Antenna Analyzer & So Much More: NanoVNA Introduction

What It Can Do and Why You Might Be Interested in It

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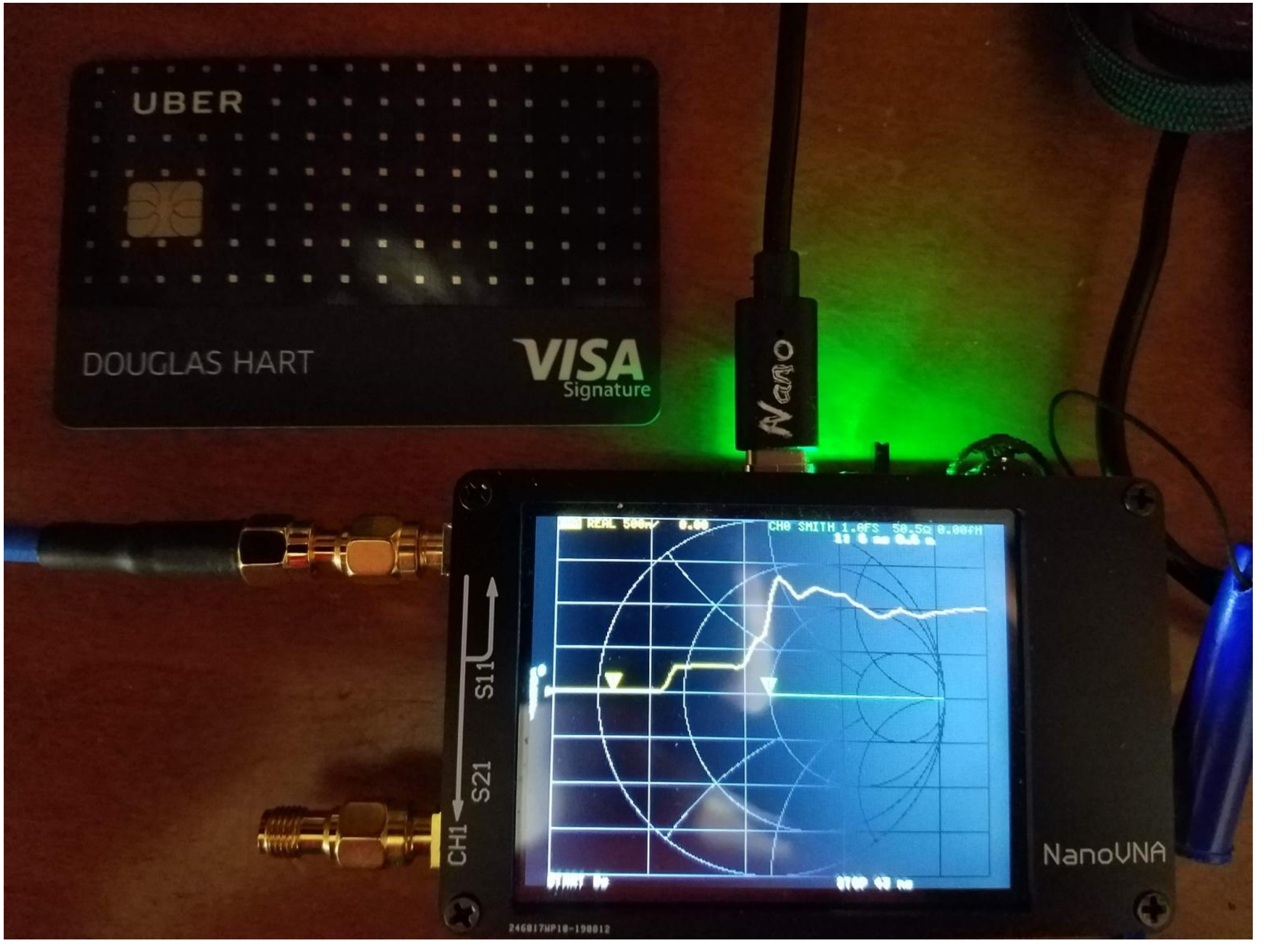
What Is a NanoVNA?

Electronic Test Instrument that Measures & Displays:

- Standing Wave Ratio (SWR)
- Performance of Common Mode Chokes (Loss vs. Freq)
- Coax Impedance (Zo)
- Distance Along Coax to Significant Change (TDR)
- Capacitance & Inductance of Discrete Components
- Resistive and Reactive Portions of Impedance (R + jX)
- Smith Chart, Coax Loss and More…

Handheld, Battery Powered, *Size = Small Smartphone*
Costs $35 to $65, Useful From 50KHz to 900MHz
Measurements Update About Every Second: Real-Time
Open Source Hardware and Firmware (Updated Frequently)
Open Source PC Software (Updated Frequently)
Several On-Line Sources of Hardware, Firmware and SW

A Handheld Vector Network Analyzer, 2-Port S-Parameters



Size: NanoVNA and a Credit Card

Why Might You Be Interested?

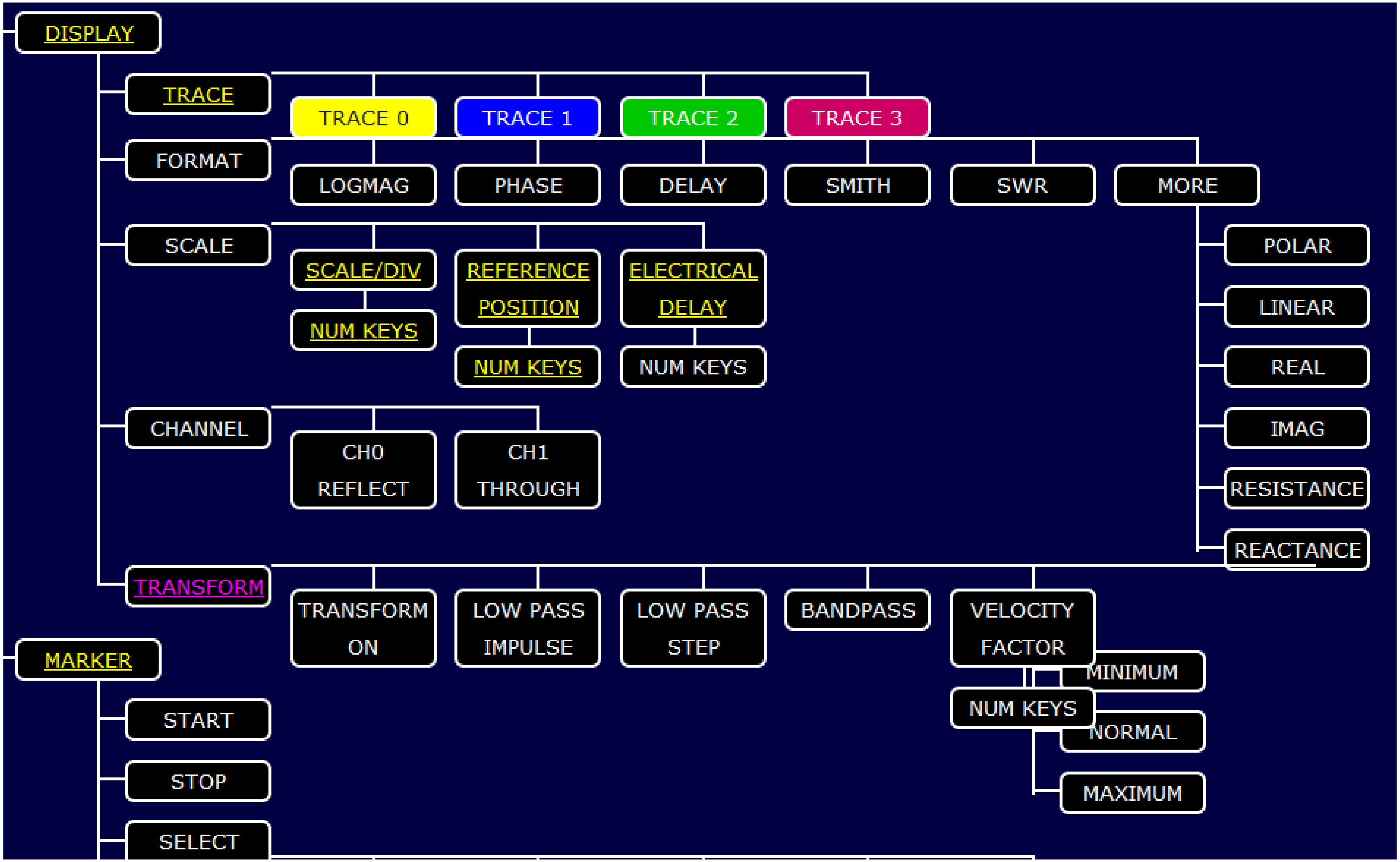
- SWR is Important to Maximize Transmitter Power (avoid ‘foldback ‘ of your amplifier’s power)
- *NanoVNA is Easily Held in One Hand While at the Antenna on a Ladder, etc. Make Real-Time Adjustments and See the Effect*
- Common Mode Choking is important to Achieve Predicted Antenna Patterns (get your RF where you want it)
- Antenna System Failure: Where is the Problem? Use Time Domain Reflectometer (TDR) mode to Determine Where to Dig or How Far to Climb the Tower…

