



Vector Network Analyzer

Measurements for Amateur Radio Communications



Don Westacott VE6HQ
March 2024

- Configure as a full, two-port VNA, time-domain reflectometer, vector voltmeter, cable and antenna analyzer, and more.

- Measure all four S-parameters simultaneously with a single connection and up to 90 dB of dynamic range.

- Perform accurate testing with QuickCal, full two-port unknown thru Cal, and Thru, Reflect, Line (TRL) calibration in the field.

- Measure average and pulse power easily with a USB power sensor.



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PRODUCTS AND SERVICES LEARN BUY SUPPORT

A lightweight, durable, full two-port network analyzer, cable and antenna analyzer, distance-to-fault tester, power meter, and vector voltmeter

Sold by: Keysight Online Sales

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- ▶ **N9923A 4 GHz RF vector network analyzer, transmission/reflection** **US\$ 10,209**
+ Show Details [Add to Cart](#)
5 Week Delivery - Included
- ▶ **N9923A 6 GHz RF vector network analyzer, transmission/reflection** **US\$ 11,165**
+ Show Details [Add to Cart](#)
5 Week Delivery - Included

NANOVNA-F V2 3 GHz Mini Vector Network Analyzer is a new generation of portable, stand-alone VNA, featuring a 4.3 inch IPS LCD screen, metal enclosure, 5000 mAh battery and SMA connectors. The measurement frequency range of NanoVNA-F V2 is up to 3GHz. The S21 dynamic range is greater than 70dB at 50kHz-1.5GHz and greater than 60dB at 1.5GHz – 3GHz. **\$ 190 USD**



AE5X Conclusion : 1 to 4 GHz: nanoVNA 2 Plus4 vs. Keysight FieldFox

A 4 GHz FieldFox costs \$12,000 - this does not include the calibration terminations - they're an additional \$800. We have ours professionally calibrated every year in June - the one used for these comparisons was just calibrated.

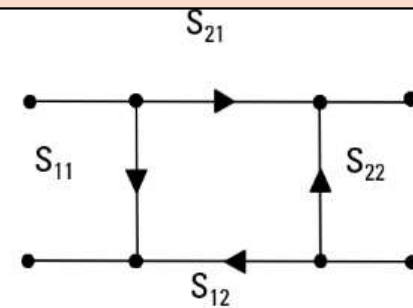
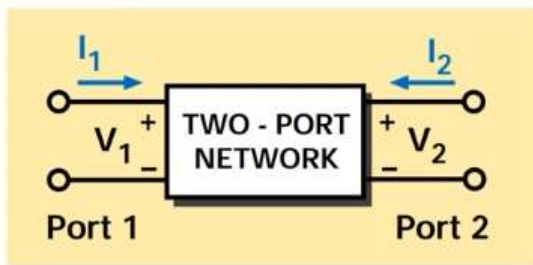
The nanoVNA costs \$160, includes three SMA terminations (SOL) and has no means of being internally calibrated.

How can anyone not be impressed by the close correlation of these two VNA's, especially given the huge price delta? No, I'm not getting paid to say that and am in no way affiliated with anyone having anything to do with nanoVNA sales, development or anything else.



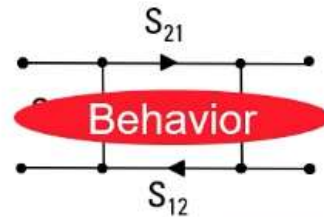
Vector Network Analyzer

A vector network analyzer (**VNA**) is a device used to measure the electrical properties of RF and microwave devices and networks. It does this by sending a signal down a transmission line and measuring the reflected and transmitted signals. The VNA then uses these measurements to calculate the S-parameters of the device or network.



Vector Network Analyzer Measurements

1. Complete characterization of linear networks



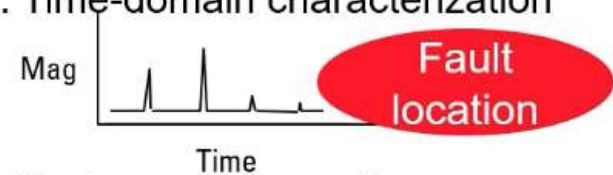
2. Complex impedance needed to design matching circuits



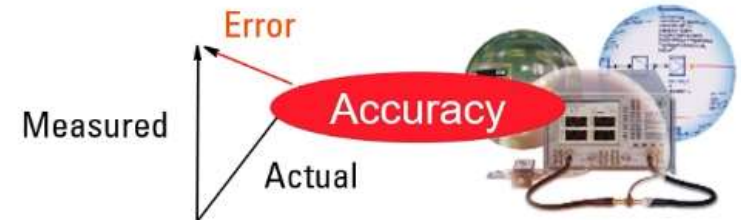
3. Complex values needed for device modeling



4. Time-domain characterization



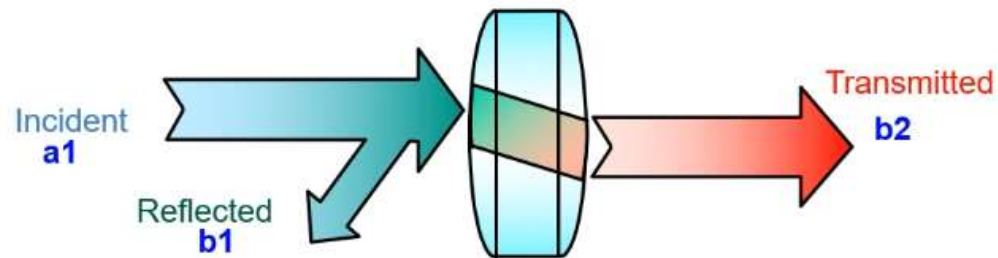
5. Vector-error correction



6. X-parameter (nonlinear) characterization

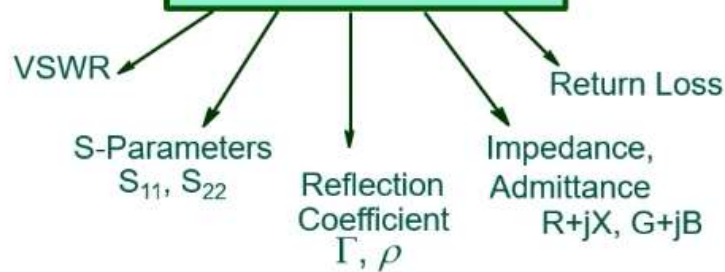
Pre-distortion

High-frequency Device Characterization



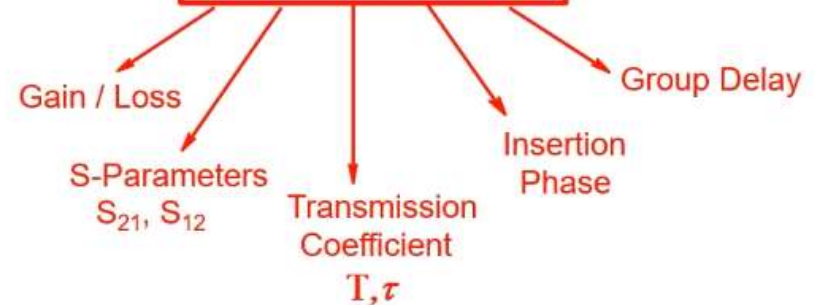
REFLECTION

$$\frac{\text{Reflected}}{\text{Incident}} = \frac{b1}{a1}$$

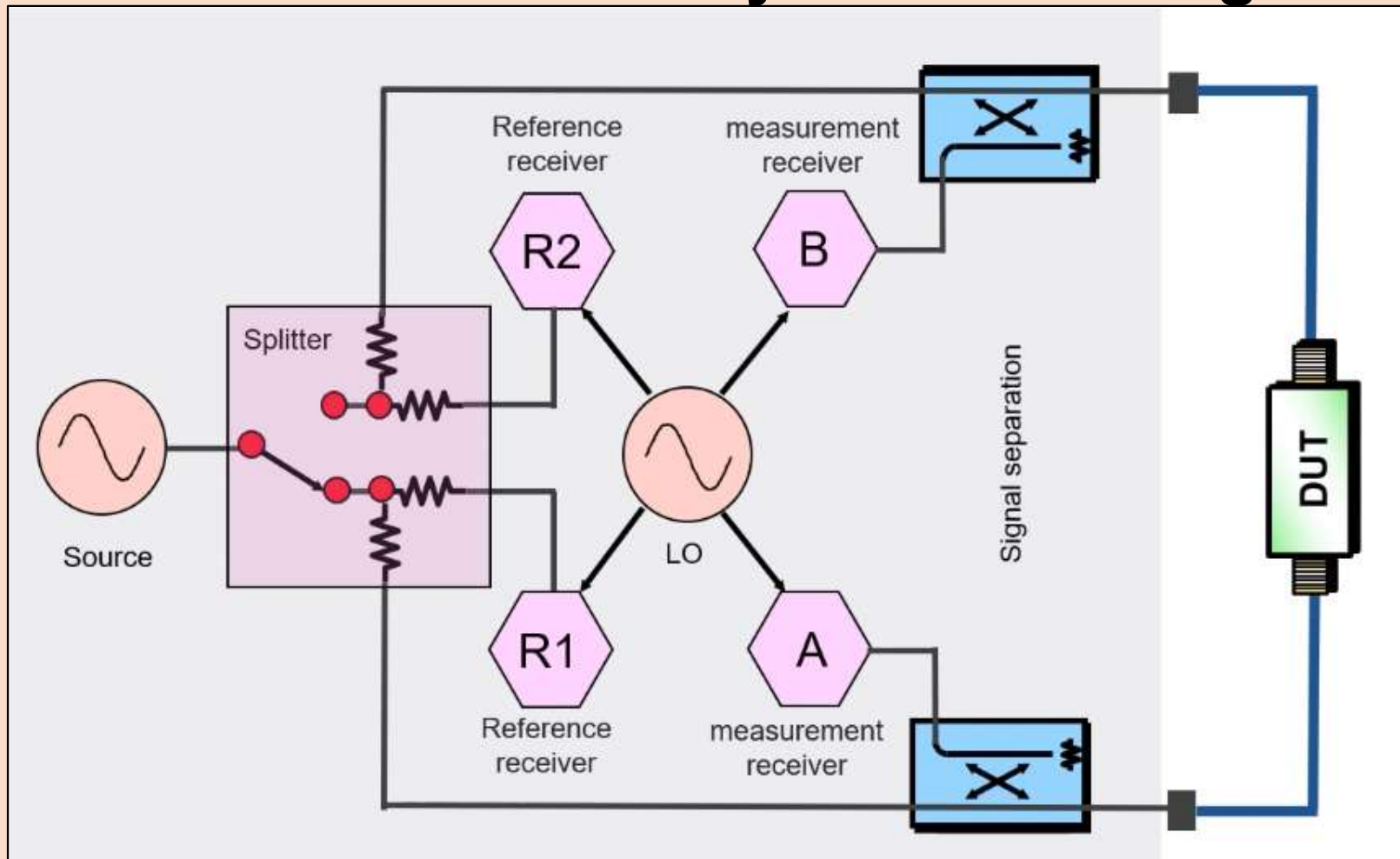


TRANSMISSION

$$\frac{\text{Transmitted}}{\text{Incident}} = \frac{b2}{a1}$$



Vector Network Analyzer Block Diagram





NanoVNA H

0.5 MHz - 1.5 GHz

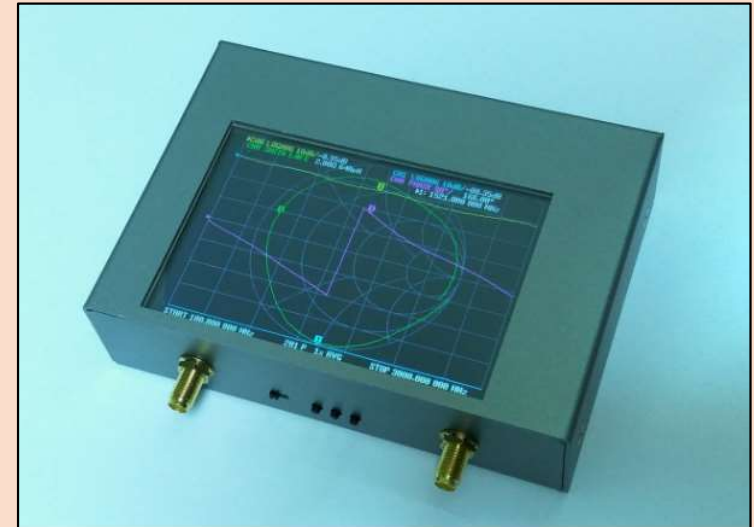
2.8" TOUCHSCREEN



NanoVNA SAA2N

0.5 KHz - 3.0 GHz

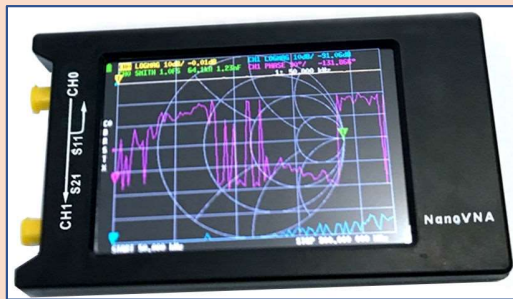
4" TOUCHSCREEN



NanoVNA V2 Plus4

0.5 KHz - 4.0 GHz

4" TOUCHSCREEN



NanoVNA H4

0.5 MHz - 1.5 GHz

4" TOUCHSCREEN

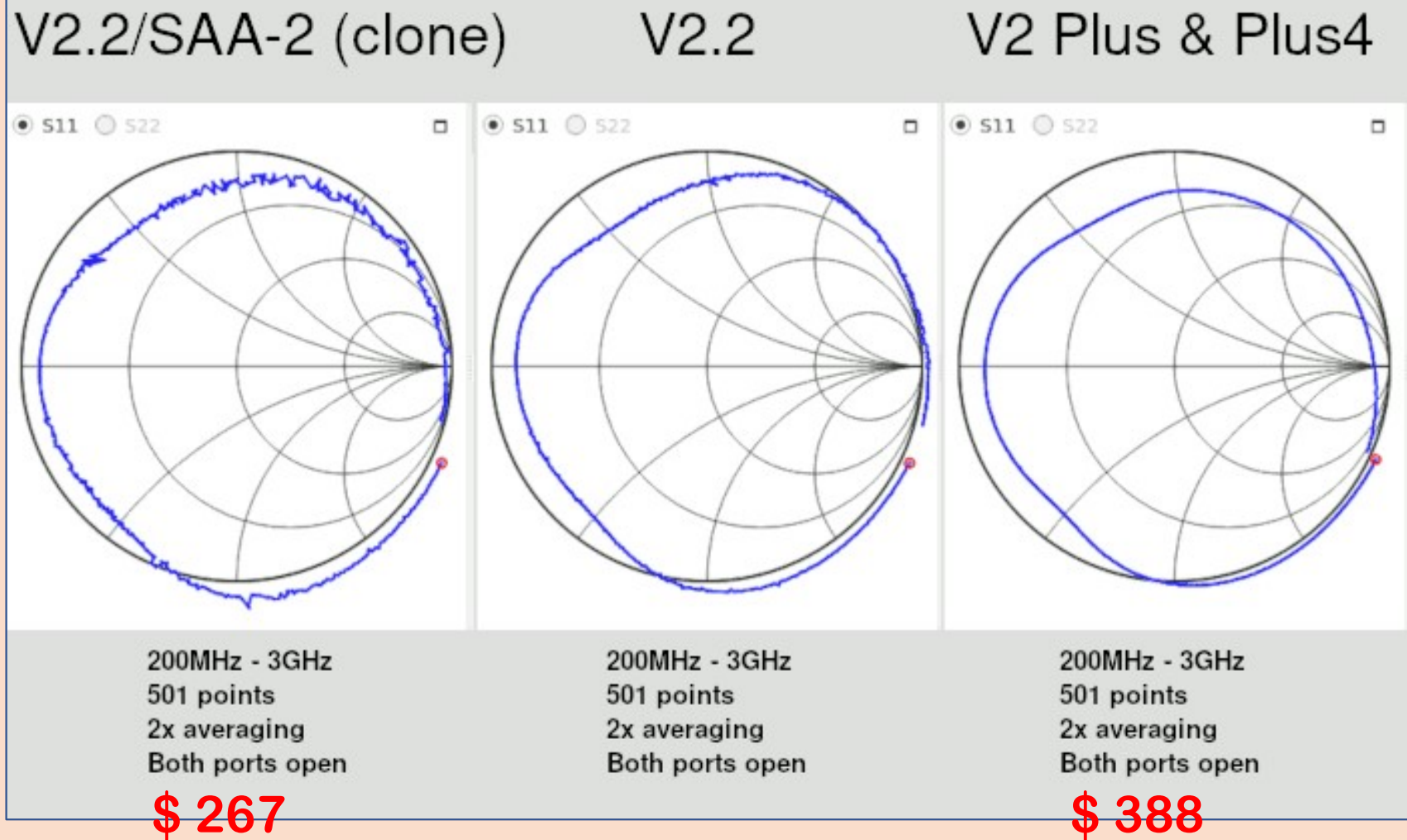


NANO VNA-F V2

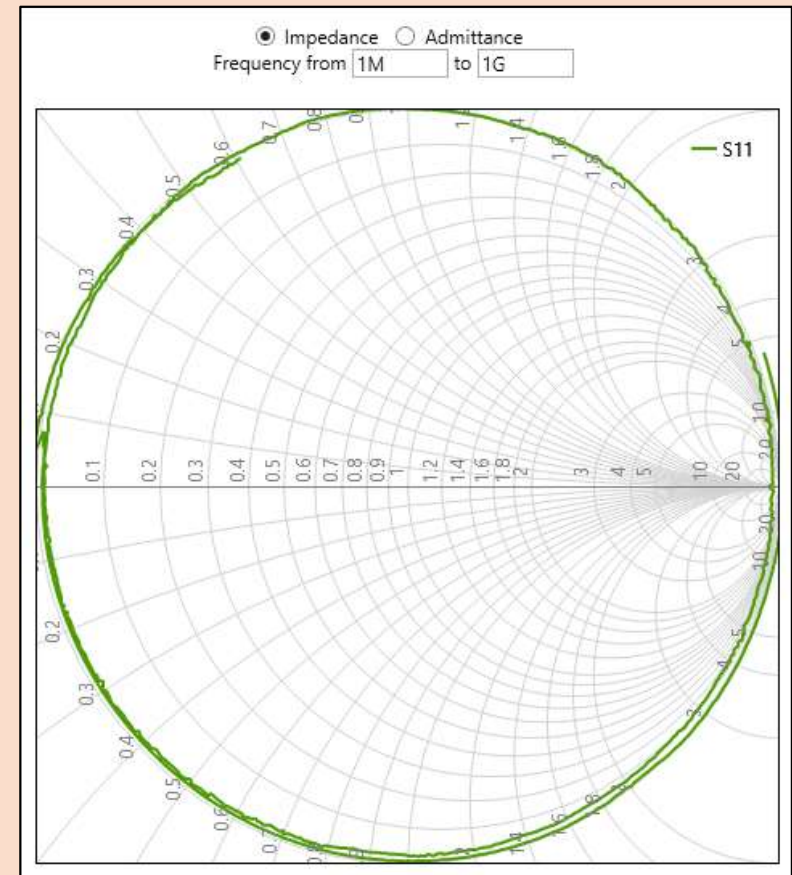
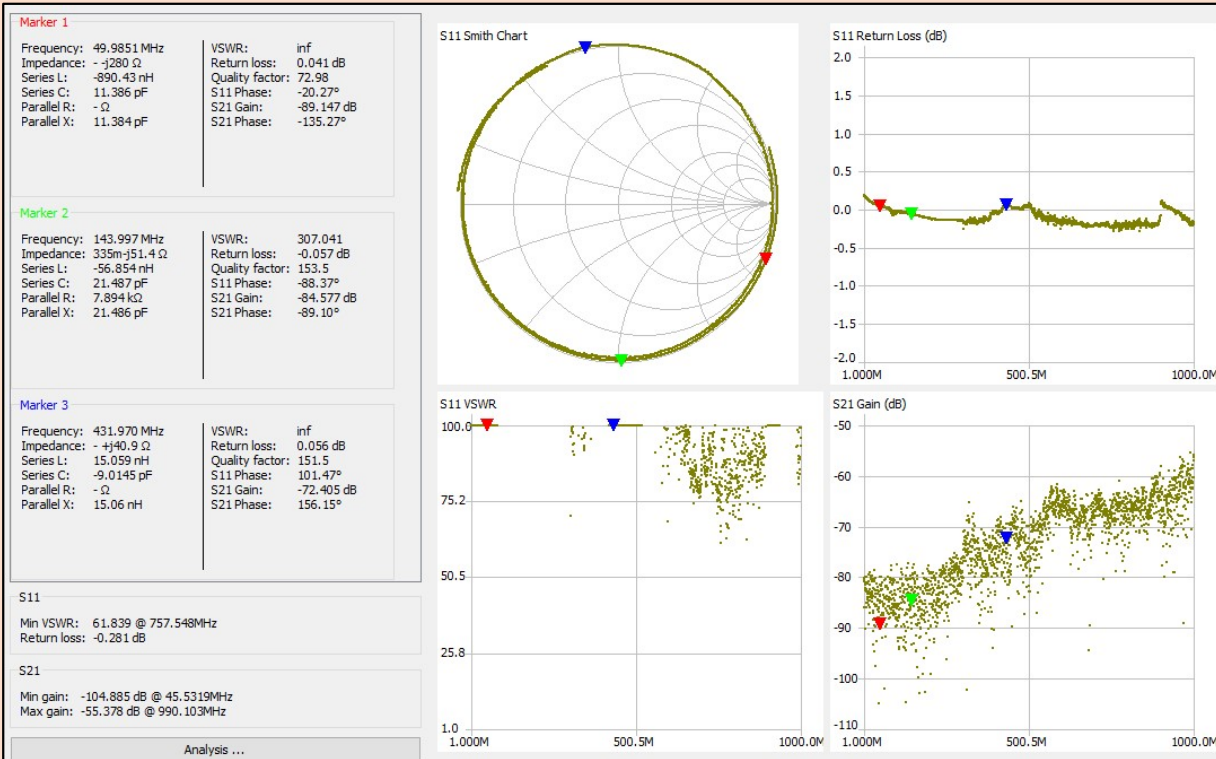
50 kHz – 3 GHz

4" TOUCHSCREEN

Vector Network Analyzer **Clones** versus Original

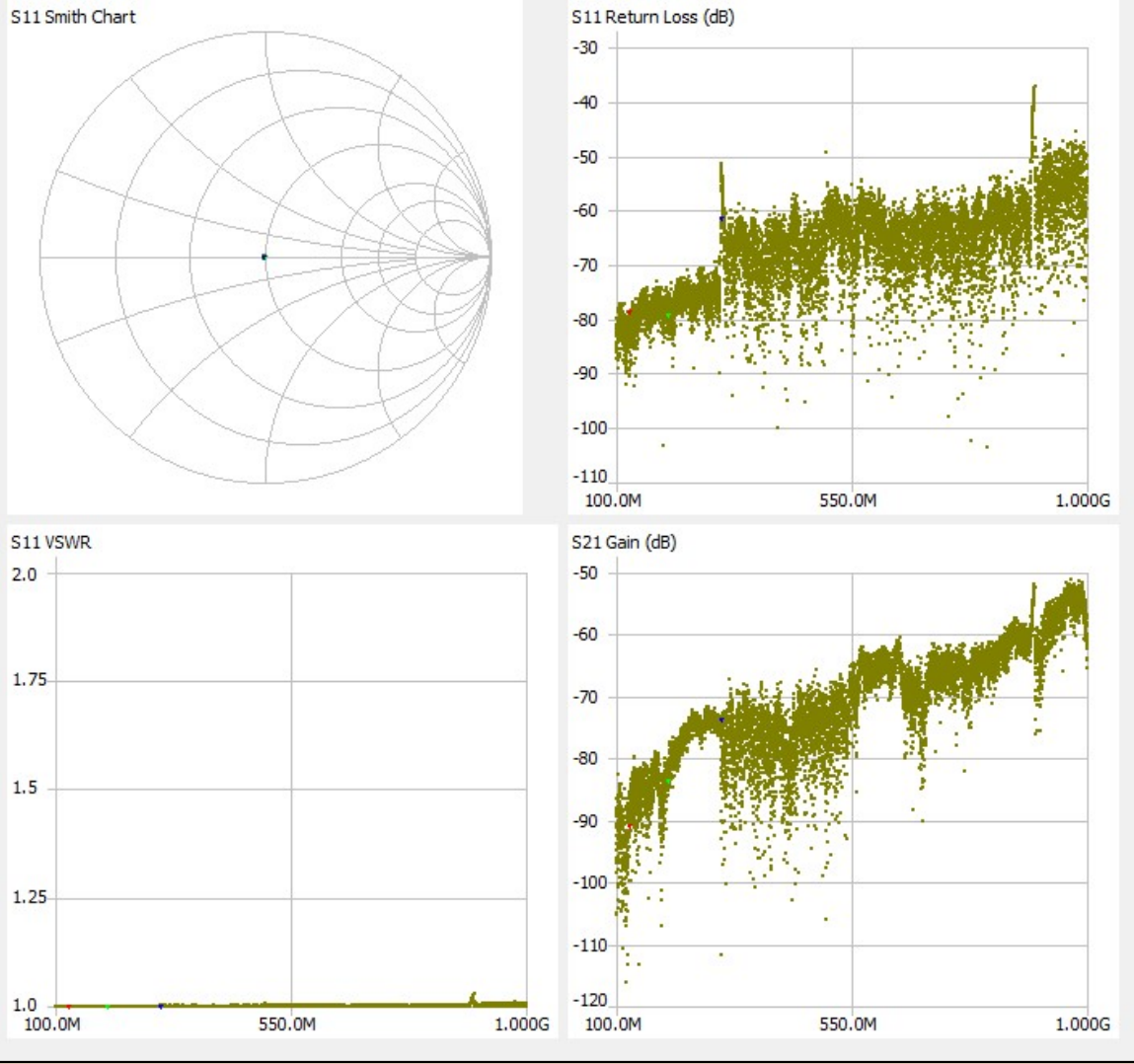


Vector Network Analyzer NanoVNA H



Calibrated Instrument provides Quantitative Measurements





Accuracy

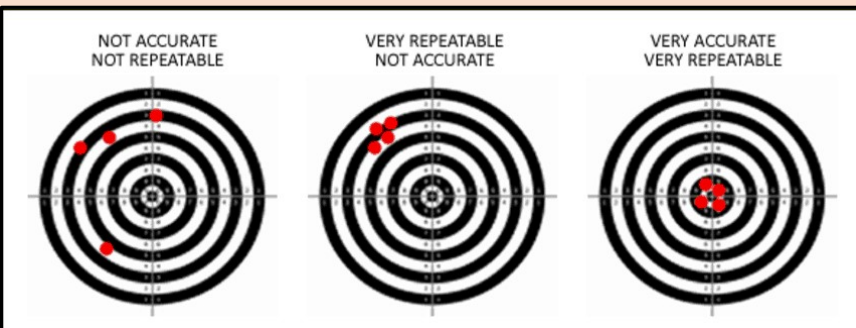
designates how close a measured value is to the true quantity of what is being measured.

Resolution

is the **smallest increment** the system can display or measure.

Repeatability

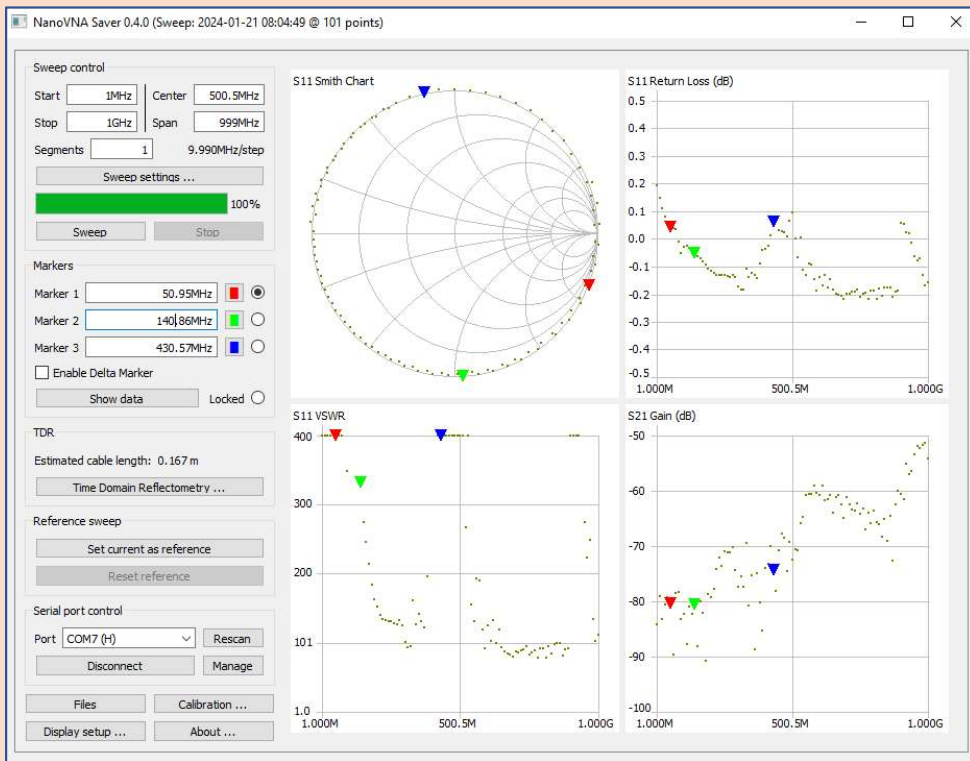
describes how well a system or device can **reproduce an outcome**.



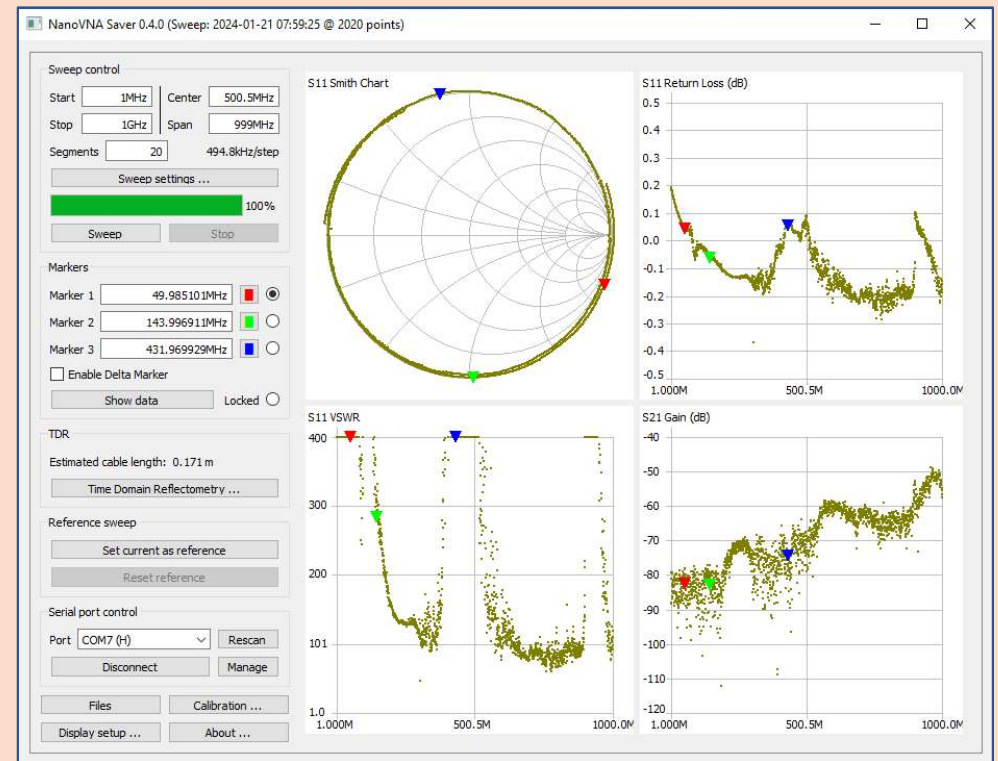
Example NanoVNA H 50 ohm load



NanoVNA Saver Software



1 MHz – 1000 MHz, 1 Segment

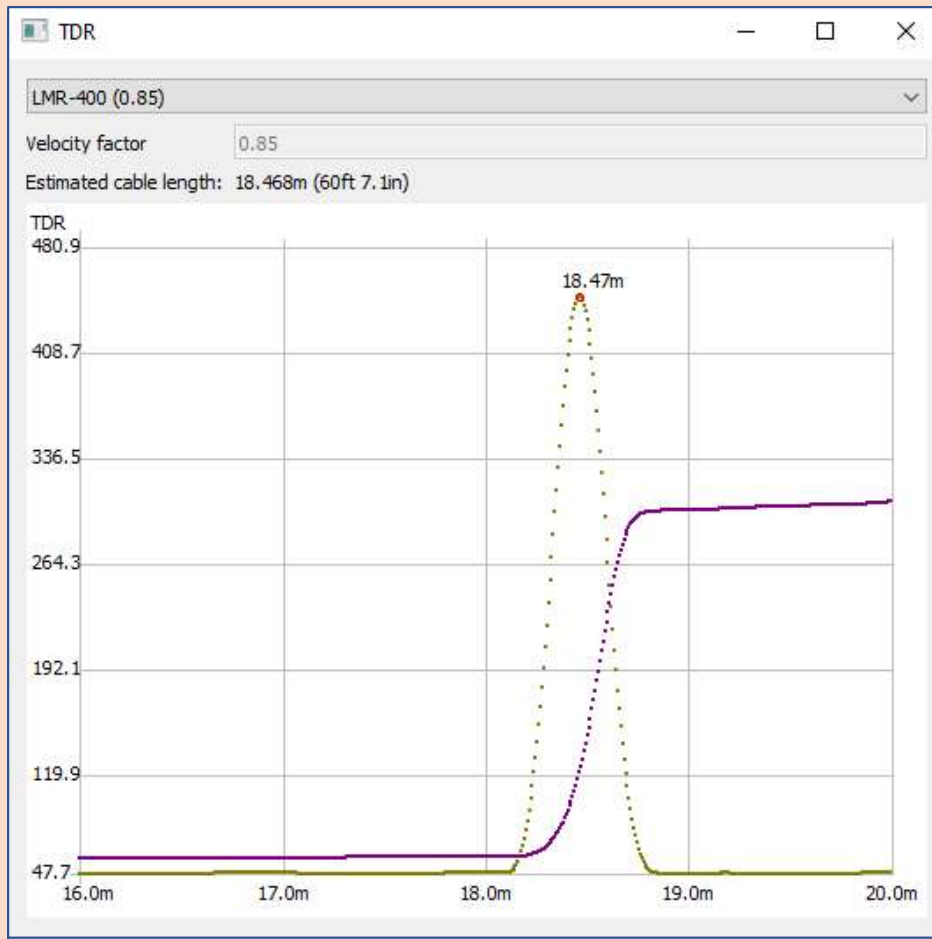


1 MHz – 1000 MHz, 20 Segments



Vector Network Analyzer

Time Domain Reflectometry



Identify both distance and magnitude of impedance discontinuities along a transmission line.

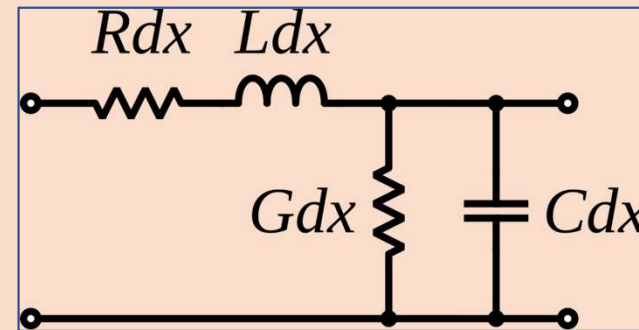
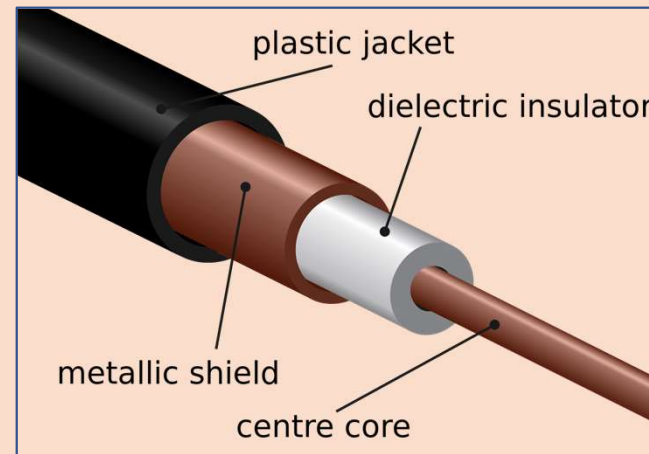
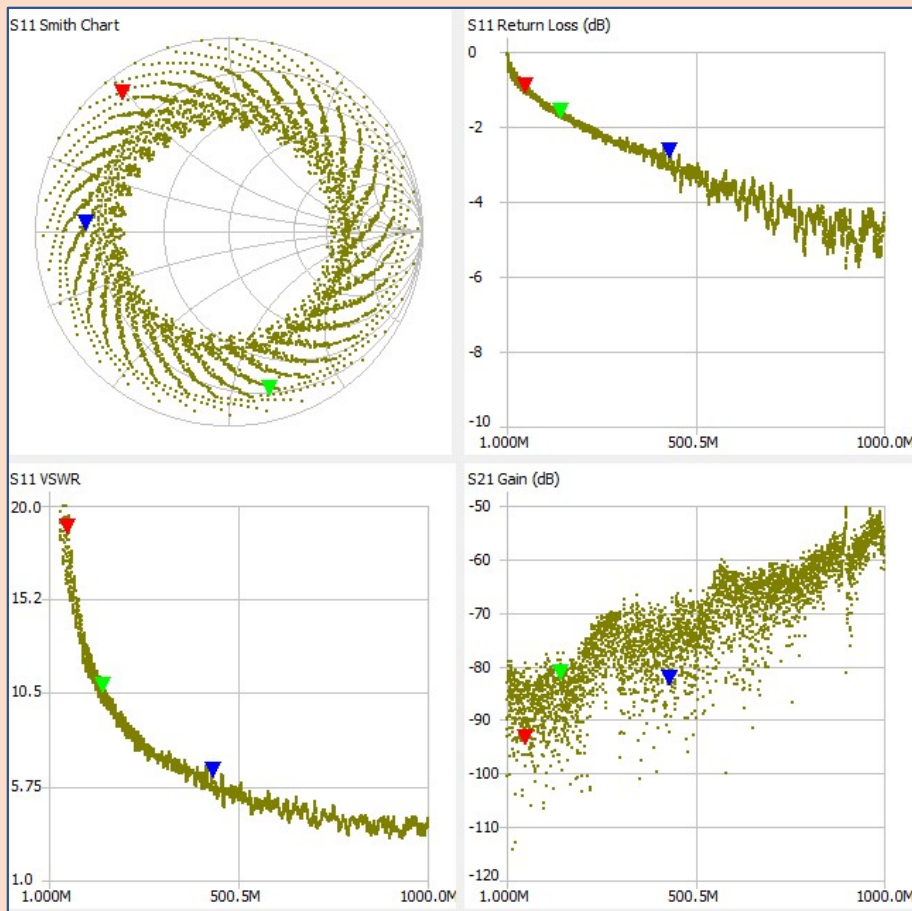
Commonly called distance to fault (DFT).

