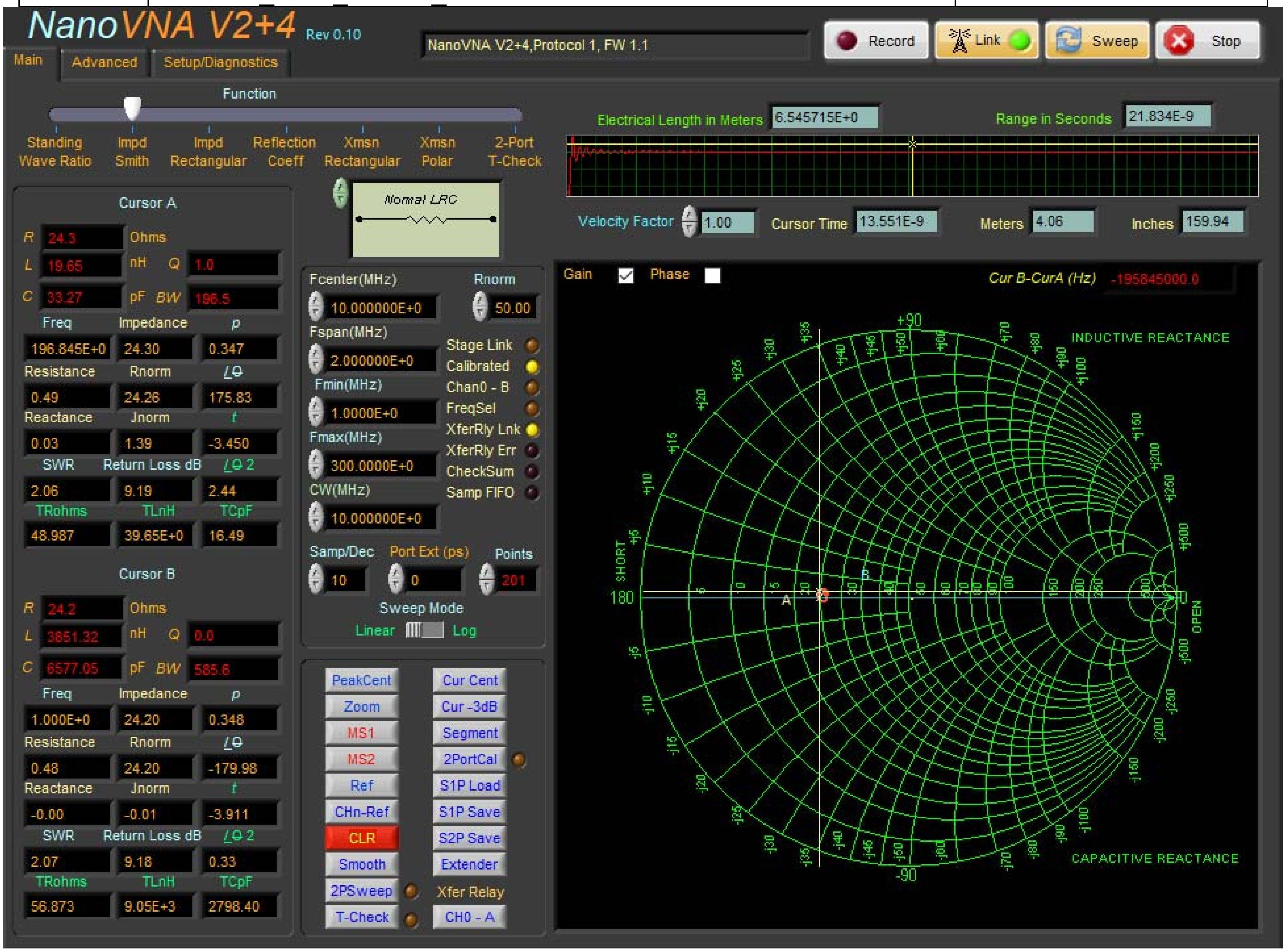
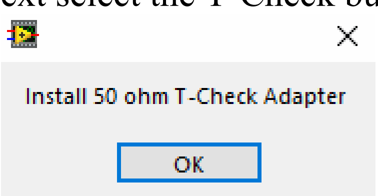


Figure 89

Next select the T-Check button. You will be prompted to install the T-Check adapter.



Select OK after you have everything ready. The software will then select the 2-Port T-Check function. You can also manually select it at anytime. It will then run through a series of sweeps while automatically programming the transfer relay.

Once complete, you should see a graph similar to the following example. Deviations of +/-10 are minor. You should not see more than +/-15%.