Makes Measurements That a One-Port “Antenna” Analyzer Cannot Make

How to Use It

NanoVNA Top-Level Menu (Touchscreen)

Menu Options

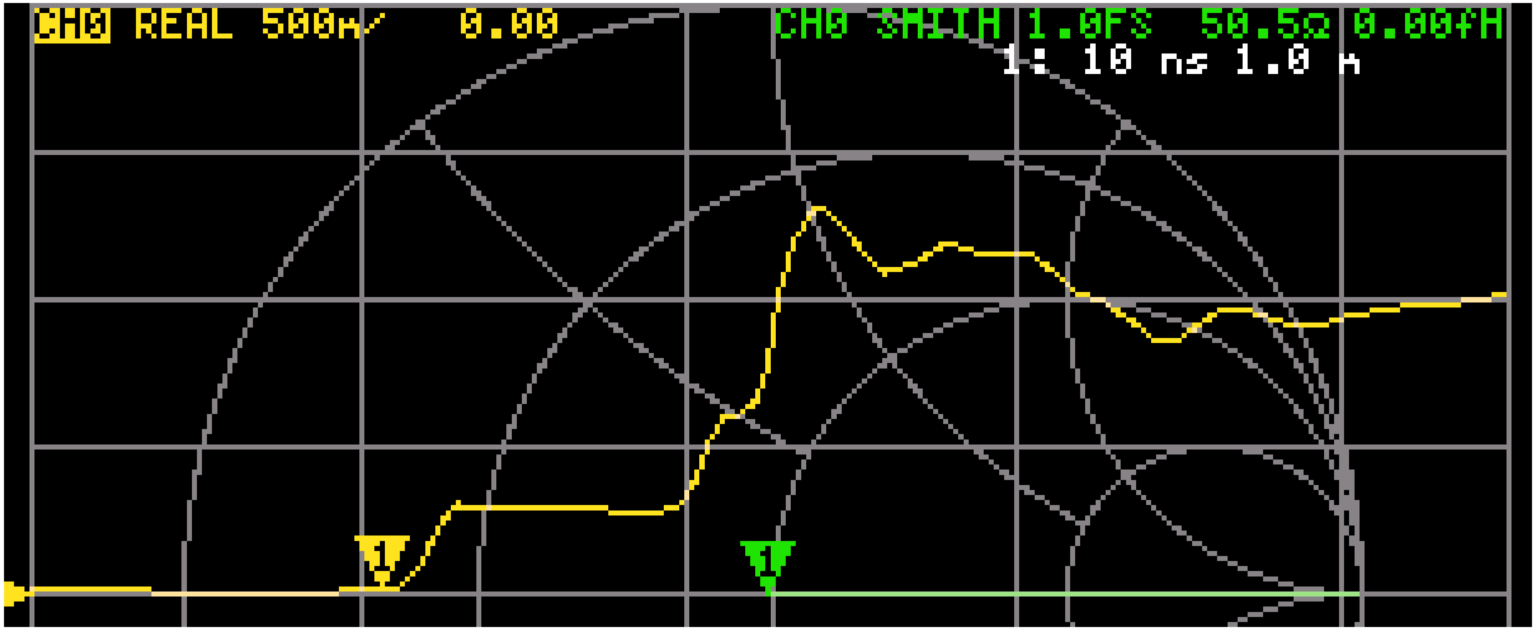


Partial Menu Tree

TDR – Distance & Impedance

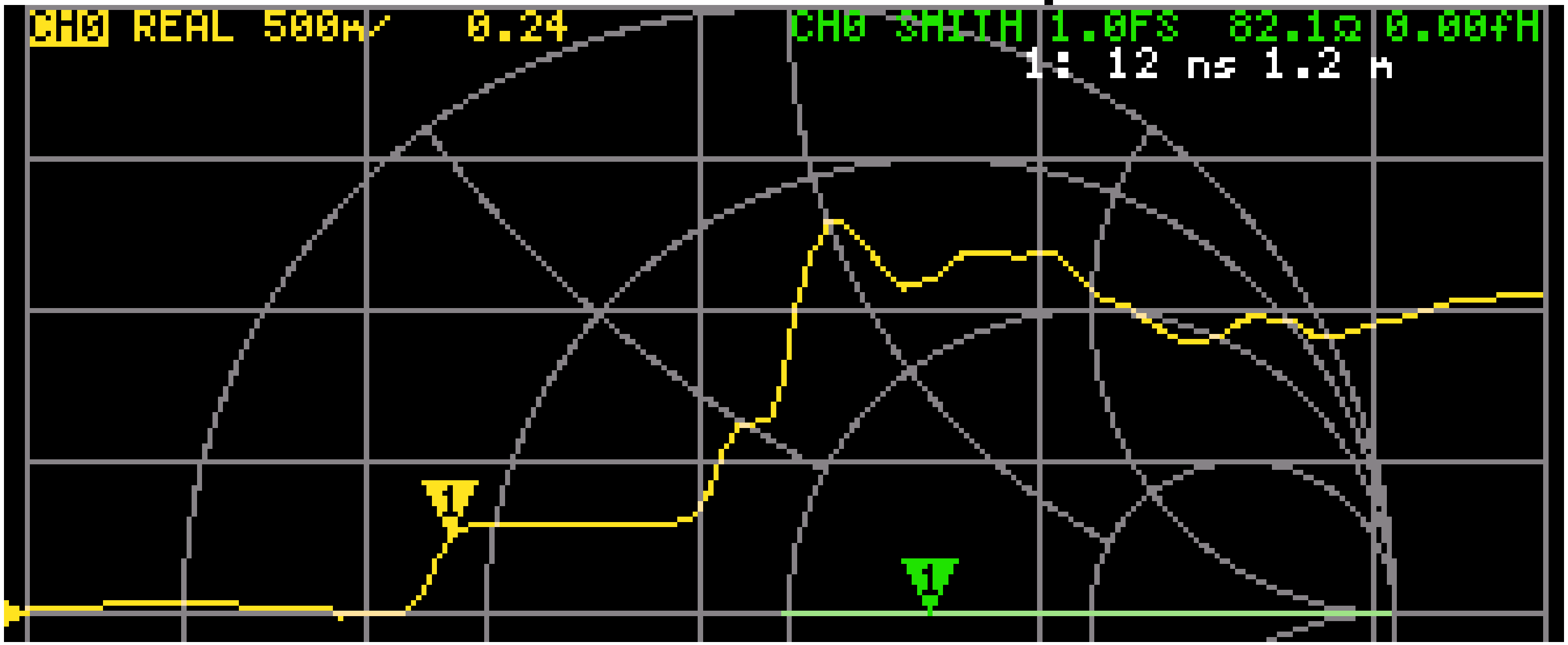
- Measures on the Vertical Axis the 'Amount of Reflection' & Calculates the Impedance of What is Connected to NanoVNA vs. Distance from NanoVNA on the Horizontal Axis
- Example: A Four Foot Section of 50 ohm Type Coax Followed by a Four Foot Section of 93 ohm Type Coax
- Far End of Coax is Left Open
- Setup NanoVNA for **TDR**:
  - Calibrate 50 KHz to 900 MHz
  - 2 Traces, Both on Port 0 (Trace1 = REAL, Trace2 = SMITH)
  - One Marker on Channel 1
  - Select TRANSFORM and Set Your Coax Velocity Factor % and LOW PASS STEP
- Save These Settings & Recall Them at Next Power-Up
- Never Enter Them Again!