TDR nanoVNA, 10 feet cable, 50 feet LMR400, open load



Vector Network Analyzer

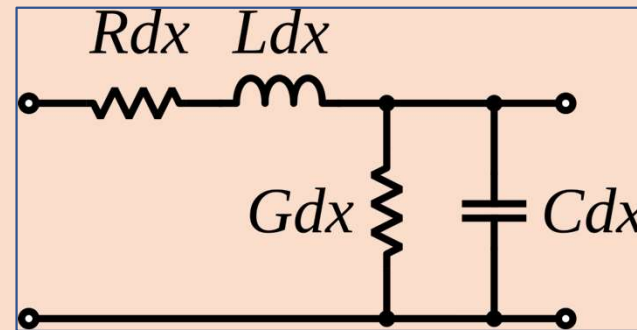
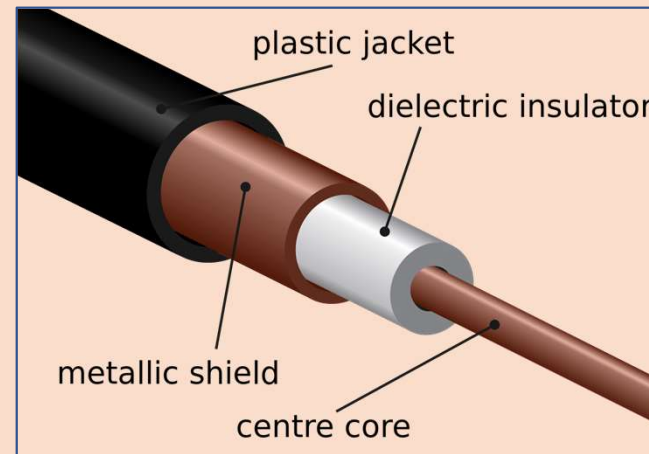
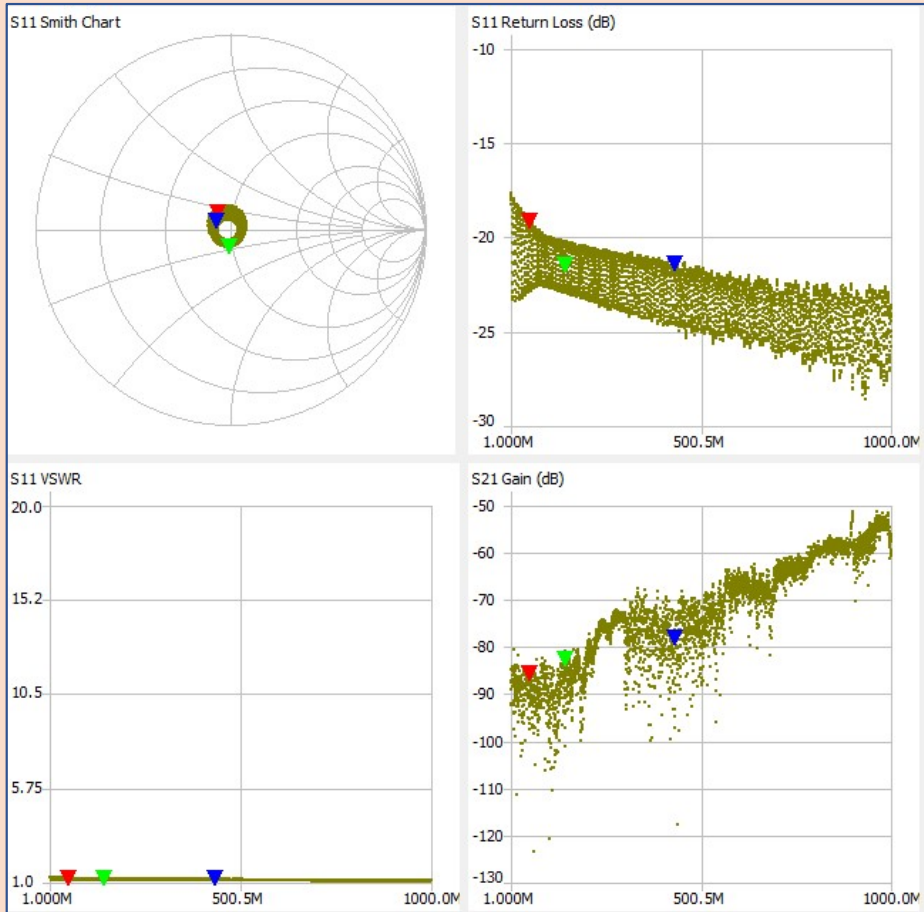
Frequency Domain Analysis



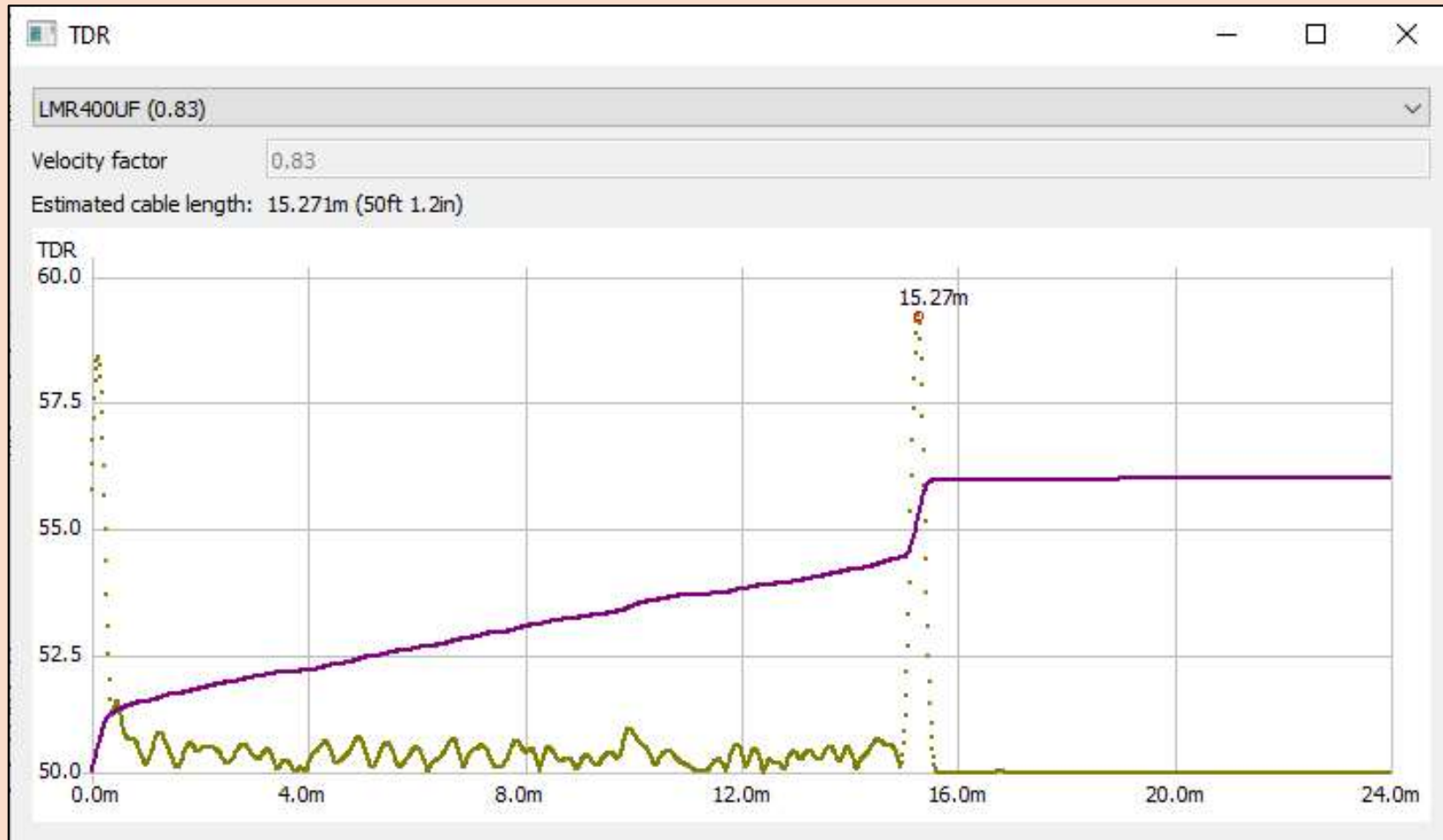
TDR nanoVNA, 50 feet LMR400, open load

Vector Network Analyzer

Frequency Domain Analysis



TDR nanoVNA, 10 dB Pad, 50 feet LMR400, open load



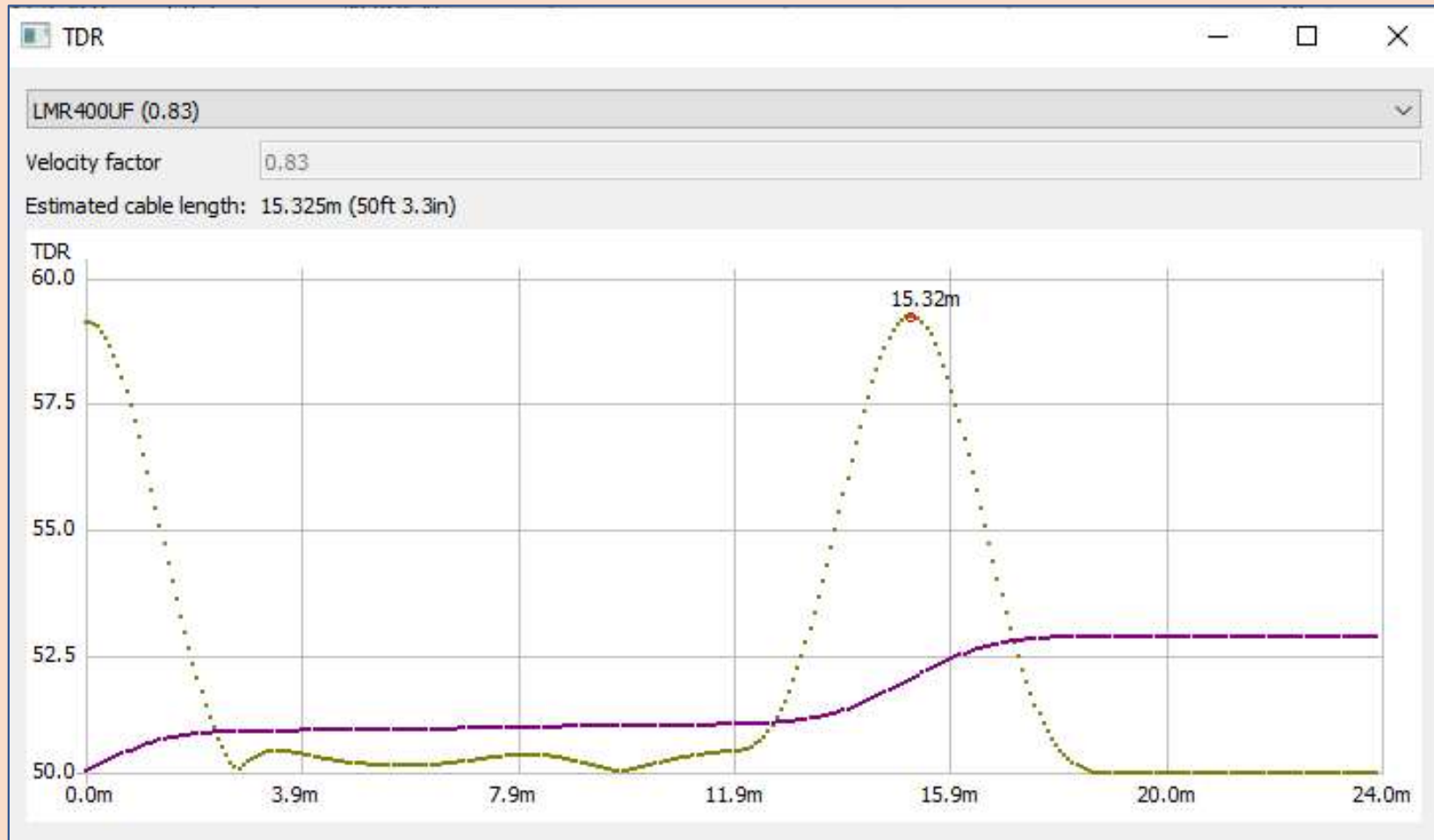
LMR 400

50 feet

50 ohm Load

1 MHz – 1000 MHz Sweep





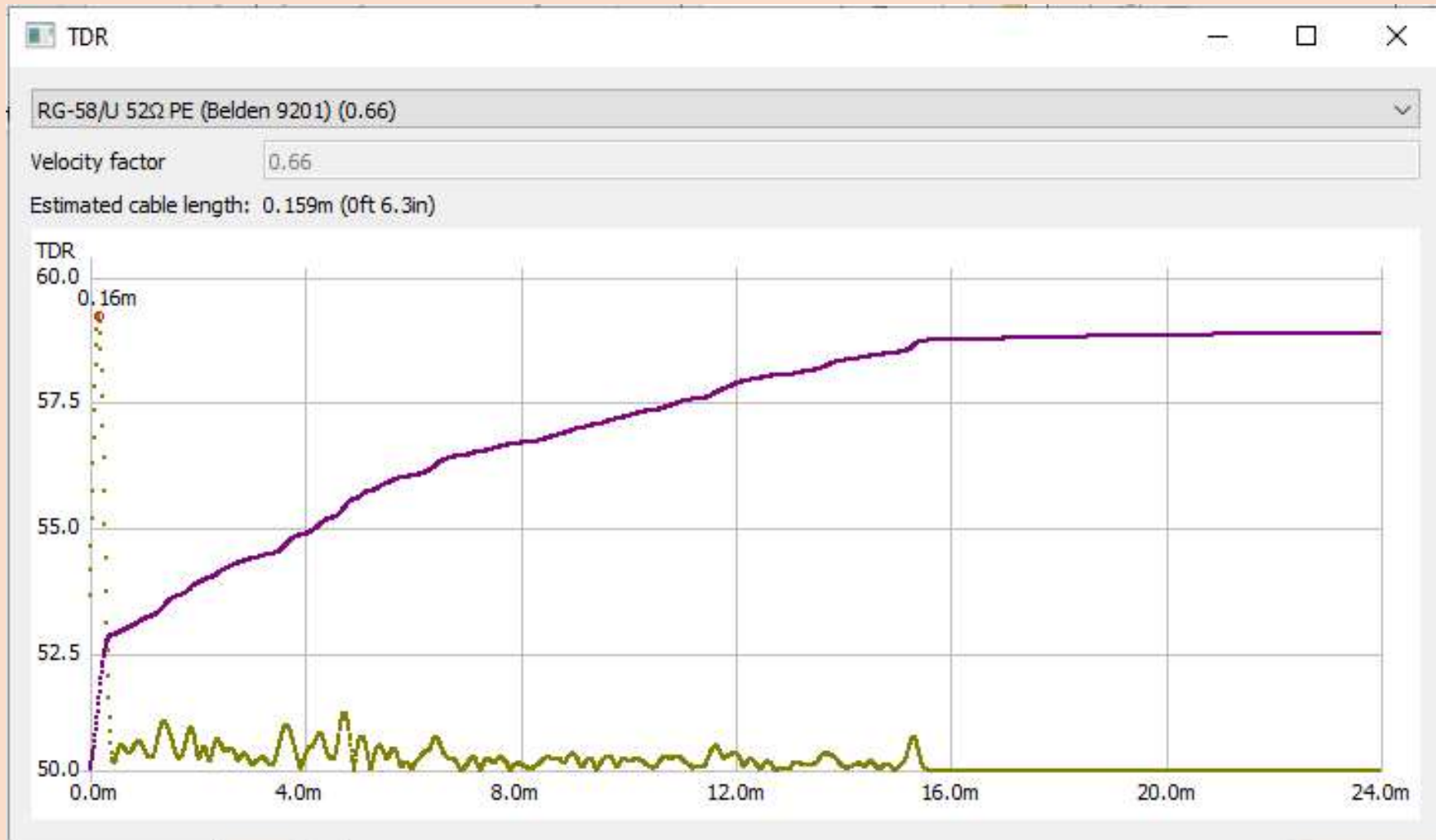
LMR 400

50 feet

50 ohm Load

1 MHz – 100 MHz Sweep





RG58

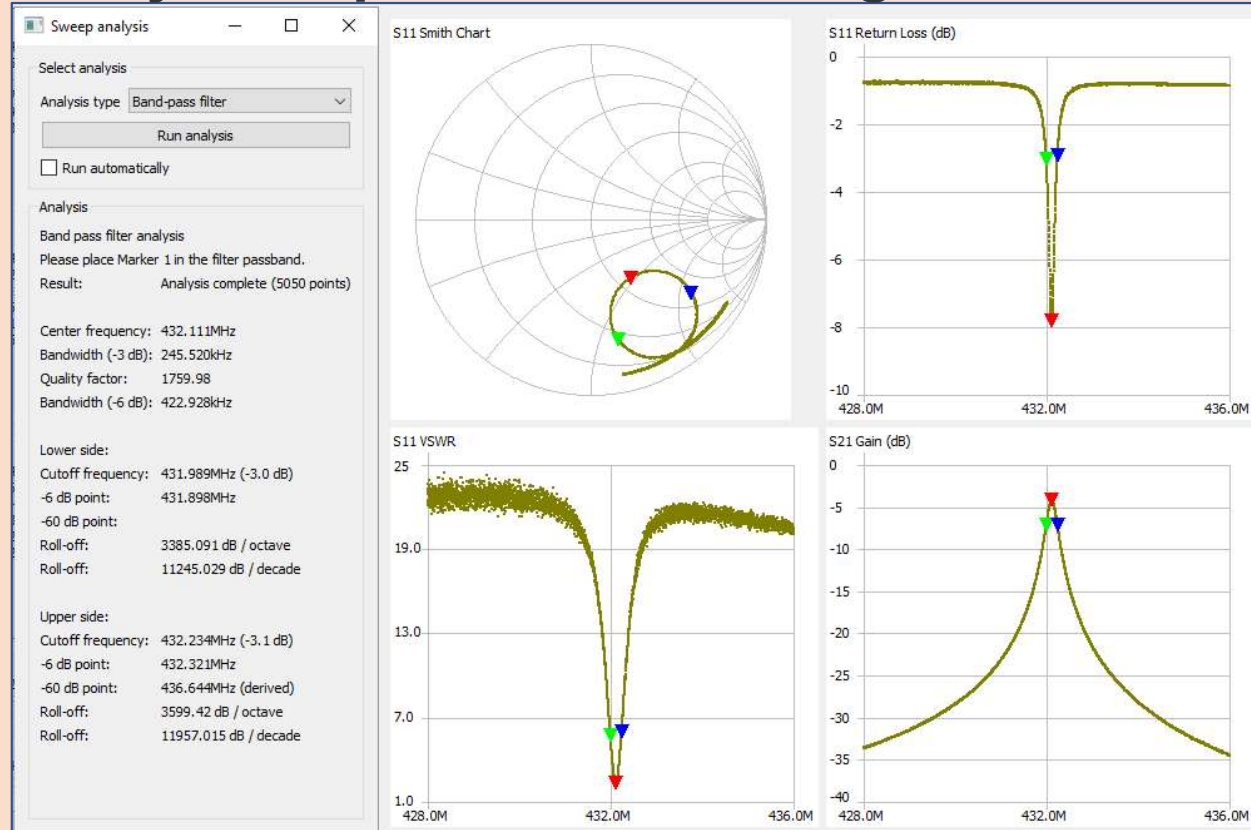
50 feet

50 ohm Load

1 MHz – 1000 MHz Sweep



UHF Resonant Cavity Bandpass Filter Testing

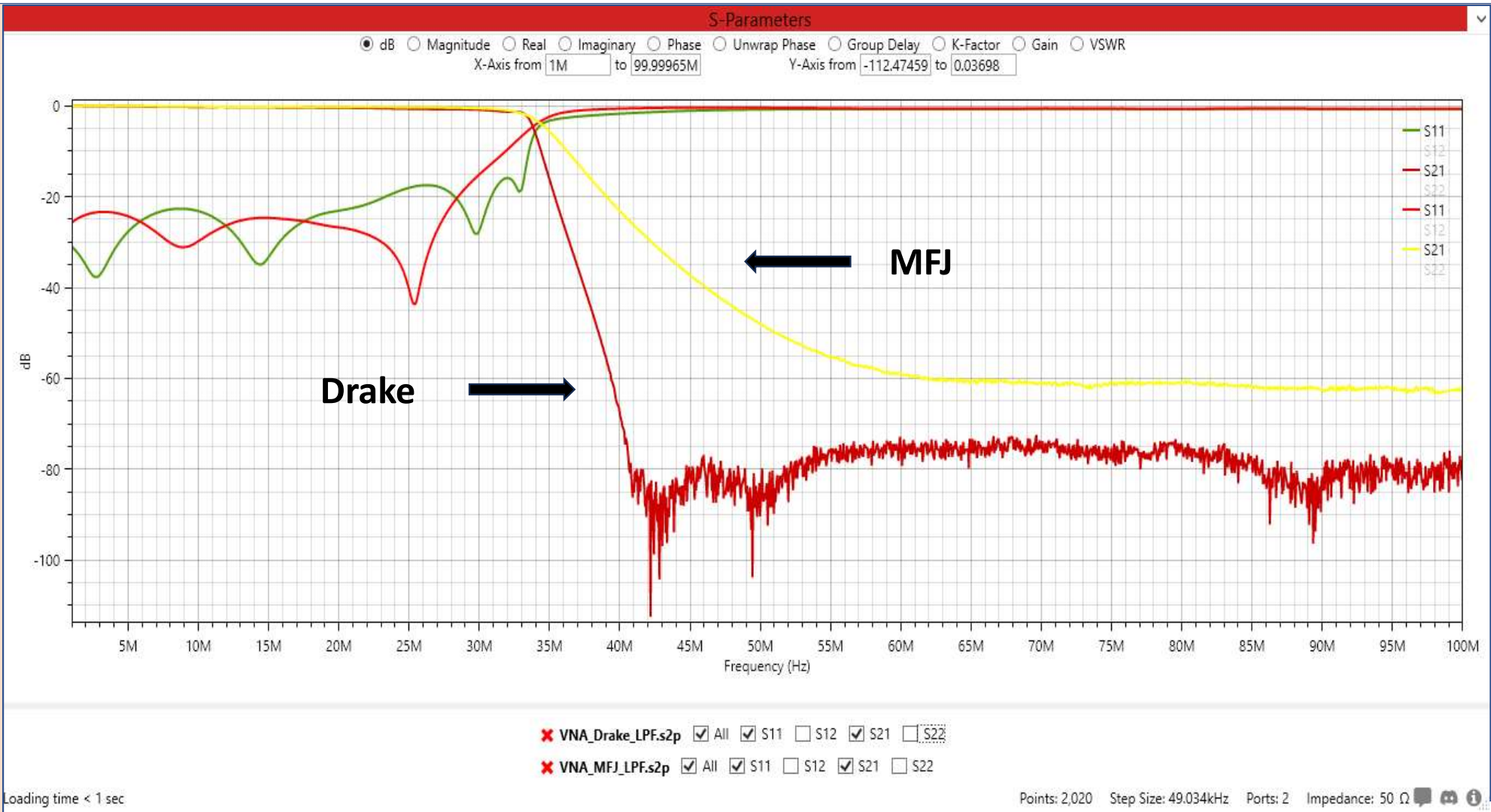


Center Frequency 421.111 MHz
Bandwidth 245.520 KHz

Test and Compare HF Low Pass Filters



Vintage versus Modern , how do they compare?

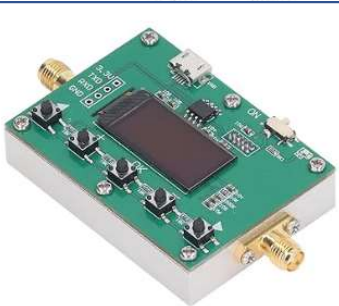
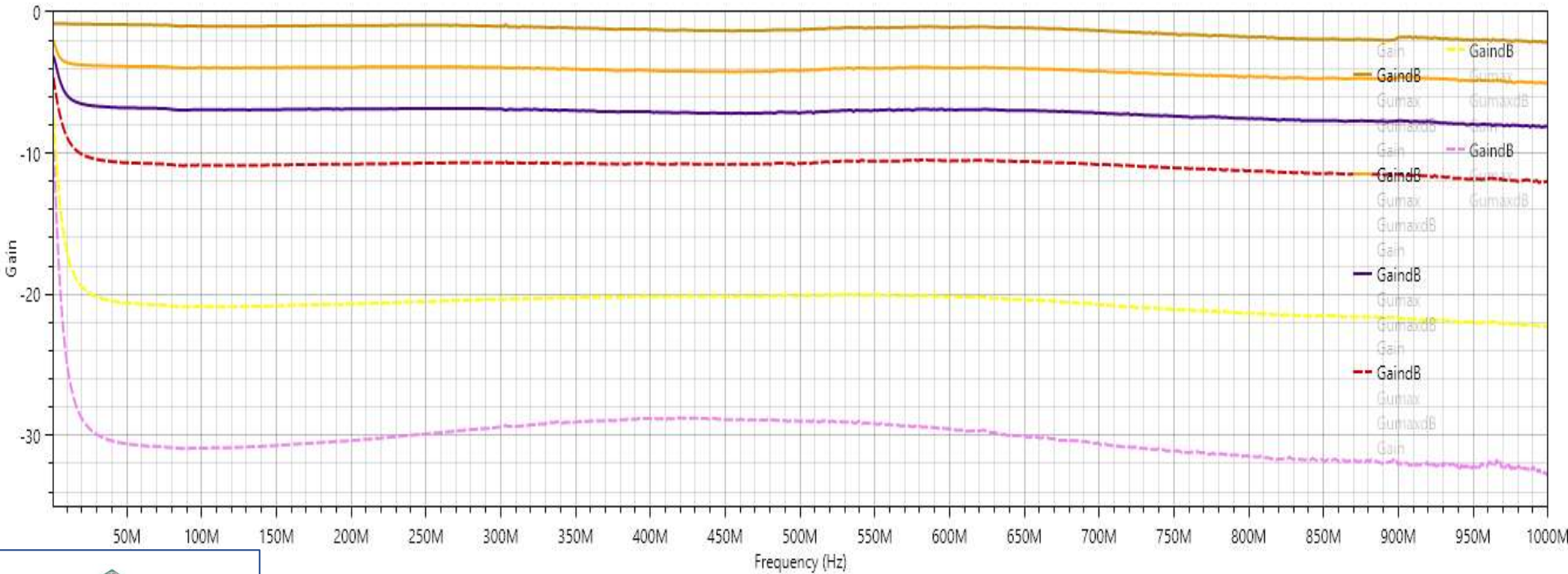


S11 , S21 Comparison Drake versus MFJ HF Low Pass Filters



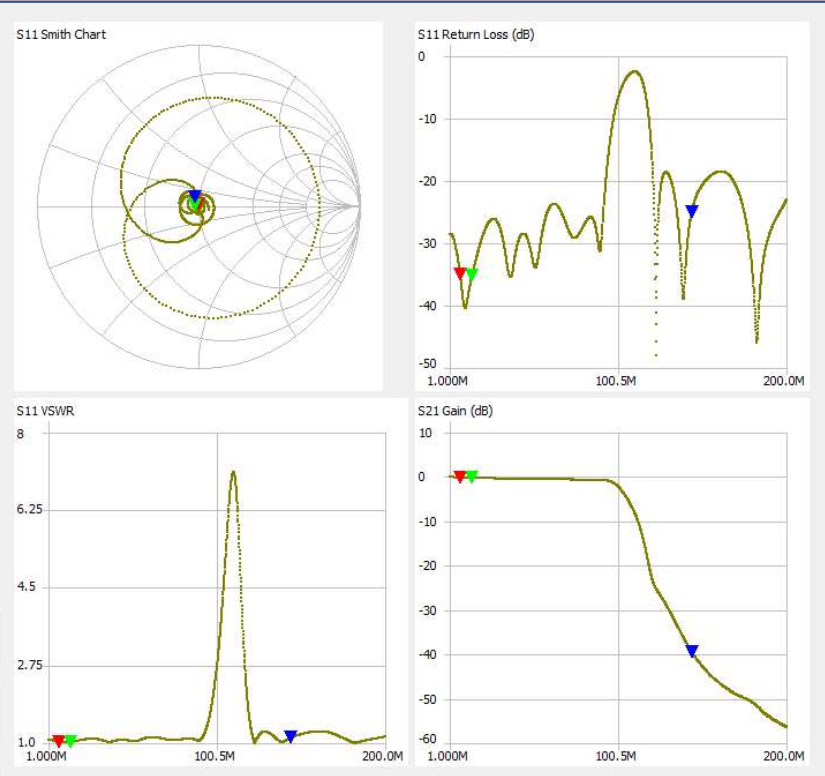
S-Parameters

dB Magnitude Real Imaginary Phase Unwrap Phase Group Delay K-Factor Gain VSWR
X-Axis from 1M to 1000M Y-Axis from -35 to 0



Digital RF Attenuator

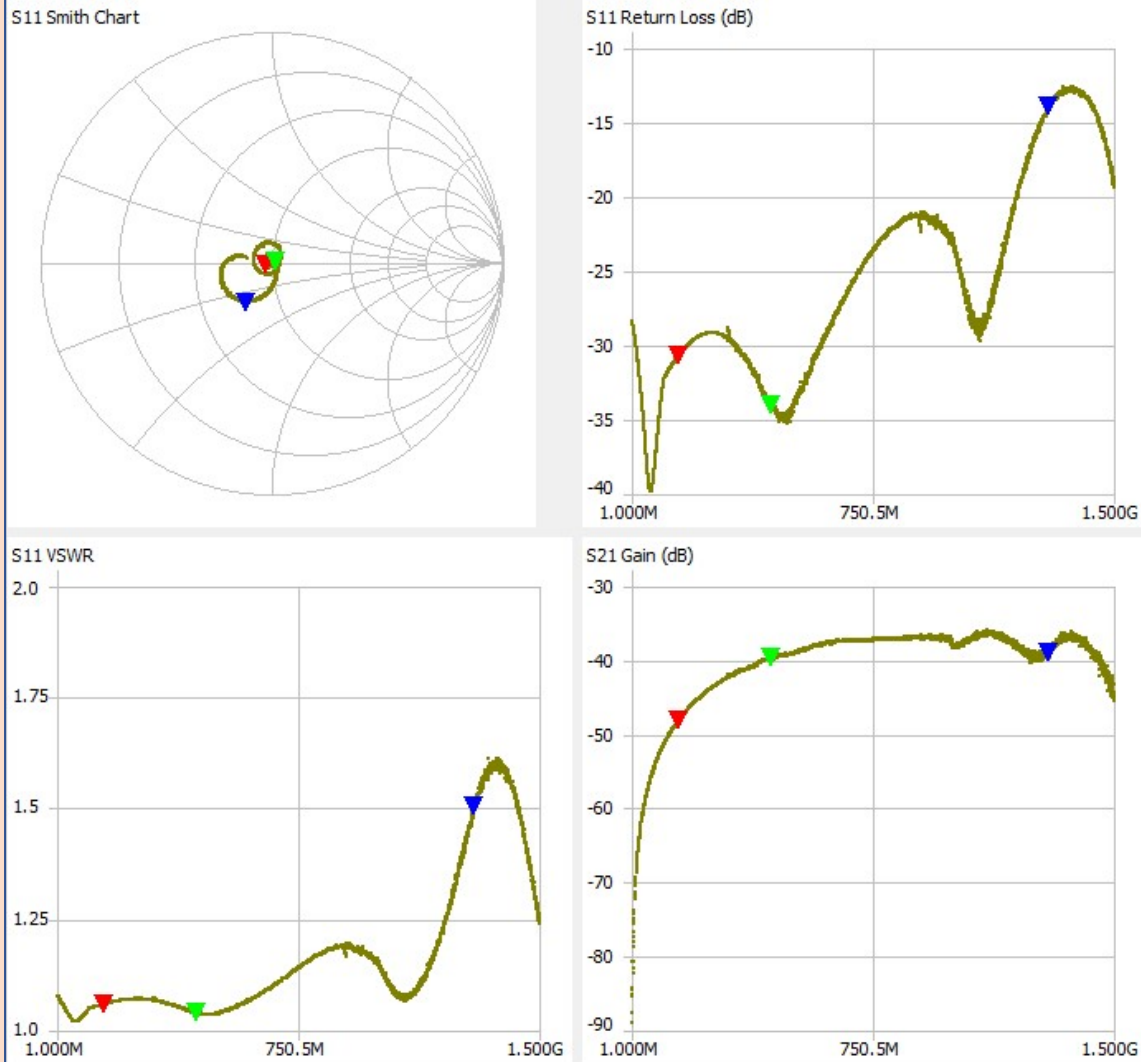
Marker 1	
Frequency: 7.01240 MHz	VSWR: 1.036
Impedance: 50.6+j1.69 Ω	Return loss: -34.951 dB
Series L: 38.407 nH	Quality factor: 0.033
Series C: -13.412 nF	S11 Phase: 69.16°
Parallel R: 50.668 Ω	S21 Gain: -0.078 dB
Parallel X: 34.394 μH	S21 Phase: -20.64°
Marker 2	
Frequency: 14.0104 MHz	VSWR: 1.035
Impedance: 48.5+j880m Ω	Return loss: -35.246 dB
Series L: 9.9941 nH	Quality factor: 0.018
Series C: -12.912 nF	S11 Phase: 148.39°
Parallel R: 48.557 Ω	S21 Gain: -0.163 dB
Parallel X: 30.434 μH	S21 Phase: -94.19°
Marker 3	
Frequency: 144.016 MHz	VSWR: 1.120
Impedance: 48.1+j5.24 Ω	Return loss: -24.947 dB
Series L: 5.7949 nH	Quality factor: 0.109
Series C: -210.75 pF	S11 Phase: 106.39°
Parallel R: 48.719 Ω	S21 Gain: -39.463 dB
Parallel X: 494.36 nH	S21 Phase: -77.09°
S11	
Min VSWR: 1.008 @ 122.924MHz	
Return loss: -47.875 dB	
S21	
Min gain: -56.321 dB @ 199.902MHz	
Max gain: 0.046 dB @ 1.00000MHz	
Analysis ...	



Comet CF-530 Duplexer

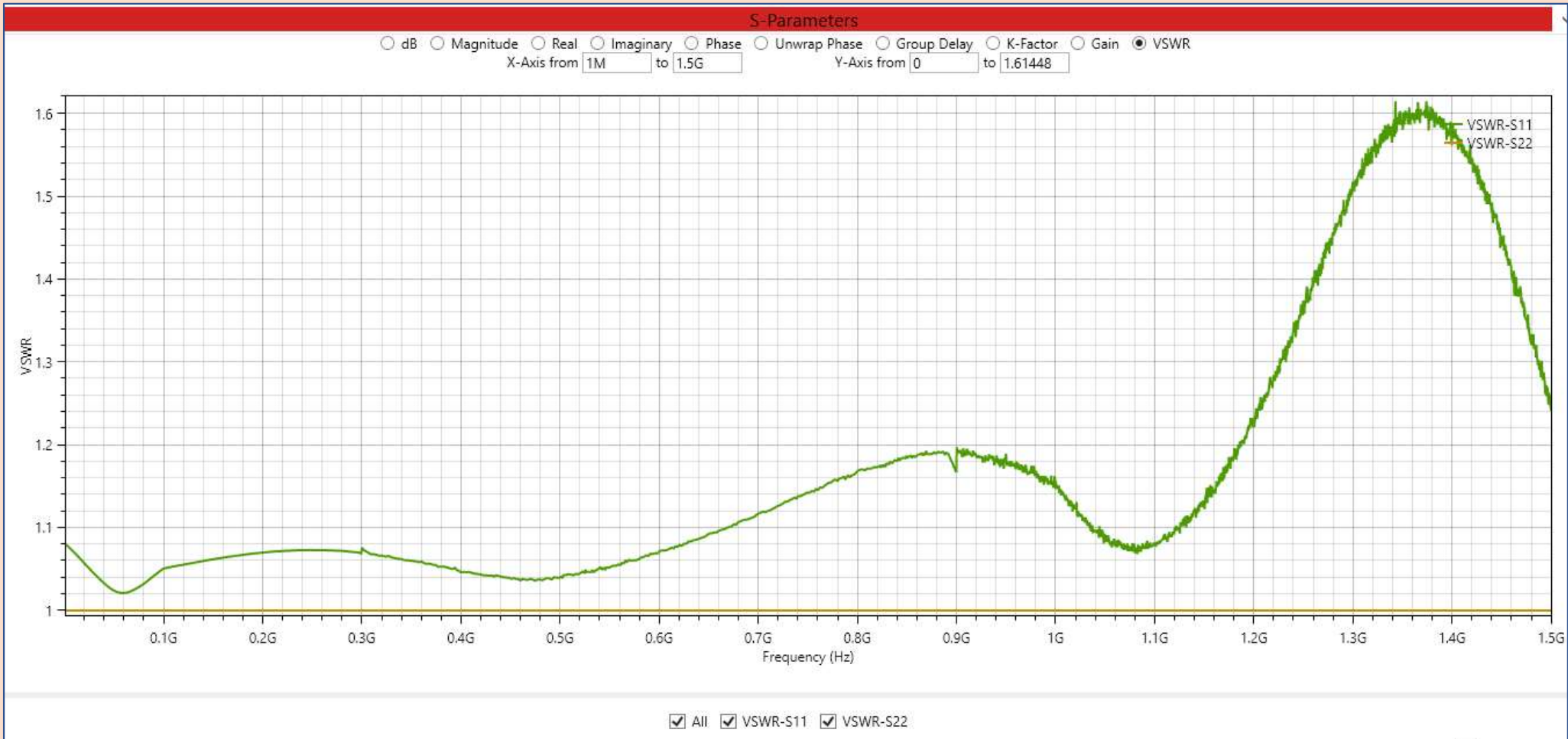
	<u>Band Pass</u>	<u>Ins Loss</u>	<u>Max Power</u>
	Low Pass: 1.3 - 90MHz	.2dB	600W PEP
	High Pass: 125 - 470MHz	.2dB	600W PEP
	Isolation: 45dB minimum		





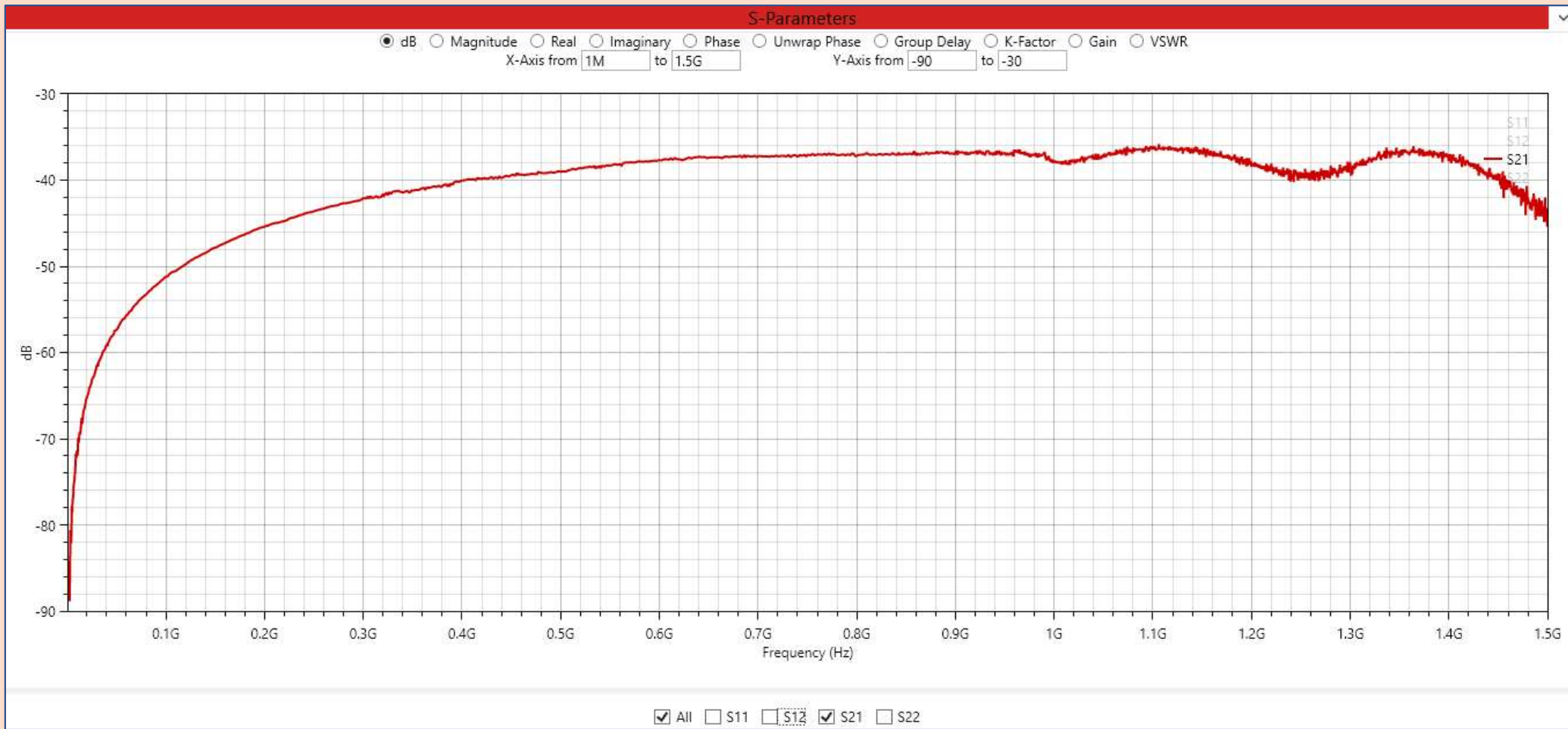
RF Coaxial Directional Coupler
400 - 470MHz
40dB 500 Watt





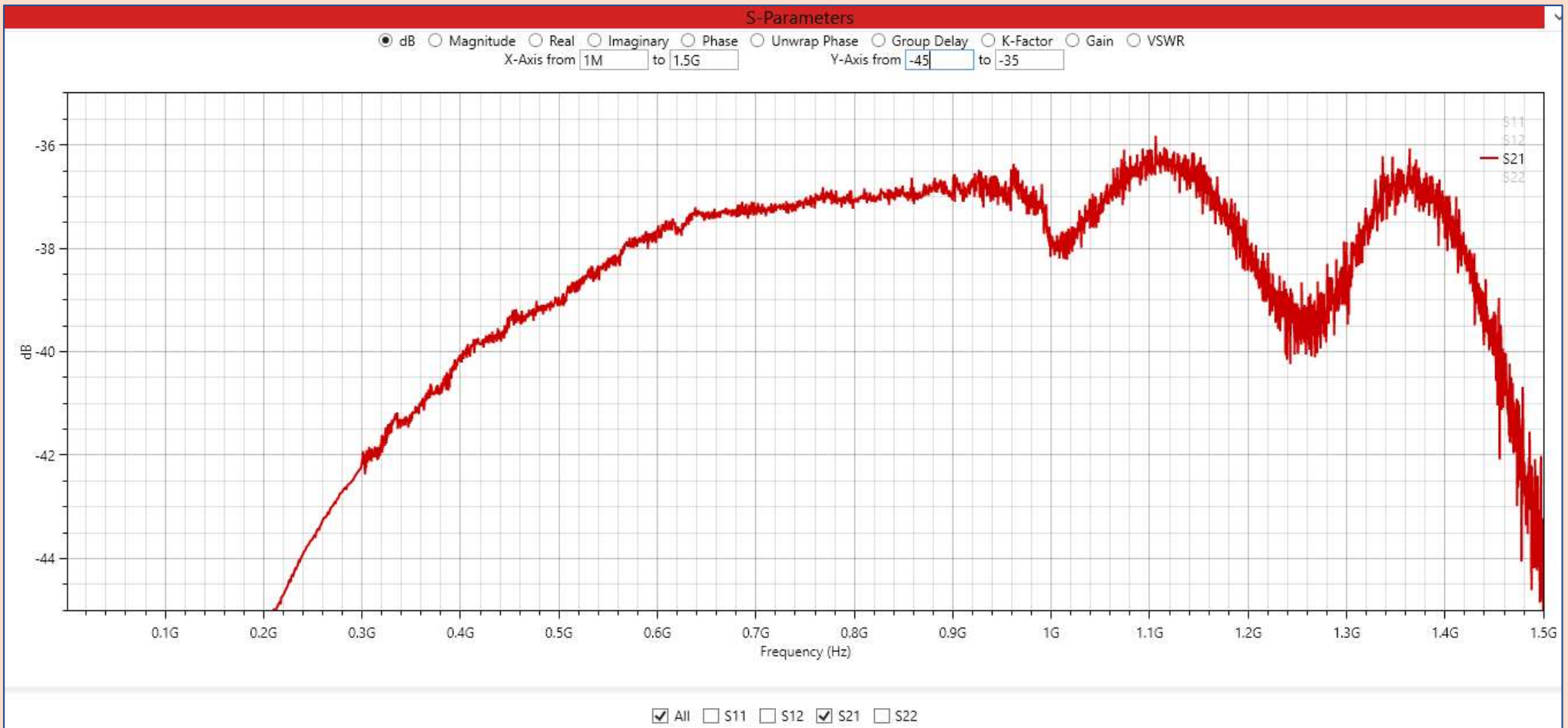
RF Coaxial Directional Coupler 400 - 470MHz
40dB 500 Watt