Figure 90

18.4 2-Port Sweep

To run a 2-Port sweep, select the 2PSweep button. The software will sweep then automatically change the state of the transfer relay before collecting a second sweep. Once complete, it will turn off the 2PSweep indicator and change the transfer relay back to the original state.

The transfer relay is controlled by the state of the RTS pin. When RTS is de-asserted, Port 1 and 2 of the VNA will route to Ports 1 and 2 of the transfer relay. When RTS is asserted, Port 1 and 2 of the VNA will route to Ports 2 and 1 of the transfer relay. The software expects the transfer relay to always assert the CTS pin, or it will set the transfer relay error (XferRly Err).

The software will store Port 1 data to memory 1 and Port 2 data to memory 2. Here a short has been applied to Port 1 of the transfer relay and Port 2 is left open.

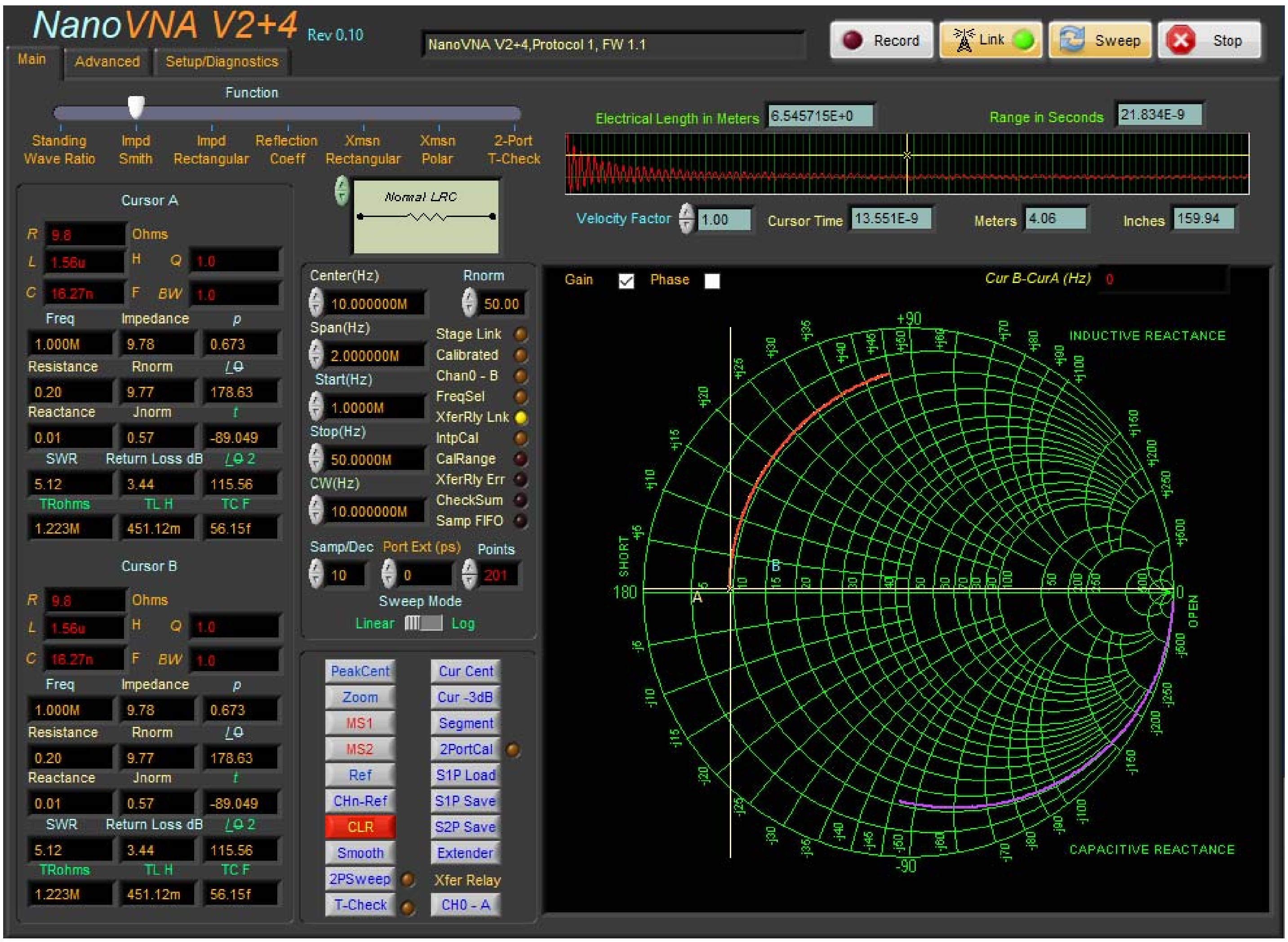


Figure 91

Select the Advanced tab and then the 2-Port Plot to view all of the data on a single page.