TDR – Distance & Impedance



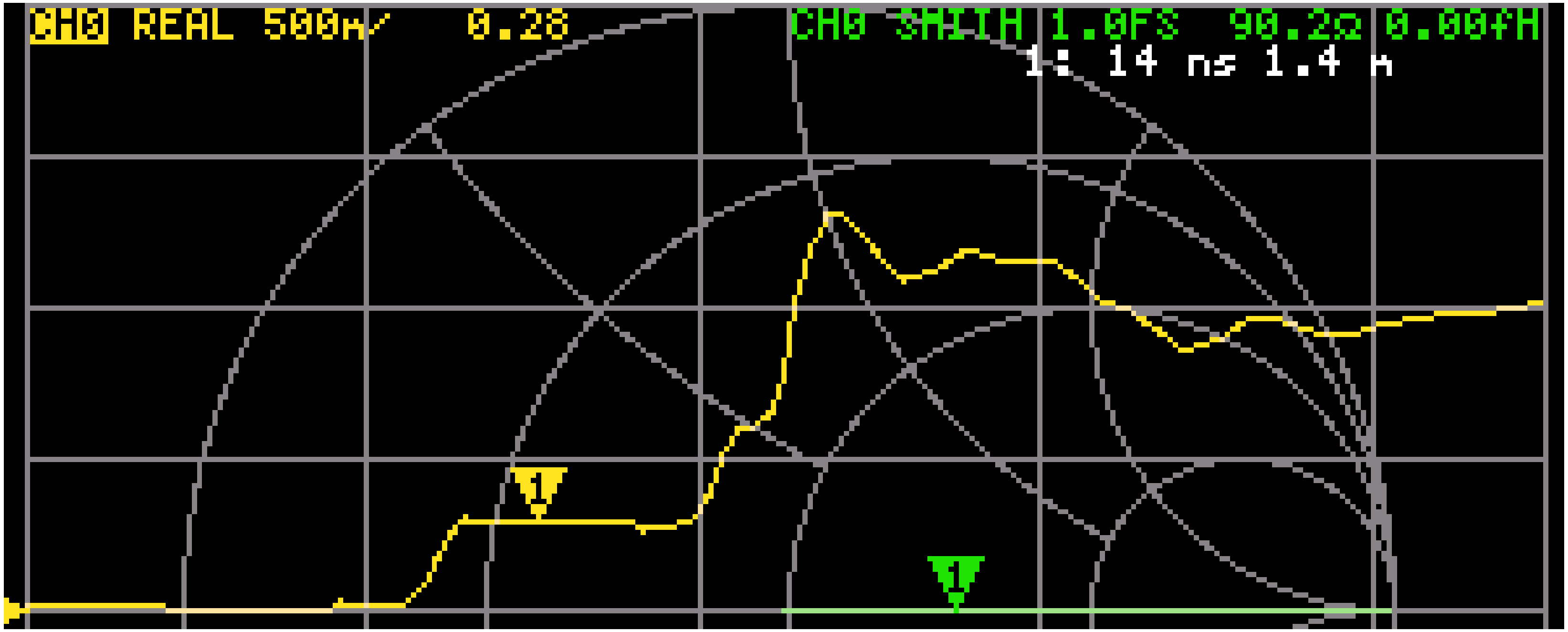
- Impedance vs. Distance from NanoVNA
- First Section of Coax is 50 ohm Type & Measures 50.5 ohms (green text) at Marker 1 (yellow triangle)
- Marker 1 is at 1.0 meters (white text)

TDR – Distance & Impedance



- Abrupt Change vs. Distance from NanoVNA
- Coax Assembly Transitions from 50 ohm Type to 93 Ohm Type at About 4 Feet (yellow triangle)
- Marker 1 is at 1.2 meters (white text, about 4 feet)

TDR – Distance & Impedance



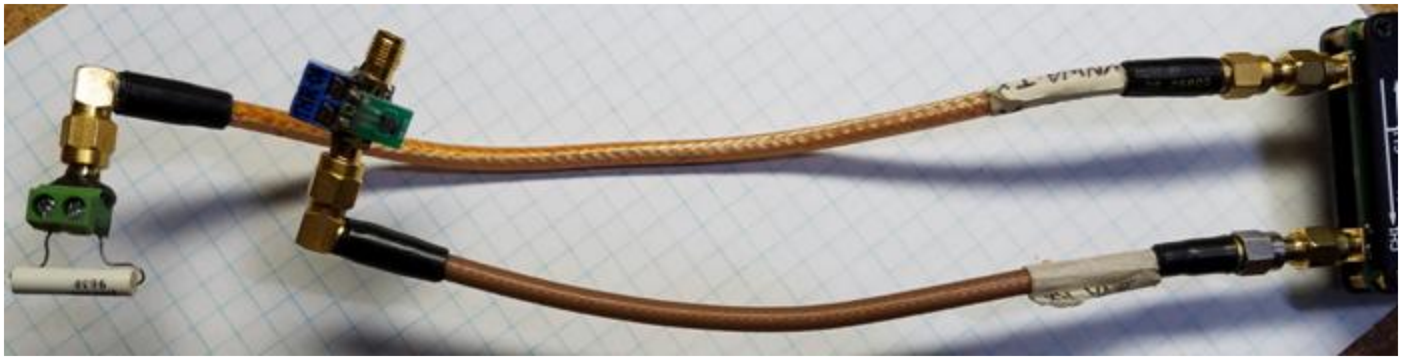
Second Section of Coax is 93 Ohm Type & Measures 90.2 ohms (at 1.4 meters, white text)

TDR Distance & Resolution: Vf = 84%

STOP Frequency (MHz)	Distance Maximum (meter)	Approximate Resolution (meter)	Velocity Factor (%)	**Distance Maximum (feet)**	**Approximate Resolution (inches)**	Resolution as % of Max Distance
900	5.4	0.1	84	**17.6**	**4**	2%
450	10.9	0.1	84	**35.6**	**4**	1%
300	16.3	0.2	84	**53.6**	**8**	1%
225	21.8	0.2	84	**71.6**	**8**	1%
150	32.8	0.3	84	**107.6**	**12**	1%
100	49.2	0.5	84	**161.3**	**20**	1%
50	98.4	0.8	84	**322.9**	**31**	1%

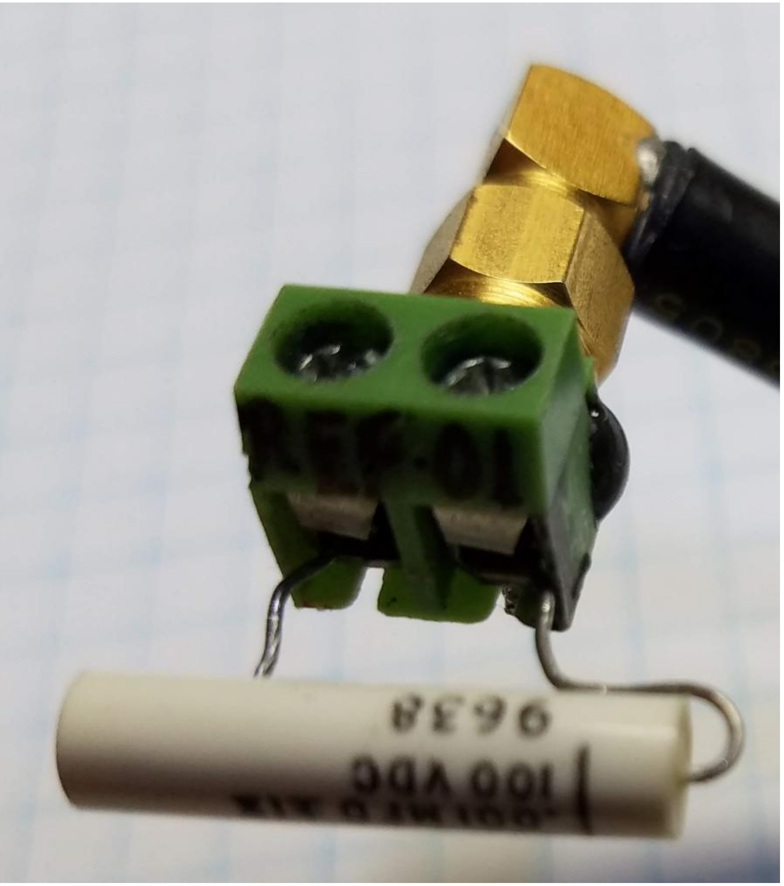
- Calibration from 50KHz to 900MHz, S11 REAL: 0.5/div, Low Pass Impulse easier to resolve distance. Low Pass Step to determine Impedance (Zo)
- Vf = **67%** Yields Max Distance = **256 Feet**.