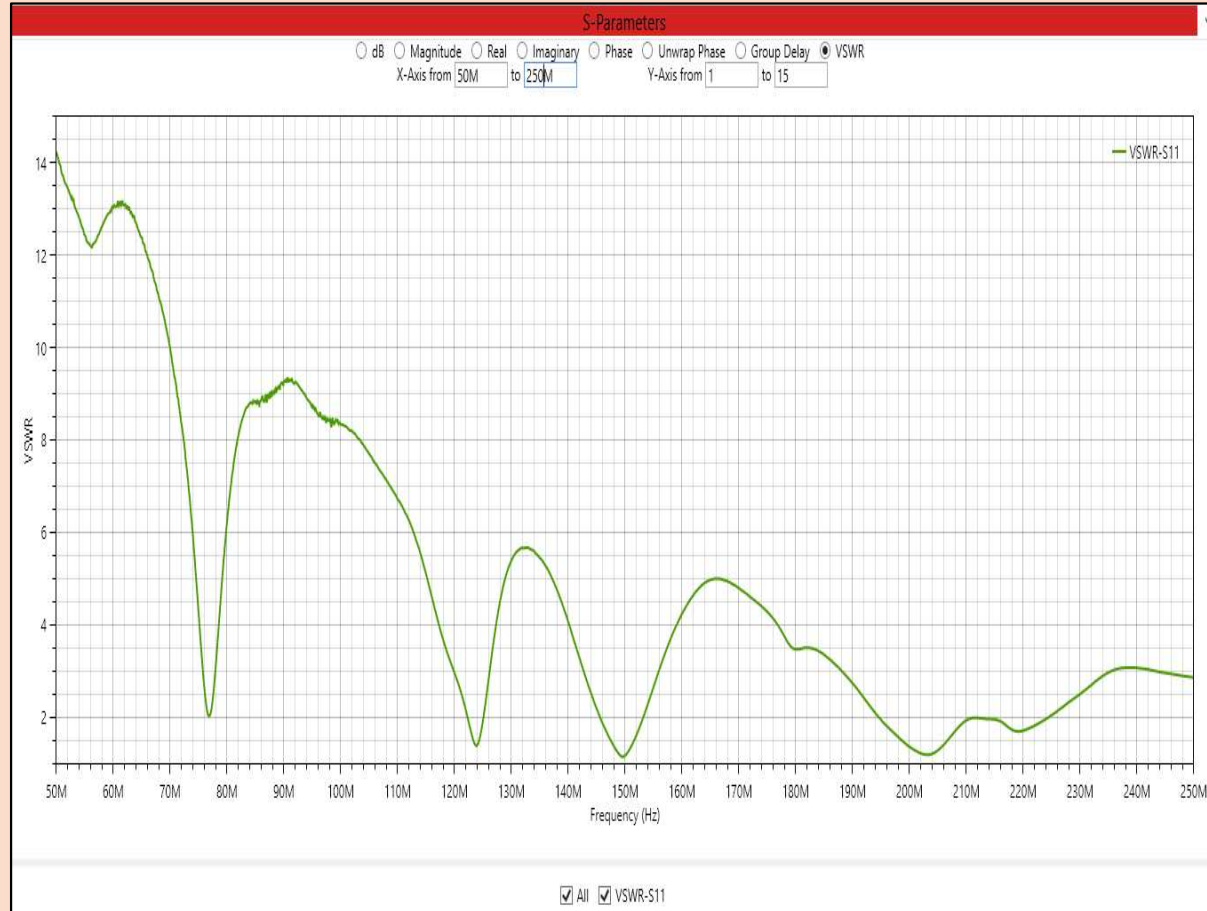
**RF Coaxial Directional Coupler 400 - 470MHz
40dB 500 Watt**





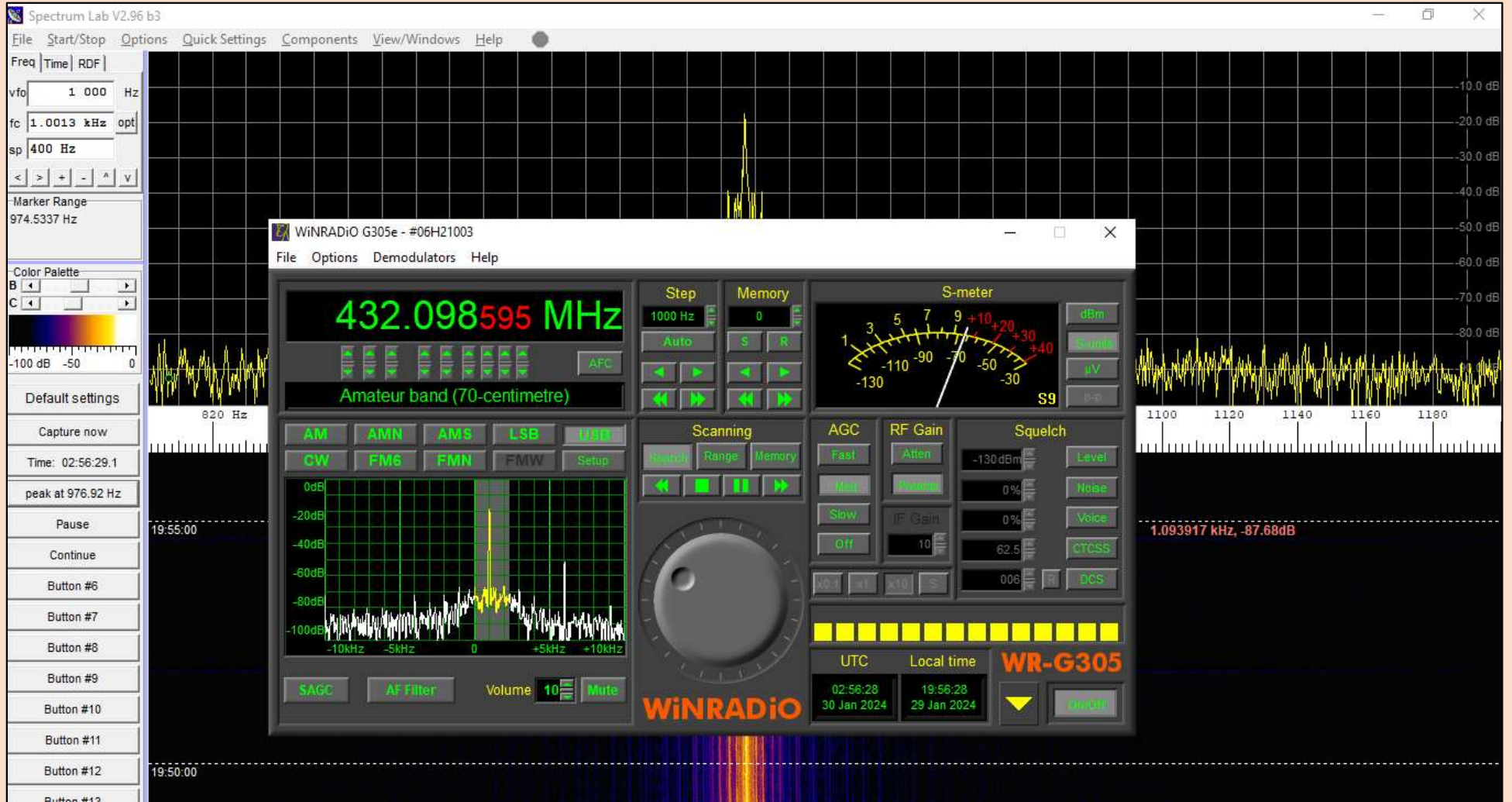
**RF Coaxial Directional Coupler 400 - 470MHz
40dB 500 Watt**



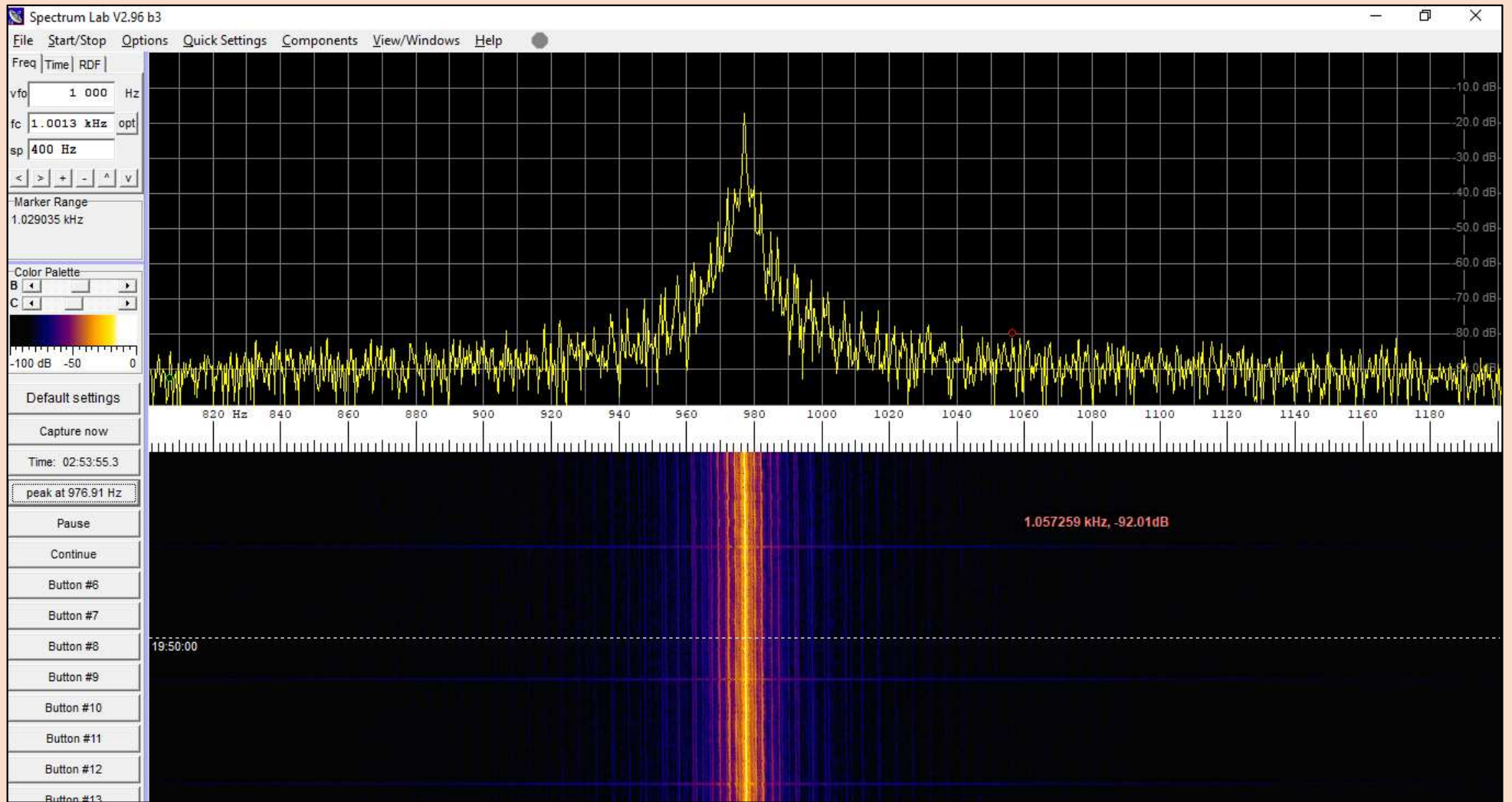


50 cm Vertical Antenna



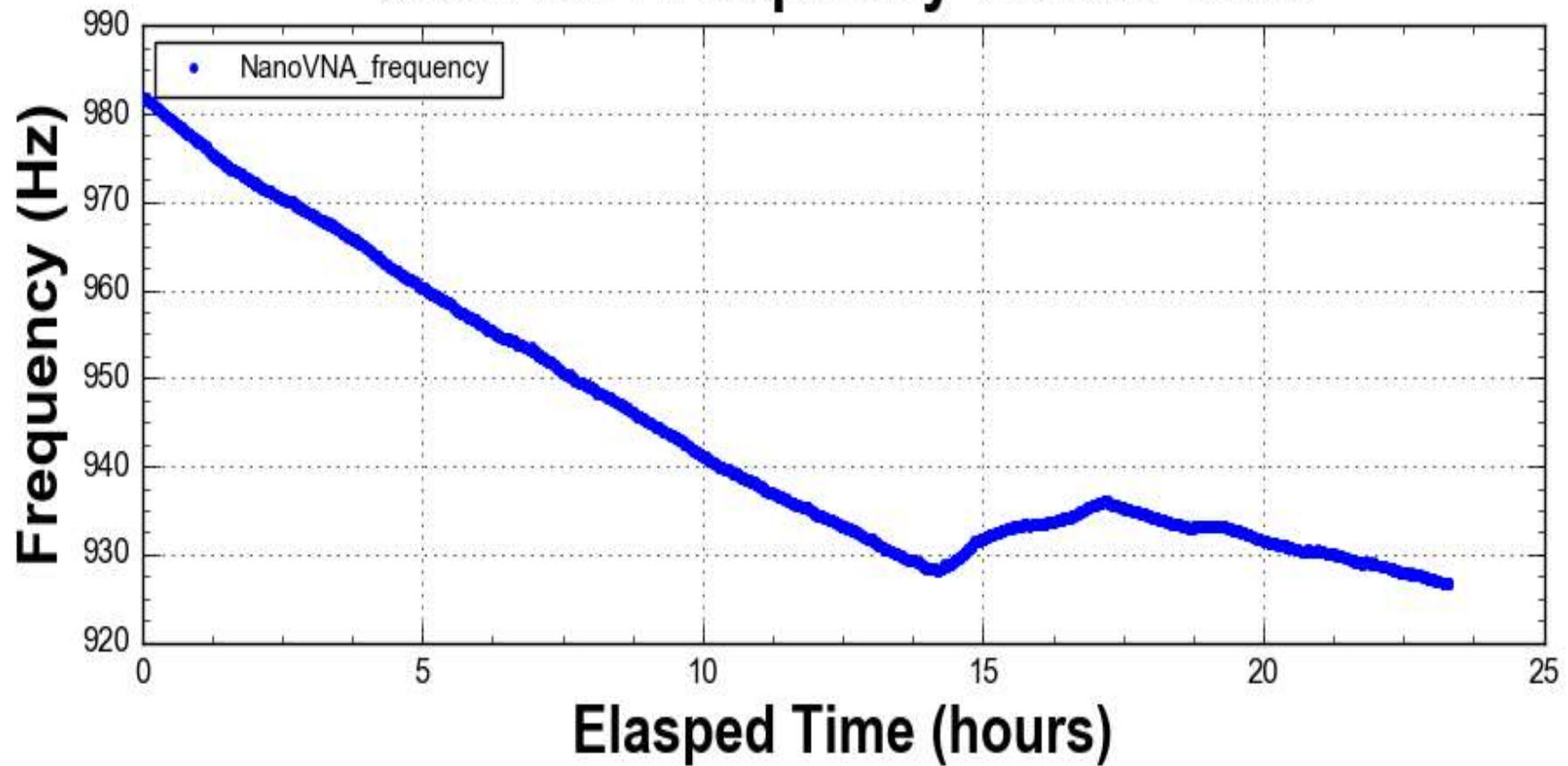


NanoVNA RF Signal Generator



NanoVNA RF Signal Generator

NanoVNA Frequency versus Time



NanoVNA RF Signal Generator @ 432 MHZ



Don has pursued a lifelong interest in science and engineering beginning as a youth in western Canada. He received his first amateur radio license at the age of 15 while attending high school in Edmonton, Alberta, Canada.

Don continued this interest and graduated from the University of Alberta receiving a Bachelor Science in Electrical Engineering. During the last 41 years he has worked in energy industry in Canada, the United States, Europe, South America, the Middle East and the Far East.

His technical area of interest lead to publications of nuclear magnetic resonance applied to reservoir characterization. He was granted numerous US patents for developments of pressure core technology. Don was honored to be the Distinguish Speaker at the Harvard University Energy Conference. During 2020, Don received the prestigious Hart Energy Innovators Award.

I obtained an amateur radio license in 1967 as VE6ANW, a year later achieved the advanced certification as VE6RI. I initially pursued 20-meter DX working. Soon after, I became interested in weak signal UHF propagation. After more than 50 years have passed, I have rejoined the amateur radio ranks and currently active on 20 meters and VHF / UHF bands.



Cable Test Experiment

RG 58a/u

Determine Cable Quality

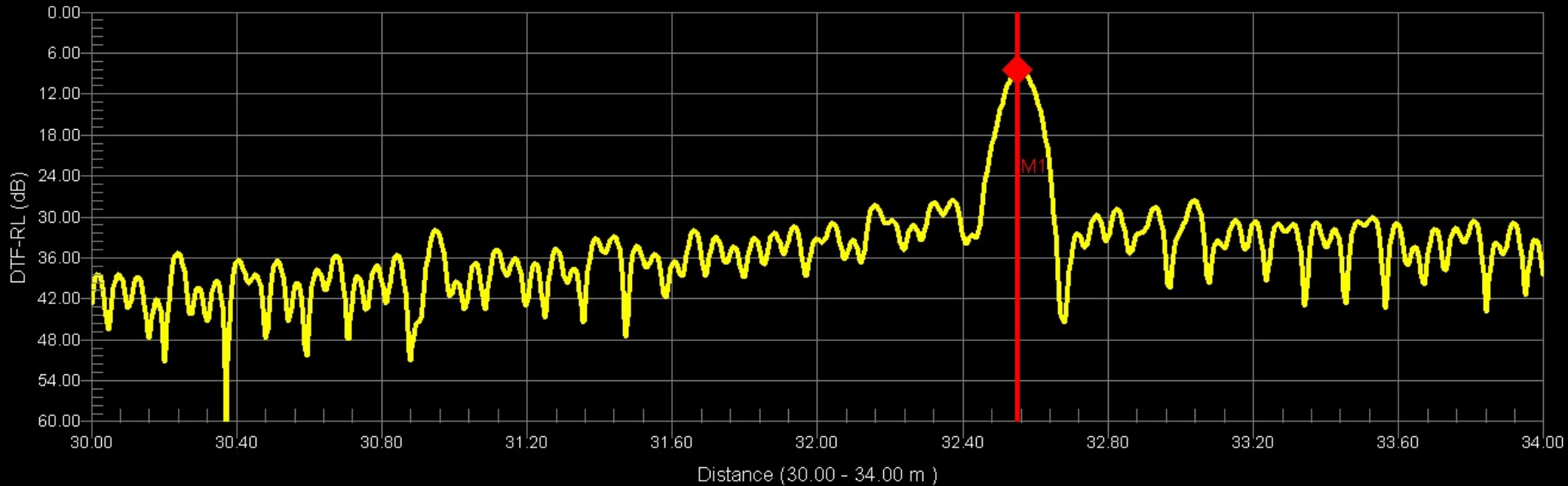
Cable A and **Cable B**



DTF Return Loss

Instrument File

M1 8.42 dB @ 32.55 m



Resolution: 1033
Std: None
Date: Sunday, March 17, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 4:14:05 PM
Serial: 1520069

RF Immunity: High
Freq: Start/Stop: 2.0 MHz/2000.0 MHz
Ins. Loss: 0.594 dB/m
Prop.Vel: 0.730

SiteMaster S331L

DTF

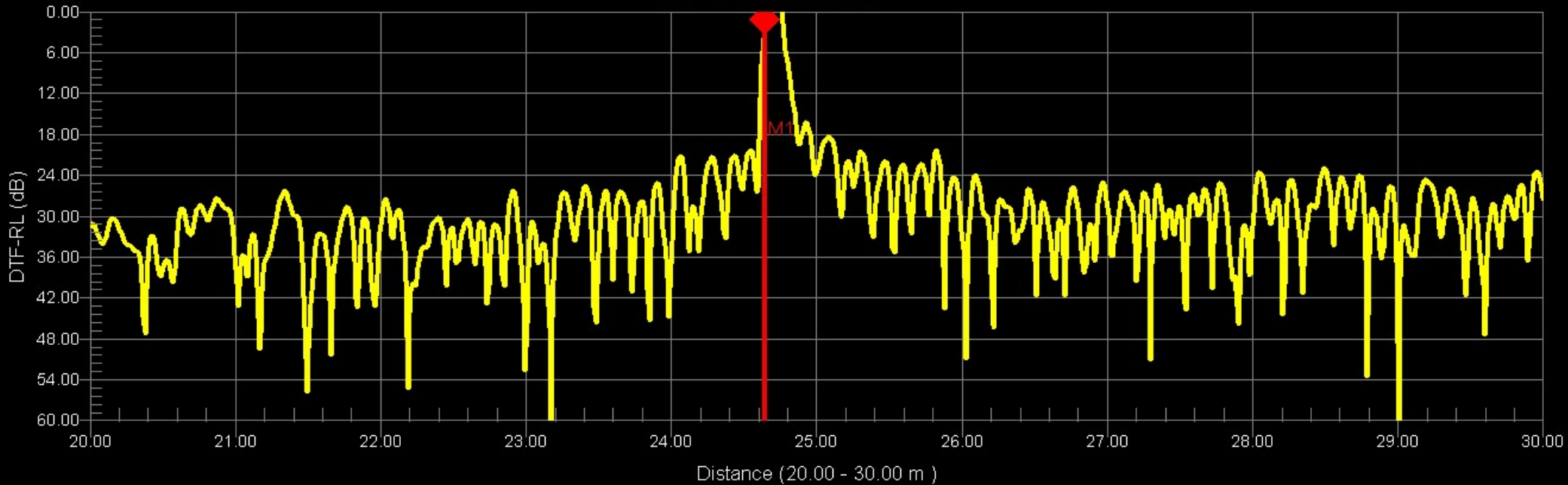
Cable A



DTF Return Loss

Instrument File

M1 1.14 dB @ 24.64 m



Resolution: 1033
Std: None
Date: Sunday, March 17, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 3:48:31 PM
Serial: 1520069

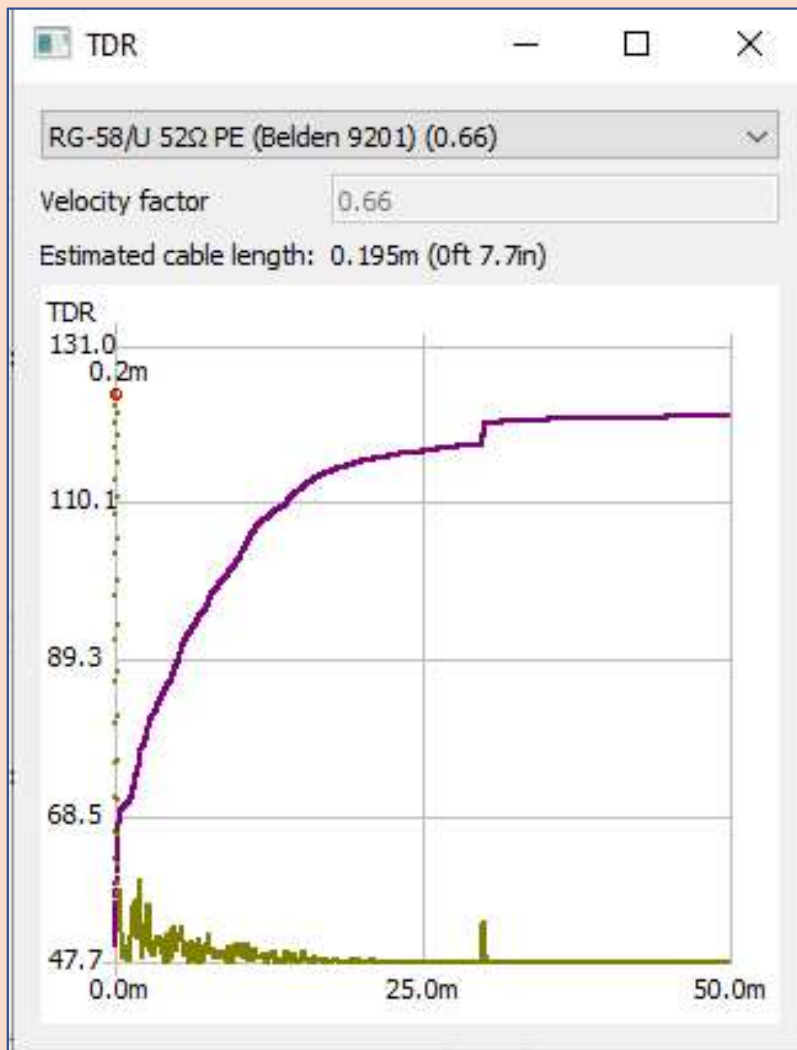
RF Immunity: High
Freq: Start/Stop: 2.0 MHz/2000.0 MHz
Ins. Loss: 0.594 dB/m
Prop.Vel: 0.730

SiteMaster S331L

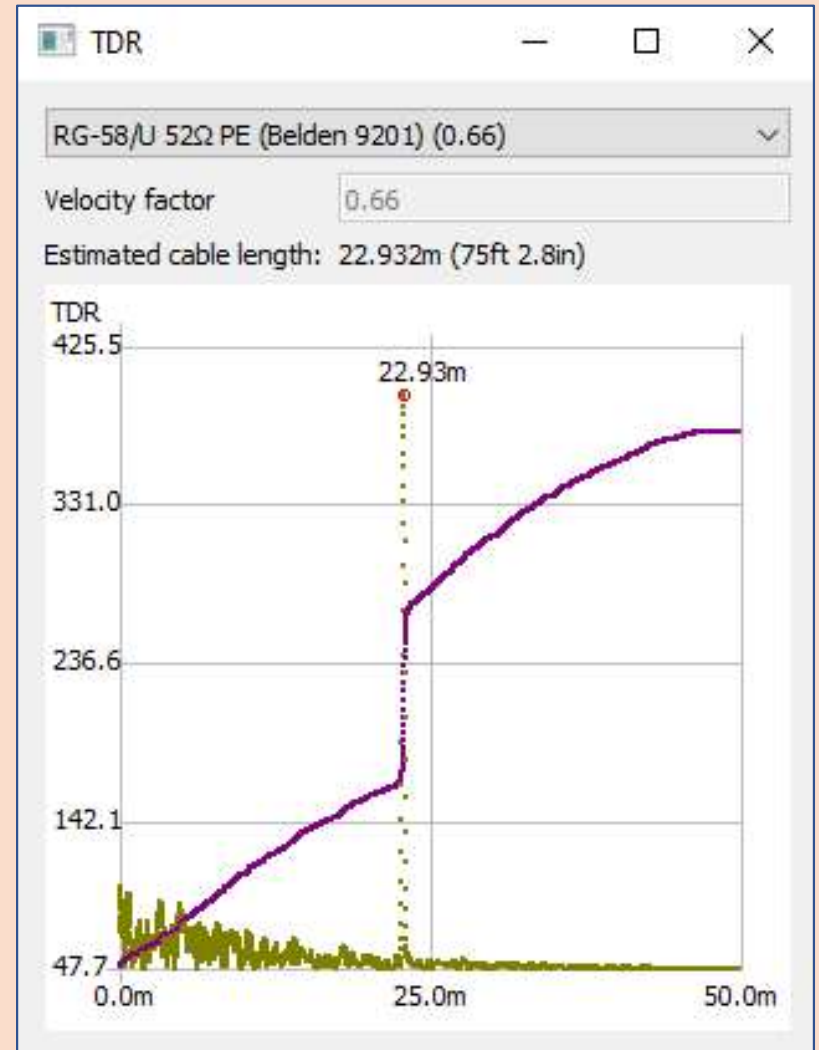
DTF

Cable B





nanoVNA Cable A



nanoVNA Cable B

Marker 1

Frequency: 143.997 MHz	VSWR: 1.057
Impedance: 52.3+j1.65 Ω	Return loss: -31.144 dB
Series L: 1.825 nH	Quality factor: 0.032
Series C: -669.39 pF	S11 Phase: 34.68°
Parallel R: 52.358 Ω	S21 Gain: -106.976 dB
Parallel X: 1.8332 μH	S21 Phase: -171.60°

Marker 2

Frequency: 431.970 MHz	VSWR: 1.179
Impedance: 47.1+j7.46 Ω	Return loss: -21.704 dB
Series L: 2.7478 nH	Quality factor: 0.158
Series C: -49.403 pF	S11 Phase: 106.88°
Parallel R: 48.277 Ω	S21 Gain: -75.617 dB
Parallel X: 112.33 nH	S21 Phase: -127.81°

Marker 3

Frequency: 900.050 MHz	VSWR: 2.097
Impedance: 25.6+j11.7 Ω	Return loss: -9.012 dB
Series L: 2.0717 nH	Quality factor: 0.458
Series C: -15.093 pF	S11 Phase: 145.57°
Parallel R: 30.938 Ω	S21 Gain: -70.063 dB
Parallel X: 11.939 nH	S21 Phase: -103.00°

S11

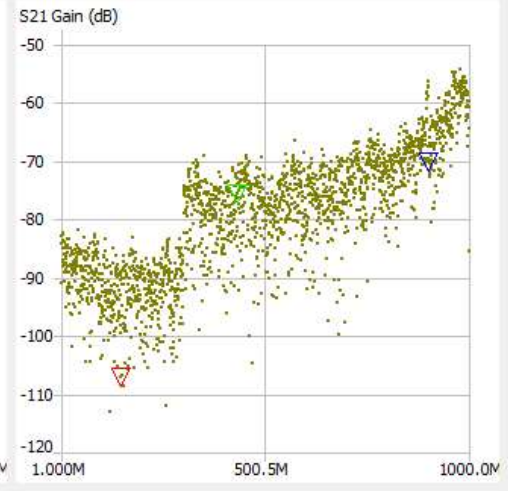
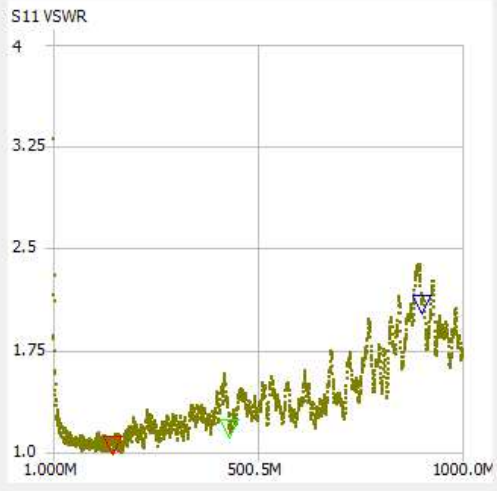
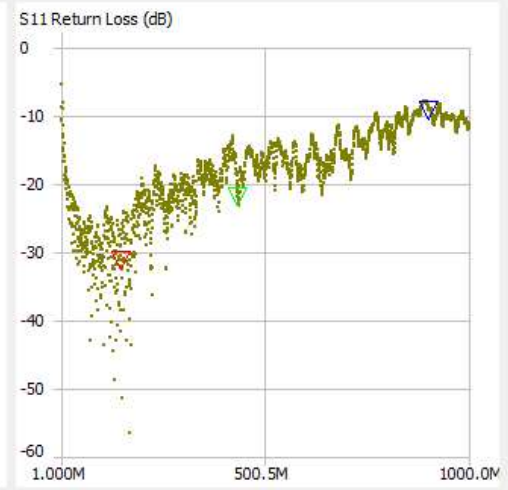
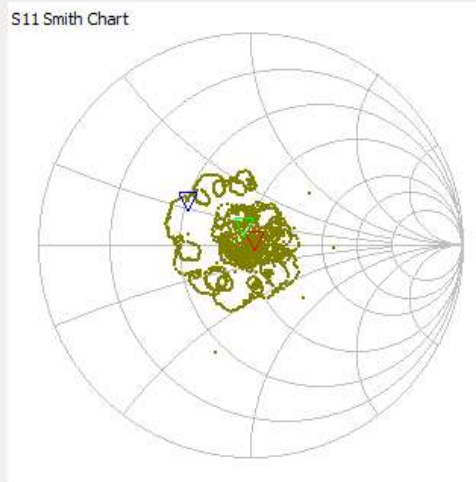
Min VSWR: 1.003 @ 166.758MHz
Return loss: -56.441 dB

S21

Min gain: -112.943 dB @ 118.267MHz
Max gain: -54.060 dB @ 979.218MHz

Analysis ...

Cable A



nanoVNA

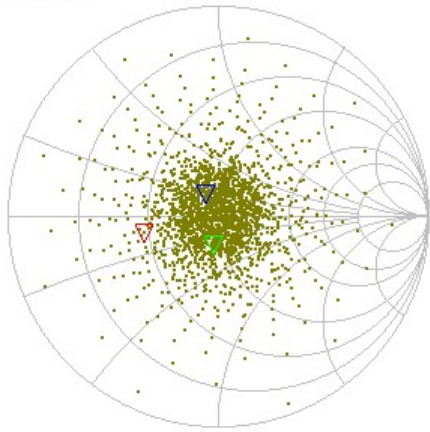
Cable A



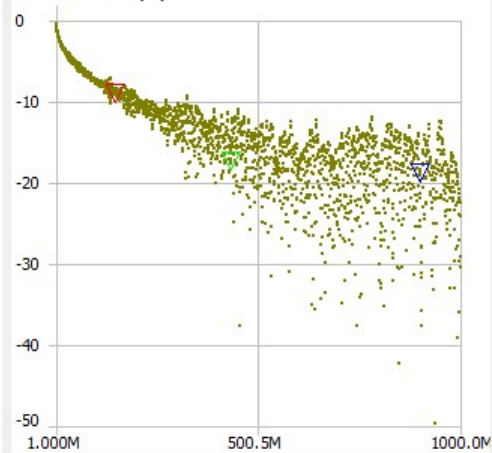
Marker 1	
Frequency: 143.997 MHz	VSWR: 2.119
Impedance: 23.9-j4.67 Ω	Return loss: -8.904 dB
Series L: -5.1646 nH	Quality factor: 0.196
Series C: 236.53 pF	S11 Phase: -166.24°
Parallel R: 24.778 Ω	S21 Gain: -91.139 dB
Parallel X: 8.7344 pF	S21 Phase: -141.83°
Marker 2	
Frequency: 431.970 MHz	VSWR: 1.321
Impedance: 46.3-j12.9 Ω	Return loss: -17.186 dB
Series L: -4.755 nH	Quality factor: 0.279
Series C: 28.548 pF	S11 Phase: -98.44°
Parallel R: 49.879 Ω	S21 Gain: -77.554 dB
Parallel X: 2.0599 pF	S21 Phase: -47.21°
Marker 3	
Frequency: 900.050 MHz	VSWR: 1.261
Impedance: 43.8+j8.91 Ω	Return loss: -18.764 dB
Series L: 1.5763 nH	Quality factor: 0.204
Series C: -19.837 pF	S11 Phase: 119.42°
Parallel R: 45.608 Ω	S21 Gain: -72.829 dB
Parallel X: 39.621 nH	S21 Phase: -132.53°
S11	
Min VSWR: 1.007 @ 937.160MHz	
Return loss: -49.621 dB	
S21	
Min gain: -112.694 dB @ 148.450MHz	
Max gain: -56.325 dB @ 961.405MHz	
Analysis ...	

Cable B

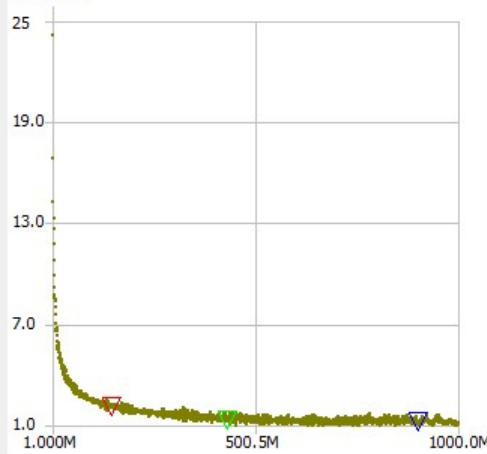
S11 Smith Chart



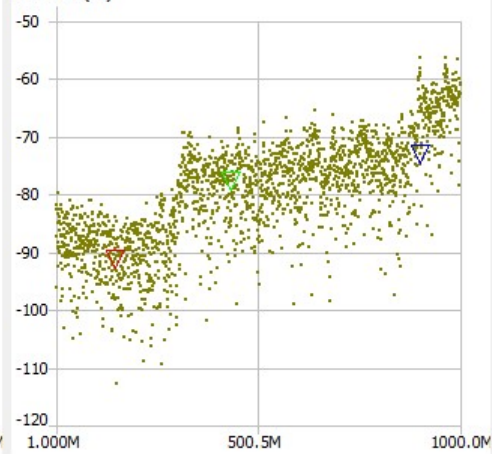
S11 Return Loss (dB)



S11 VSWR



S21 Gain (dB)



nanoVNA

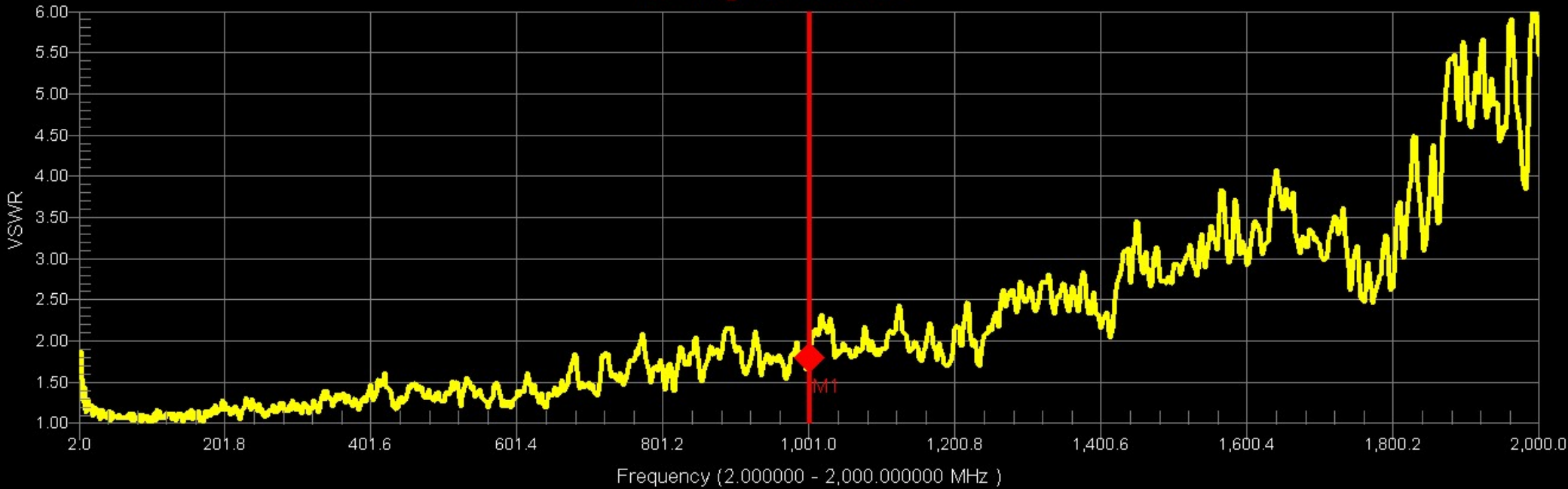
Cable B



VSWR

Instrument File

M1 1.80 @ 1,001.000100 MHz



Resolution: 1033
Std: None
Date: Sunday, March 17, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 3:37:20 PM
Serial: 1520069

RF Immunity: High

SiteMaster S331L

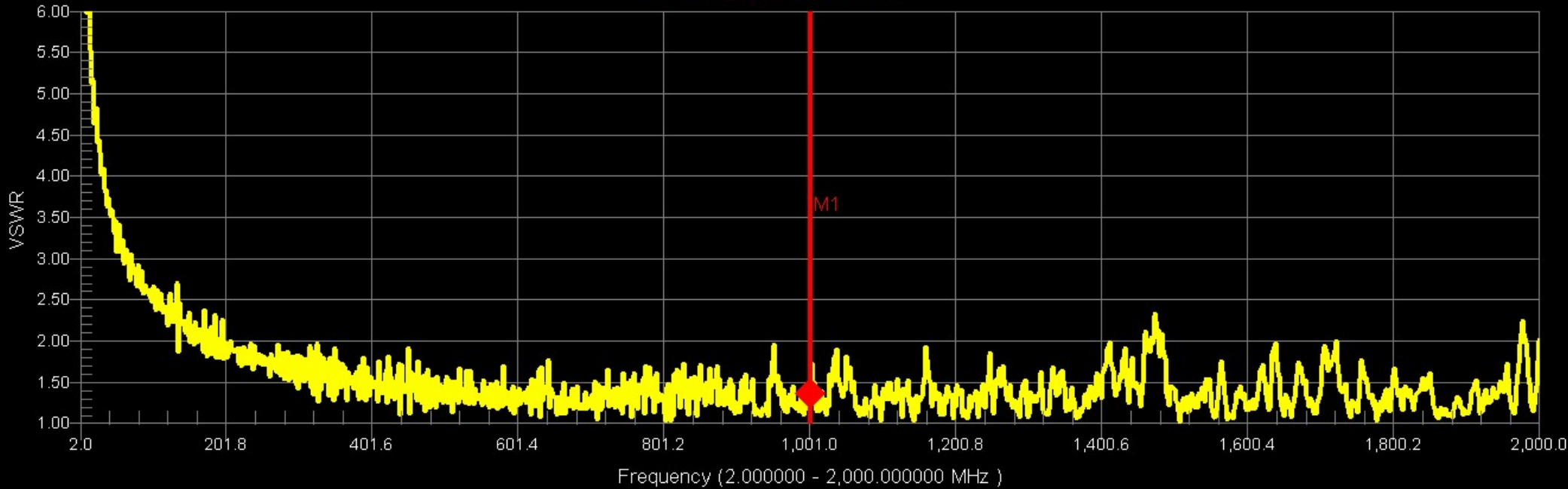
Cable A



VSWR

Instrument File

M1 1.36 @ 1,001.000100 MHz



Resolution: 1033
Std: None
Date: Sunday, March 17, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 3:41:30 PM
Serial: 1520069