Figure 92

18.5 Transco PN# 82152-70070200 Driver

The Transco relay requires 24V and is a latching type relay. A simple DC-DC converter was designed using a 7400 gate that boosts the USB voltage to 24V and charges a large capacitor. This capacitor holds the charge needed to drive the relay.

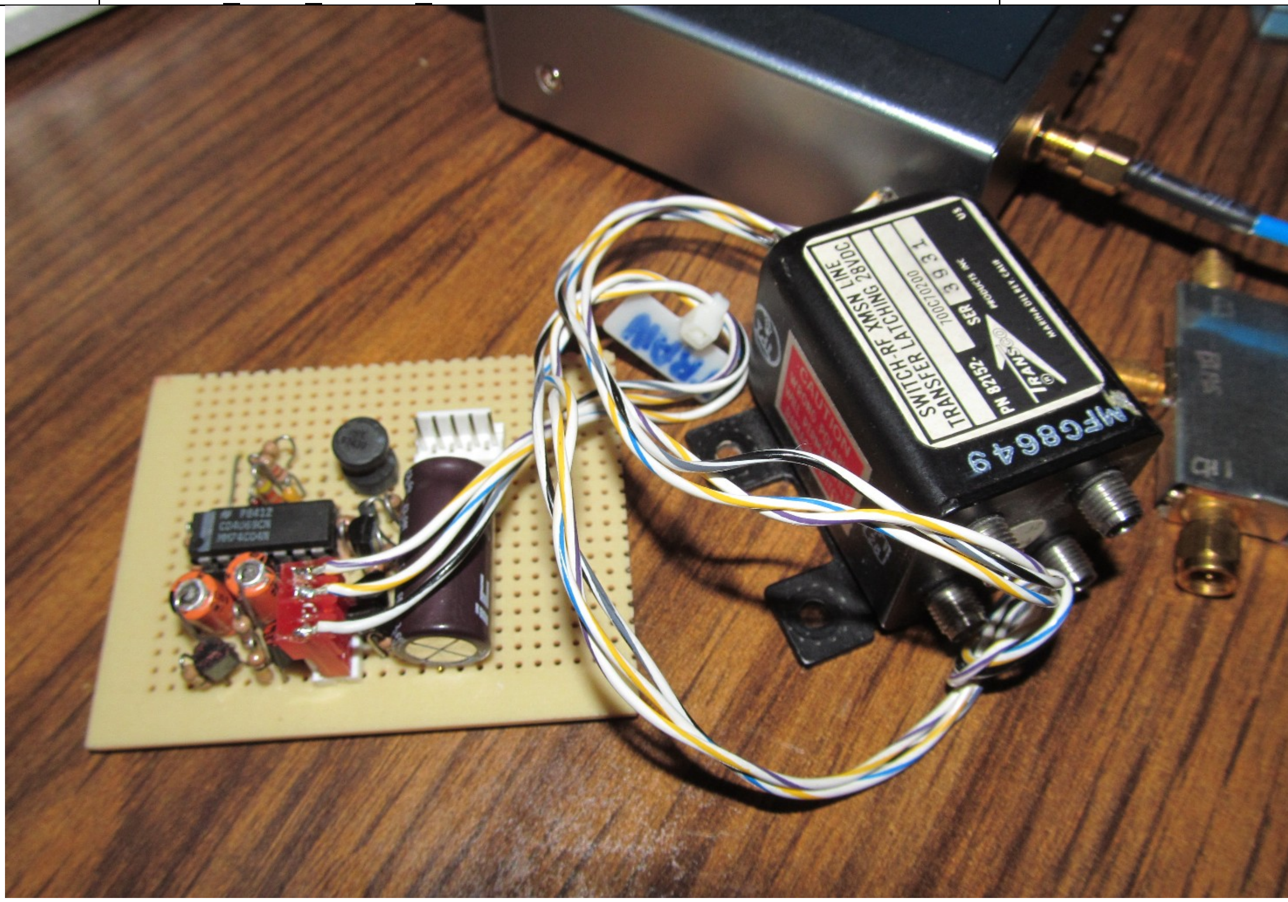


Figure 93

Figure 93 shows the DC-DC converter made from a 7404 hex inverter. The two remaining gates are used to buffer the signals to drive the relay coils. This is not meant as a reference to base your own design from. Rather this is what I put together with what I had on hand.