Measuring Discrete Components



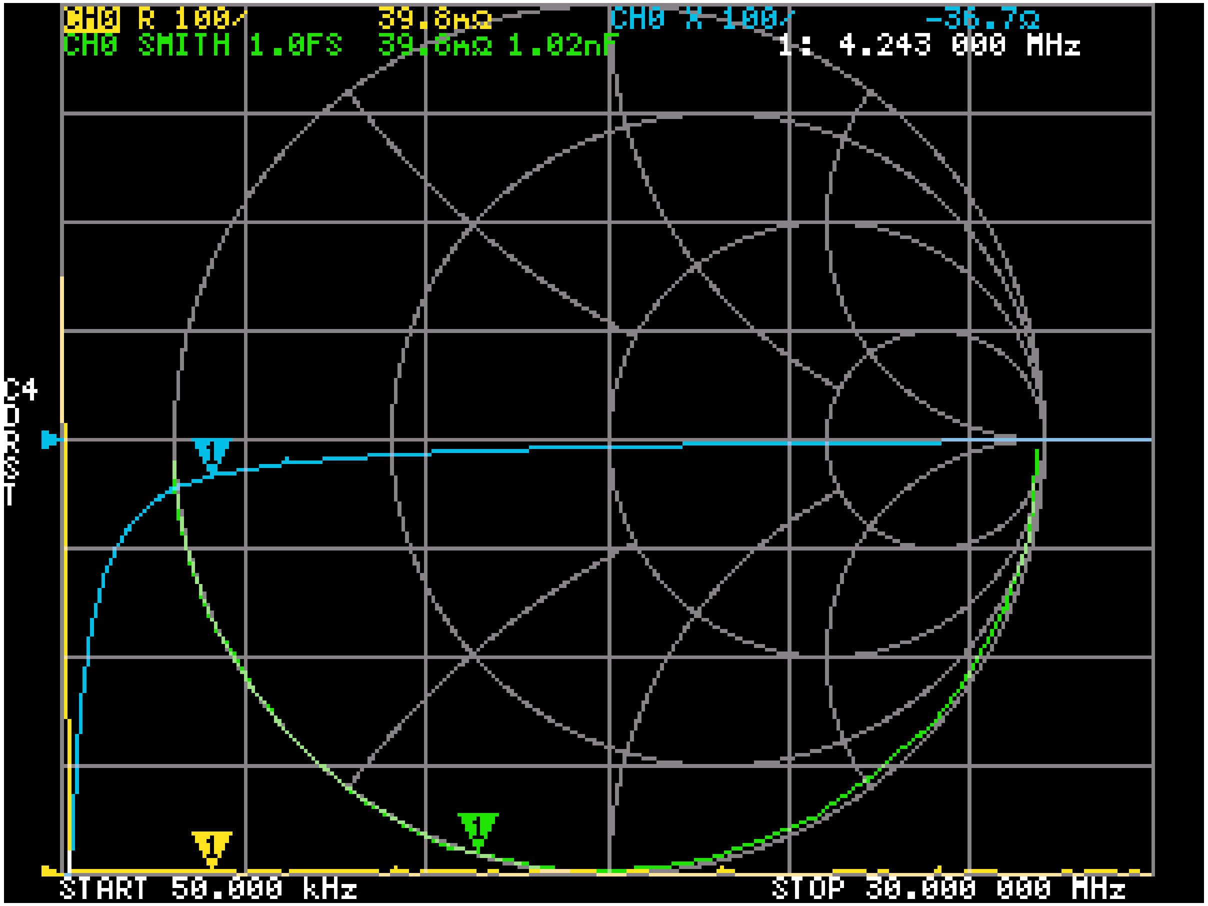
- Make Fixtures to Hold the Device Under Test (DUT)
- Top cable connects to NanoVNA Port 0 and First Fixture for Reflection measurements of Low-Z DUTs
- Bottom cable connects to NanoVNA Port 1 and one side of 2nd Fixture for "THRU" measurements, Hi-Z
- Early Measurements at 50KHz to 30 MHz, But Useful >300MHz

Measuring Discrete Components



- Close-Up of Reflection Test Fixture Holding the DUT: a 1000pF 1% Capacitor
- We Will Now Measure Real and Imaginary Parts of the Impedance
- the NanoVNA Does the Math to Display Impedance from Reflection Data (S11)