RF Immunity: High

SiteMaster S331L

Cable B



Benchmark Tests

nanoVNA_H

and

Anristu SiteMaster S331L





Anritsu SiteMaster S331L

2 MHz – 4 GHz

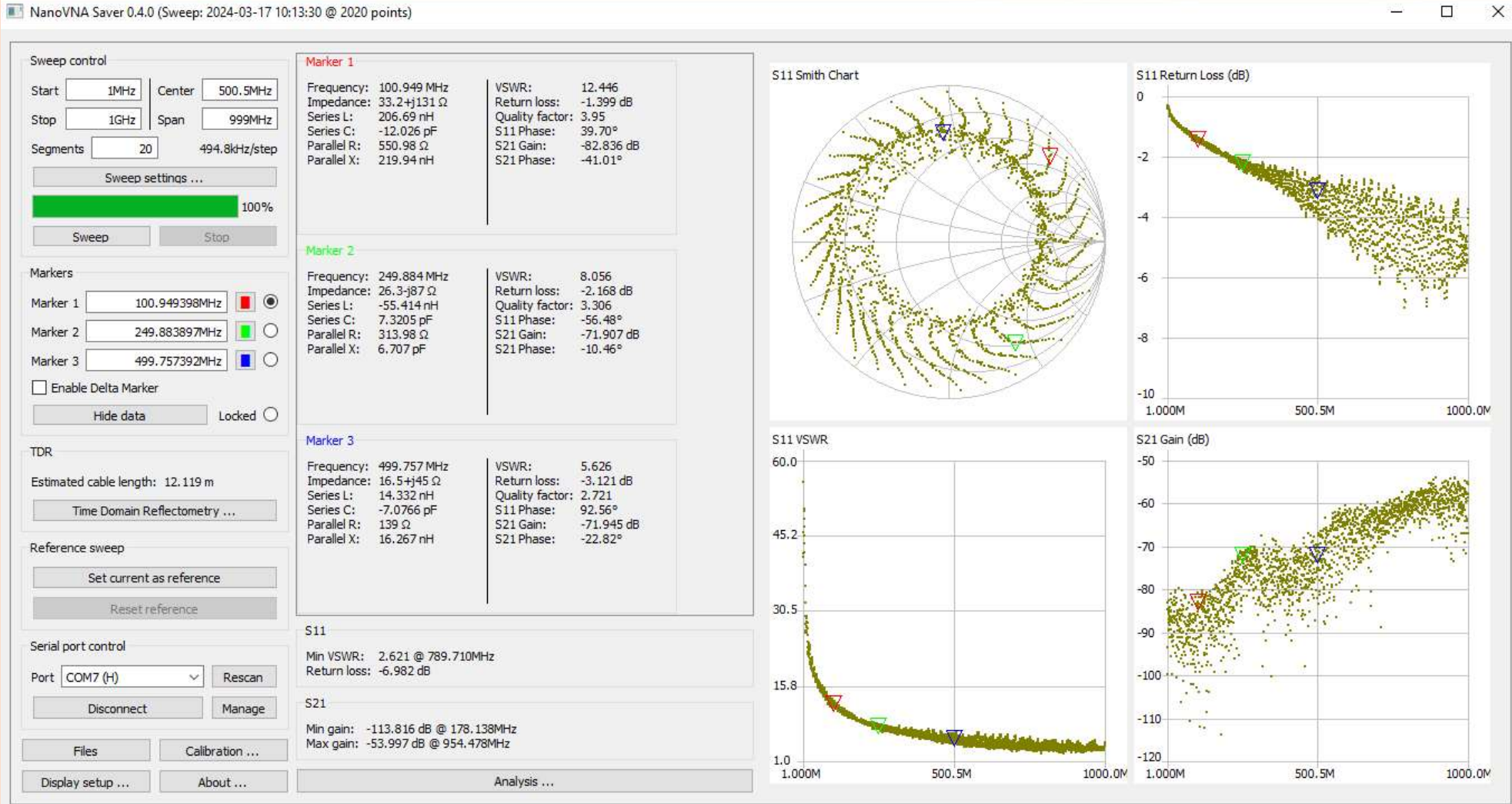
\$ 8500



NanoVNA H

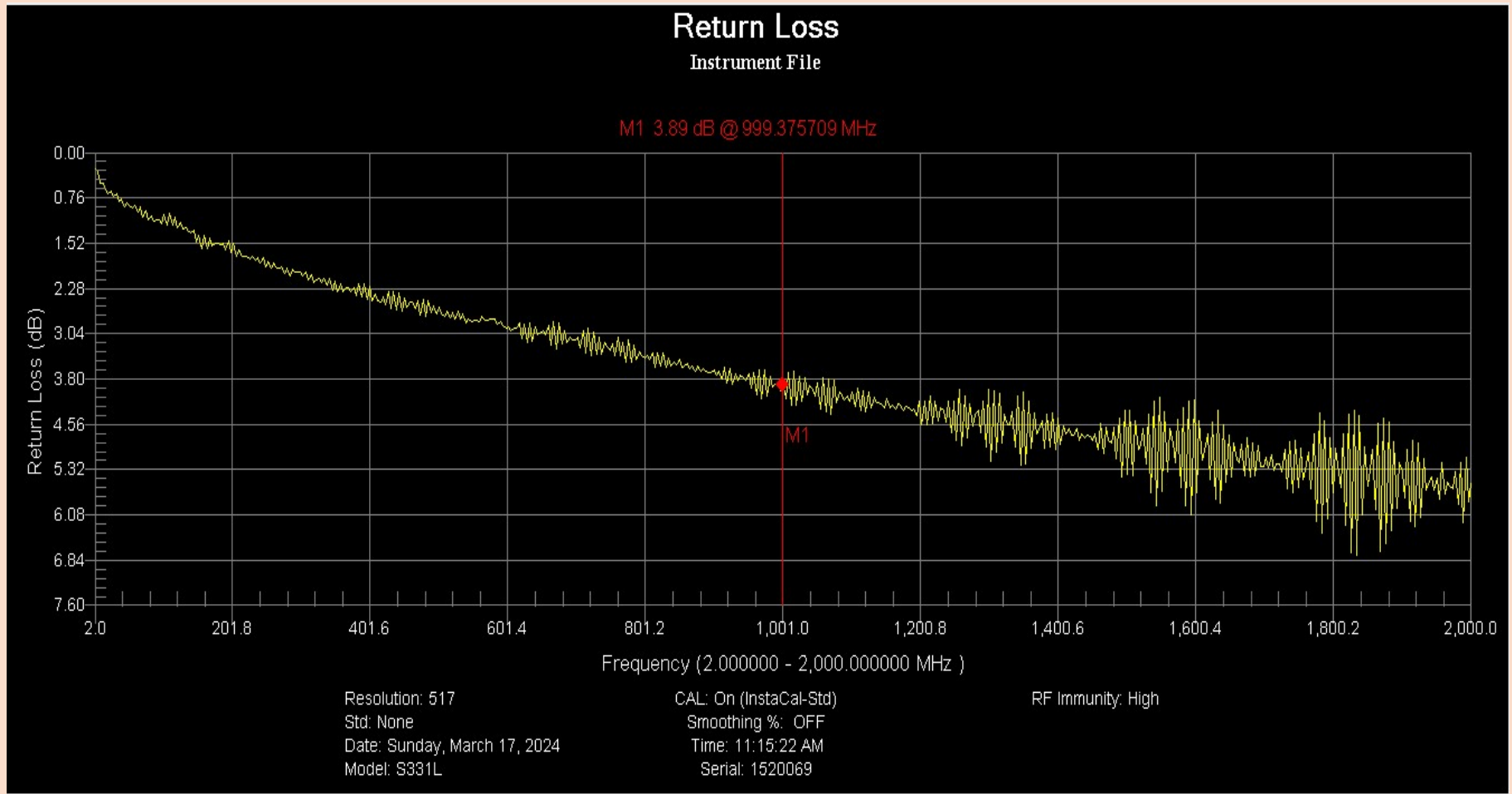
0.5 MHz - 1.5 GHz

\$ 75



nanoVNA_H LMR 400 15 m (50 ft) Shorted

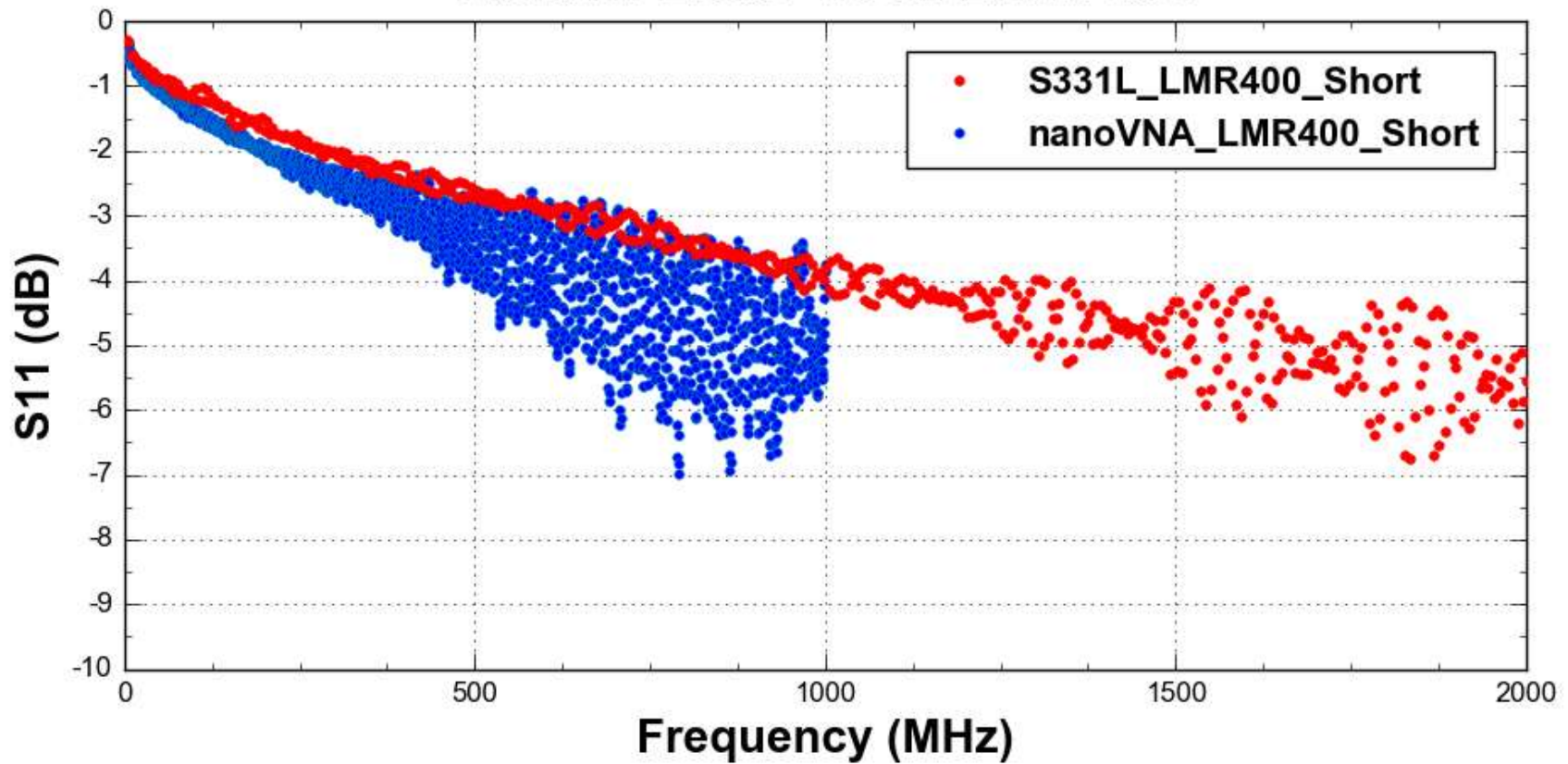




SiteMaster S331L LMR 400 15 m (50 ft) Shorted

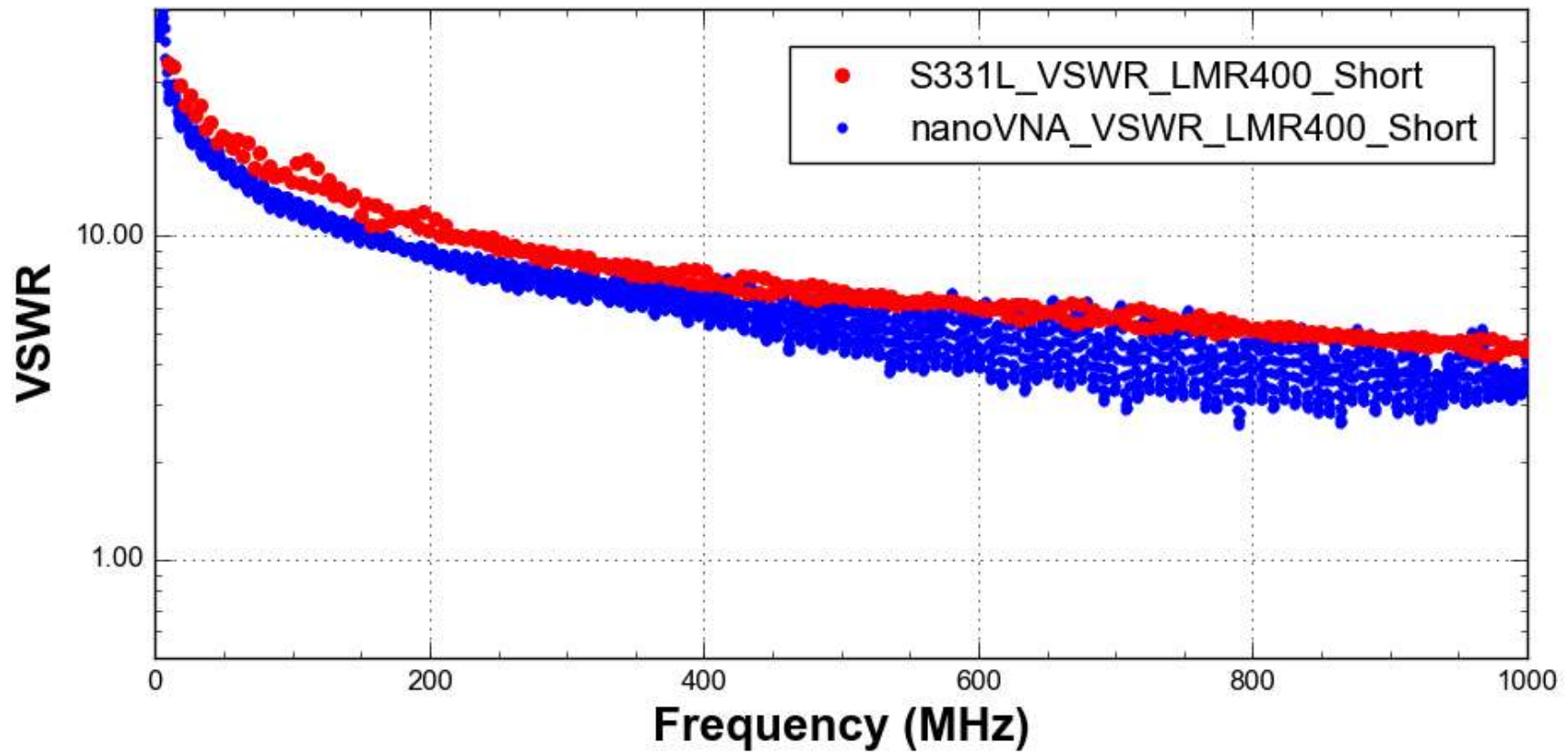


Return Loss 15 m LMR 400



S11 nanoVNA_H and SiteMaster S331L

VSWR 15 m LMR 400



S11 / VSWR nanoVNA_H and SiteMaster S331L

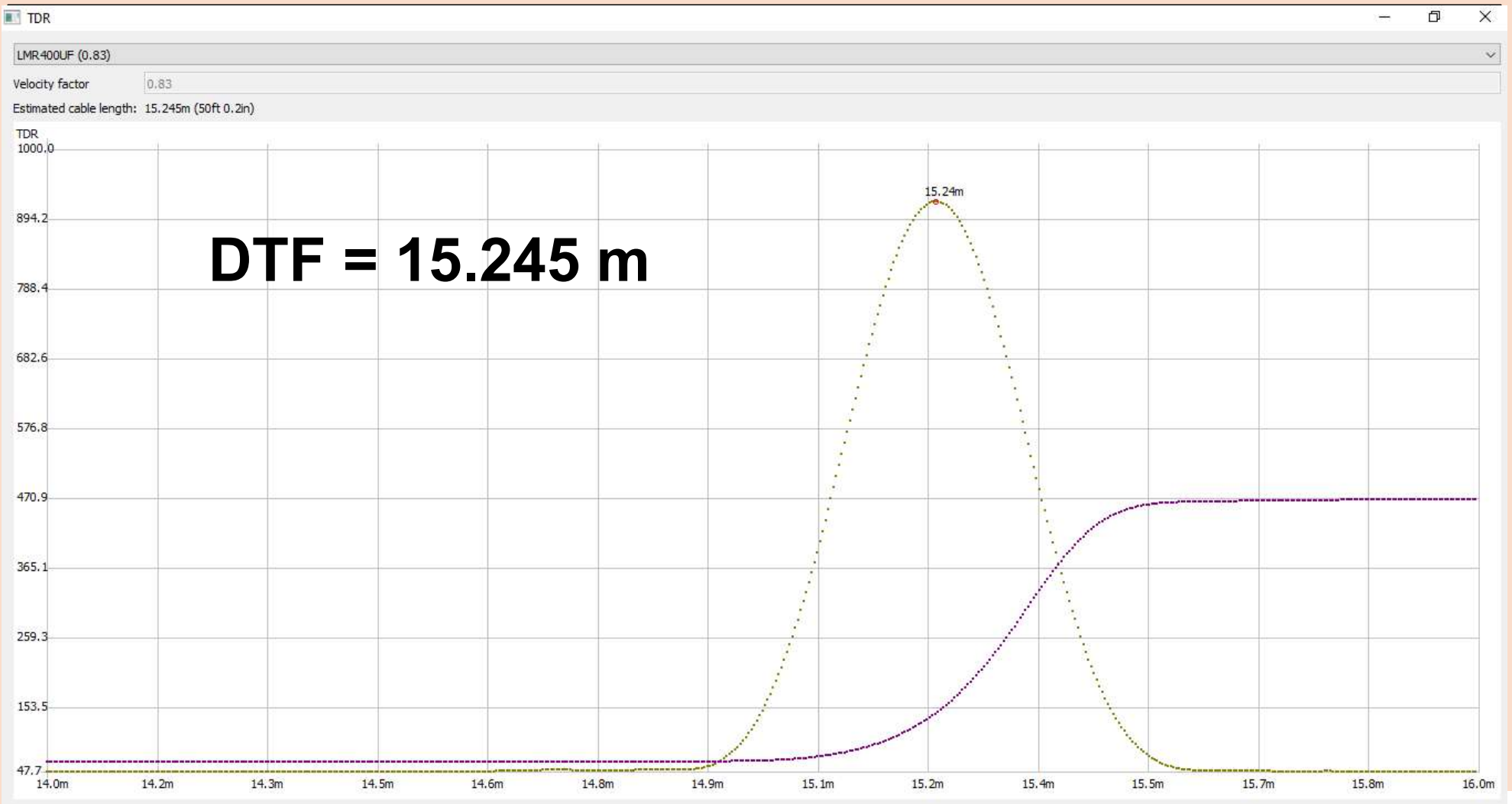
Benchmark Tests

Distance to Fault

nanoVNA H

Anristu SiteMaster S331L





nanoVNA_H LMR 400 15 m (50 ft) Shorted

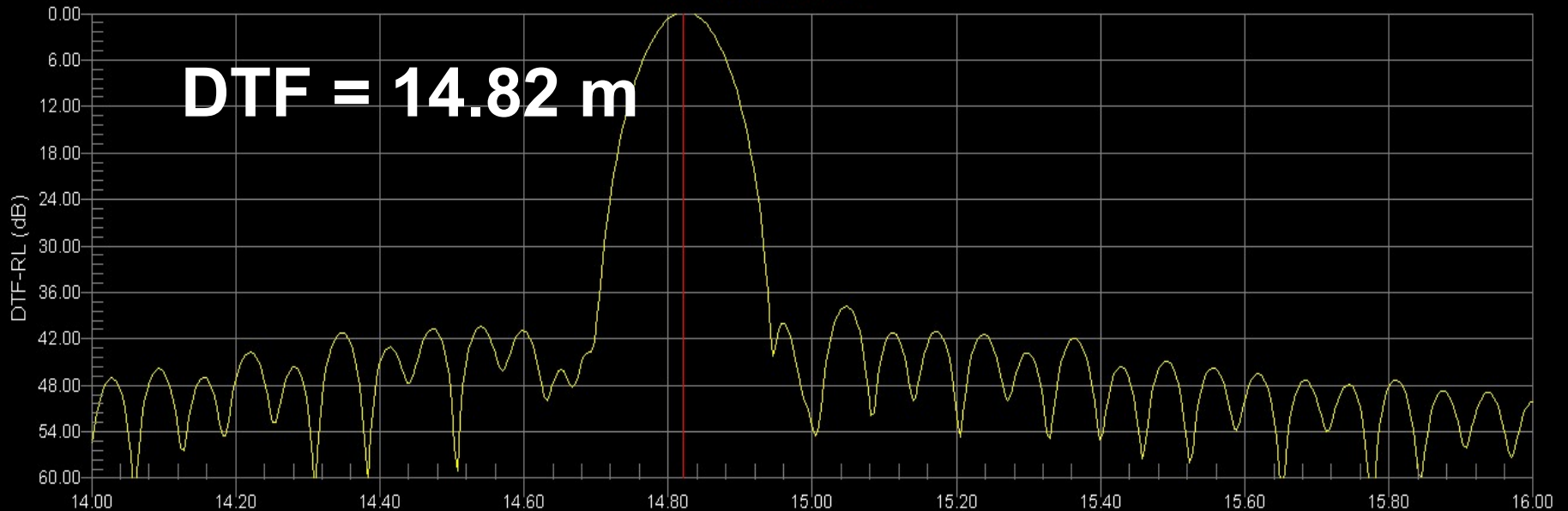


DTF Return Loss

Instrument File

M1 -0.21 dB @ 14.82 m

DTF = 14.82 m



Distance (14.00 - 16.00 m)

Resolution: 517
Std: None
Date: Sunday, March 17, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 12:39:10 PM
Serial: 1520069

RF Immunity: High
Freq: Start/Stop: 2.0 MHz/2000.0 MHz
Ins. Loss: 0.135 dB/m
Prop.Vel: 0.850

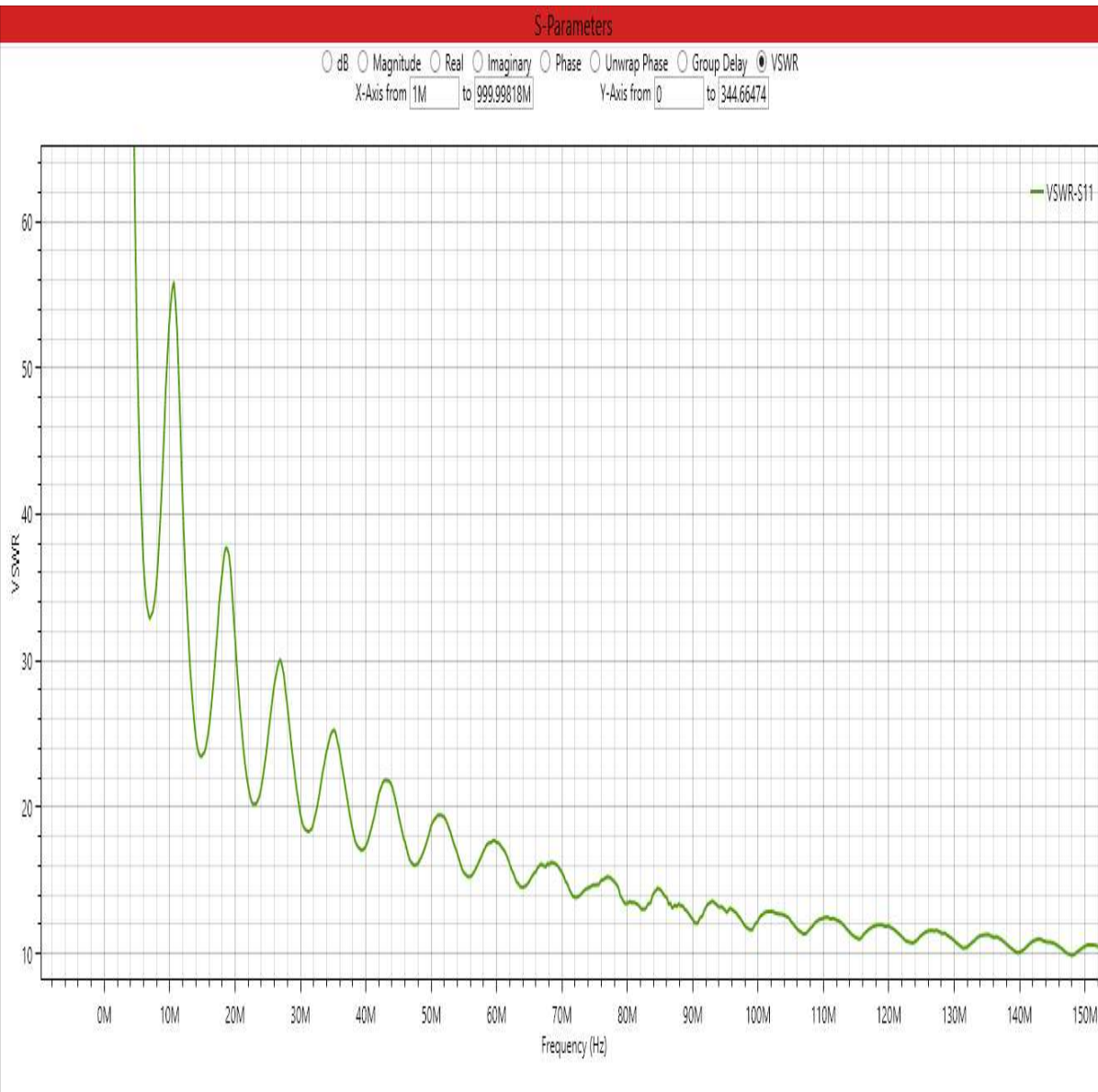
SiteMaster S331L LMR 400 15 m (50 ft) Shorted



Some VNAs are capable of **using inverse Fourier transforms** to convert swept frequency measurements into the time domain. In this way, data displayed in the time domain allows the VNA to be used to find problems in cables and connections by detecting the locations of impedance mismatches or discontinuities as the signal passes through the DUT.

For time domain measurements, the ability to resolve two signals is inversely proportional to the measured frequency span. Therefore, the wider the frequency span, the greater the ability the VNA has to distinguish between closely spaced discontinuities. The maximum frequency span is set by the user and may be defined by either the frequency range of the VNA or the viable bandwidth of the DUT.





Sweep analysis

Select analysis

Analysis type: Resonance analysis

Run analysis

Run automatically

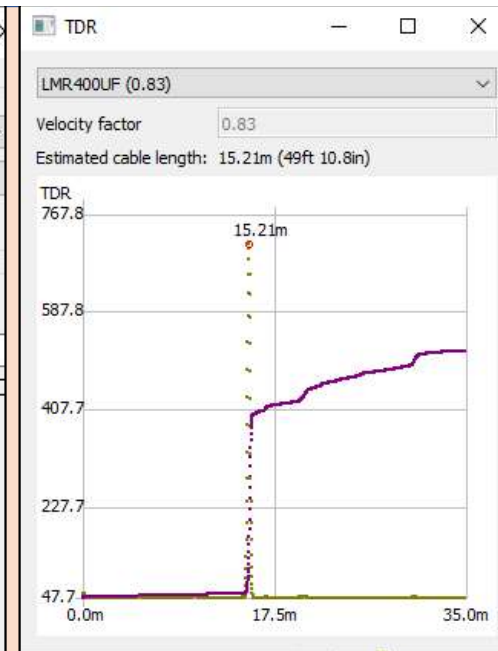
Analysis

Settings

Description: Resonance

Results

Resonance	3.96879MHz	(959m-j8.58 Ω)
Resonance	8.42198MHz	(334+j805 Ω)
Resonance	12.8752MHz	(1.44+j6.58 Ω)
Resonance	16.8336MHz	(370-j639 Ω)
Resonance	20.2972MHz	(2.08-j7.08 Ω)
Resonance	24.7504MHz	(933+j593 Ω)
Resonance	29.2035MHz	(2.14+j7.77 Ω)
Resonance	33.1619MHz	(238-j454 Ω)
Resonance	36.6255MHz	(2.61-j6.01 Ω)
Resonance	41.0787MHz	(1.05k-j37.5 Ω)
Resonance	45.5319MHz	(2.68+j8.78 Ω)
Resonance	48.9955MHz	(292+j448 Ω)
Resonance	52.9539MHz	(3.01-j4.93 Ω)
Resonance	57.4071MHz	(720-j357 Ω)
Resonance	60.8707MHz	(3.31-j9.23 Ω)
Resonance	65.3239MHz	(438+j427 Ω)
Resonance	69.7771MHz	(3.33+j5.44 Ω)
Resonance	73.7355MHz	(522-j385 Ω)
Resonance	77.1990MHz	(3.66-j8.43 Ω)
Resonance	81.6522MHz	(600+j306 Ω)
Resonance	86.1054MHz	(3.91+j6.41 Ω)
Resonance	90.0638MHz	(337-j350 Ω)
Resonance	93.5274MHz	(3.95-j7.48 Ω)
Resonance	97.9806MHz	(669+j66.5 Ω)

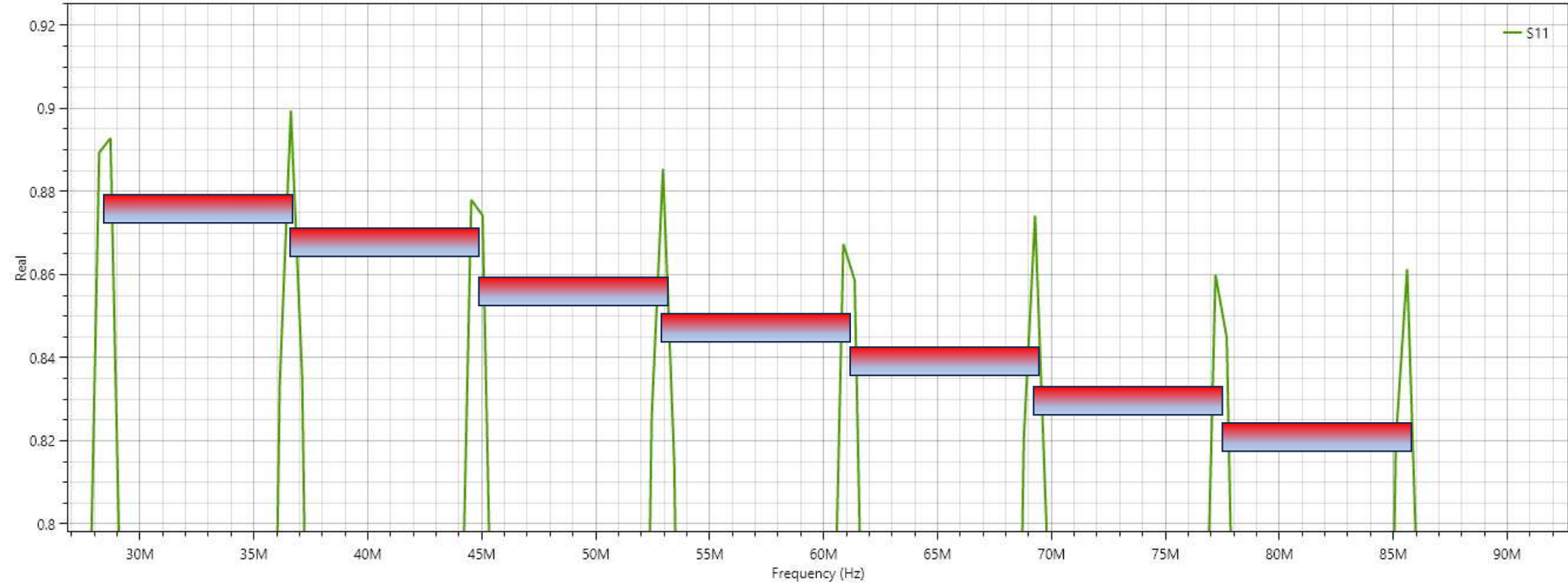


LMR 400 50 feet
Open Load
1 – 1000 MHz



S-Parameters

dB Magnitude Real Imaginary Phase Unwrap Phase Group Delay VSWR
X-Axis from 1M to 999.99918M Y-Axis from -0.93096 to 0.95574



All S11

Loading time < 1 sec

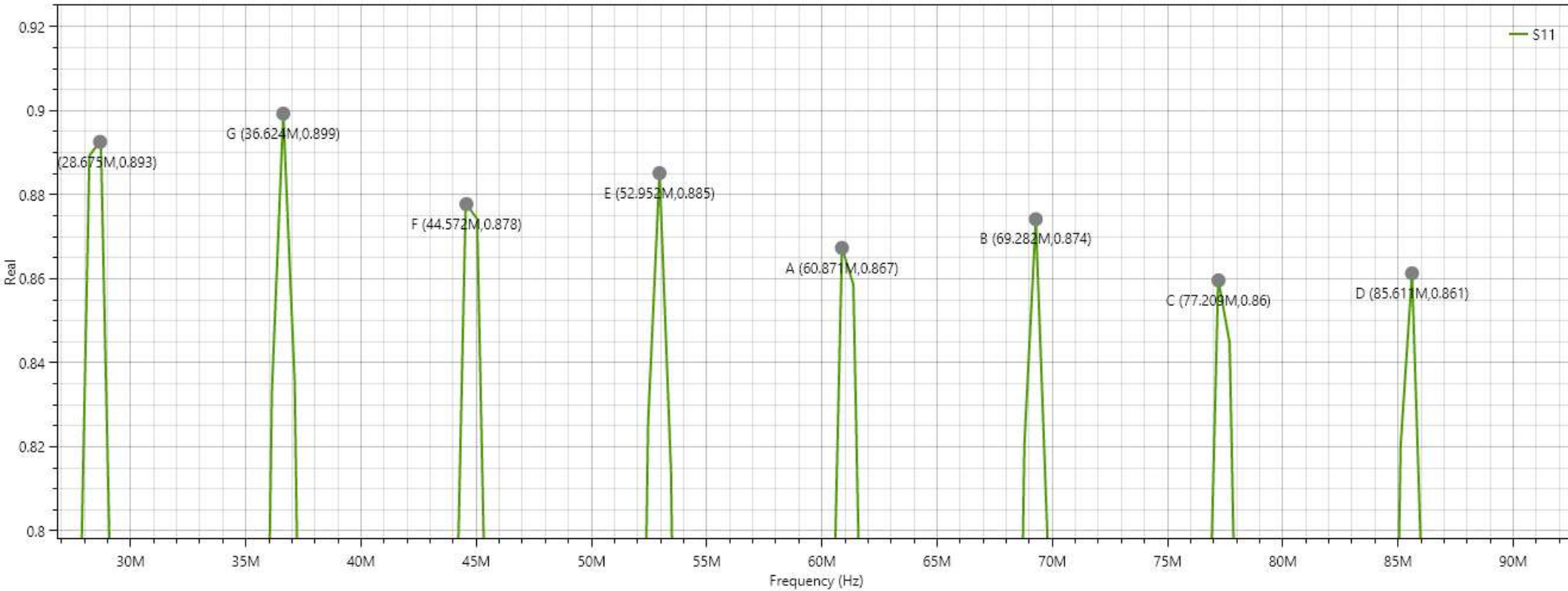
Points: 2,020 Step Size: 494.799kHz Ports: 1 Impedance: 50 Ω

LMR 400 50 feet Short Load 1 – 1000 MHz (detail presentation)



S-Parameters

dB Magnitude Real Imaginary Phase Unwrap Phase Group Delay VSWR
X-Axis from 1M to 999.99918M Y-Axis from -0.93096 to 0.95574



LMR 400 50 feet Short Load 1 – 1000 MHz (detail presentation)



LMR 400 50 feet Short Load nanoVNA Data

- Peaks are 8.2 MHz Spacing
- LMR 400 Velocity Factor = 0.83

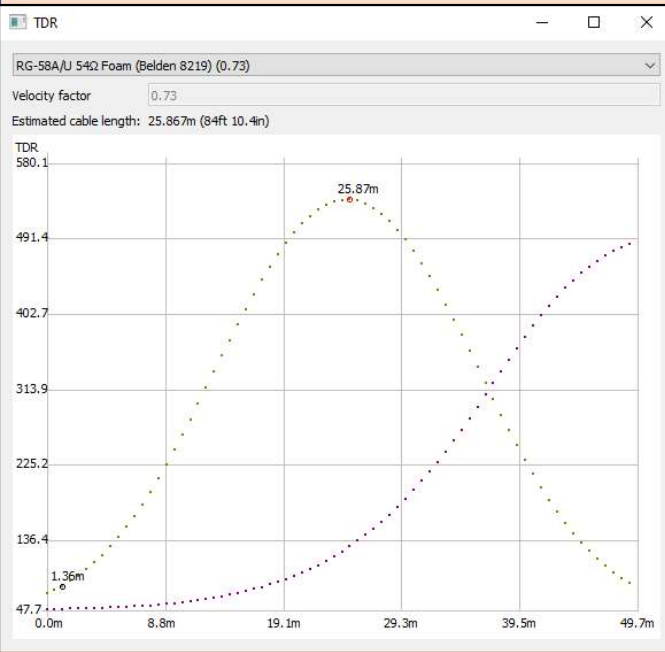
Since : $\lambda = c/f$

Then $\lambda = 0.83 * 3e8 / 8.2e6$

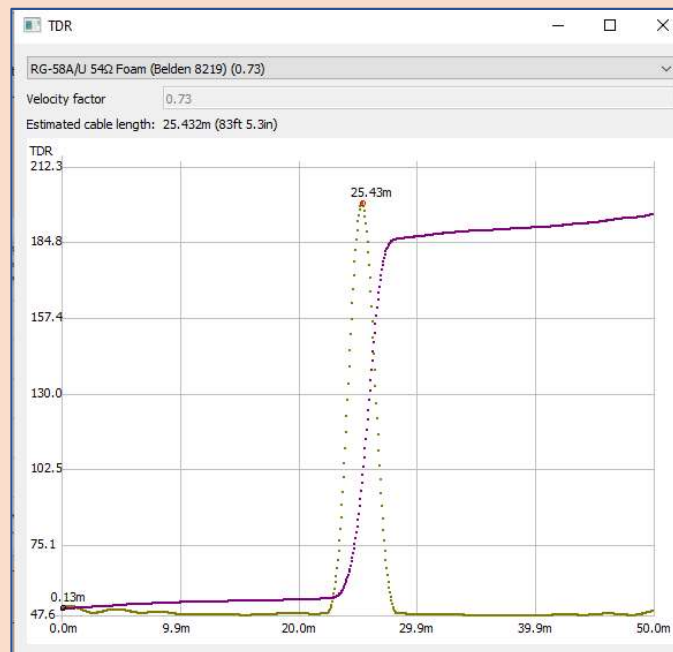
$\lambda = 30.365 \text{ m}$ (2 way length /time)

Thus Cable Length = 15.18 m (49.8 feet)

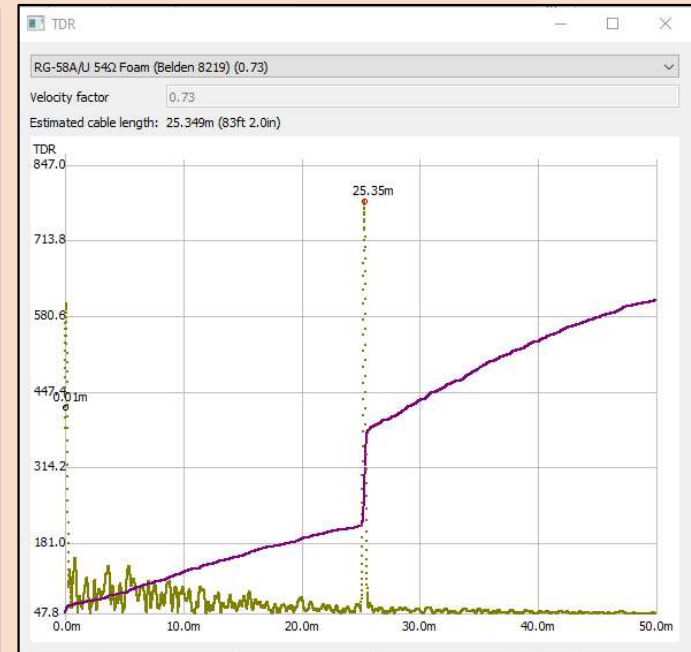
Fourier Transform and Spatial Resolution