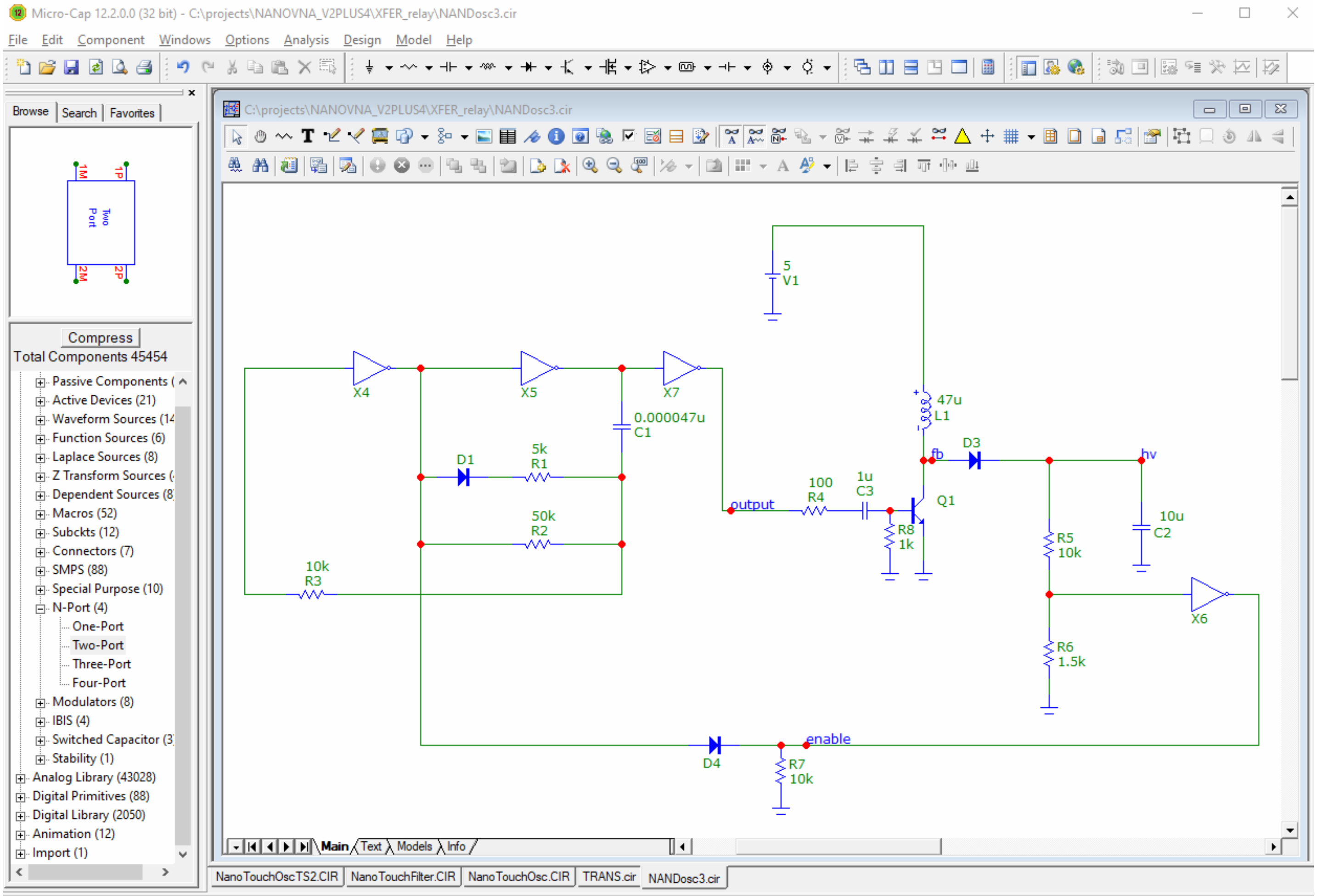


Figure 94

19. Up/Down conversion

The software supports adding an external up / down converter to the V2+ to extend its frequency range.

Appendix A – Factory Settings and Parameters

		FACTORY SETTINGS	
SETTING	RANGE	DEFAULTS	USER
Fcenter(MHz)		10	
Fspan(MHz)		2	
Fmin(MHz)		1	
Fmax(MHz)		300	
CW(MHz)		10	
Samp/Dec		10	
Port Ext (ns)		0	
Points		201	
Sweep Mode		Linear	
Rnorm		50 ohms	
Gain		Enabled	
Phase		Disabled	
Units		Inches	

Appendix B – Warranty

Because the software is available for use free of charge, there is no warranty for it, to the extent permitted by applicable law. Except when otherwise stated in writing the copyright holders and/or other parties provide the software as is *without warranty of any kind*, either expressed or implied, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose and the accuracy of the information contained within it. The entire risk as to the quality and performance of the software and associated parts is with you. Should the software and/or associated devices fail to work on your system, you assume the cost of all necessary servicing, repair or correction.

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