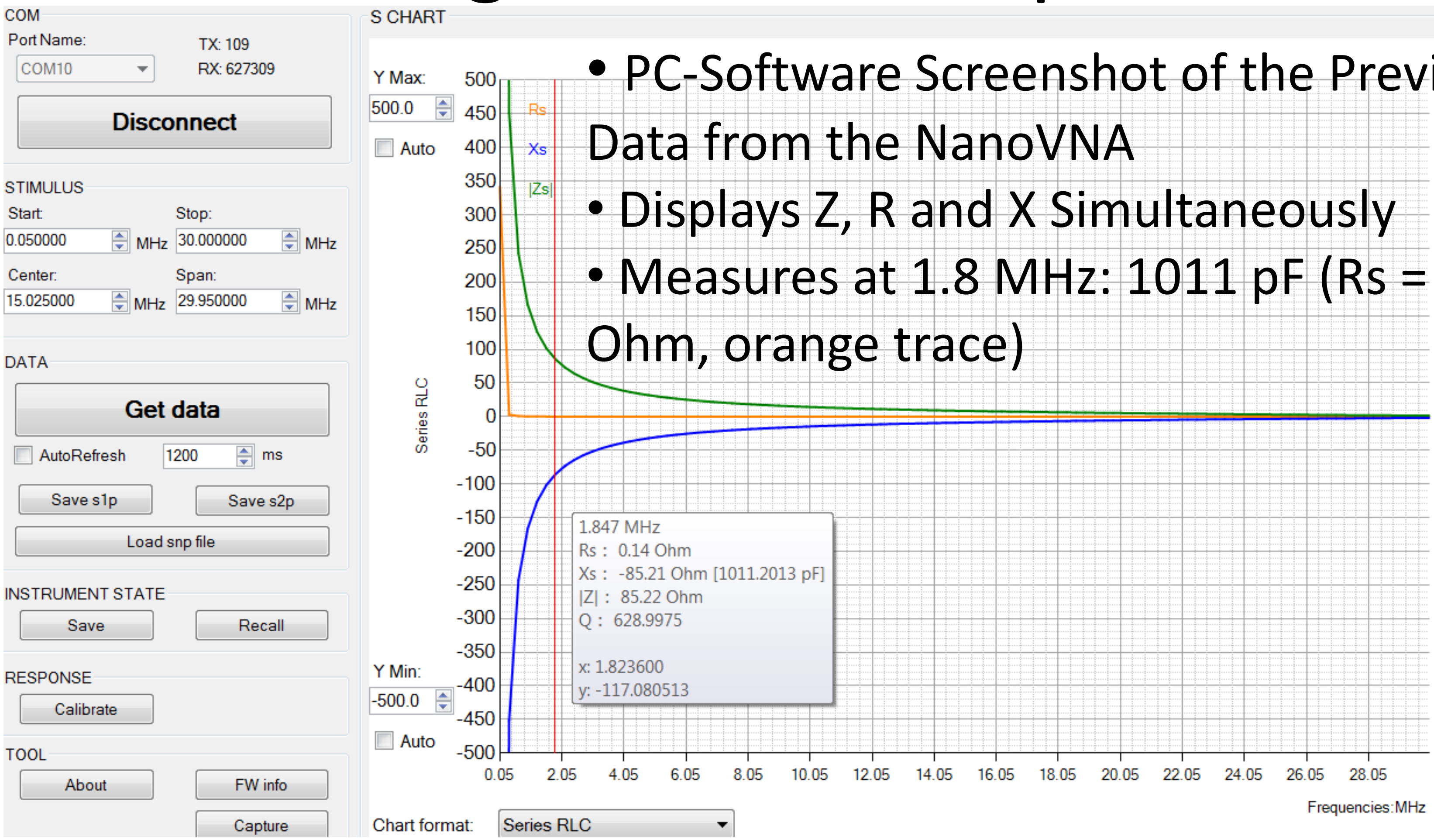
Measuring Discrete Components



DUT is 1000 pF Capacitor

- Measures at 4 MHz: 1.02 nF (= 1020 pF)
- jX (blue trace) is always < 0 : No Self-Resonance Below 30 MHz !
- Smith Plot (green) is at Lower Edge of Semi-Circle (good!)

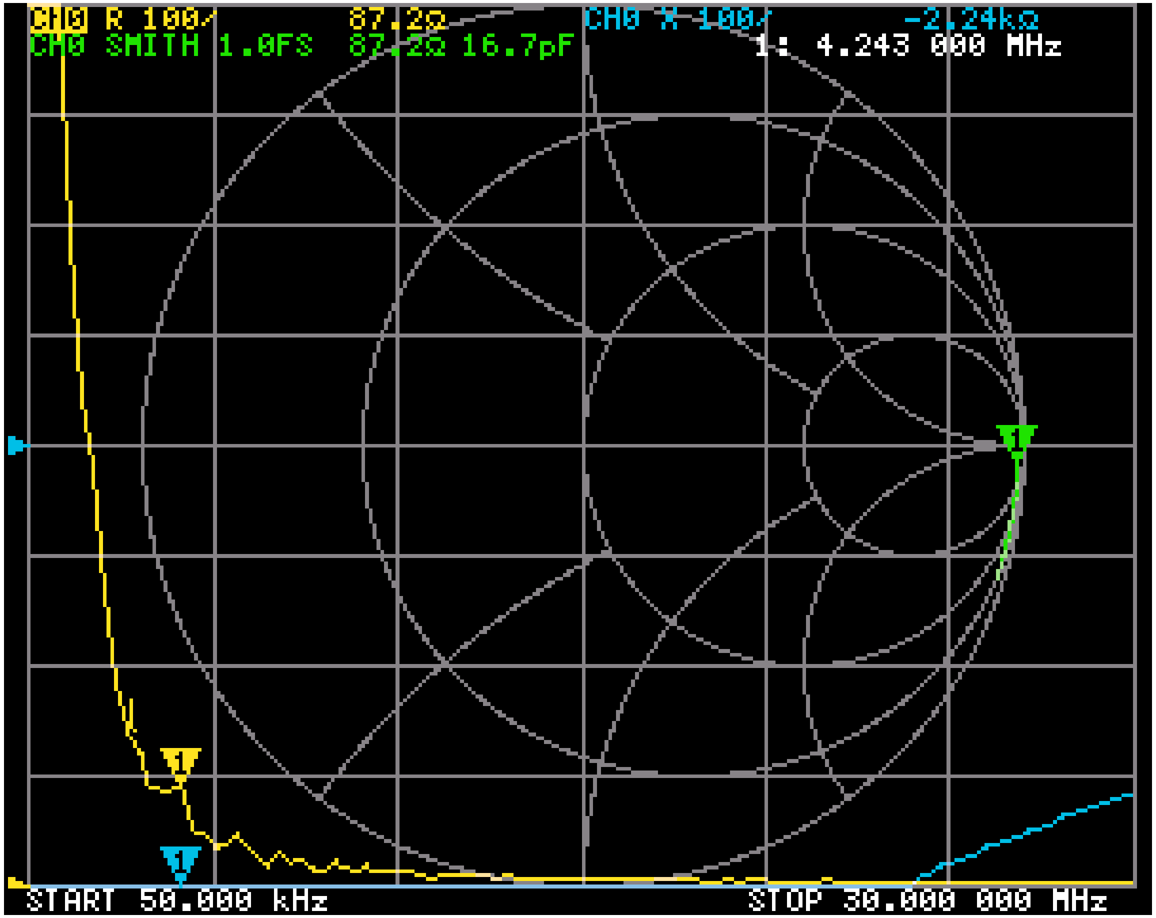
Measuring Discrete Components



- PC-Software Screenshot of the Previous Data from the NanoVNA
- Displays Z, R and X Simultaneously
- Measures at 1.8 MHz: 1011 pF (Rs = 0.14 Ohm, orange trace)

- Can Easily Move Cursor in Frequency to Display Values at that Frequency

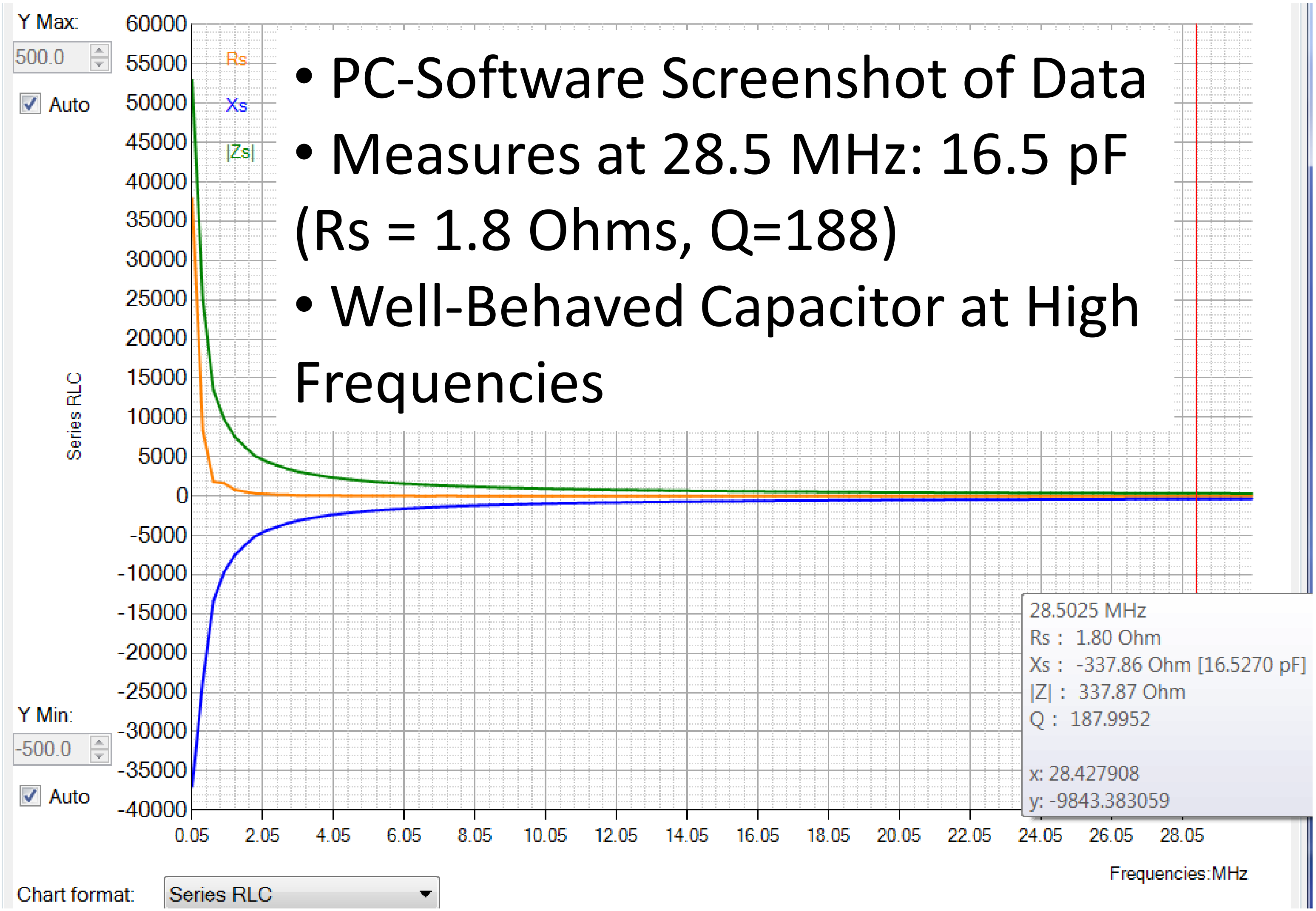
Measuring Discrete Components



- DUT = Old MIL-Type Capacitor Labeled 18 pF
- Measures at 4 MHz: 16.7 pF (green text)