0.1 – 10 MHz



0.1 – 100 MHz



0.1 – 1000 MHz

nanoVNA data

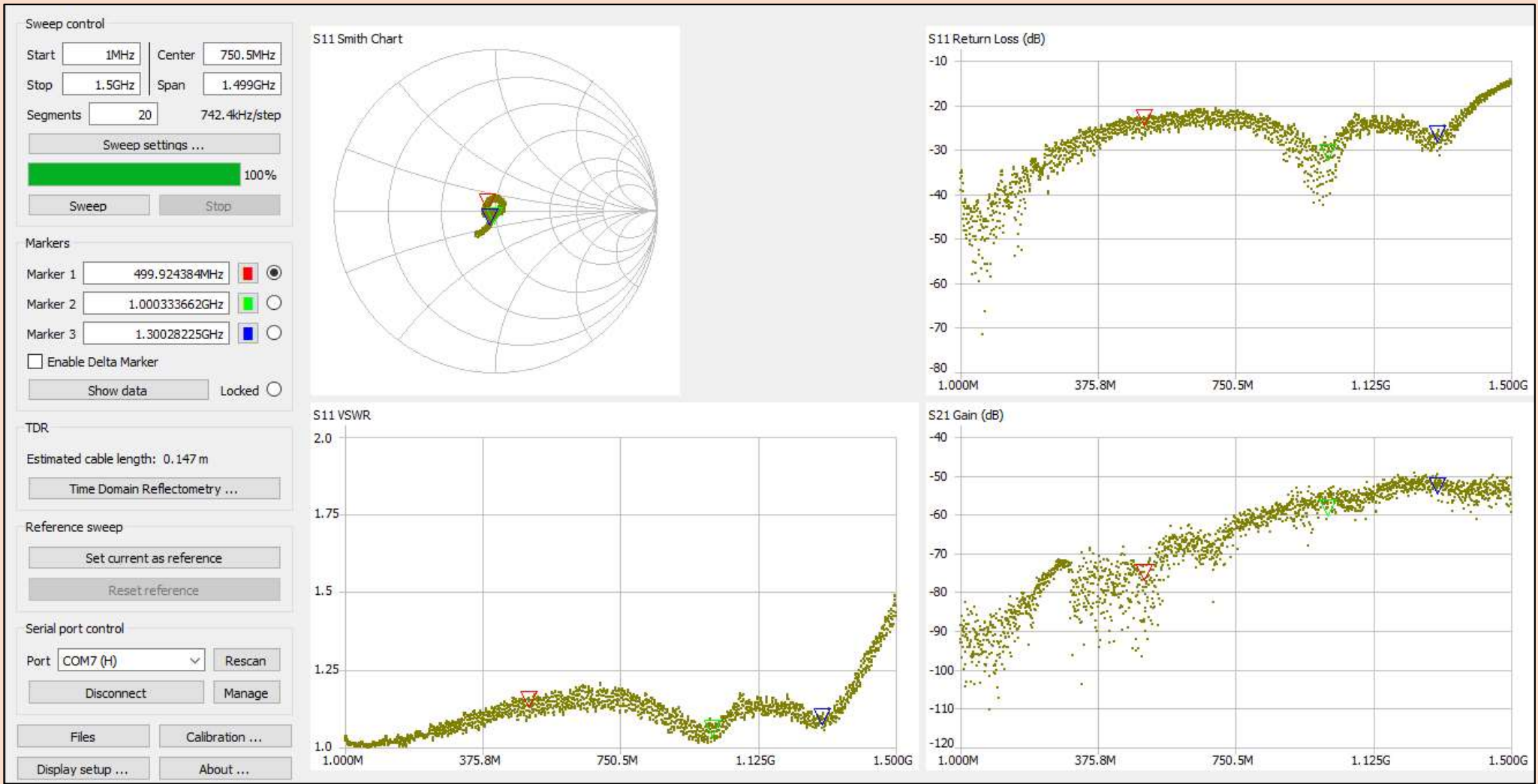
Benchmark Tests

Response > 1 GHz

nanoVNA H

Anristu SiteMaster S331L





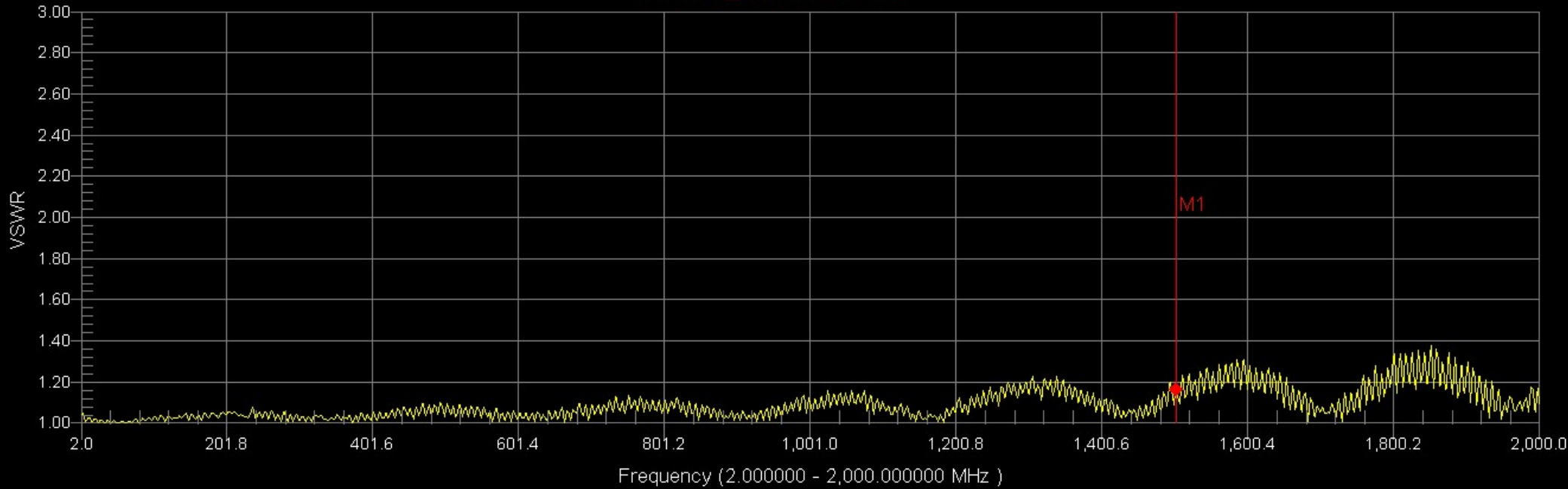
nanoVNA 1 – 1500 MHz 50 feet LMR 400 plus 50 ohm termination load



VSWR

Instrument File

M1 1.16 @ 1,501.312345 MHz



Resolution: 1033
Std: None
Date: Monday, March 18, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 8:40:53 PM
Serial: 1520069

RF Immunity: High

SiteMaster S331L 1 – 1500 MHz 50 feet LMR 400 plus 50 ohm termination



Transmission Line Network

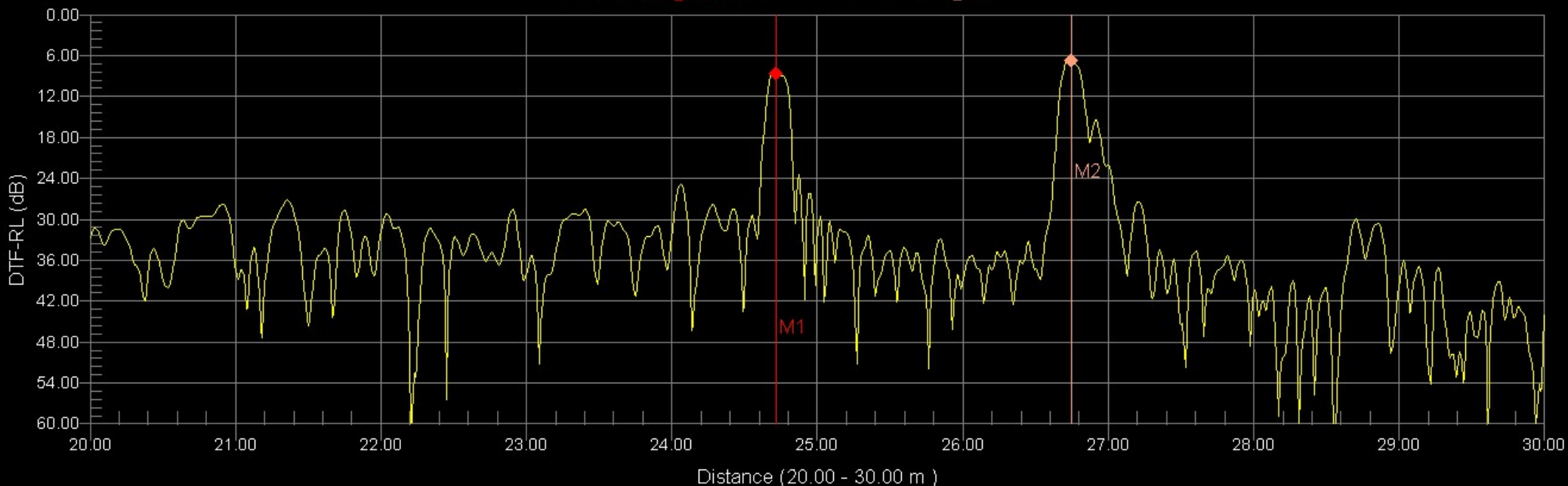
- **RG 58a/u** **Z = 50 ohm** **75 feet**
- **RG 59u** **Z = 75 ohm** **6 feet**
- **Load** **Z = 50 ohm**

DTF Return Loss

Instrument File

M1 8.55 dB @ 24.72 m

M2 6.70 dB @ 26.75 m



Resolution: 1033
Std: None
Date: Tuesday, March 19, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 9:34:52 AM
Serial: 1520069

RF Immunity: High
Freq: Start/Stop: 2.0 MHz/2000.0 MHz
Ins. Loss: 0.594 dB/m
Prop.Vel: 0.730

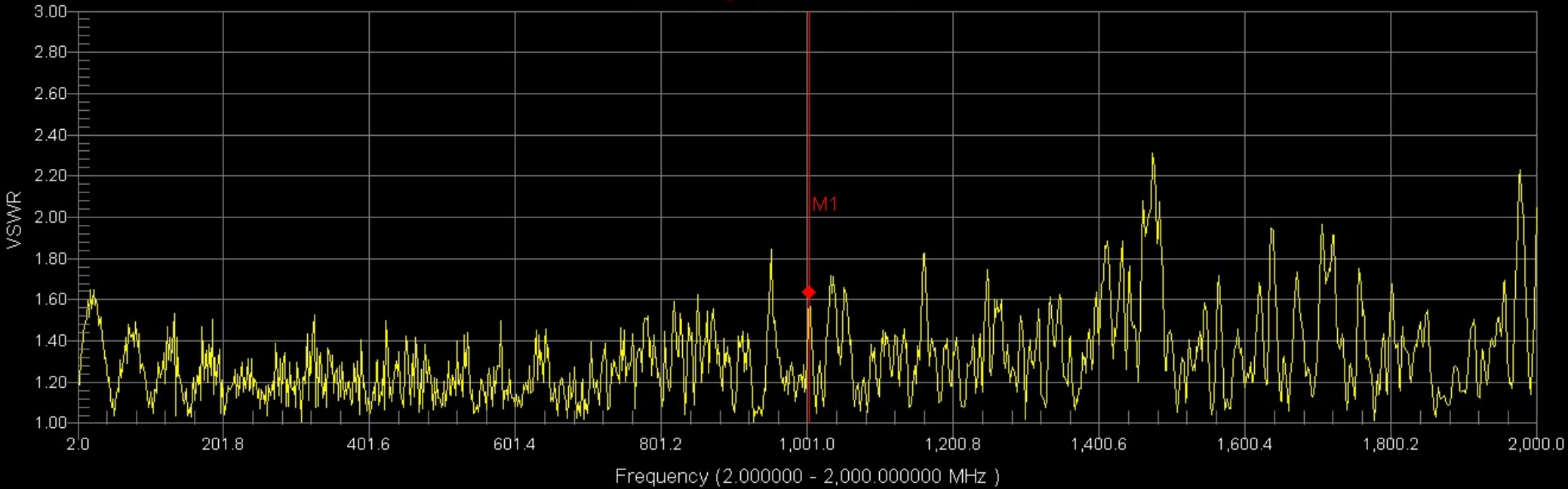
SiteMaster S331L DTF Transmission Line Network



VSWR

Instrument File

M1 1.64 @ 1,002.936000 MHz



Resolution: 1033
Std: None
Date: Tuesday, March 19, 2024
Model: S331L

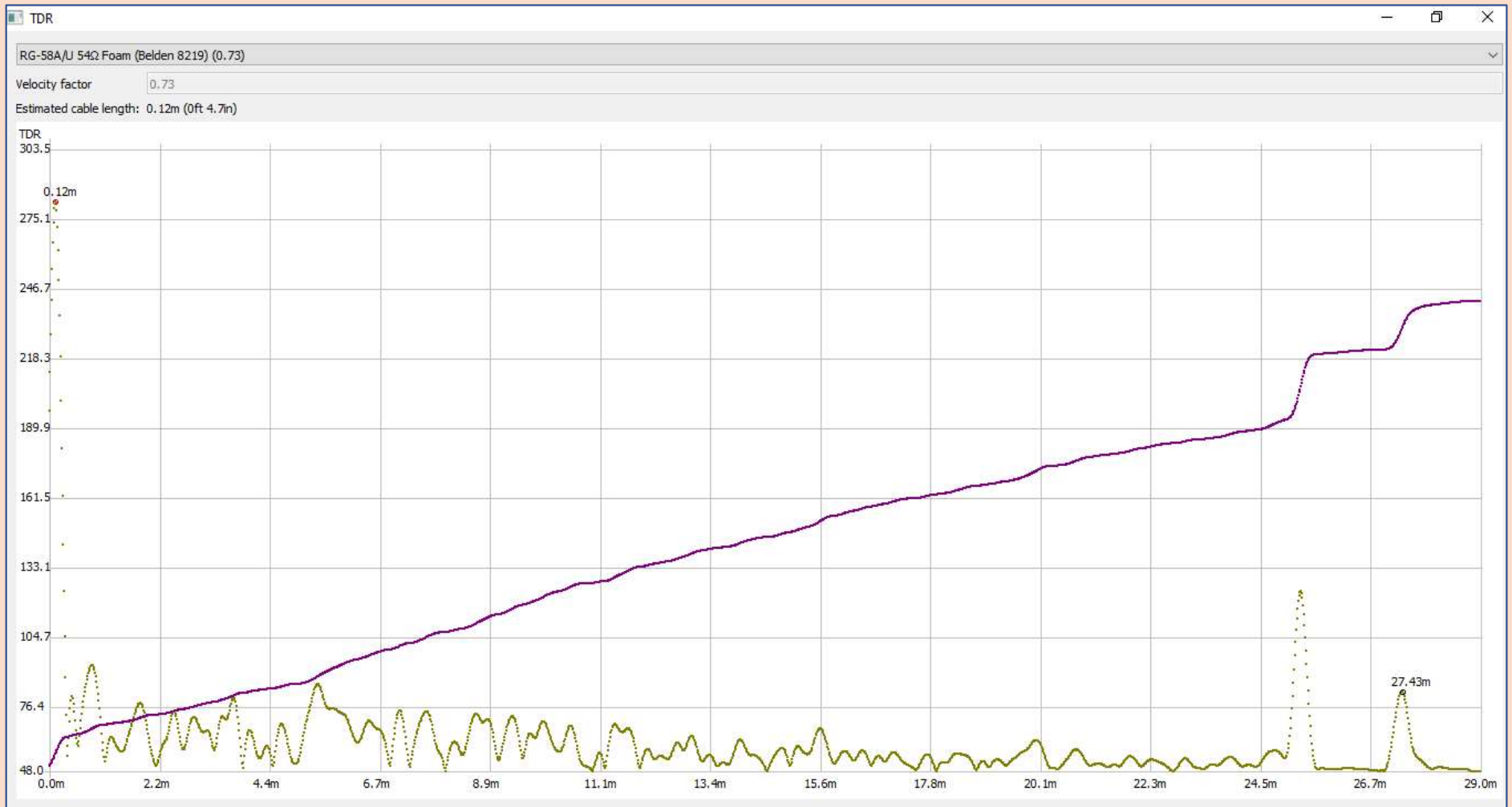
CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 9:47:51 AM
Serial: 1520069

RF Immunity: High

SiteMaster S331L VSWR

Transmission Line Network

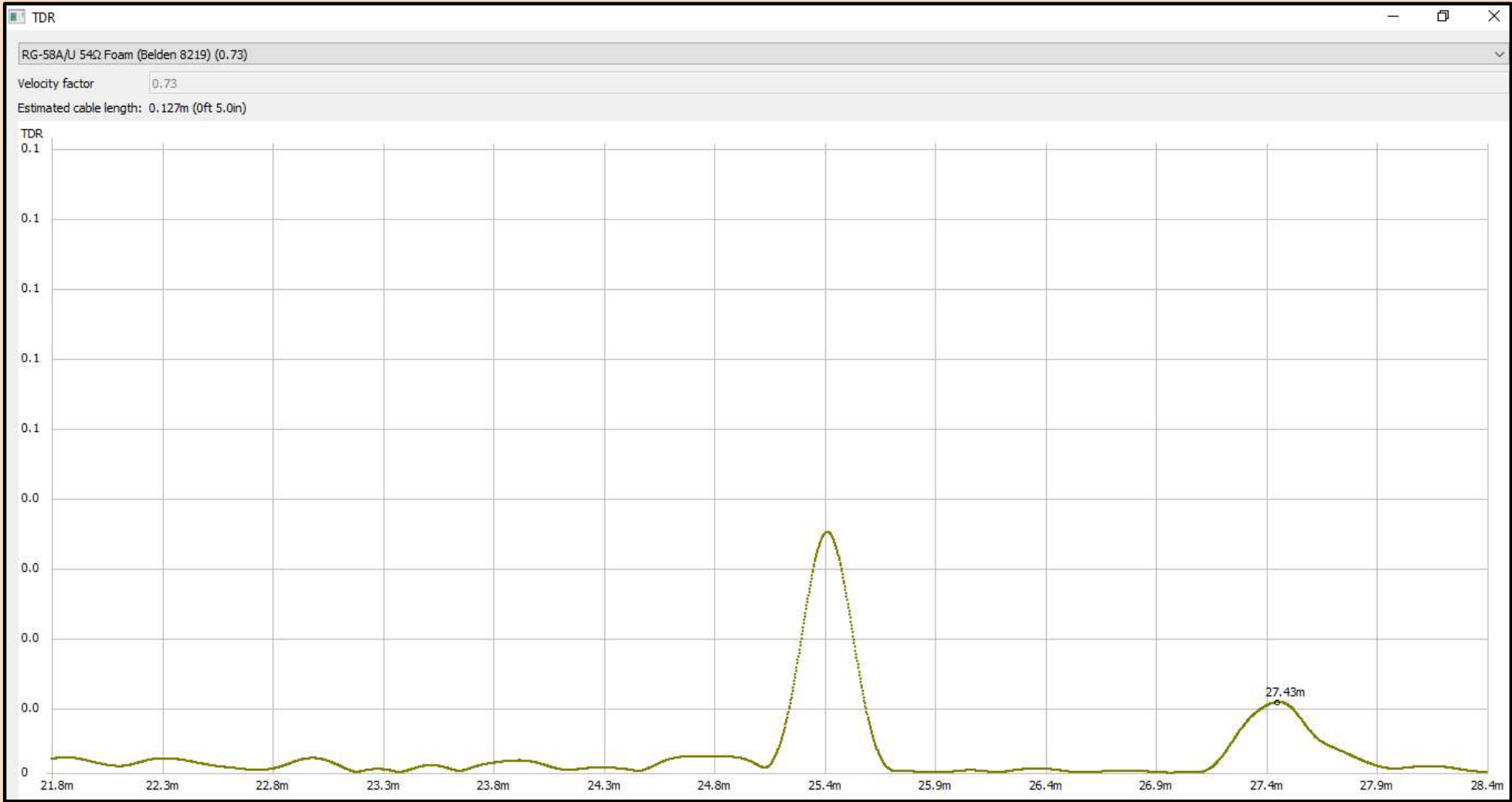




nanoVNA DTF

Transmission Line Network

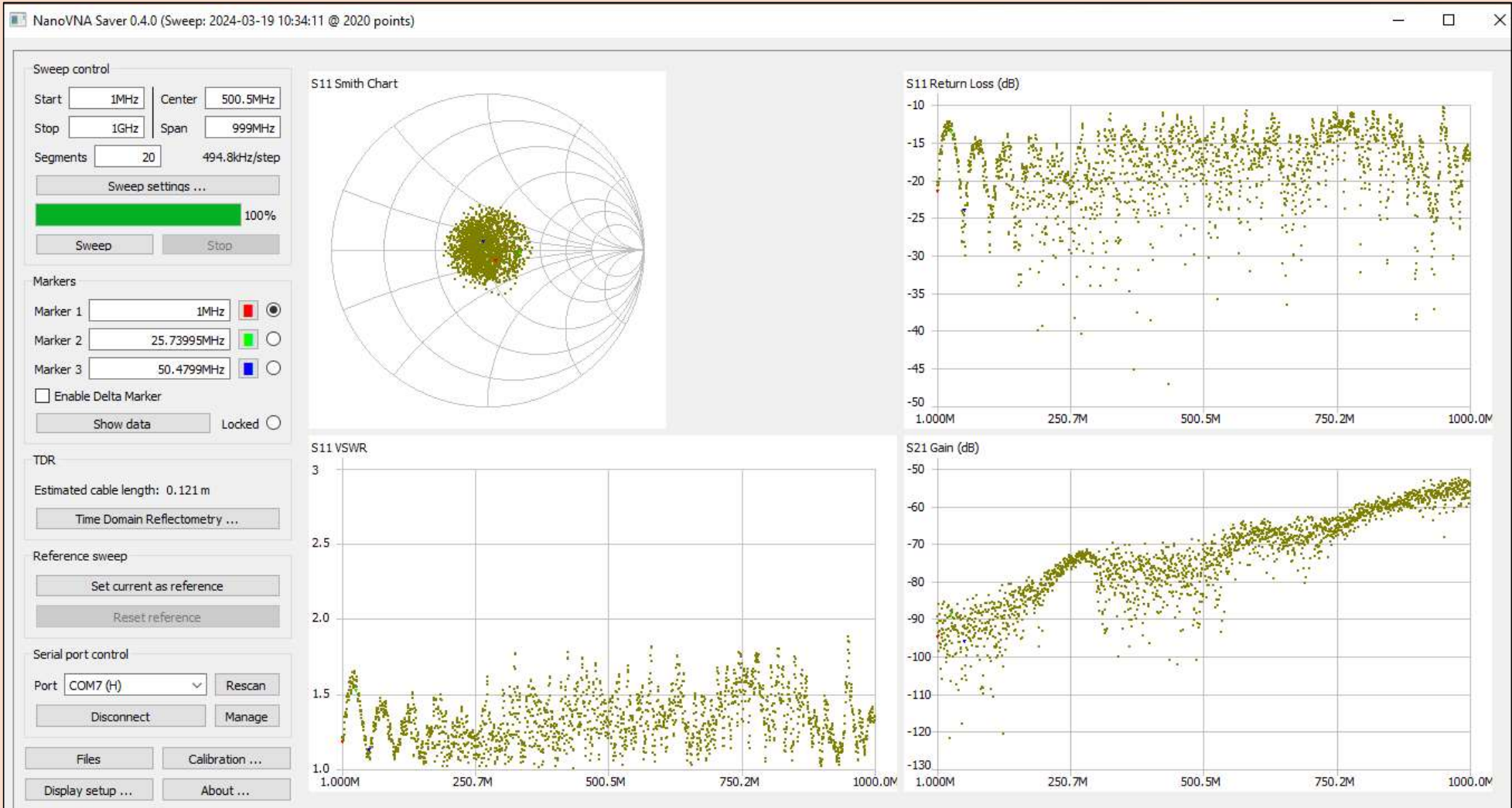




nanoVNA DTF

Transmission Line Network





nanoVNA VSWR Transmission Line Network



Benchmark Tests

Dummy Loads

Anristu SiteMaster S331L

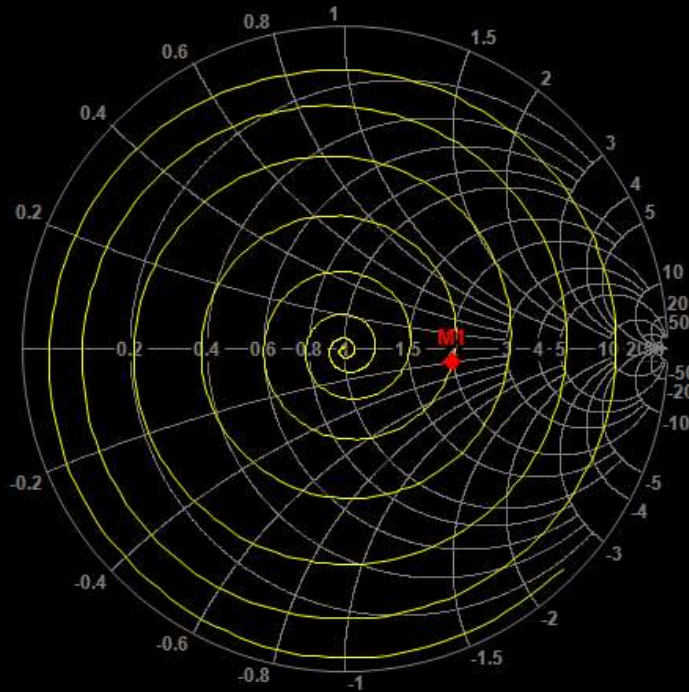




50 Ω Smith Chart

Instrument File

M1 1,002.936000 MHz Z(100.078 Ω , -9.037 Ω)



CAL: On (InstaCal-Std)

Time: 11:42:44 AM

Serial: 1520069

RF Immunity: High

Reference Impedance: 50 Ω

Resolution: 1033

Std: None

Date: Tuesday, March 19, 2024

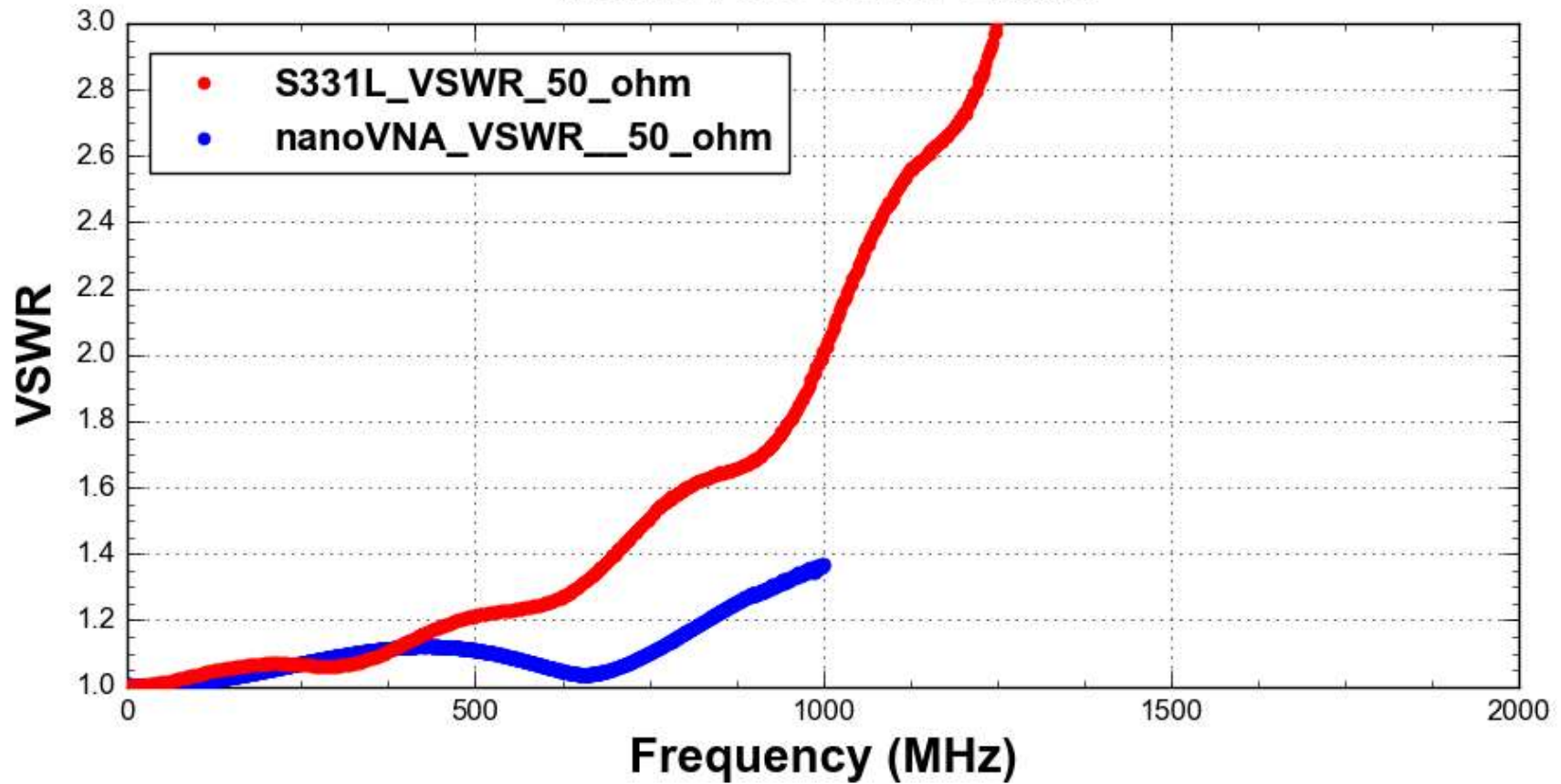
Model: S331L

SiteMaster S331L Smith Chart

50 ohm Load



VSWR 50 ohm Load

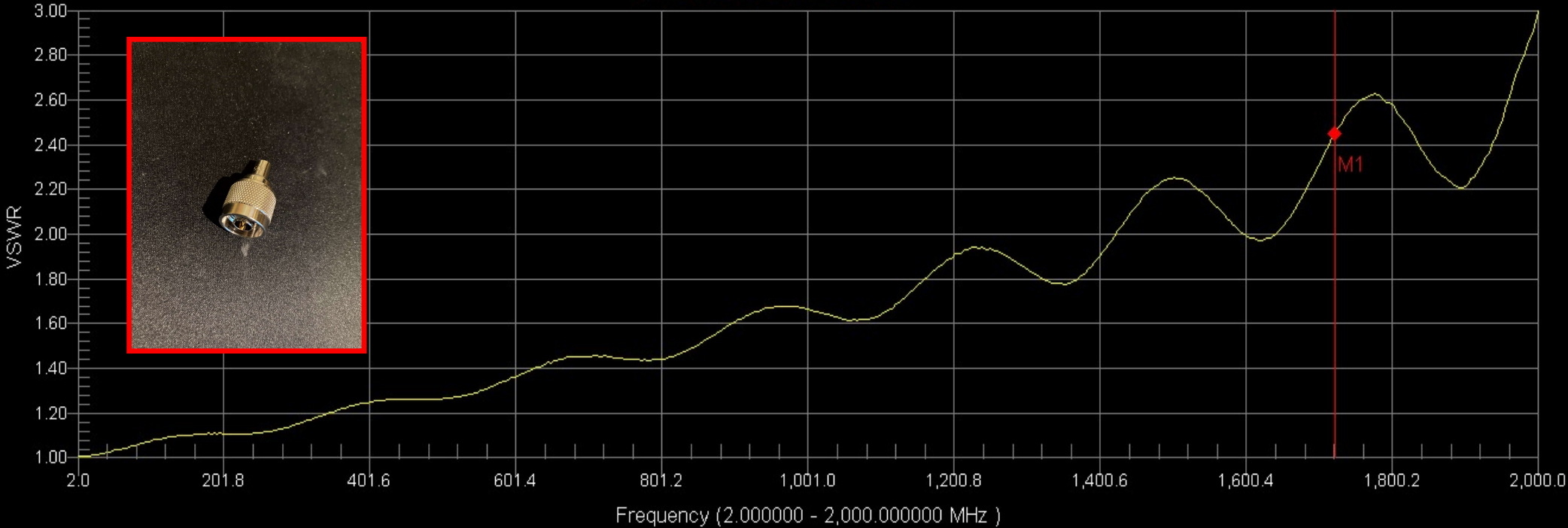


SiteMaster S331L and nanoVNA SWR **50 ohm Load**

VSWR

Instrument File

M1 2.45 @ 1,721.209000 MHz



Resolution: 517
Std: None
Date: Sunday, March 17, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 12:55:38 PM
Serial: 1520069

RF Immunity: High

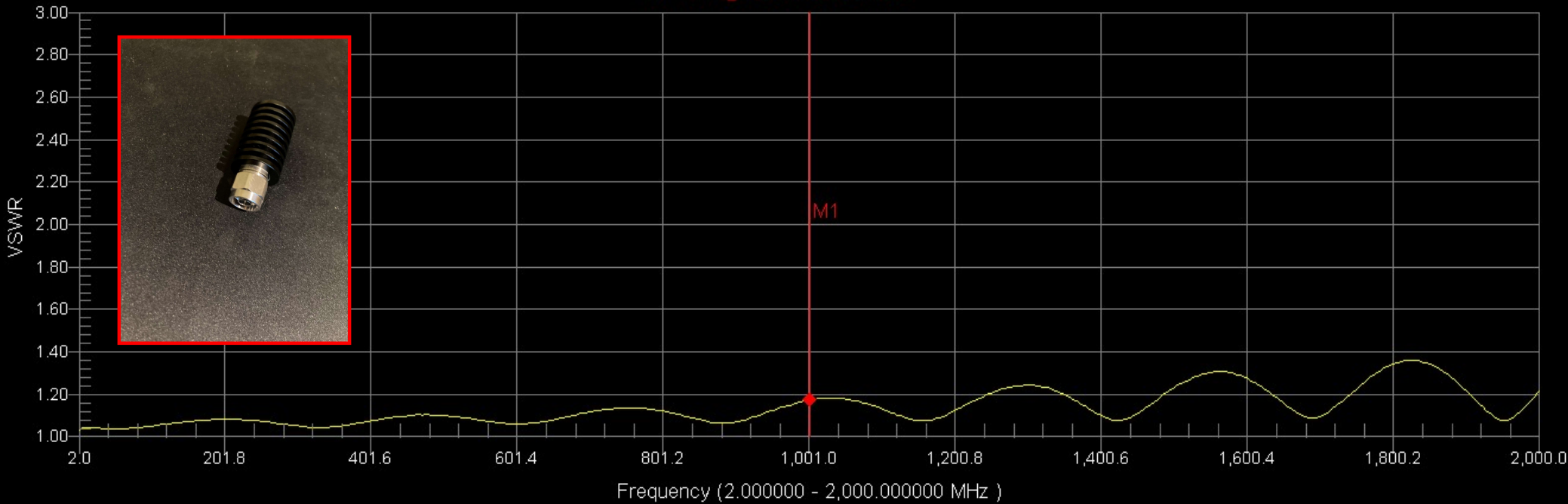
SiteMaster S331L Dummy Load 1



VSWR

Instrument File

M1 1.17 @ 1,001.000100 MHz



Resolution: 517
Std: None
Date: Sunday, March 17, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 1:02:25 PM
Serial: 1520069

RF Immunity: High

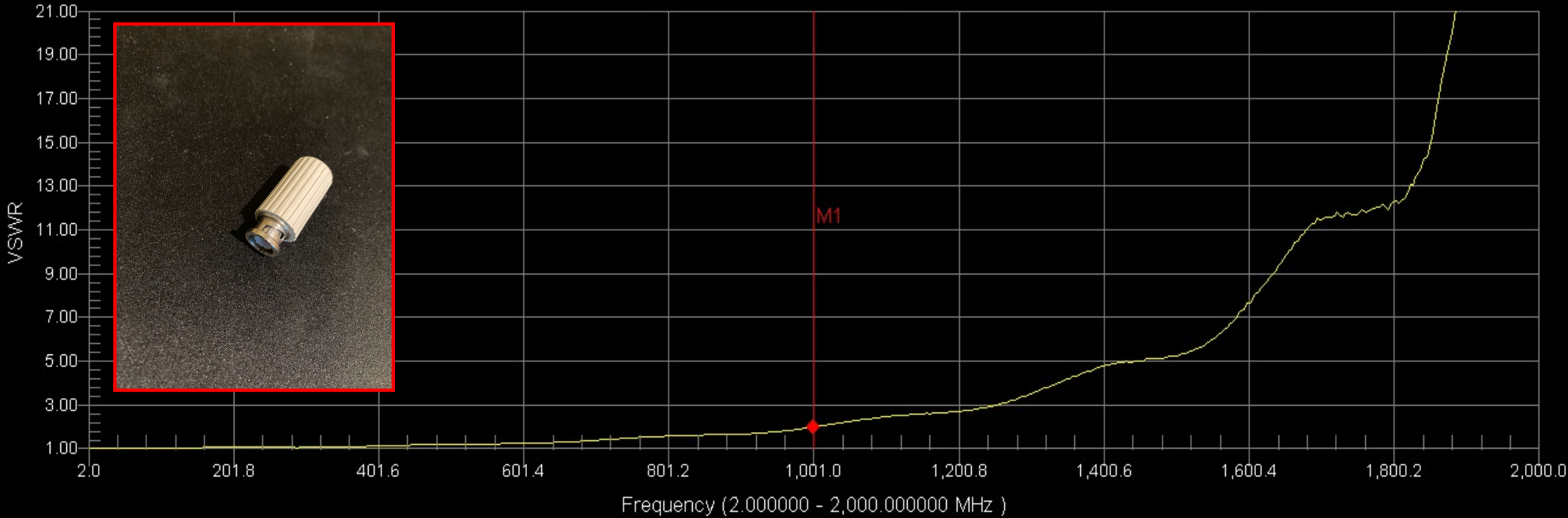
SiteMaster S331L Dummy Load 2



VSWR

Instrument File

M1 1.99 @ 999.365075 MHz



Resolution: 517
Std: None
Date: Sunday, March 17, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 1:10:00 PM
Serial: 1520069

RF Immunity: High

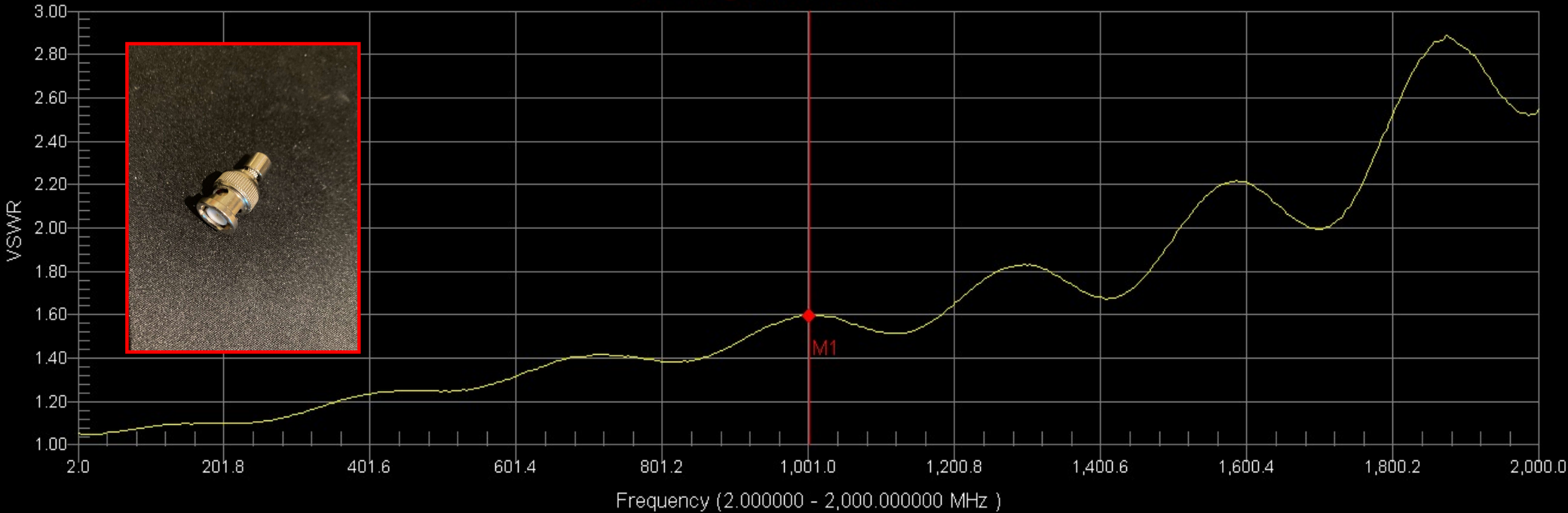
SiteMaster S331L Dummy Load 3



VSWR

Instrument File

M1 1.60 @ 1,001.000100 MHz



Resolution: 517
Std: None
Date: Sunday, March 17, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 1:15:06 PM
Serial: 1520069

RF Immunity: High

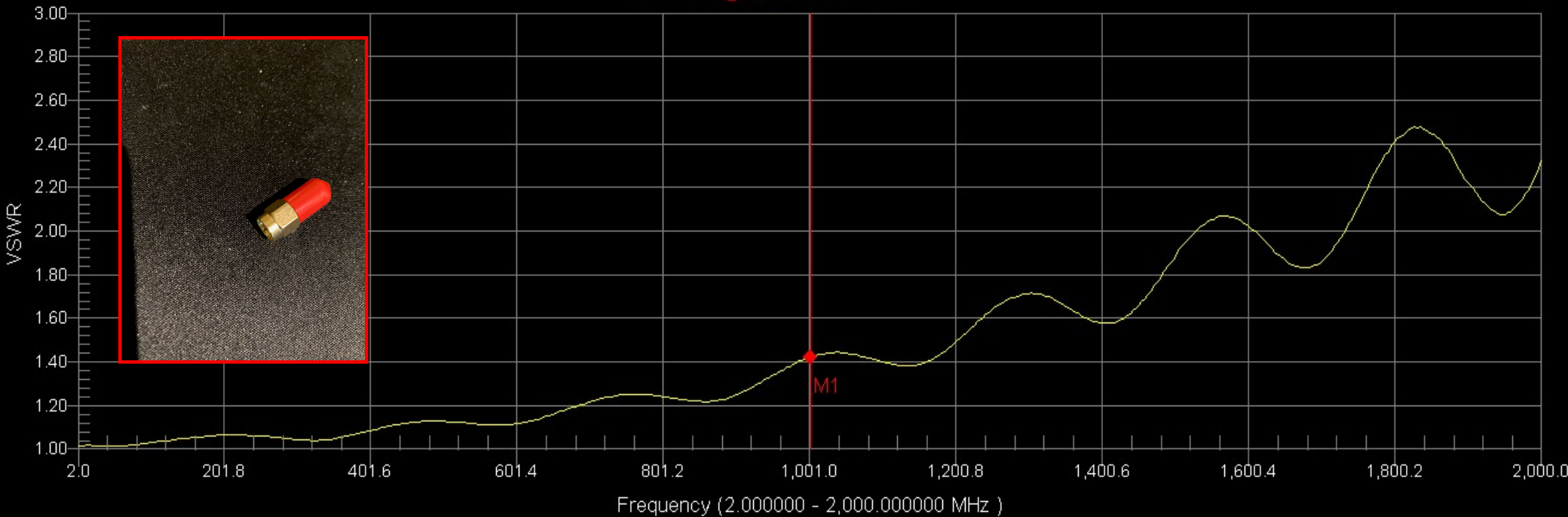
SiteMaster S331L Dummy Load 4



VSWR

Instrument File

M1 1.42 @ 1,001.000100 MHz



Resolution: 517
Std: None
Date: Sunday, March 17, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 1:36:09 PM
Serial: 1520069

RF Immunity: High

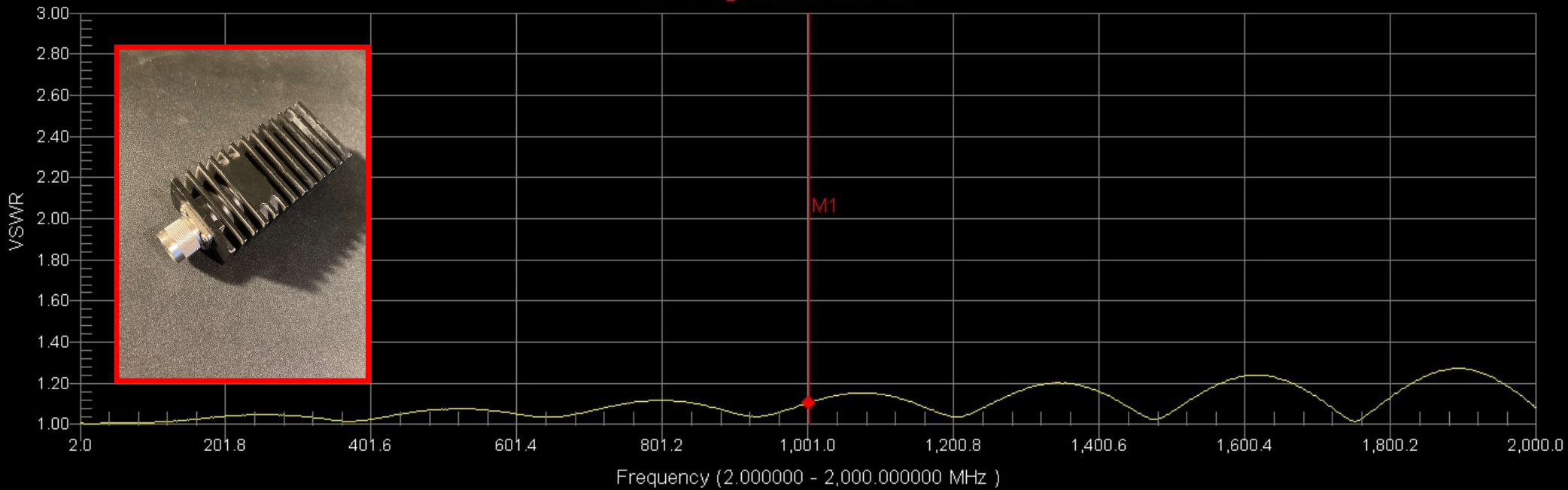
SiteMaster S331L Dummy Load 5



VSWR

Instrument File

M1 1.11 @ 1,001.000100 MHz



Resolution: 1033
Std: None
Date: Monday, March 18, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 10:56:27 AM
Serial: 1520069

RF Immunity: High

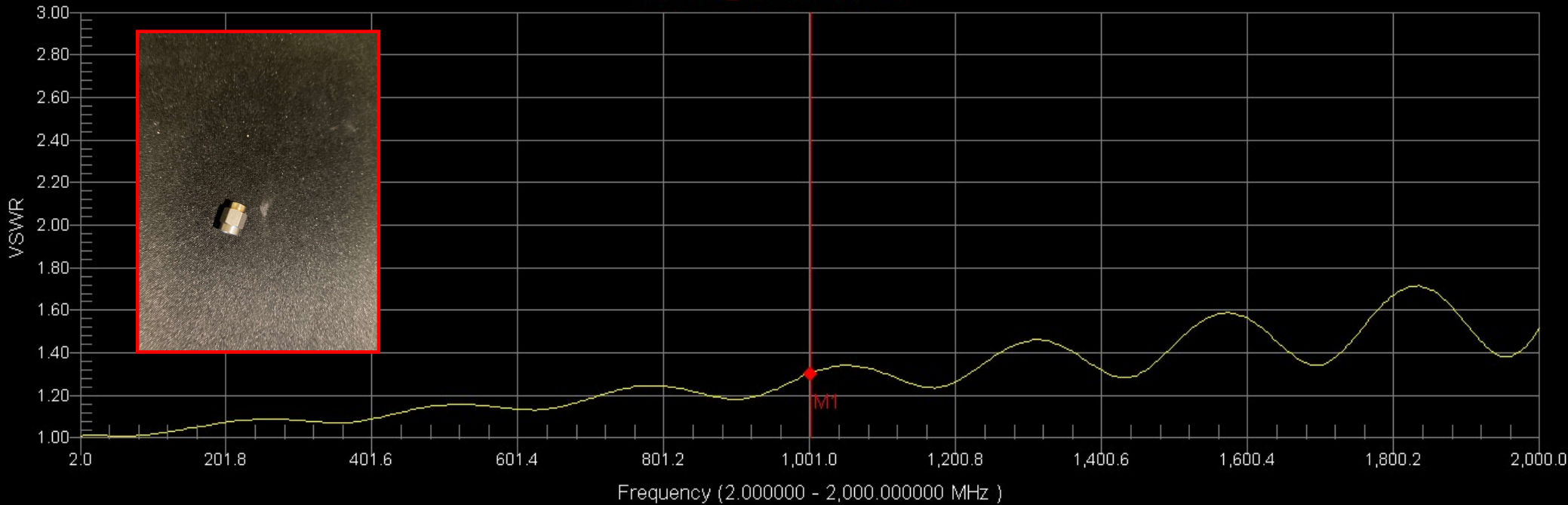
SiteMaster S331L Dummy Load 6



VSWR

Instrument File

M1 1.30 @ 1,001.000100 MHz



Resolution: 517
Std: None
Date: Sunday, March 17, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 1:40:08 PM
Serial: 1520069

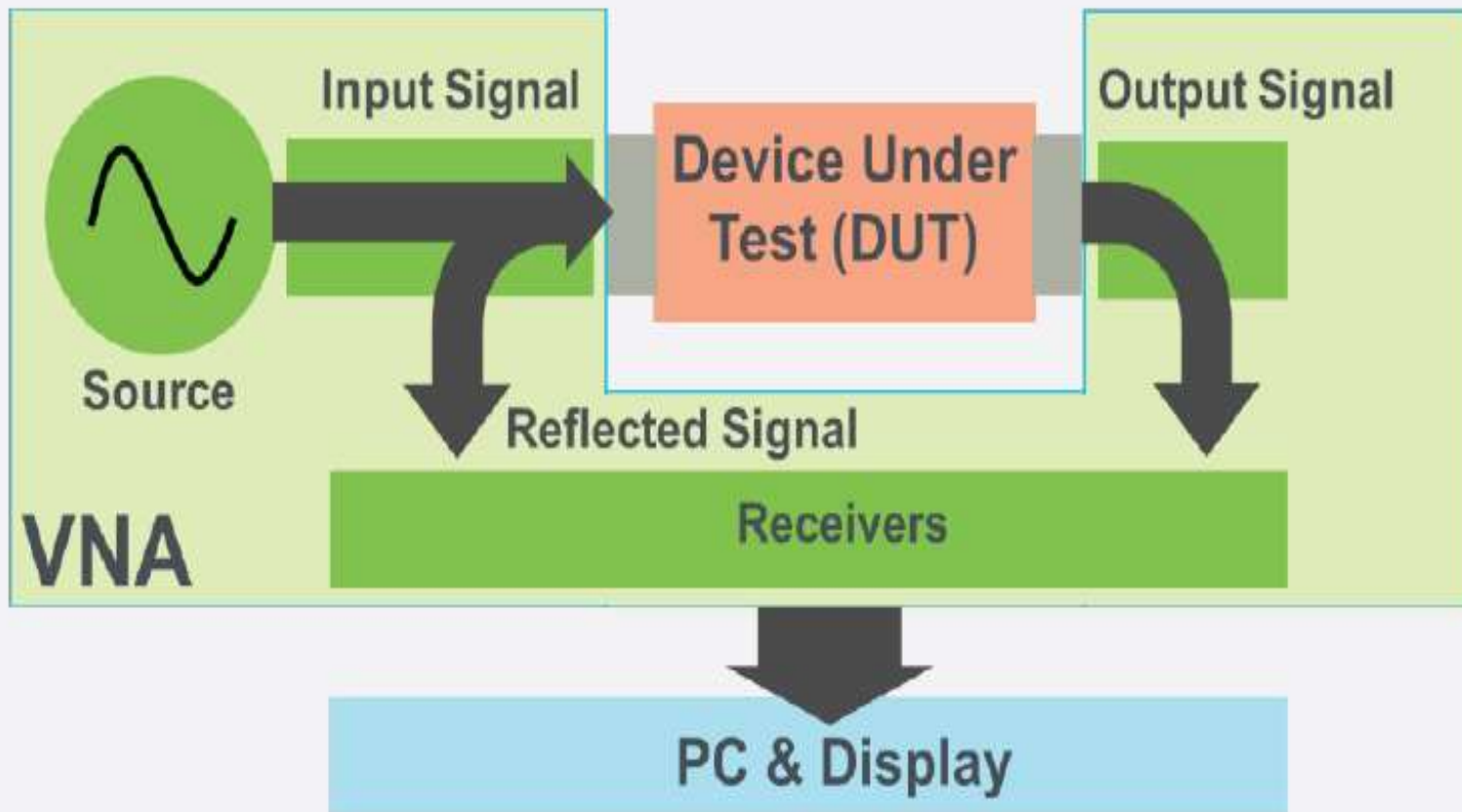
RF Immunity: High

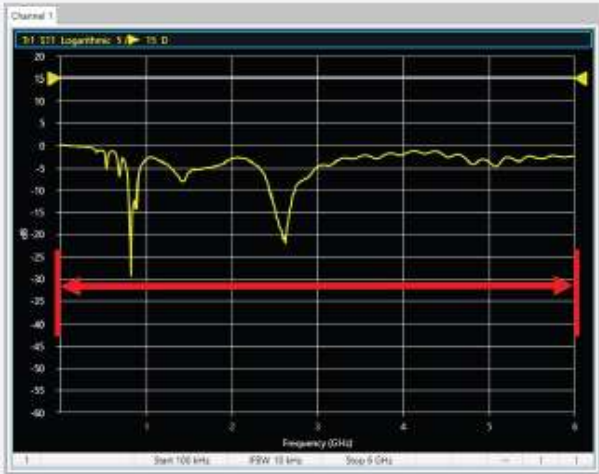
SiteMaster S331L Dummy Load 7 nanoVNA 50 ohm



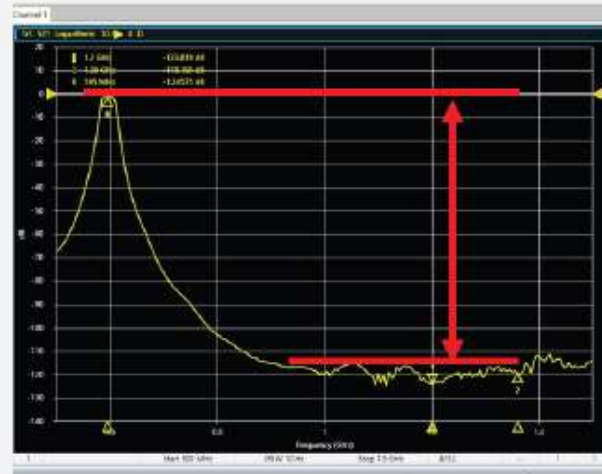
Additional Documentation



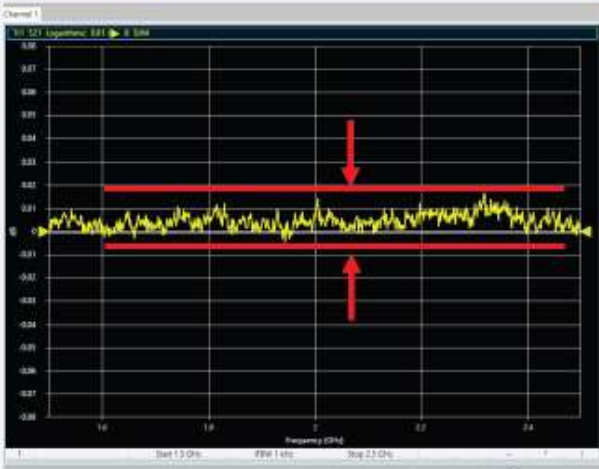




(a) Frequency Range



(b) Dynamic Range

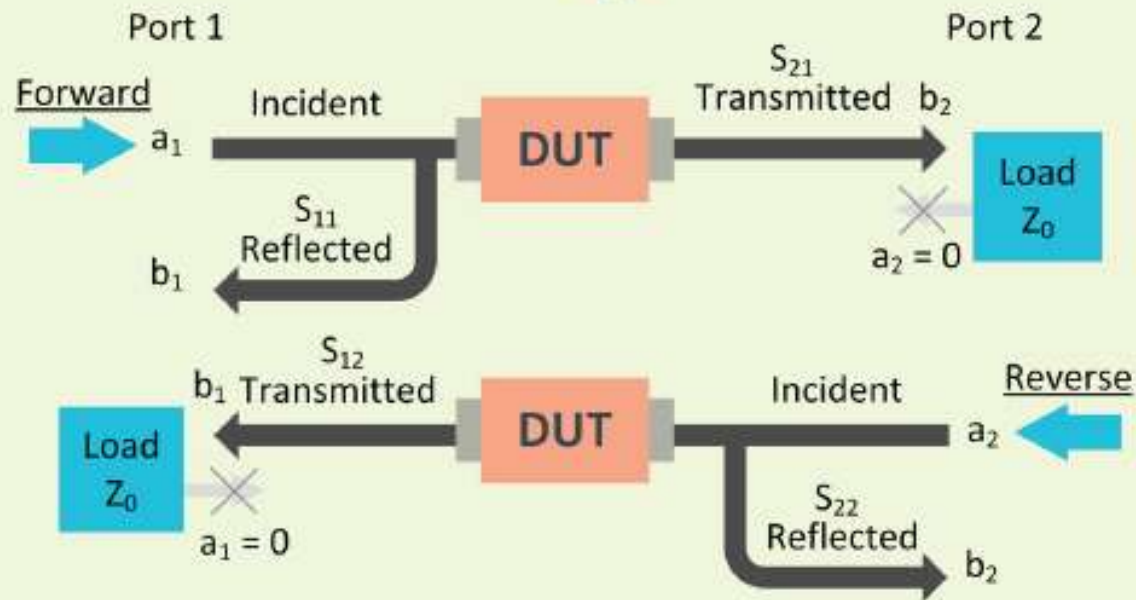


(c) Trace Noise



(d) Measurement speed

S-Parameter Theory View



Forward:

Reverse:

Reflection:

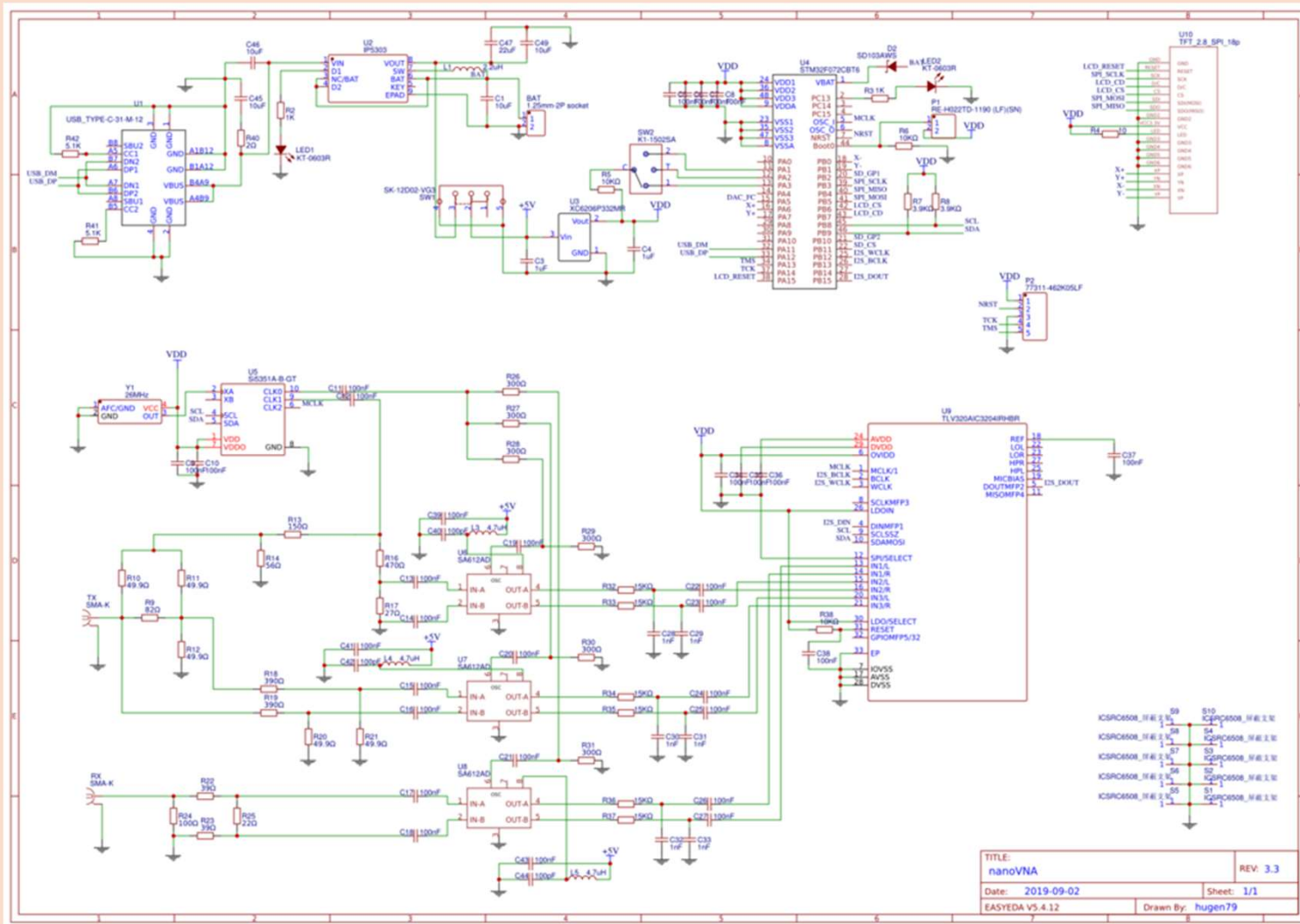
$$S_{11} = \frac{\text{Reflected}}{\text{Incident}} = \frac{b_1}{a_1} \Big|_{a_2=0}$$

$$S_{22} = \frac{\text{Reflected}}{\text{Incident}} = \frac{b_2}{a_2} \Big|_{a_1=0}$$

Transmission:

$$S_{21} = \frac{\text{Transmitted}}{\text{Incident}} = \frac{b_2}{a_1} \Big|_{a_2=0}$$

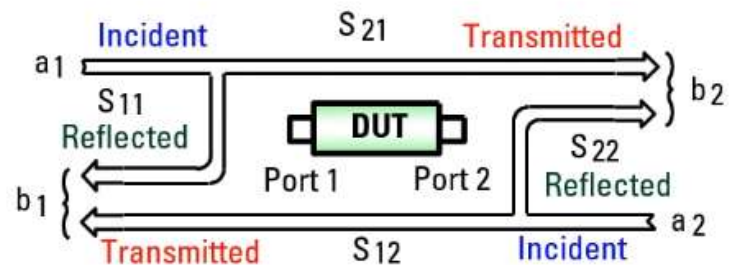
$$S_{12} = \frac{\text{Transmitted}}{\text{Incident}} = \frac{b_1}{a_2} \Big|_{a_1=0}$$



TITLE: nanoVNA		REV. 3.3
Date: 2019-09-02	Sheet: 1/1	
EASYEDA V5.4.12	Drawn By: hugen79	



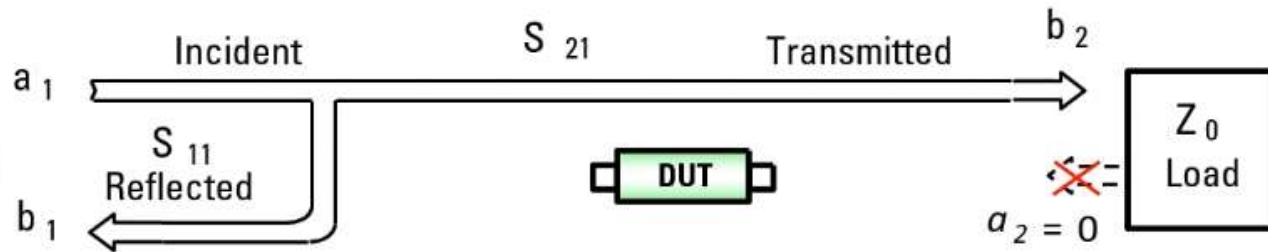
- Relatively easy to **obtain** at high frequencies
 - Measure voltage traveling waves with a vector network analyzer
 - Don't need shorts/opens (can cause active devices to oscillate or self-destruct)
- Relate to **familiar** measurements (gain, loss, reflection coefficient ...)
- Can **cascade** S-parameters of multiple devices to predict system performance
- Can **compute** H-, Y-, or Z-parameters from S-parameters if desired
- Can easily import and use S-parameter files in **electronic-simulation** tools



$$b_1 = S_{11} a_1 + S_{12} a_2$$

$$b_2 = S_{21} a_1 + S_{22} a_2$$

Forward

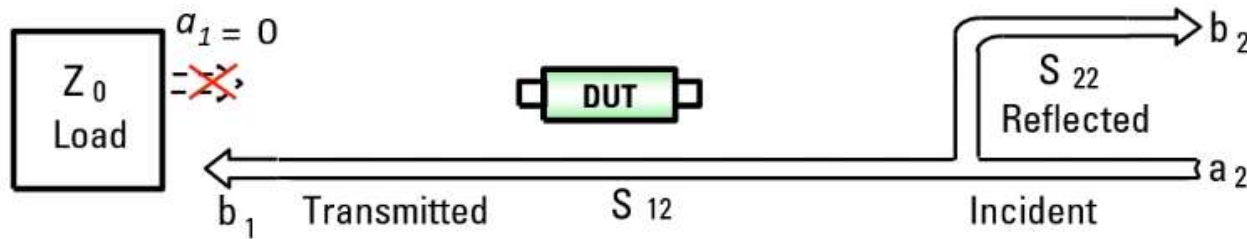


$$S_{11} = \frac{\text{Reflected}}{\text{Incident}} = \frac{b_1}{a_1} \Big|_{a_2 = 0}$$

$$S_{21} = \frac{\text{Transmitted}}{\text{Incident}} = \frac{b_2}{a_1} \Big|_{a_2 = 0}$$

$$S_{22} = \frac{\text{Reflected}}{\text{Incident}} = \frac{b_2}{a_2} \Big|_{a_1 = 0}$$

$$S_{12} = \frac{\text{Transmitted}}{\text{Incident}} = \frac{b_1}{a_2} \Big|_{a_1 = 0}$$



Reverse



S_{11} = forward reflection coefficient (*input match*)

S_{22} = reverse reflection coefficient (*output match*)

S_{21} = forward transmission coefficient (*gain or loss*)

S_{12} = reverse transmission coefficient (*isolation*)

Remember S-parameters are inherently complex, linear quantities – however, we often express them in a log-magnitude format

V2 Plus4 fixes the drift and linearity issues with older NanoVNA/S-A-A-2 based analyzers. It is a complete redesign using our new VNA-R architecture, which features the following improvements:

Temperature drift cancellation, only available in the V2 Plus4 and VNA6000 series, gives you repeatable and reliable measurements, allowing you to keep calibrations for longer (>3 months compared to <30 minutes for earlier versions).

Synthesizer rated for the full frequency range - V2 Plus4 does not overclock the synthesizer or use harmonics, making accurate measurements without interference from spurious signals.

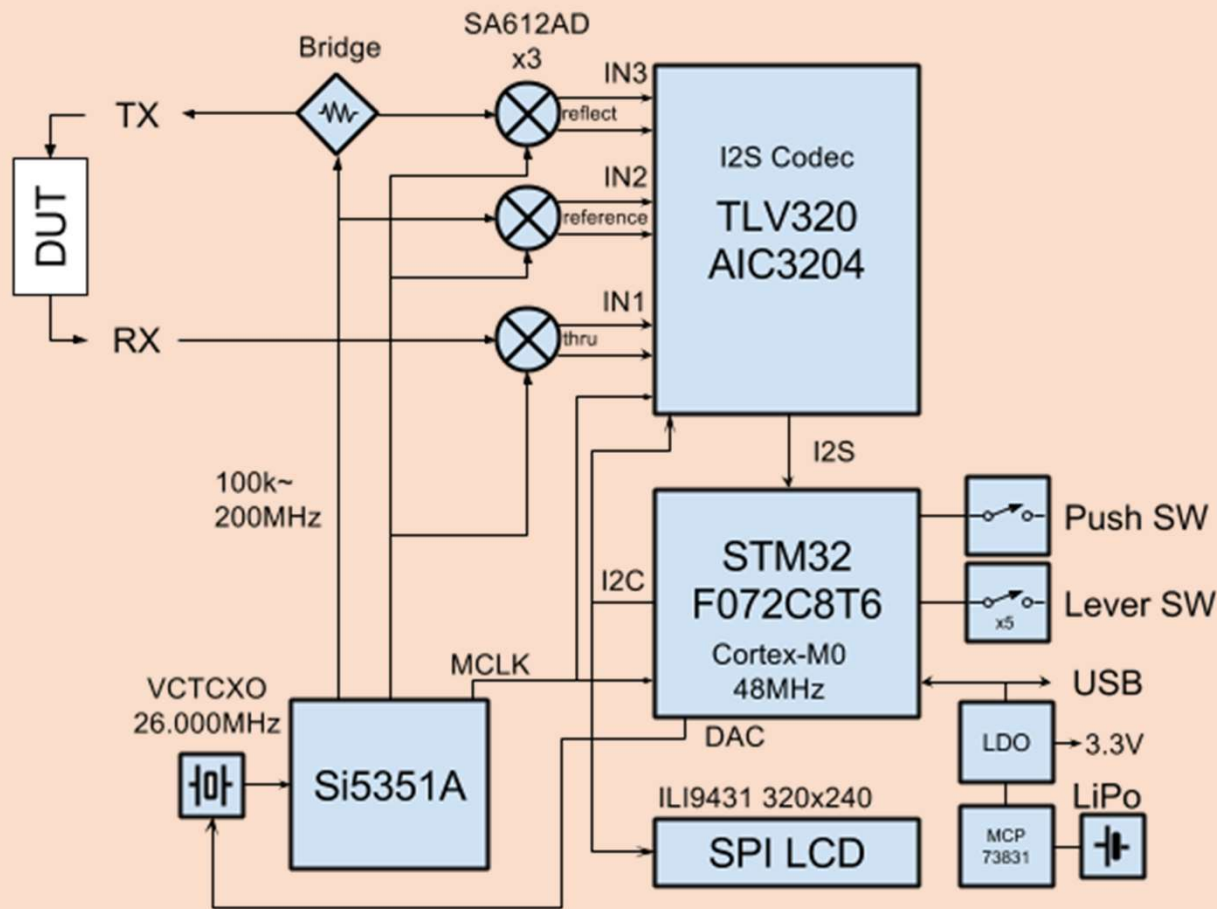
Factory tuning of each individual instrument allows the V2 Plus4 to have trace noise 90% lower than previous versions, and improved linearity eliminating harmonic response.

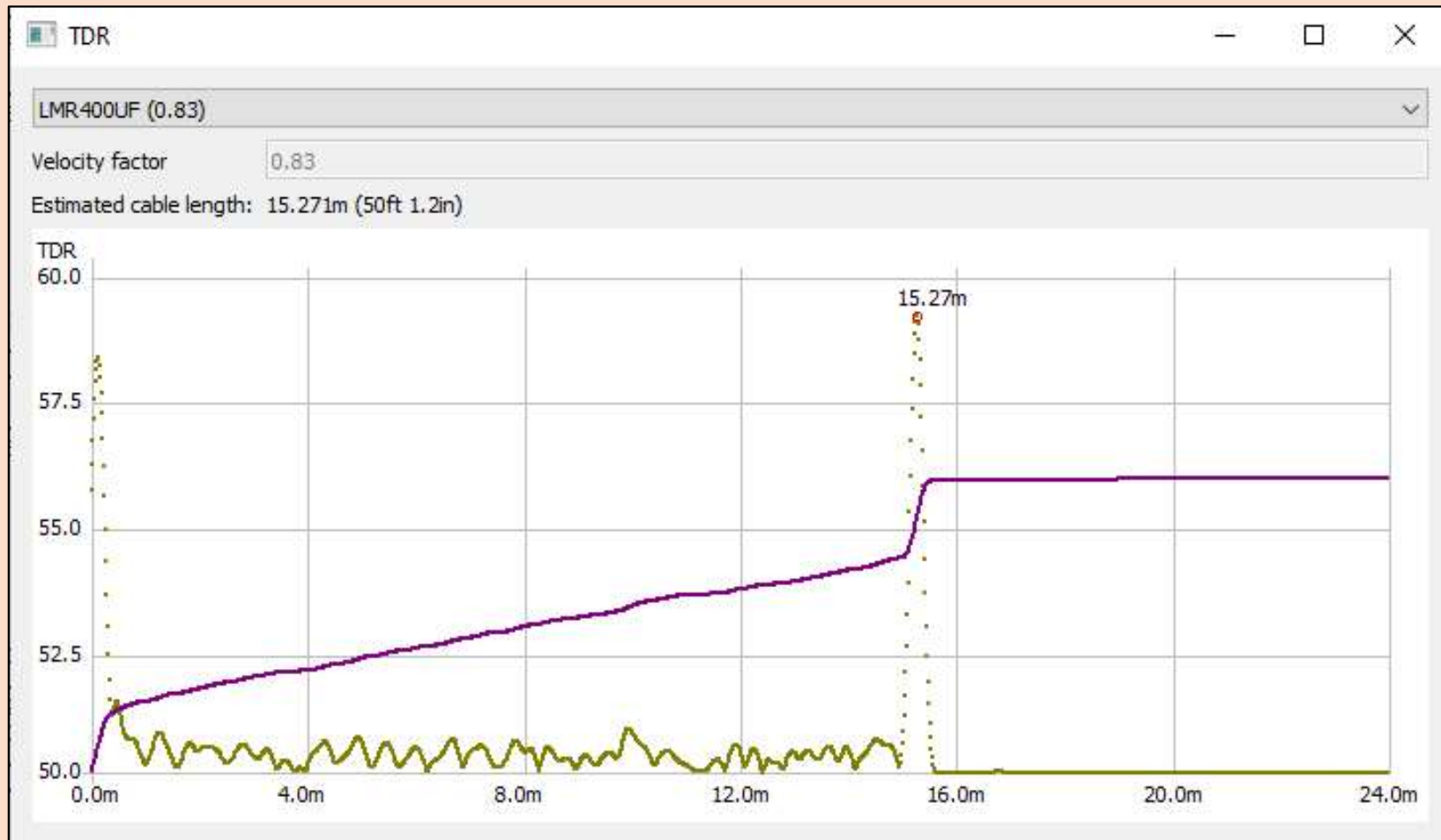
Improved USB protocol allows full speed streaming of measured data to the PC, achieving 4x faster measurement than our earlier S-A-A-2 (6x faster for V2 Plus4 Pro).

The **all aluminum enclosure and improved shielding** allows the V2 Plus4 to reach >90dB real dynamic range, achieving similar results as professional VNAs, and allows measuring duplexers.



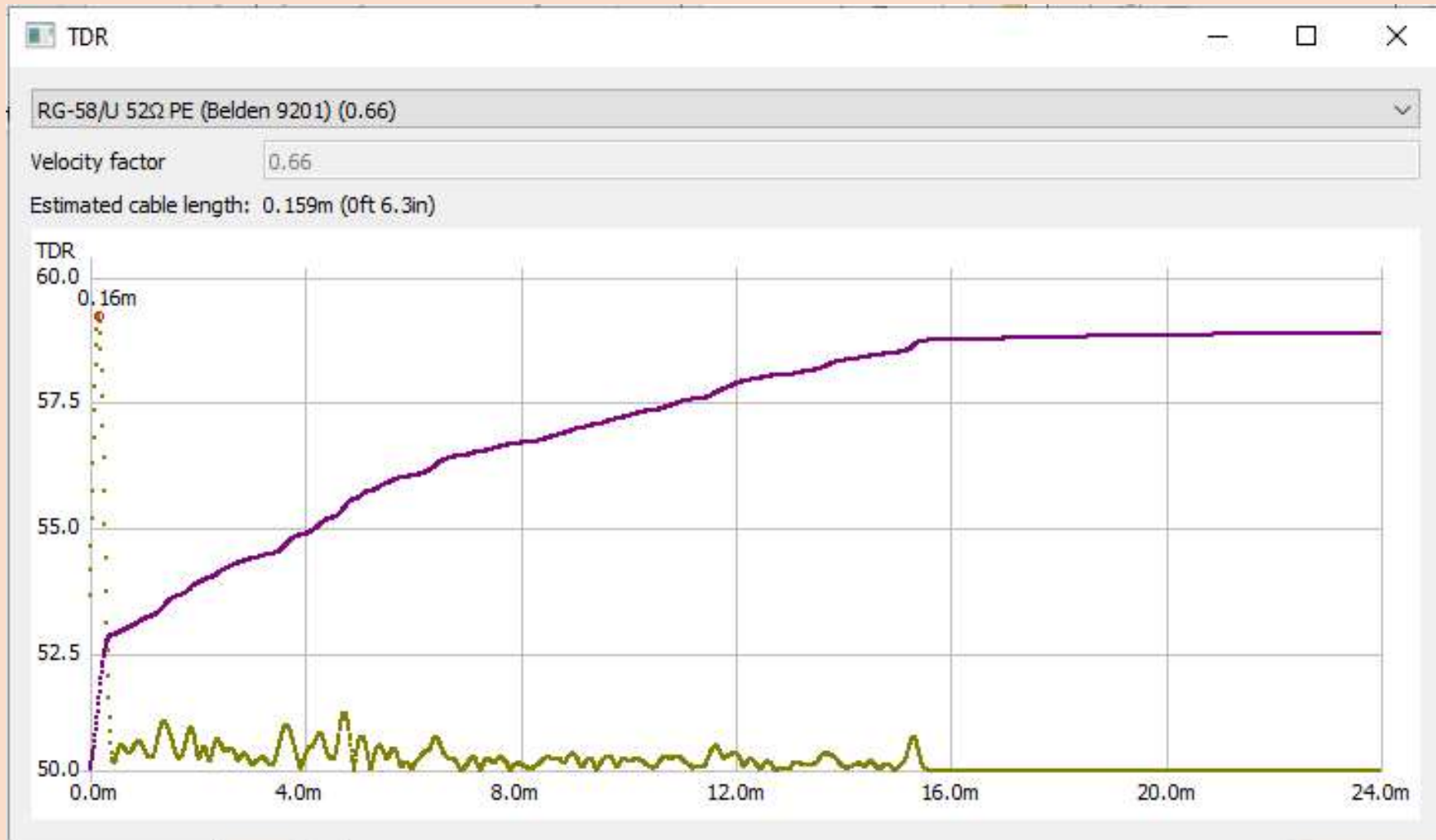
	NanoRFE portable VNA series				Other portable VNAs		
	V2 Plus4	V2 Plus4 Pro	VNA6000-A	VNA6000-B	KeyS FieldF N9912A	Anr MS2025B	R-S ZNH4
Max dynamic range	90dB	90dB	95dB	110dB	72dB	100dB	100dB
Freq. range (Hz)	50k - 4G	50k - 4G	50k - 6G	50k - 6G	2M - 6G	500k - 6G	30k - 4G
Trace noise	Low	Lower	Lower	Lower	Lower	Lower	Lower
Sweep time	0.25s	< 0.2s	< 0.2s	< 0.2s	< 0.1s	< 0.1s	< 0.1s
Adjustable IFBW		✓	✓	✓	✓	✓	✓
Temperature drift compensation	✓	✓	✓	✓	?	?	?
TDR	✓	✓	✓	✓	✓	✓	✓
TDR resolution	9mm	9mm	6mm	6mm	6mm	6mm	9mm
Weight	300g	300g	300g	300g	2.8kg	3.5kg	3.1kg
Touchscreen	✓	✓	✓	✓		✓	✓