Measuring Discrete Components

- PC-Software Screenshot of Data
- Measures at 28.5 MHz: 16.5 pF (Rs = 1.8 Ohms, Q=188)
- Well-Behaved Capacitor at High Frequencies



Measuring Discrete Components

- Use Similarly for Inductors
- And Bandpass Filters
- Or Band-Reject Filters
- Any Passive Device You Connect is Measured and Useful Characteristics are Presented on the NanoVNA or on the PC Screen
- Experiment and Learn-By-Doing!

Common Mode Choke – Why?

- Your Desired Antenna Radiation Pattern Depends on Predictable RF Current Distribution in Your Antenna
- Predicted Antenna Currents May Not Occur If Your TX Current Has Unwanted Path, e.g. Outside of Coax
- Use CMC to Reduce Unwanted RF Paths
- High Impedance (i.e. High Loss) of the CMC to CM Current at Your Frequency of Interest is Necessary But Not Sufficient to Result in Desired Choking , e.g. System Reactance Could Cancel the CMC Reactance!
- Measuring Your CM Currents Is Desired, But Not What the NanoVNA Does

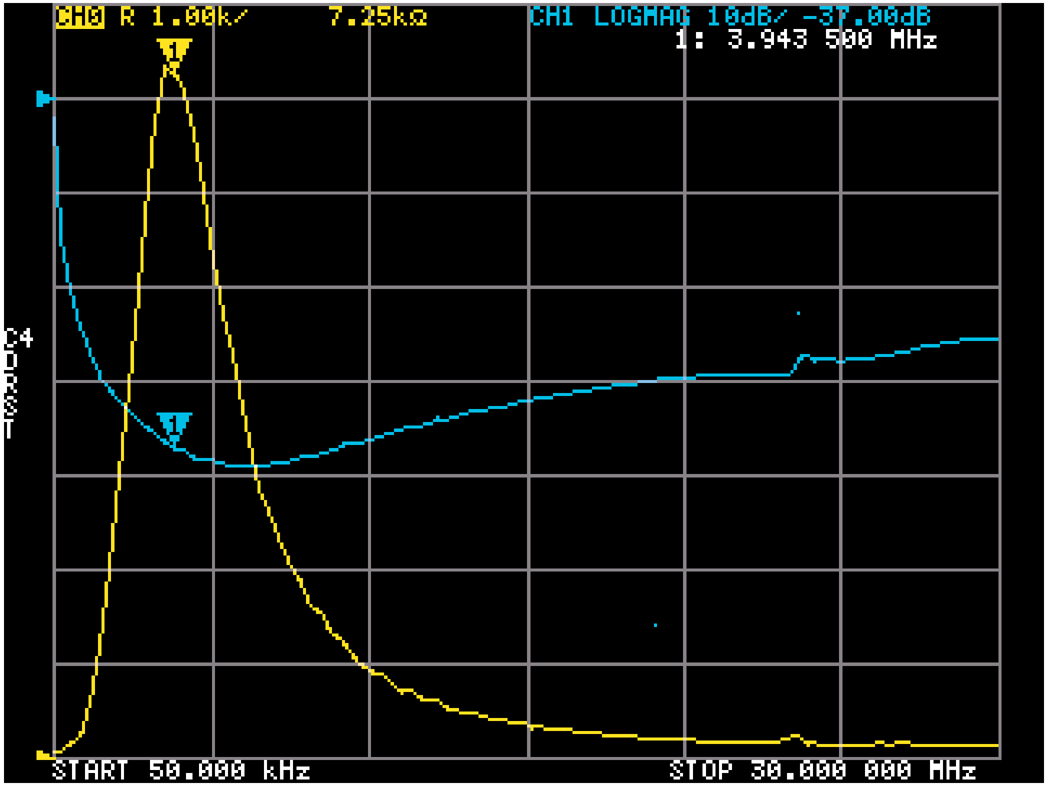
Common Mode Choke – Loss vs. Freq.

- NanoVNA Displays Loss vs. Frequency From Its Channel 0 to Channel 1 – “Through” Mode (S21)
- The Higher the Impedance of the CMC (We Want 1000’s of Ohms), the Lower the ‘Valley’ of the Plotted Loss
- Put Your CMC Between CH 0 and CH 1 and Display Log of Magnitude (LOGMAG) for Channel 1
- Look For Acceptable Loss at Your Frequency of Interest
- If Not Acceptable, Change CMC, e.g. More/Less Turns or Ferrite Material… Until Acceptable
- When CMC Loss Is ‘Acceptable’, Then You’d Like to Know the Real Part of the CMC Impedance Since That Cannot Be Cancelled By Your Antenna System Reactance… cont’d

Common Mode Choke – R+jX

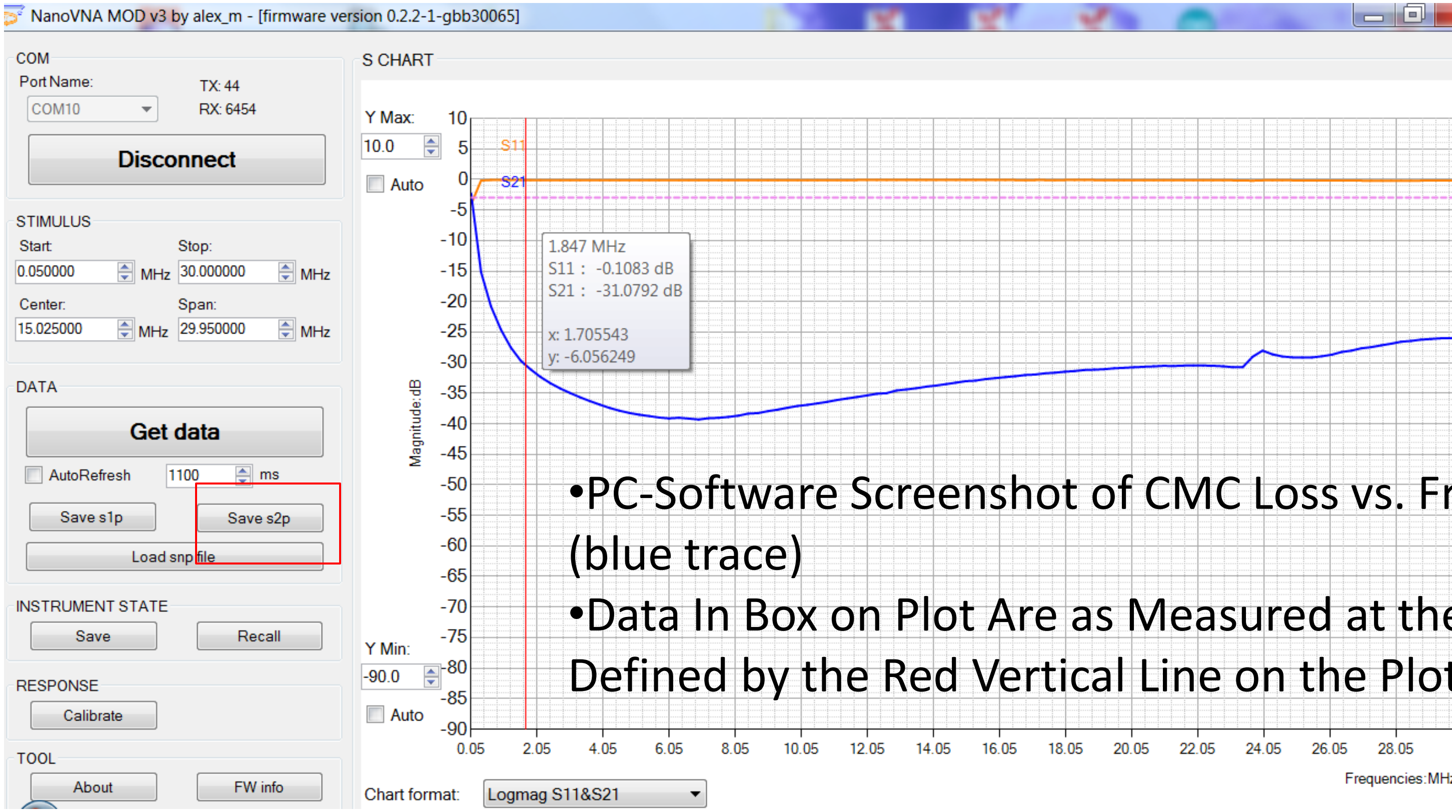
- Unfortunately the NanoVNA Displays Only the R + jX Calculated From the Reflection (1-Port, S11) and <u>Any</u> VNA Will Calculate Inaccurate R & X When Either is <u>Much</u> Larger than 50 Ohms When Using Only Reflection Data
- See Screenshot on Next Slide