LMR 400 50 feet 50 ohm Load 1 MHz – 1000 MHz Sweep



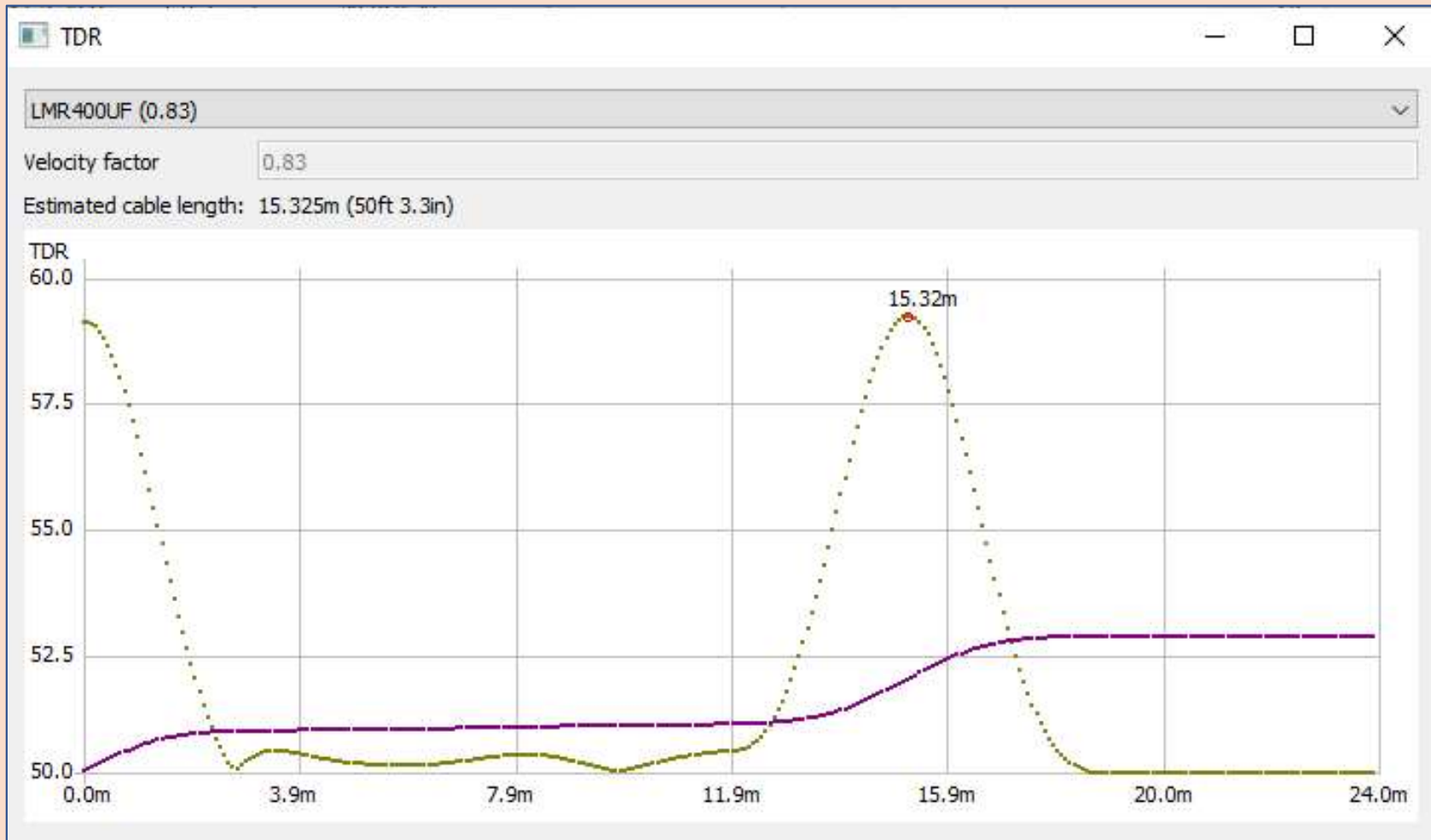


RG58

50 feet

50 ohm Load 1 MHz – 1000 MHz Sweep





LMR 400

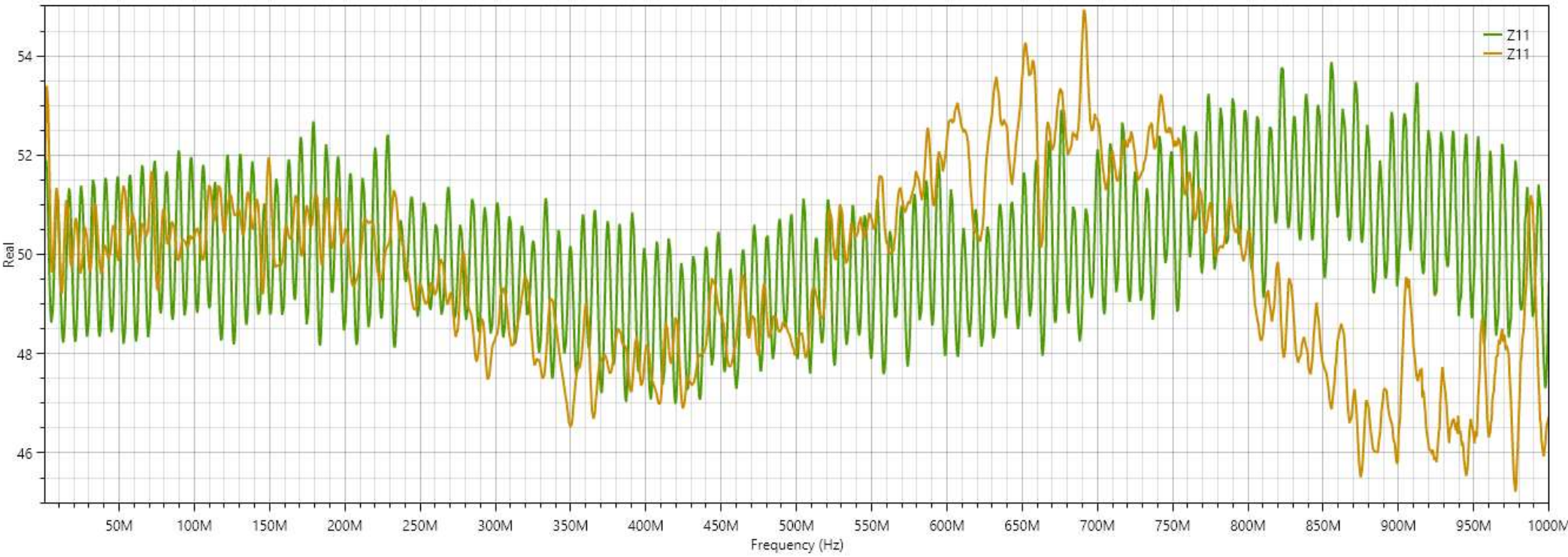
50 feet

50 ohm Load 1 MHz – 100 MHz Sweep



Z-Parameters

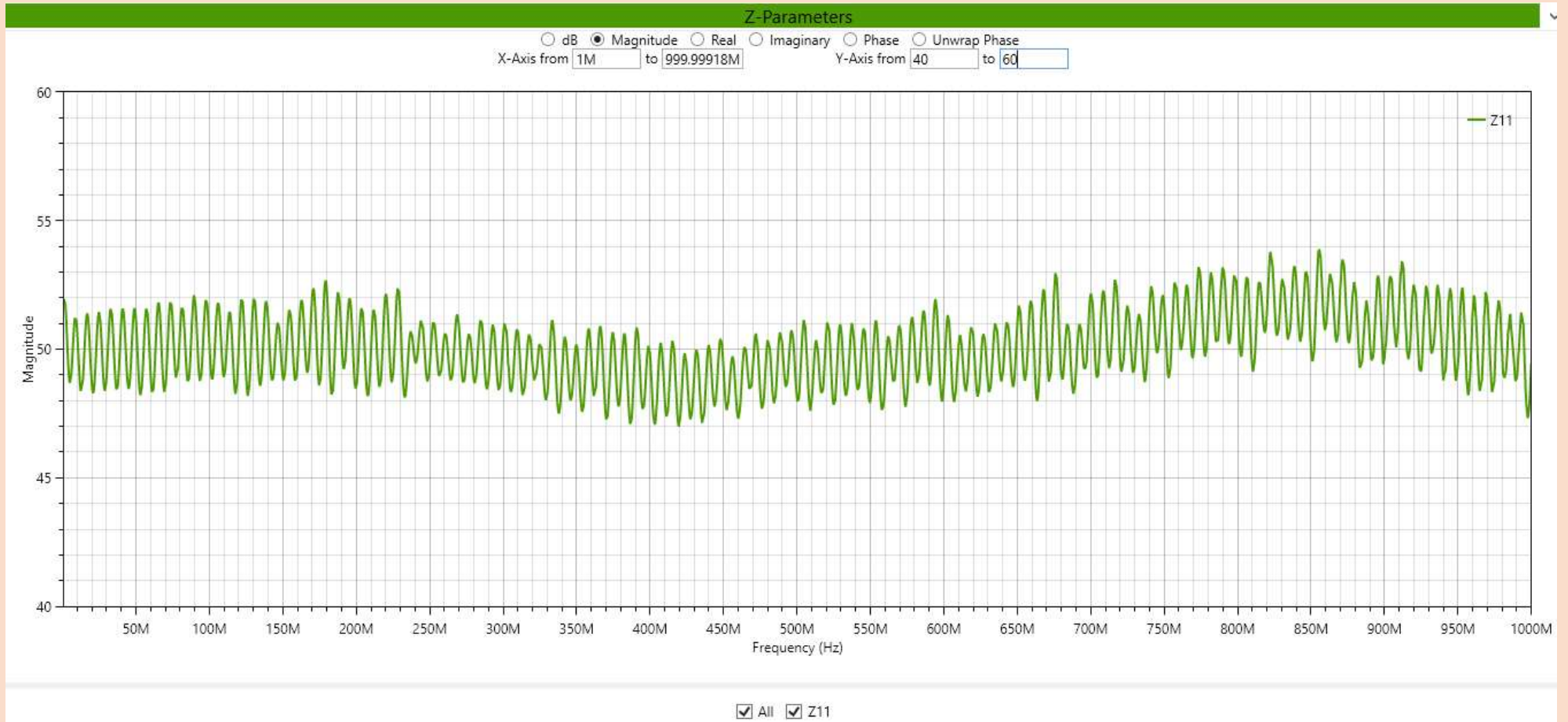
dB Magnitude Real Imaginary Phase Unwrap Phase
X-Axis from 1M to 999.99918M Y-Axis from 45 to 55



vna_LMR400_50_feet_s1p All Z11

vna_RG58_50_feet_s1p All Z11

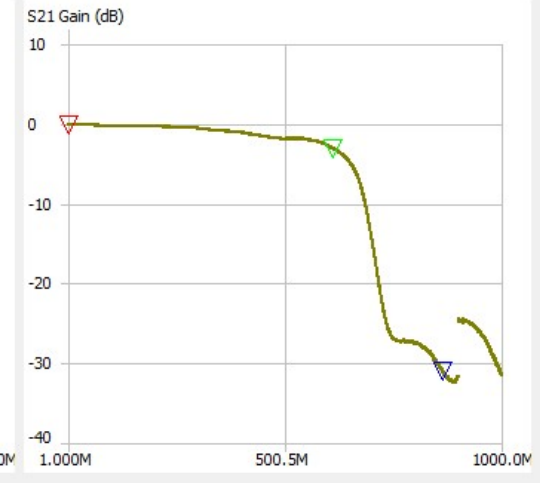
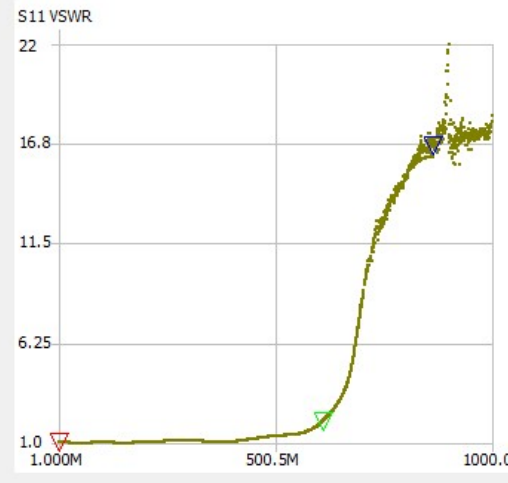
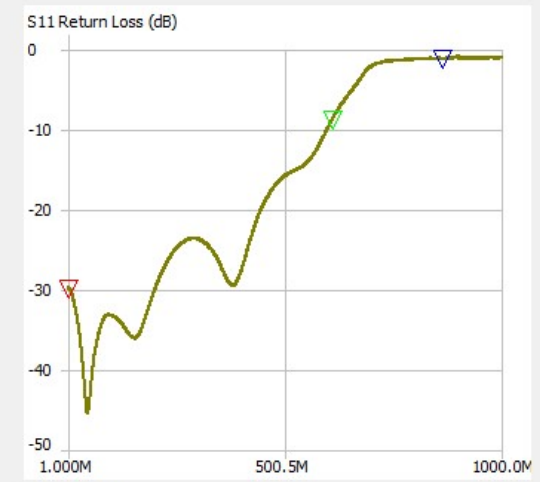
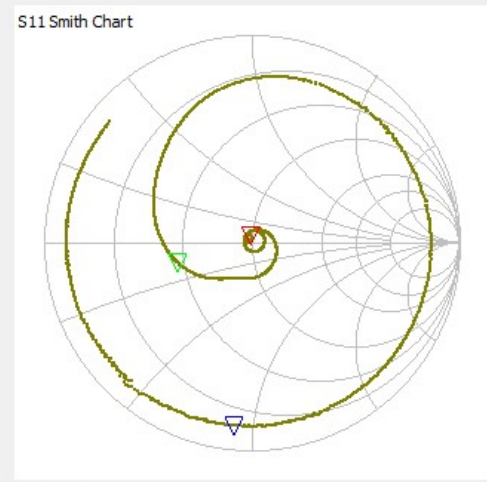




LMR 400 50 feet 50 ohm Load



Marker 1	
Frequency: 1.00000 MHz	VSWR: 1.067
Impedance: 49.4+j3.19 Ω	Return loss: -29.723 dB
Series L: 507.23 nH	Quality factor: 0.065
Series C: -49.938 nF	S11 Phase: 99.12°
Parallel R: 49.589 Ω	S21 Gain: 0.028 dB
Parallel X: 122.29 μ H	S21 Phase: 52.75°
Marker 2	
Frequency: 609.603 MHz	VSWR: 2.171
Impedance: 23.3-j5.23 Ω	Return loss: -8.652 dB
Series L: -1.3652 nH	Quality factor: 0.224
Series C: 49.928 pF	S11 Phase: -164.82°
Parallel R: 24.52 Ω	S21 Gain: -2.972 dB
Parallel X: 2.3845 pF	S21 Phase: -73.31°
Marker 3	
Frequency: 863.929 MHz	VSWR: 16.702
Impedance: 5.46-j45.3 Ω	Return loss: -1.041 dB
Series L: -8.3383 nH	Quality factor: 8.285
Series C: 4.0701 pF	S11 Phase: -95.32°
Parallel R: 380.48 Ω	S21 Gain: -30.979 dB
Parallel X: 4.0117 pF	S21 Phase: 78.67°
S11	
Min VSWR: 1.011 @ 45.5319MHz	
Return loss: -45.392 dB	
S21	
Min gain: -32.433 dB @ 889.164MHz	
Max gain: 0.028 dB @ 1.00000MHz	
Analysis ...	

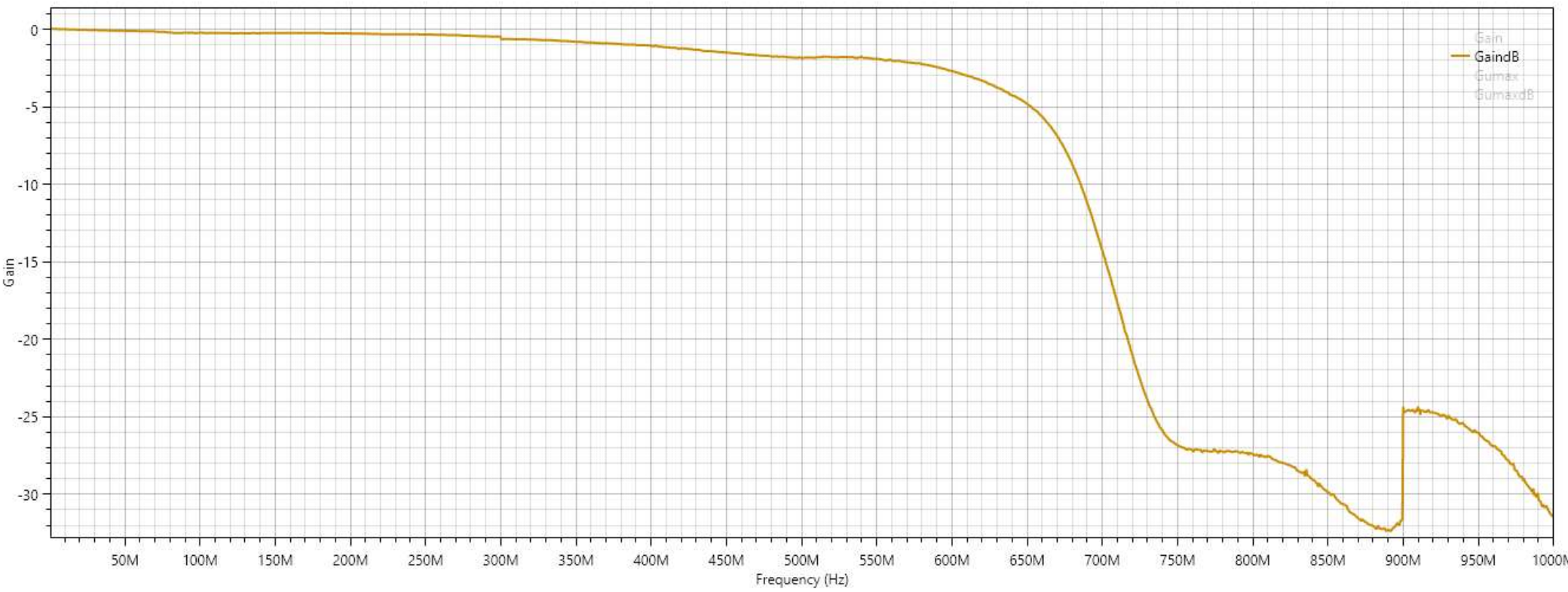


UHF Low Pass Filter



S-Parameters

dB Magnitude Real Imaginary Phase Unwrap Phase Group Delay K-Factor Gain VSWR
X-Axis from 1M to 999.99918M Y-Axis from -32.43267 to 1.00752



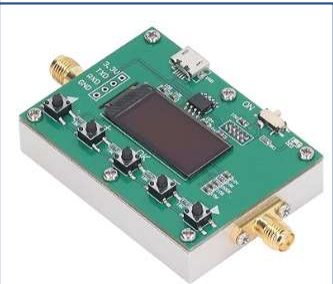
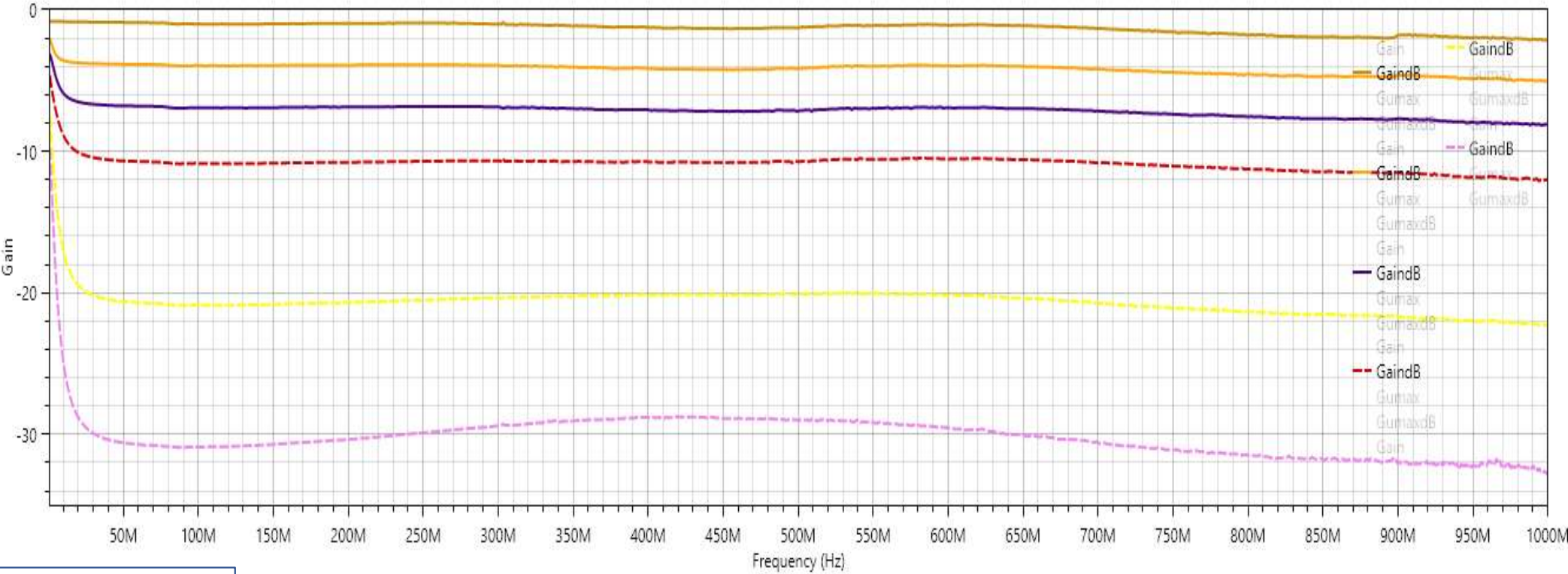
All Gain GaindB Gumax GumaxdB

UHF Low Pass Filter



S-Parameters

dB Magnitude Real Imaginary Phase Unwrap Phase Group Delay K-Factor Gain VSWR
X-Axis from 1M to 1000M Y-Axis from -35 to 0

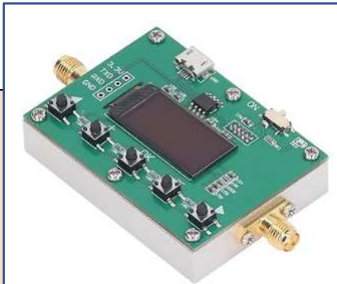
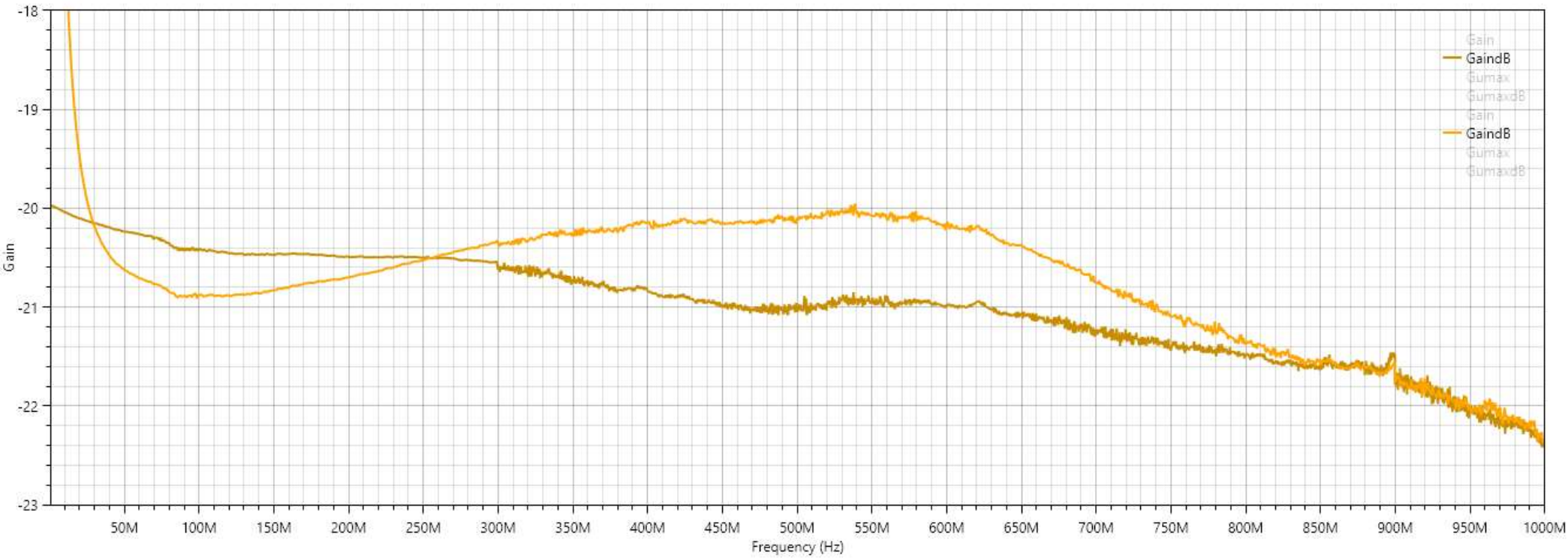


Digital RF Attenuator



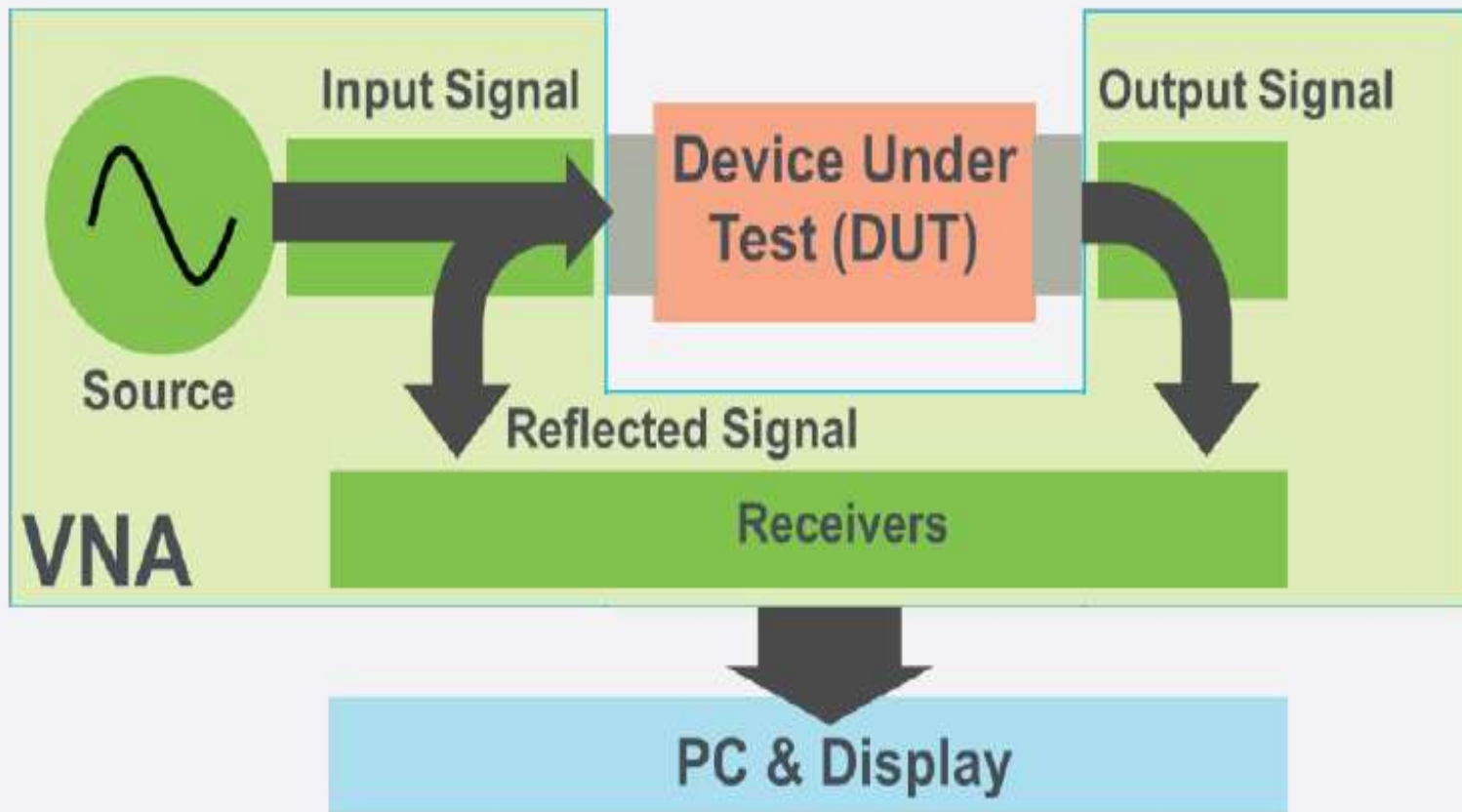
S-Parameters

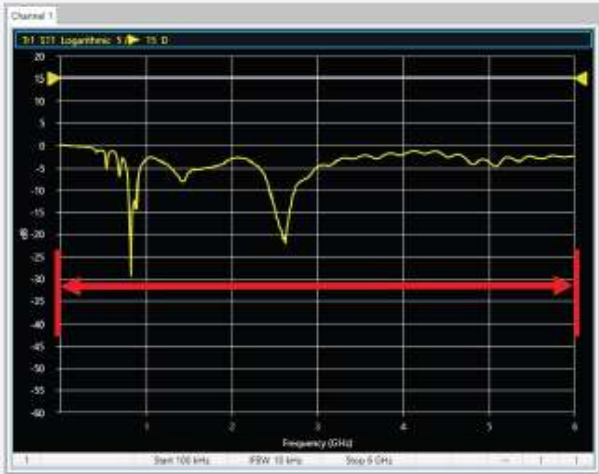
dB Magnitude Real Imaginary Phase Unwrap Phase Group Delay K-Factor Gain VSWR
 X-Axis from 1M to 999.99918M Y-Axis from -23 to -18



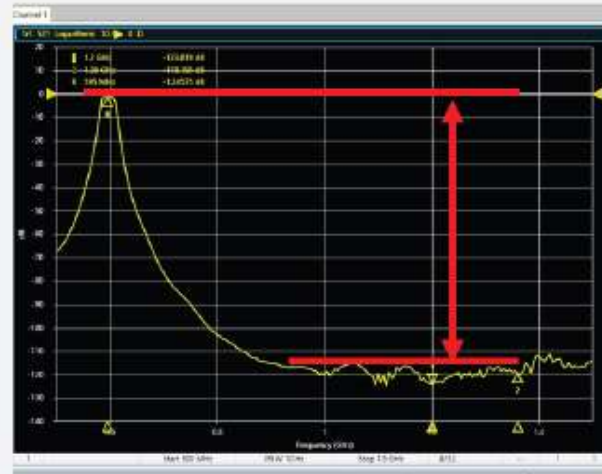
- VNA_Brick_20_dB_ATT.s2p All Gain GaindB Gumax GumaxdB
- VNA_20_dB_ATT.s2p All Gain GaindB Gumax GumaxdB



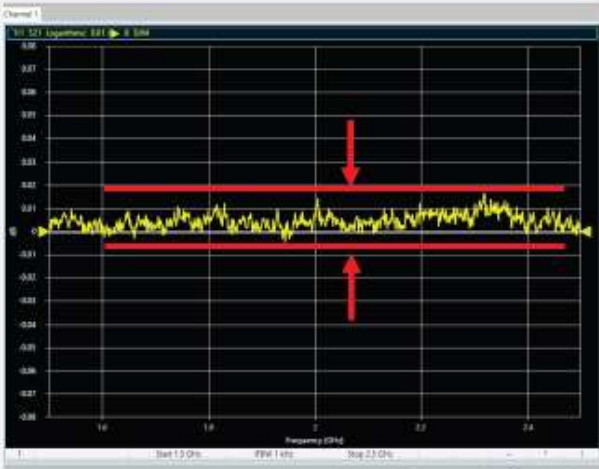




(a) Frequency Range



(b) Dynamic Range

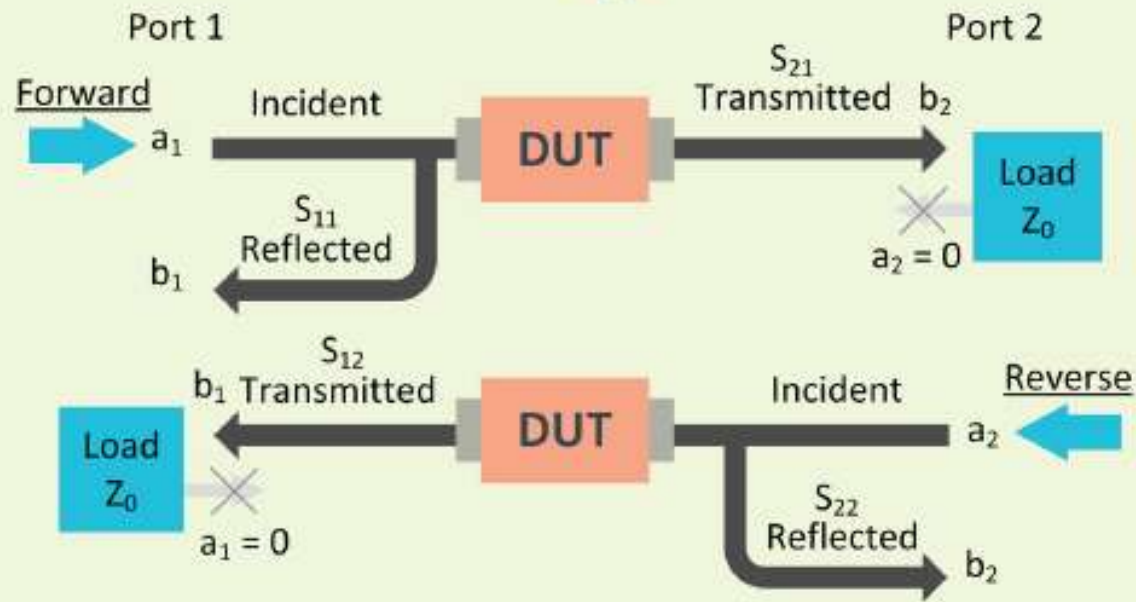


(c) Trace Noise



(d) Measurement speed

S-Parameter Theory View



Forward:

Reverse:

Reflection:

$$S_{11} = \frac{\text{Reflected}}{\text{Incident}} = \frac{b_1}{a_1} \Big|_{a_2=0}$$

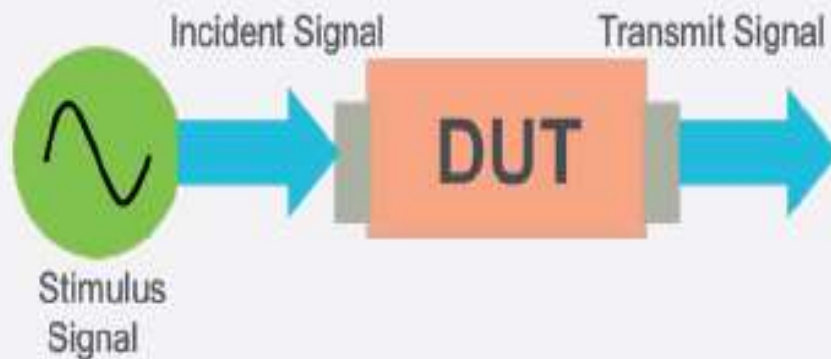
$$S_{22} = \frac{\text{Reflected}}{\text{Incident}} = \frac{b_2}{a_2} \Big|_{a_1=0}$$

Transmission:

$$S_{21} = \frac{\text{Transmitted}}{\text{Incident}} = \frac{b_2}{a_1} \Big|_{a_2=0}$$

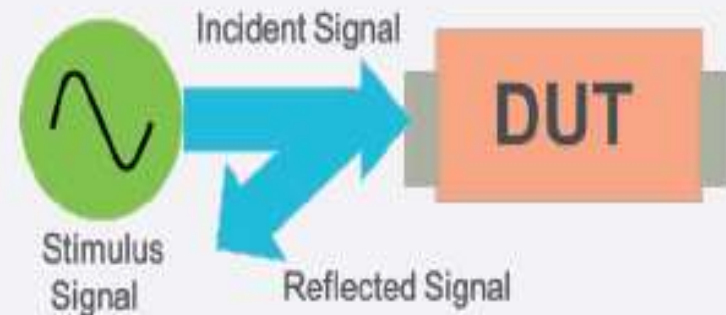
$$S_{12} = \frac{\text{Transmitted}}{\text{Incident}} = \frac{b_1}{a_2} \Big|_{a_1=0}$$

Transmission Measurements



- Transmission Coefficients (S_{21} , S_{12})
- Gain
- Insertion Loss/Phase
- Electrical Length/Delay
- Group Delay

Reflection Measurements

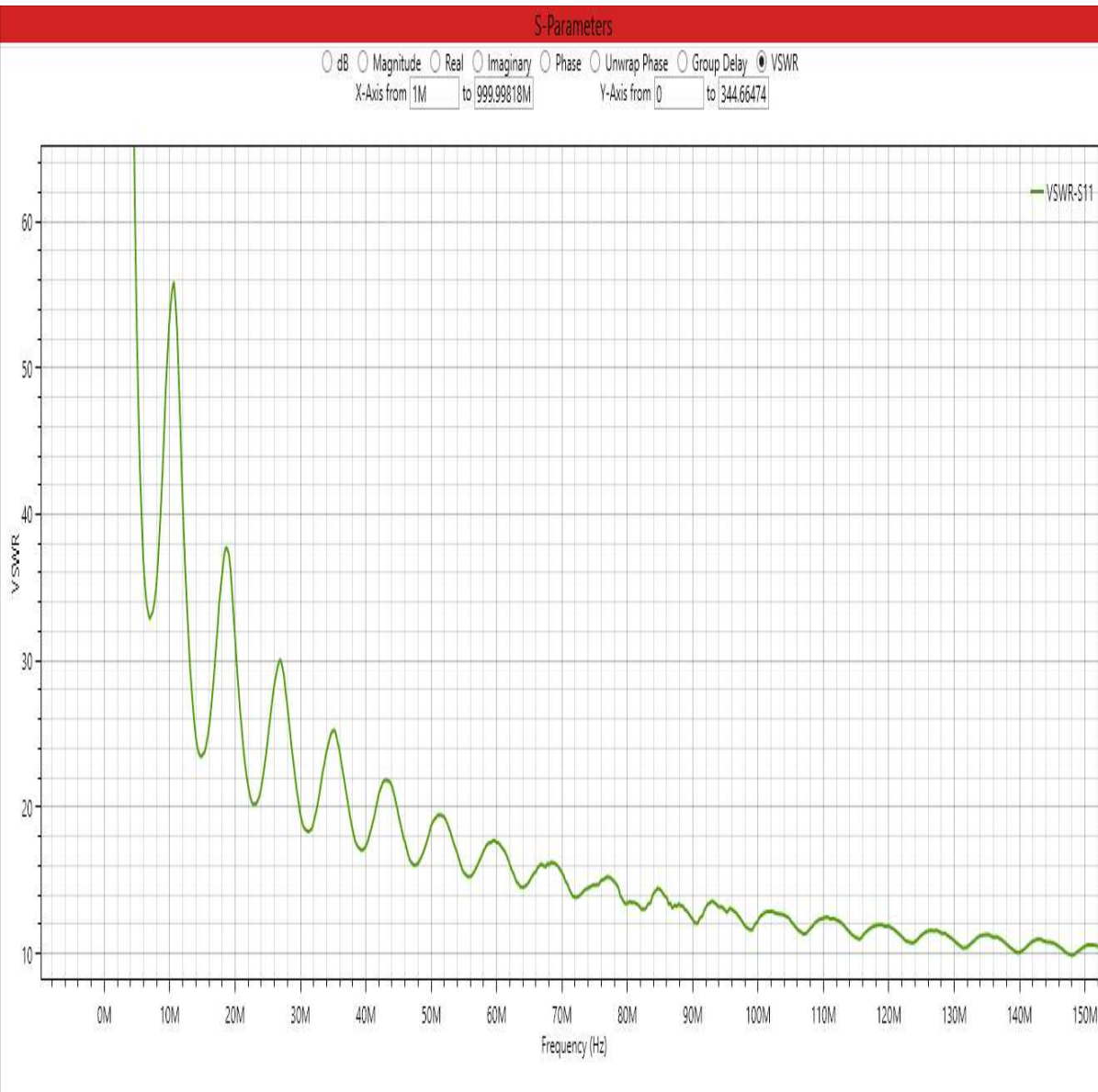


- Reflection Coefficients (S_{11} , S_{22})
- Return Loss
- VSWR (Voltage Standing Wave Ratio)
- Impedance ($R+jX$)

Some VNAs are capable of using inverse Fourier transforms to convert swept frequency measurements into the time domain. In this way, data displayed in the time domain allows the VNA to be used to find problems in cables and connections by detecting the locations of impedance mismatches or discontinuities as the signal passes through the DUT.

For time domain measurements, the ability to resolve two signals is inversely proportional to the measured frequency span. Therefore, the wider the frequency span, the greater the ability the VNA has to distinguish between closely spaced discontinuities. The maximum frequency span is set by the user and may be defined by either the frequency range of the VNA or the viable bandwidth of the DUT.





Sweep analysis

Select analysis

Analysis type: Resonance analysis

Run analysis

Run automatically

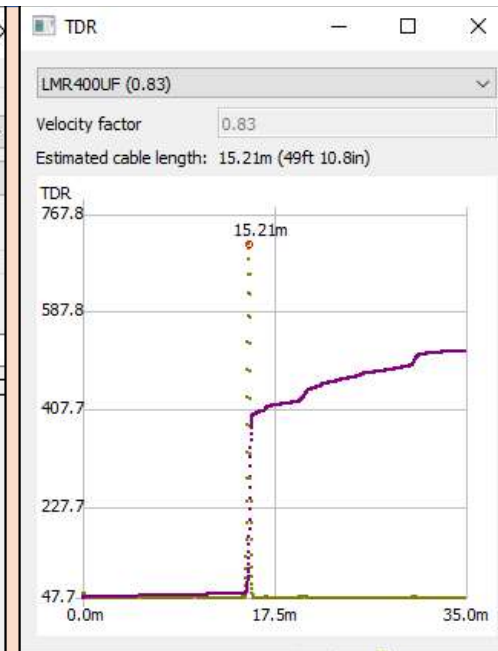
Analysis

Settings

Description: Resonance

Results

Resonance	3.96879MHz	(959m-j8.58 Ω)
Resonance	8.42198MHz	(334+j805 Ω)
Resonance	12.8752MHz	(1.44+j6.58 Ω)
Resonance	16.8336MHz	(370-j639 Ω)
Resonance	20.2972MHz	(2.08-j7.08 Ω)
Resonance	24.7504MHz	(933+j593 Ω)
Resonance	29.2035MHz	(2.14+j7.77 Ω)
Resonance	33.1619MHz	(238-j454 Ω)
Resonance	36.6255MHz	(2.61-j6.01 Ω)
Resonance	41.0787MHz	(1.05k-j37.5 Ω)
Resonance	45.5319MHz	(2.68+j8.78 Ω)
Resonance	48.9955MHz	(292+j448 Ω)
Resonance	52.9539MHz	(3.01-j4.93 Ω)
Resonance	57.4071MHz	(720-j357 Ω)
Resonance	60.8707MHz	(3.31-j9.23 Ω)
Resonance	65.3239MHz	(438+j427 Ω)
Resonance	69.7771MHz	(3.33+j5.44 Ω)
Resonance	73.7355MHz	(522-j385 Ω)
Resonance	77.1990MHz	(3.66-j8.43 Ω)
Resonance	81.6522MHz	(600+j306 Ω)
Resonance	86.1054MHz	(3.91+j6.41 Ω)
Resonance	90.0638MHz	(337-j350 Ω)
Resonance	93.5274MHz	(3.95-j7.48 Ω)
Resonance	97.9806MHz	(669+j66.5 Ω)

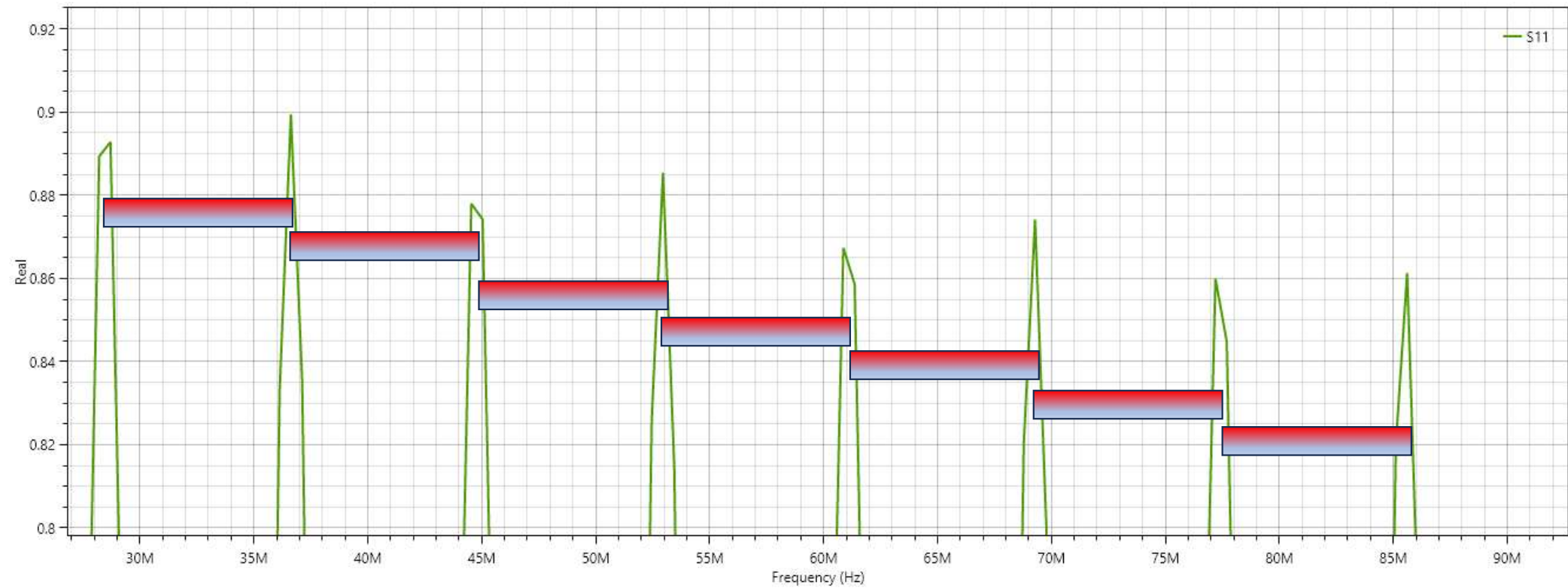


LMR 400 50 feet
Open Load
1 – 1000 MHz



S-Parameters

dB Magnitude Real Imaginary Phase Unwrap Phase Group Delay VSWR
X-Axis from 1M to 999.99918M Y-Axis from -0.93096 to 0.95574



All S11

Loading time < 1 sec

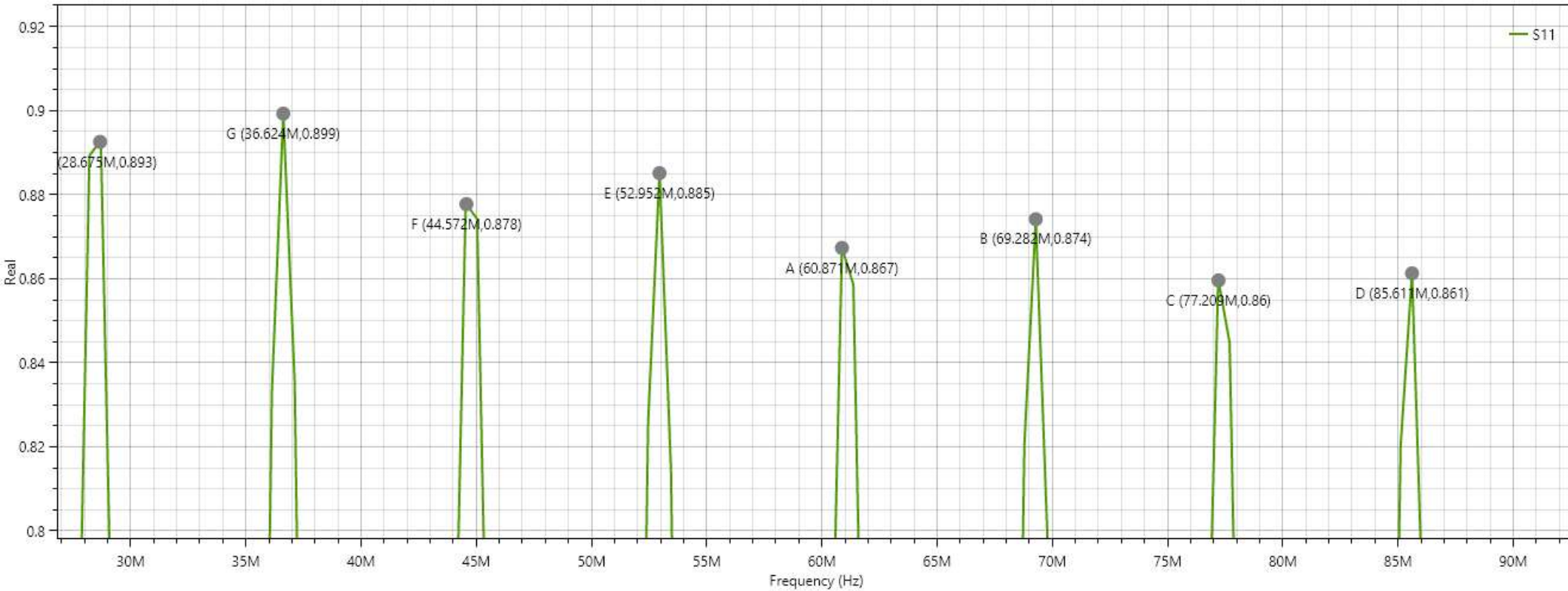
Points: 2,020 Step Size: 494.799kHz Ports: 1 Impedance: 50 Ω

LMR 400 50 feet Short Load 1 – 1000 MHz (detail presentation)



S-Parameters

dB Magnitude Real Imaginary Phase Unwrap Phase Group Delay VSWR
X-Axis from 1M to 999.99918M Y-Axis from -0.93096 to 0.95574



LMR 400 50 feet Short Load 1 – 1000 MHz (detail presentation)



LMR 400 50 feet Short Load nanoVNA Data

- Peaks are 8.2 MHz Spacing
- LMR 400 Velocity Factor = 0.83

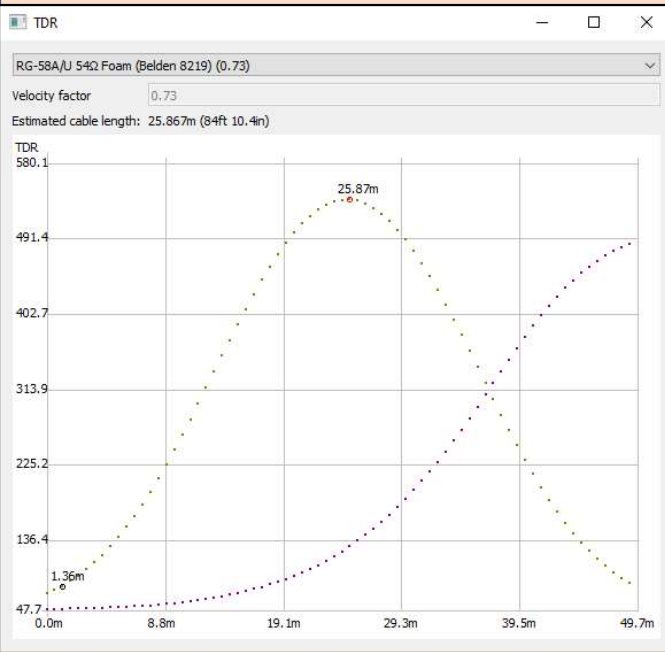
Since : $\lambda = c/f$

Then $\lambda = 0.83 * 3e8 / 8.2e6$

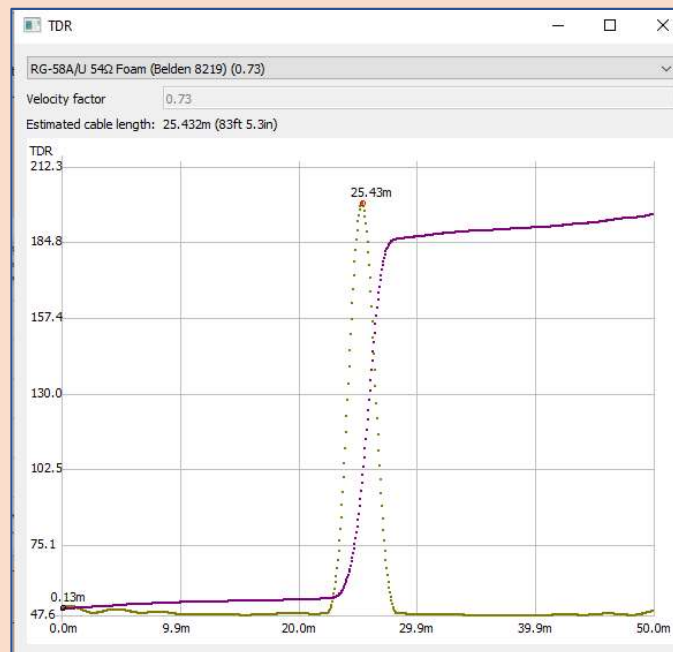
$\lambda = 30.365 \text{ m}$ (2 way length /time)

Thus Cable Length = 15.18 m (49.8 feet)

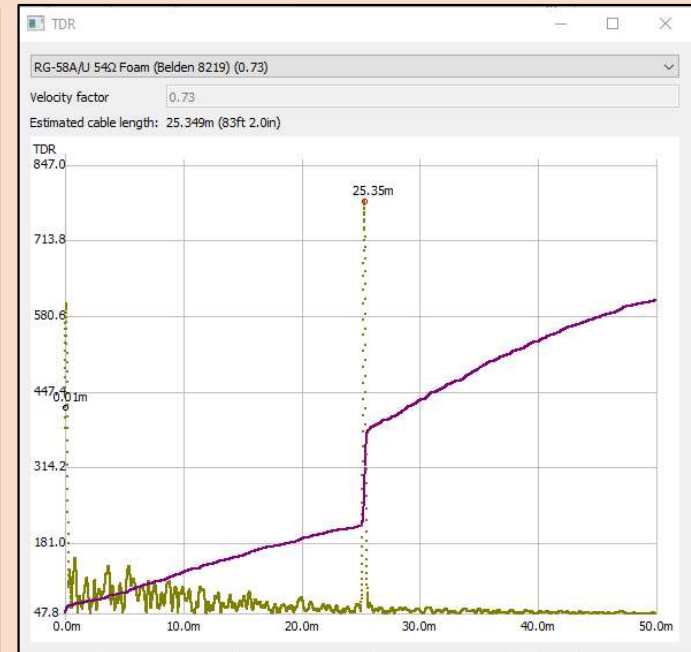
Fourier Transform and Spatial Resolution



0.1 – 10 MHz



0.1 – 100 MHz



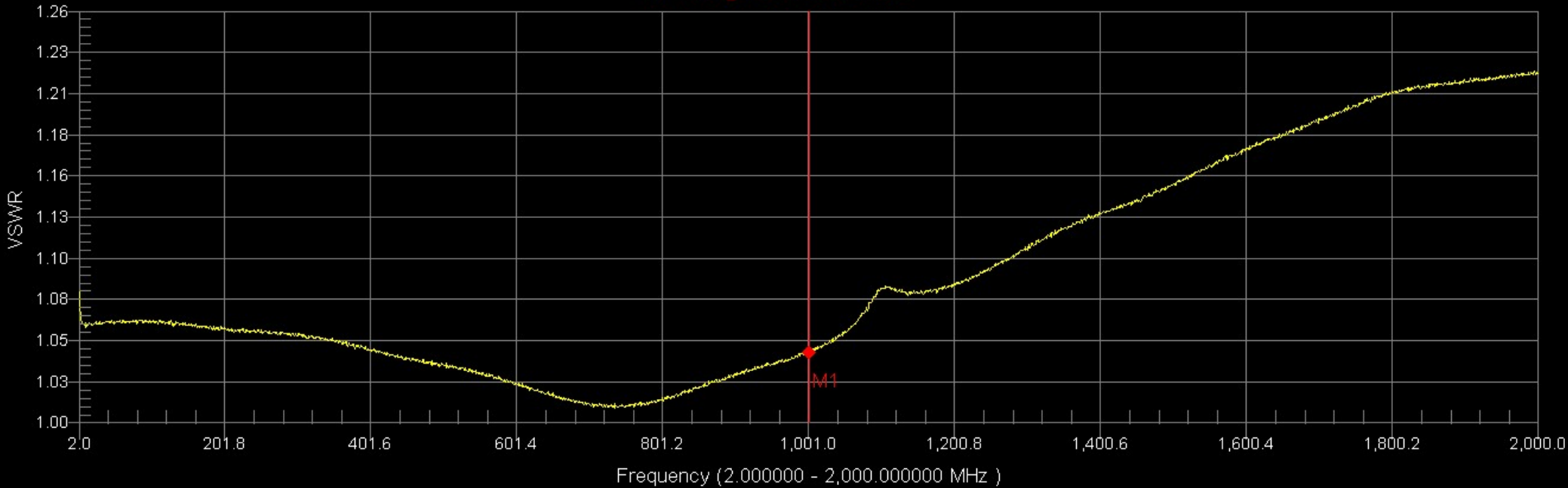
0.1 – 1000 MHz

nanoVNA data

VSWR

Instrument File

M1 1.04 @ 1,001.000100 MHz



Frequency (2.000000 - 2,000.000000 MHz)

Resolution: 2065

Std: None

Date: Wednesday, March 20, 2024

Model: S331L

CAL: On (InstaCal-Std)

Smoothing %: OFF

Time: 10:43:07 AM

Serial: 1520069

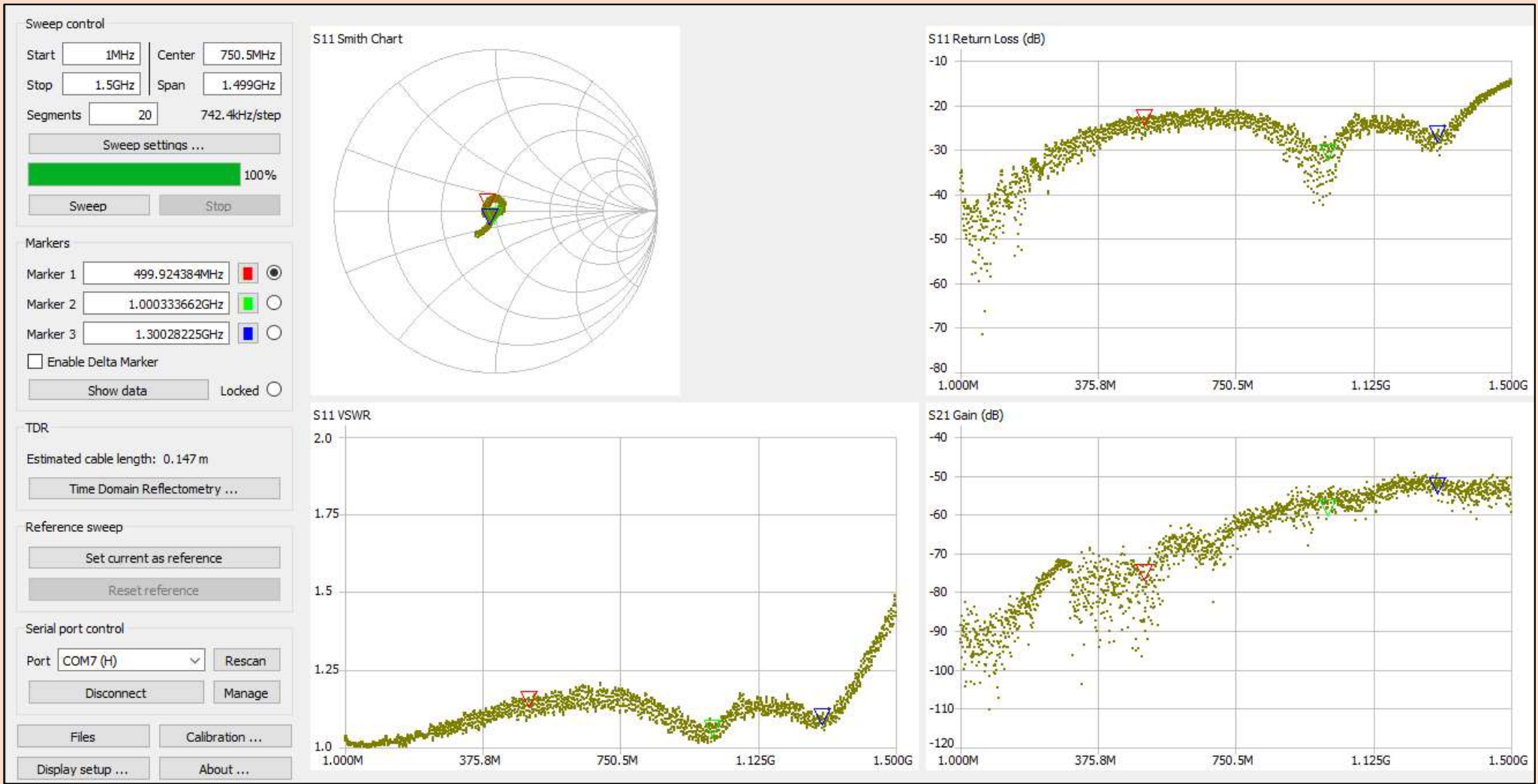
RF Immunity: High

SiteMaster S331L Calibration

2 – 2000 MHz

2065 data points





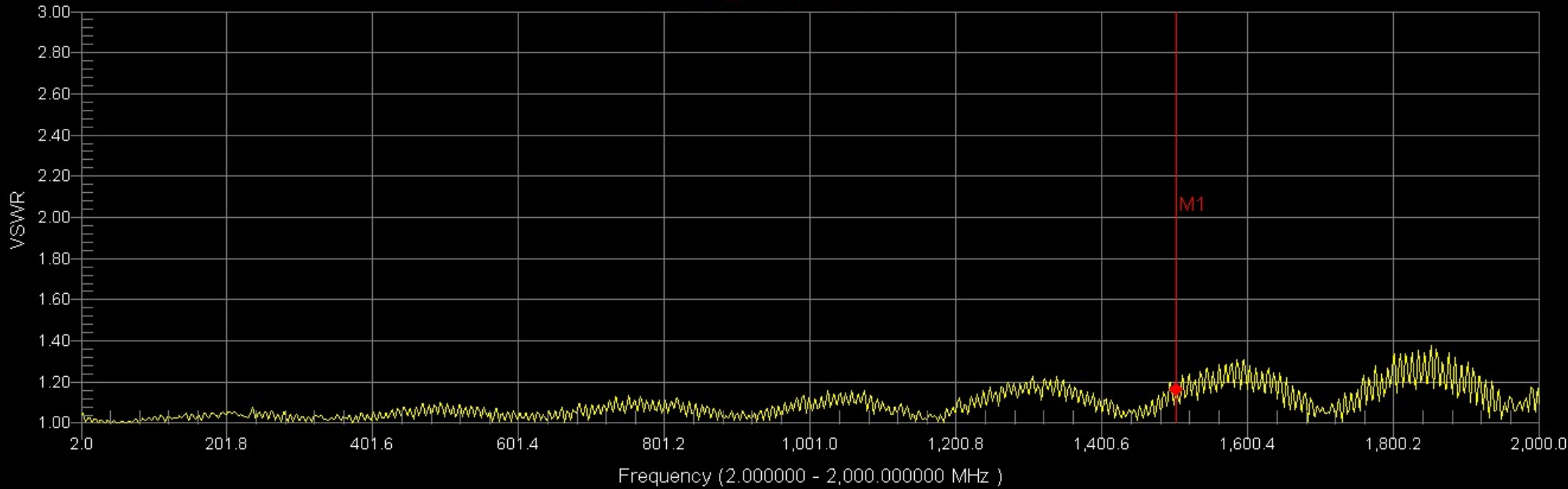
nanoVNA 1 – 1500 MHz 50 feet LMR 400 plus 50 ohm termination load



VSWR

Instrument File

M1 1.16 @ 1,501.312345 MHz



Resolution: 1033
Std: None
Date: Monday, March 18, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 8:40:53 PM
Serial: 1520069

RF Immunity: High

SiteMaster S331L 1 – 1500 MHz 50 feet LMR 400 plus 50 ohm termination



Transmission Line Network

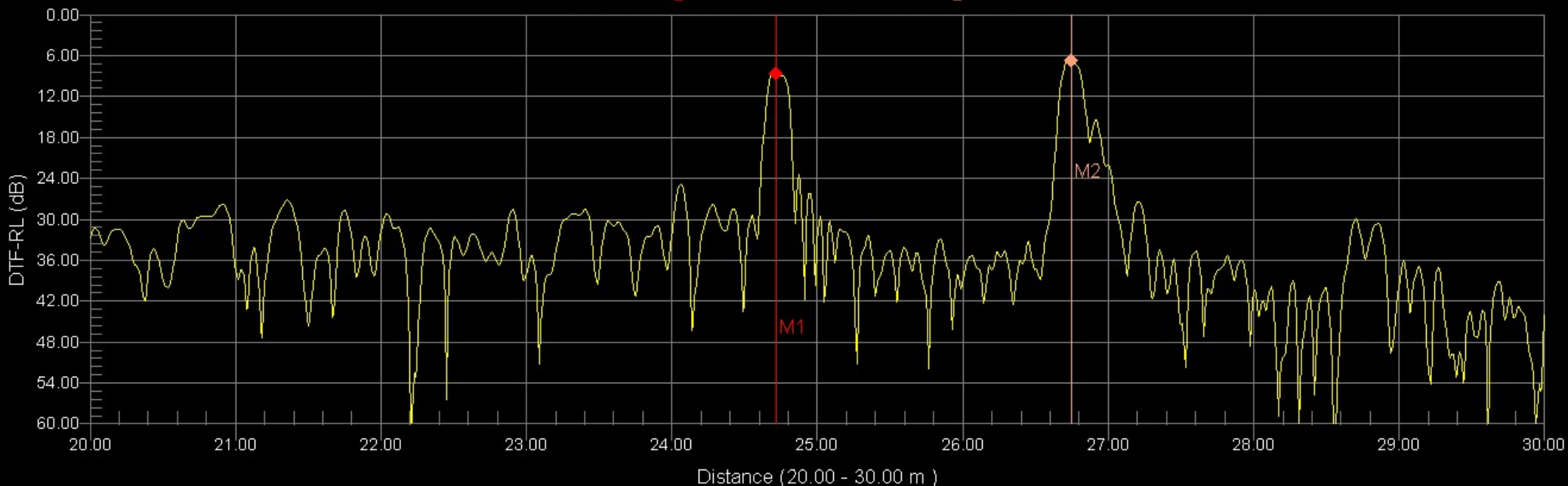
- **RG 58a/u** **Z= 50 ohm** **75 feet**
- **RG 59u** **Z = 75 ohm** **10 feet**
- **Load** **Z = 50 ohm**

DTF Return Loss

Instrument File

M1 8.55 dB @ 24.72 m

M2 6.70 dB @ 26.75 m



Resolution: 1033
Std: None
Date: Tuesday, March 19, 2024
Model: S331L

CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 9:34:52 AM
Serial: 1520069

RF Immunity: High
Freq: Start/Stop: 2.0 MHz/2000.0 MHz
Ins. Loss: 0.594 dB/m
Prop.Vel: 0.730

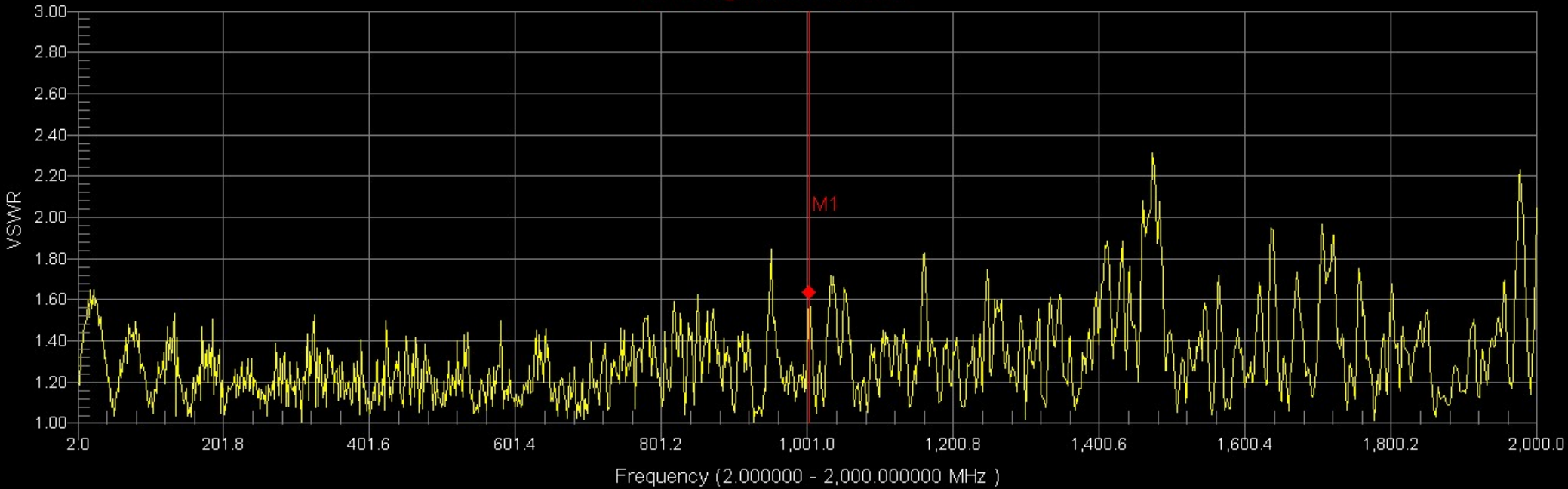
SiteMaster S331L DTF Transmission Line Network



VSWR

Instrument File

M1 1.64 @ 1,002.936000 MHz



Resolution: 1033
Std: None
Date: Tuesday, March 19, 2024
Model: S331L

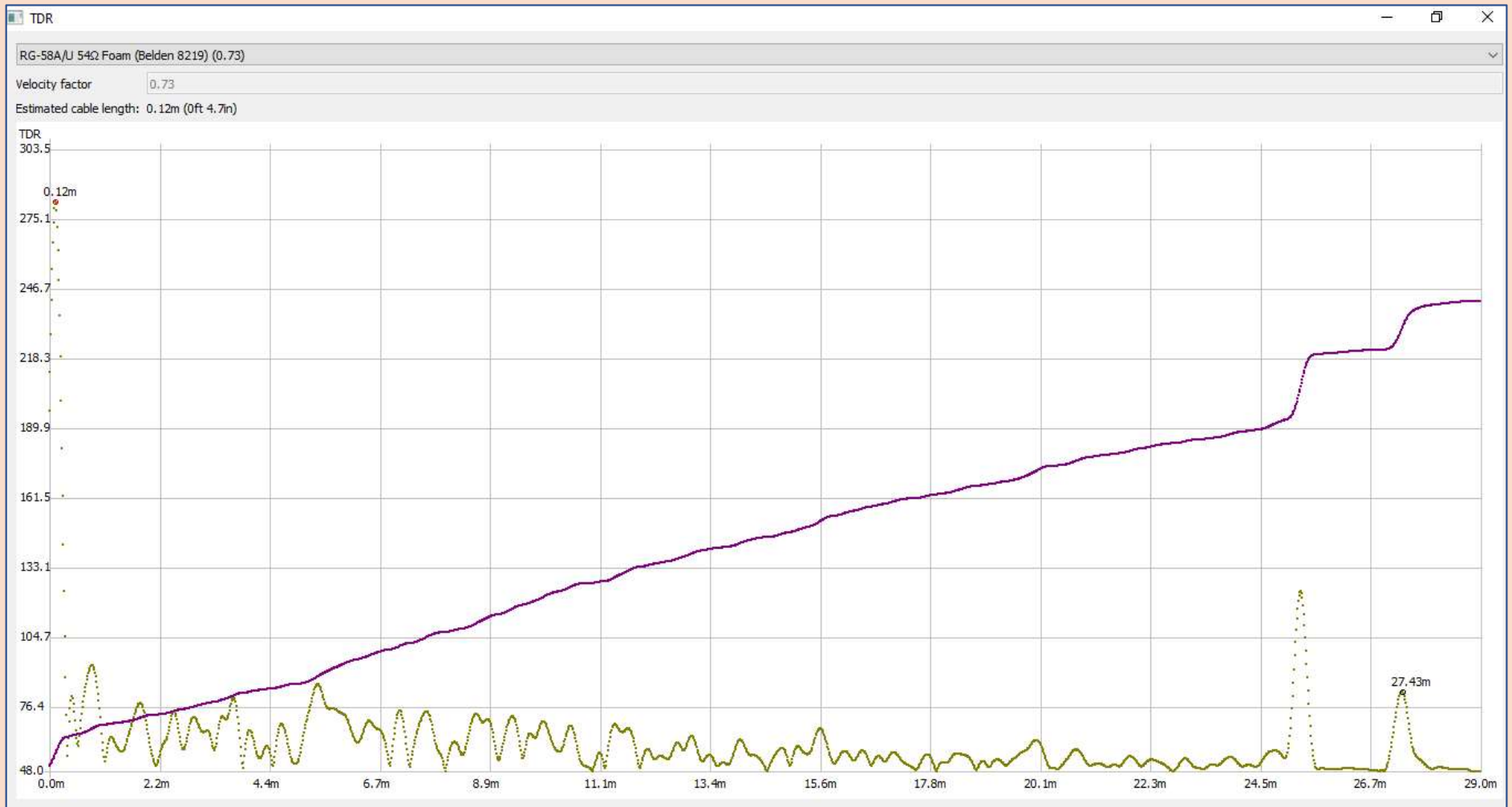
CAL: On (InstaCal-Std)
Smoothing %: OFF
Time: 9:47:51 AM
Serial: 1520069

RF Immunity: High

SiteMaster S331L VSWR

Transmission Line Network

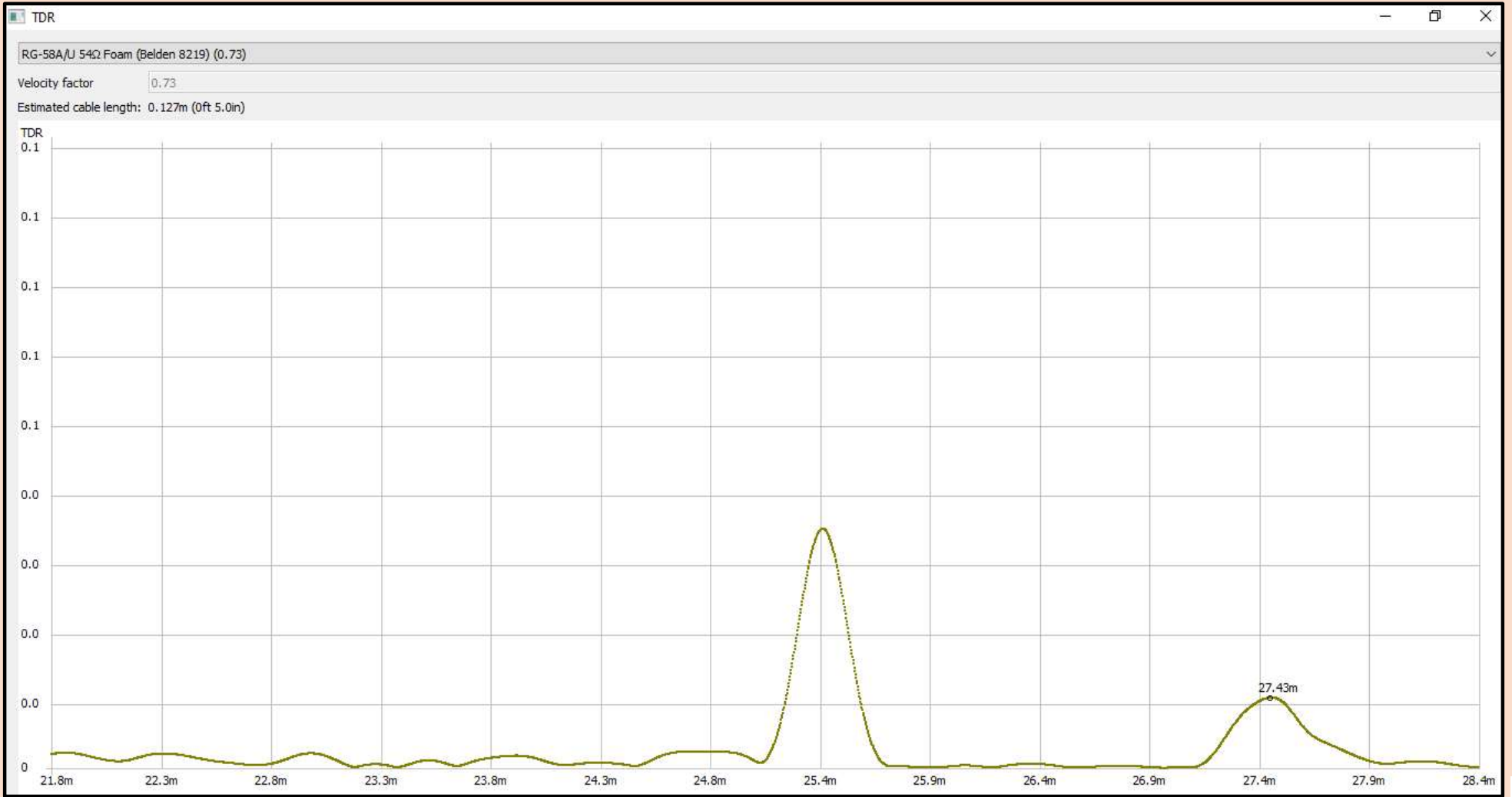




nanoVNA DTF

Transmission Line Network

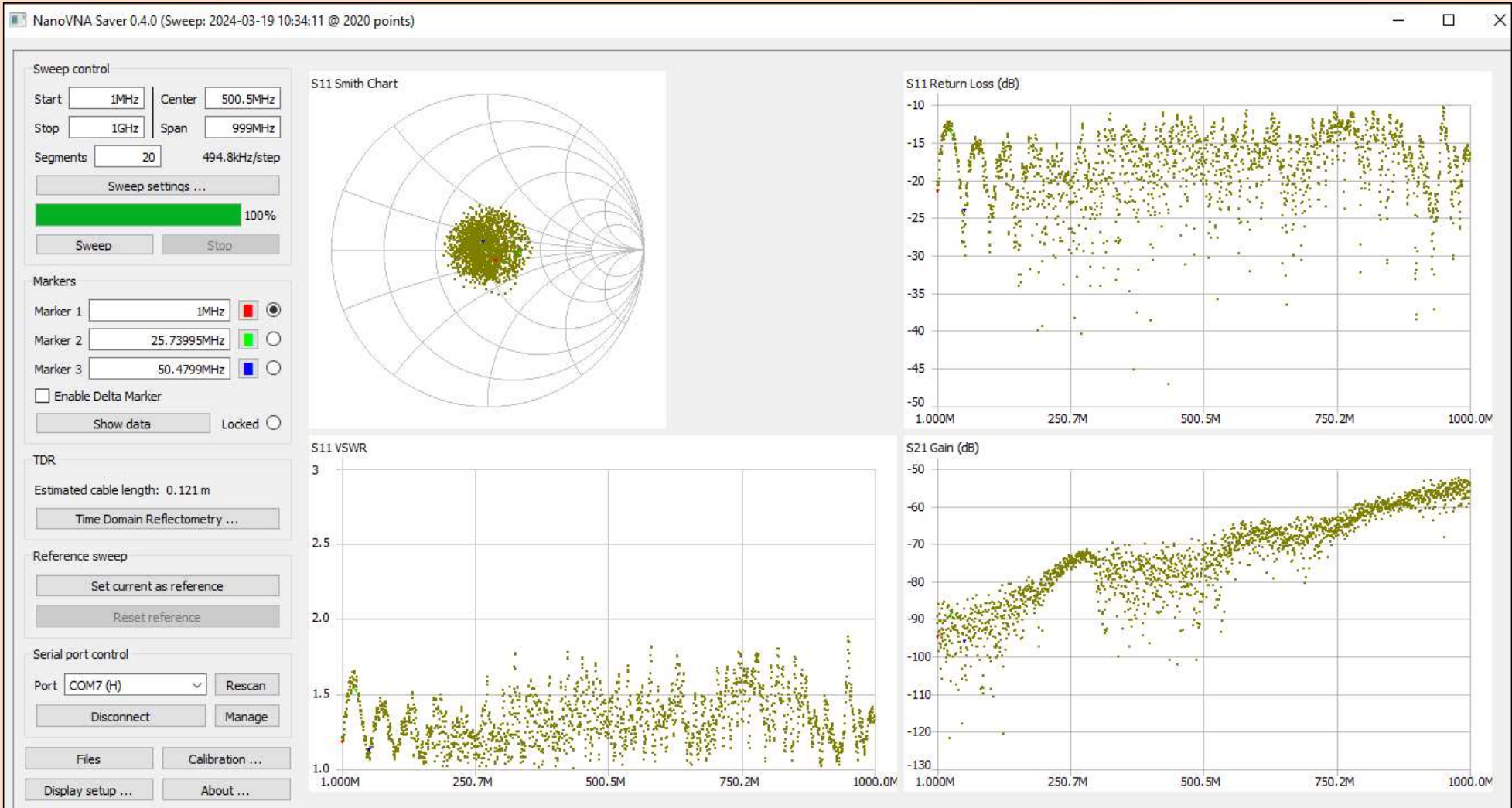




nanoVNA DTF

Transmission Line Network





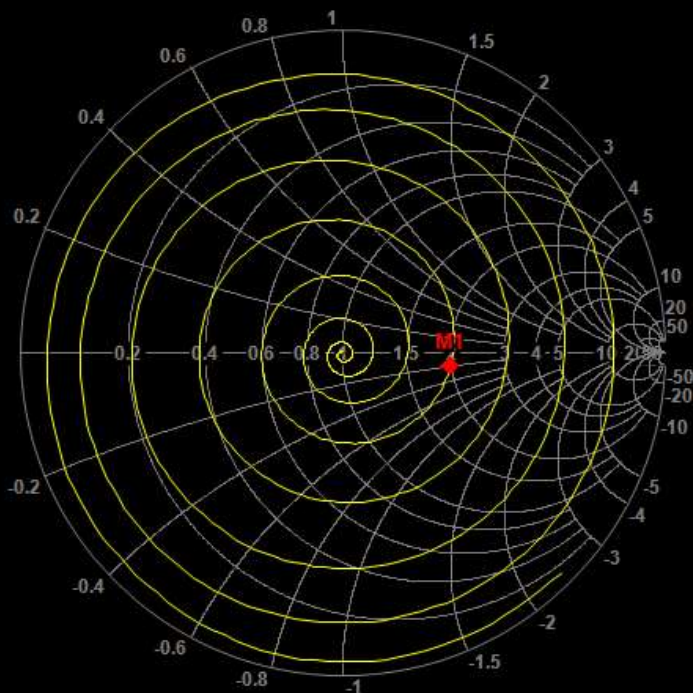
nanoVNA VSWR Transmission Line Network



50 Ω Smith Chart

Instrument File

M1 1,002.936000 MHz Z(100.078 Ω, -9.037 Ω)



Resolution: 1033
Std: None
Date: Tuesday, March 19, 2024
Model: S331L

CAL: On (InstaCal-Std)
Time: 11:42:44 AM
Serial: 1520069

RF Immunity: High

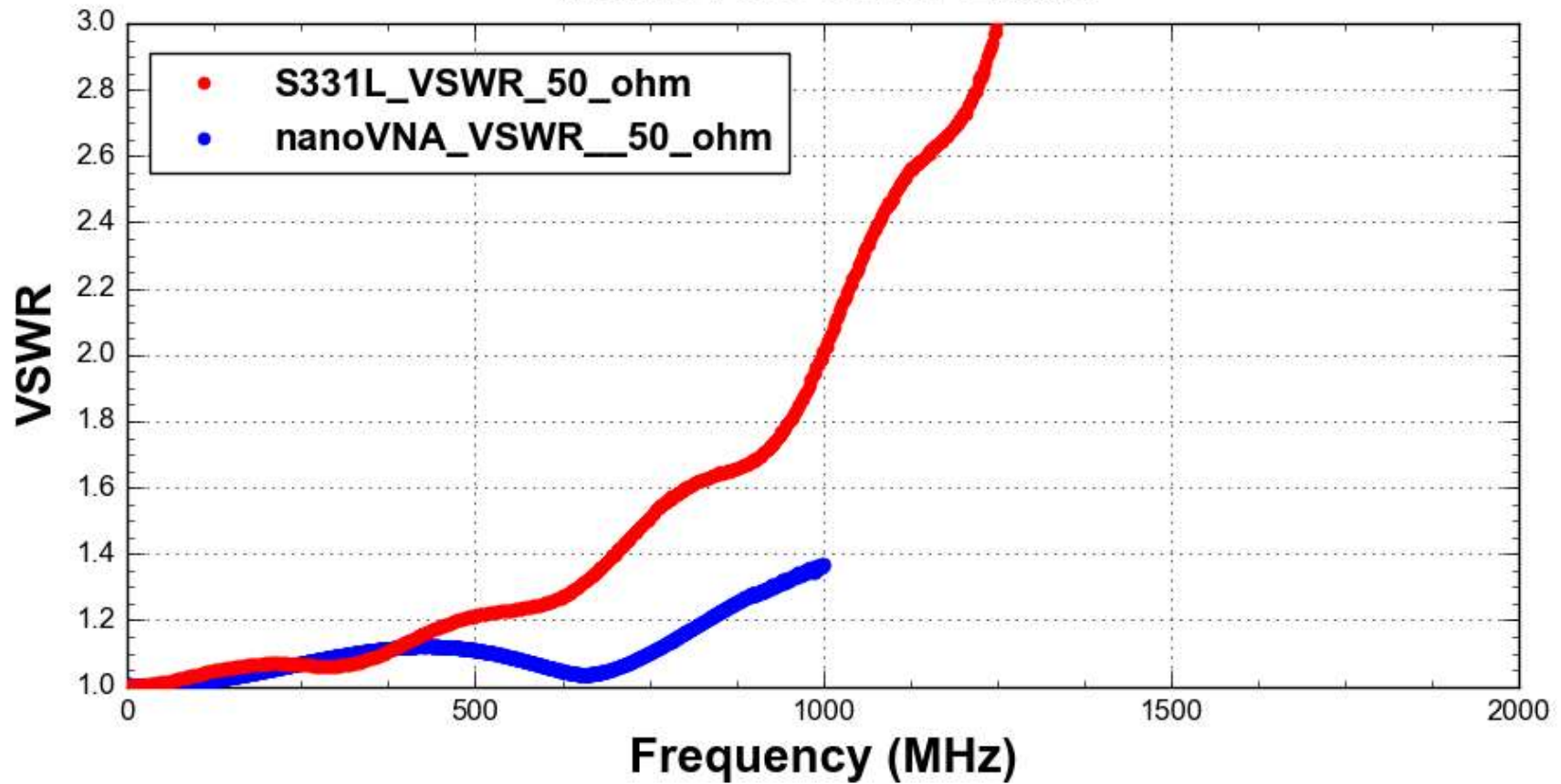
Reference Impedance: 50Ω

SiteMaster S331L Smith Chart

50 ohm Load



VSWR 50 ohm Load

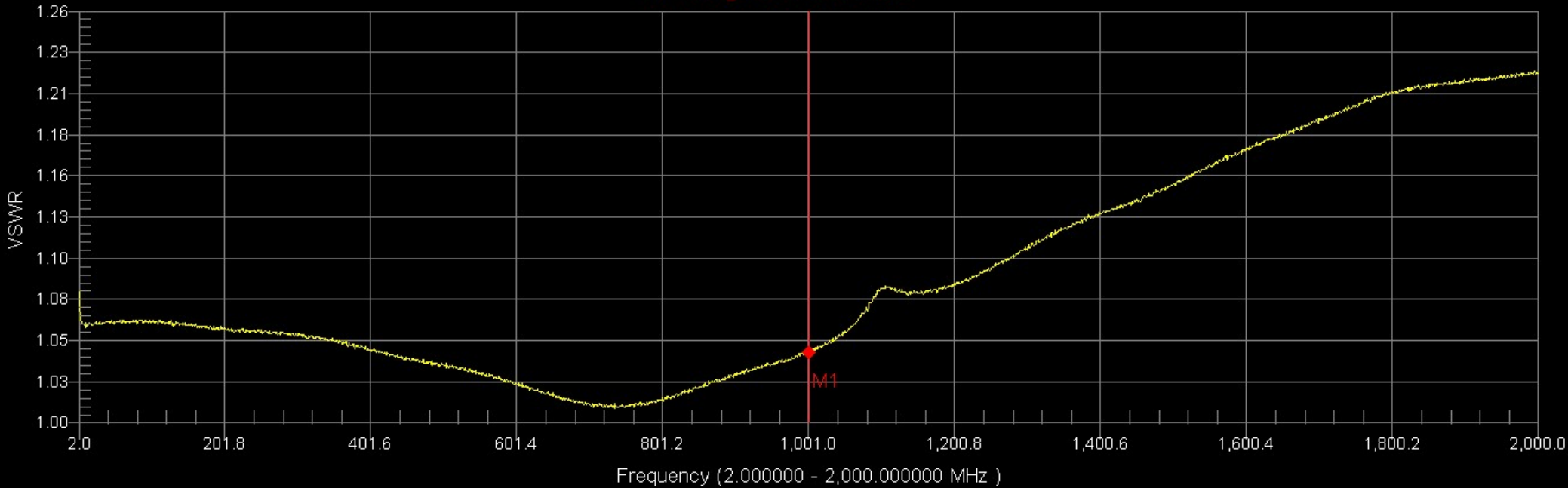


SiteMaster S331L and nanoVNA SWR **50 ohm Load**

VSWR

Instrument File

M1 1.04 @ 1,001.000100 MHz



Resolution: 2065

Std: None

Date: Wednesday, March 20, 2024

Model: S331L

CAL: On (InstaCal-Std)

Smoothing %: OFF

Time: 10:43:07 AM

Serial: 1520069

RF Immunity: High

SiteMaster S331L Calibration

2 – 2000 MHz

2065 data points