Common Mode Choke – R+jX



- NanoVNA Screenshot of CMC Loss vs. Frequency (blue trace): Data Is Good
- Calculated Real Part of Impedance (R, yellow) is Not Accurate: Peak Freq Too Low
- This is Because the NanoVNA Does Not Calculate Using the THROUGH (S21) Measurements, Only From the REFLECTED (S11) Measurements

Common Mode Choke – R+jX

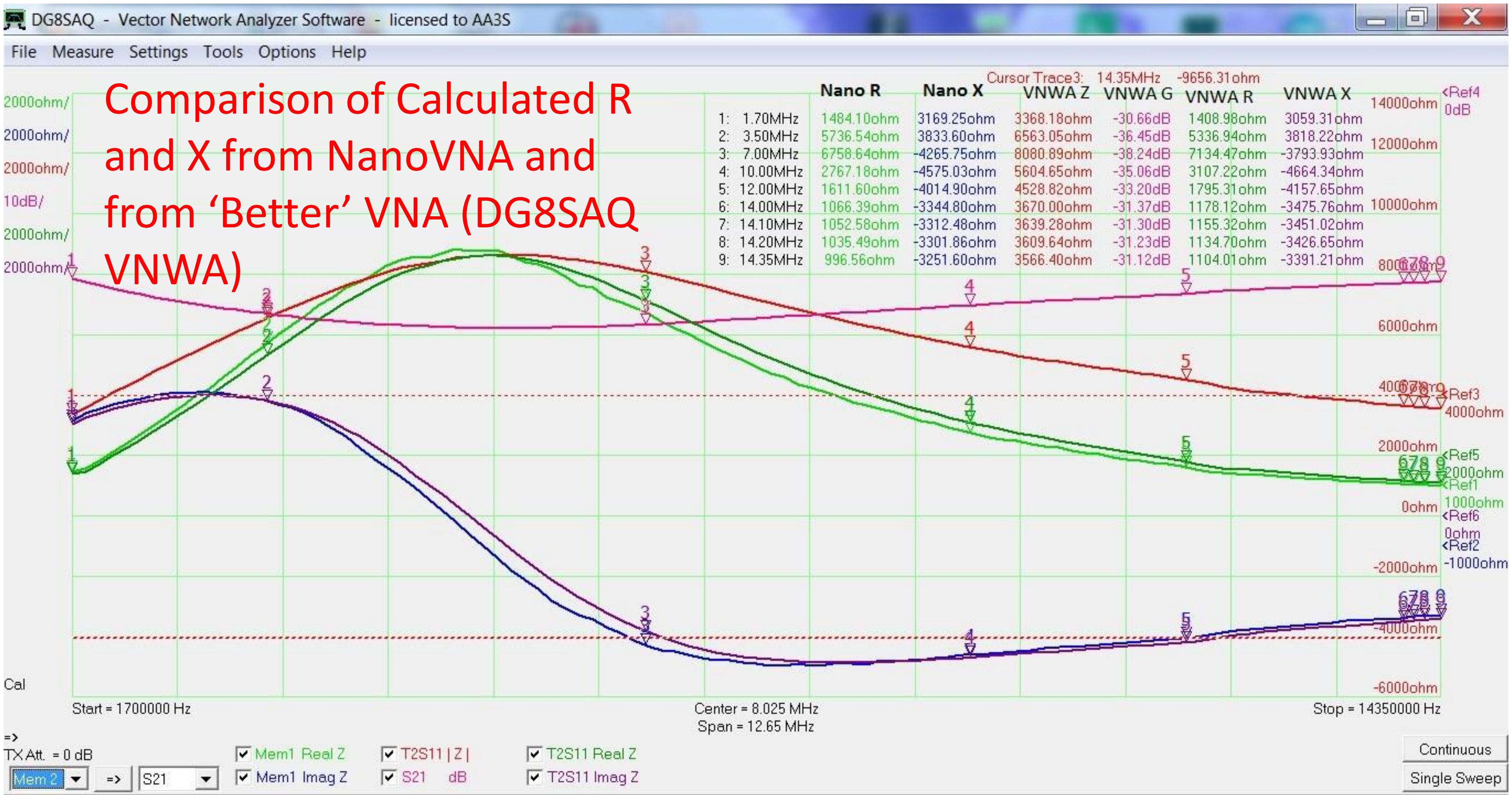


•PC-Software Screenshot of CMC Loss vs. Frequency (blue trace)

•Data In Box on Plot Are as Measured at the Frequency Defined by the Red Vertical Line on the Plot

- Fortunately NanoVNA PC-Software Can Export the Measured ‘Through’ Data for Another Program to Use for Accurate Results (Red Box: Save s2p)

Common Mode Choke – R+jX



- Software Screenshot of VNWA Software: **R and X From Both VNA's Compare Well** When the Through Data (S21) is Used
- VNWA in dark colors: Real-Z (dark green), Imag-Z (dark purple)

Common Mode Choke – R+jX

- With The Accurate R+jX Data Measured by the NanoVNA and Displayed on the VNWA PC-Software, The CMC May Be Evaluated for Acceptability Over Frequency Using R
- It Is Beyond the Scope of These Introductory Slides to Step Through the Process That Resulted in the Plot on the Previous Slide
- If Only the NanoVNA Through Loss Data is Available, Then A One-Band CMC Can Be Evaluated Assuming That The Impedance Peak Is Almost All Due to R Near the Frequency of the Peak and Using the Conversion Table on the Next Slide

DUT Z From Through Loss Data

Through Loss (S21) in dB	Calculated |Z| of DUT (ohms) (is > R)
-10	216
-20	900
-30	3062
-32	3881
-34	4912
-36	6210
-38	7843
-39	8813
-40	9900

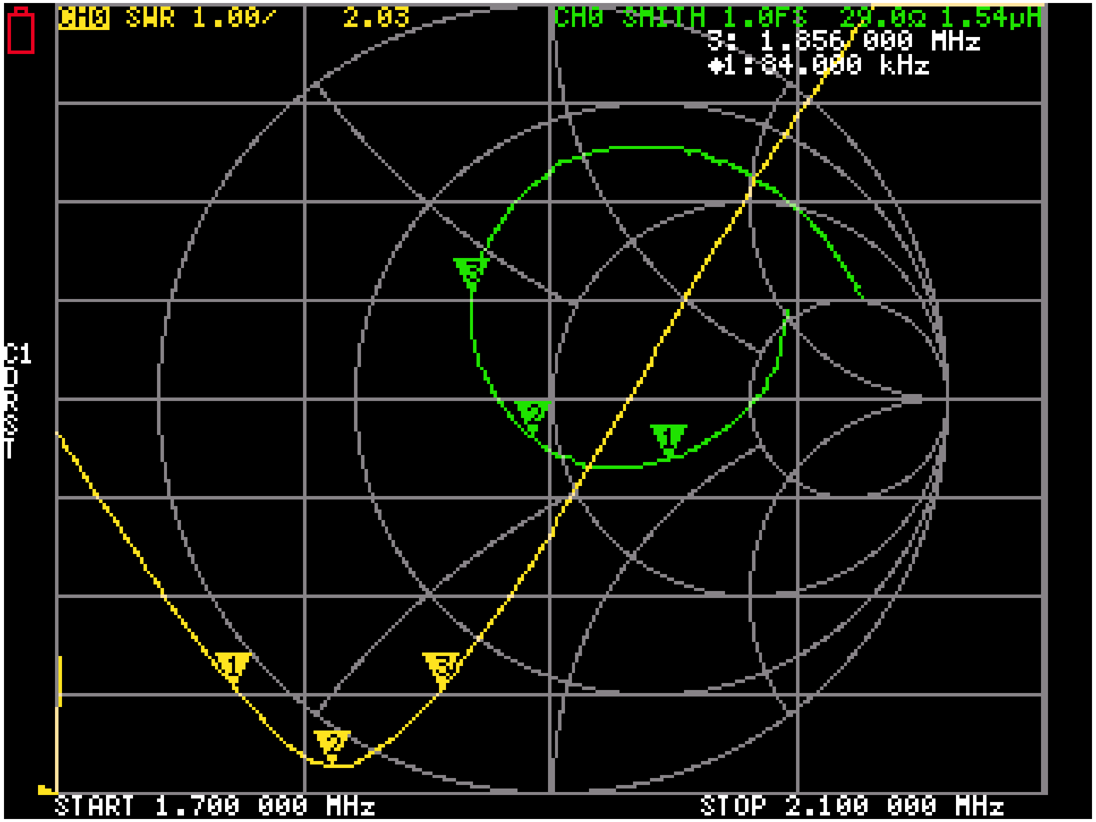
- In This Table Match Your Meaured Loss At The 'Valley' (Maximum Loss) With the Calculated Z
- Near in Frequency to That 'Valley' Almost All the Z is Due to R
- It Is Beyond the Scope of These Introductory Slides to Step Through the Calculations That Resulted in this Table
- Refer to Background Info at the TDK Technical Support Website: *https://product.tdk.com › technicalsupport › seat › pdf › etutorial_007*

SWR

- If You Made it This Far in the Slides You May Have Forgotten About What This Handheld Antenna Analyzer is Used For Most Often: SWR
- It does a Great Job of That, Too!
- SWR is Important to Maximize Transmitter Power (avoid ‘foldback ‘ of your amplifier’s power)
- *Can Be Easily Handled While at the Antenna on a Ladder, etc. Make Real-Time Adjustments and See the Effect*

- Examples Follow

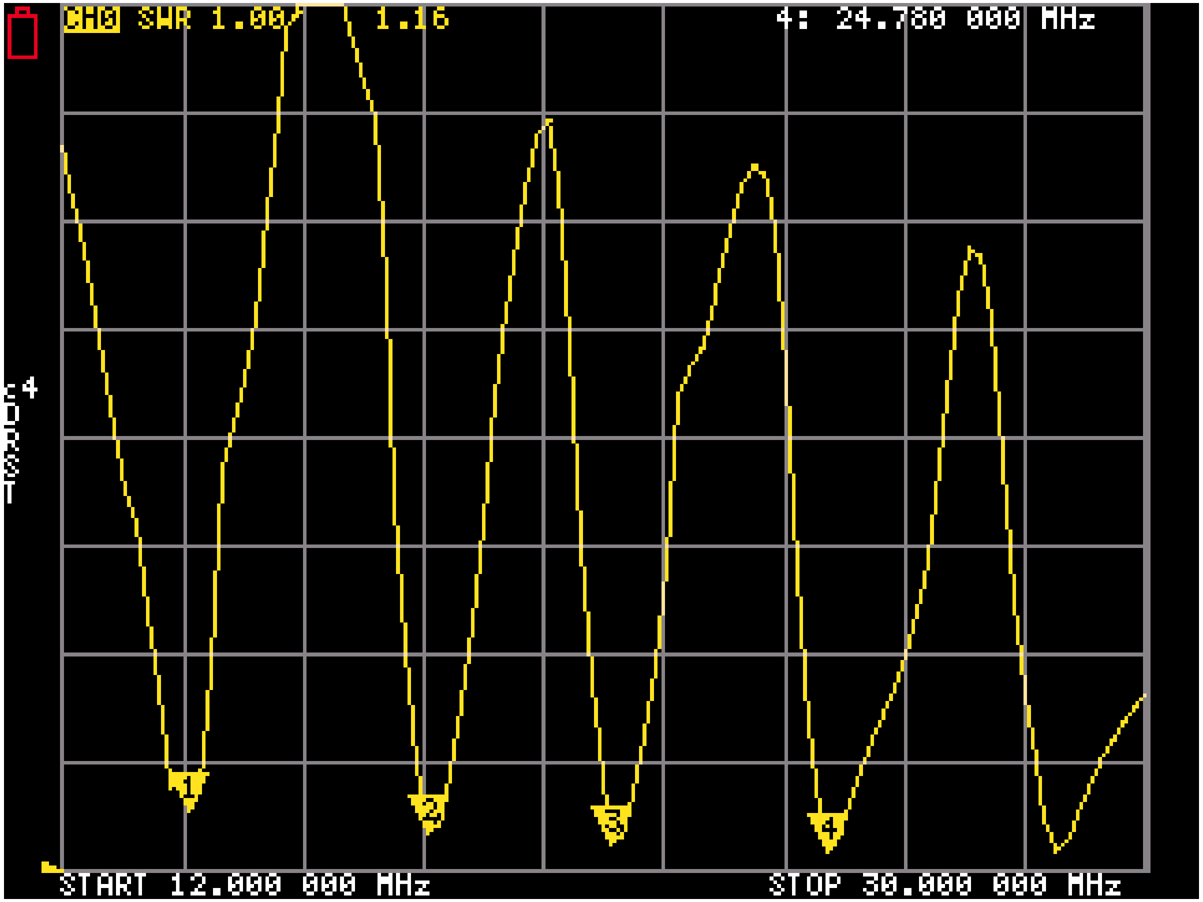
SWR



160 Meter Inverted-L Over Elevated Folded Counterpoise

- Displayed: SWR from 1.7 to 2.1 MHz & Smith Chart
- Markers 1 & 3 are 2:1 SWR, Bandwidth is 84 KHz up to 1.856 MHz (white text)
- The active marker that is selected and one marker that was previously active are displayed.

SWR



Mult-Band Beam

- Yellow Trace Displayed: SWR From 12 to 30 MHz
- Marker 4 Displayed: 1.16:1 SWR (yellow text) at 24.78 MHz (white text)

“Required” User Background Info

Join the Users Group at https://groups.io/g/**nanovna-users**

Then in “Files” Section Read at least:

- NanoVNA Tips for New and Prospective Users 2019-10-9 by WY6K
- NanoVNA User Guide-English-reformat-Oct-2-19
- Look for More Recent Versions!
- Look in the “Wiki” Section for Topics of Interest
- The User Group Will Have Frequent Updates
- ‘Original’ Vendor https://www.alibaba.com/product-detail/Hugen-NanoVNA-H-New-item-Original_62342877955.html?spm=a2700.7724838.2017115.1.506b1b80T9cUaF (volume discount!)

Some Considerations

- SMA Connector Savers (SMA-m to f)
- How to Download & Install PC Software
- How To Download & Install Firmware Upgrades
- How to Add a Higher Capacity Battery
- Calibration References (SOL, Cables, Barrel)

Inexpensive & Very Useful Tool

Hope this information helps you!

What are your experiences with VNAs?