



Nano VNA Workshop

ARRL Field Day

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Field Day 2022

Workshop Topics

What is a VNA anyway?

What can I use it for in the context of amateur radio?

Basic Concepts – Common terms used

Activity 1

Calibration step.

Activity 2

Measuring your coax cable length or change in impedance to a fault

Measure the loss of the coax for differing frequency applications

Activity 3

Analyzing a ham radio 80 m band pass filter from Low Band Systems.

Using the free computer software to make it easier to program and use.

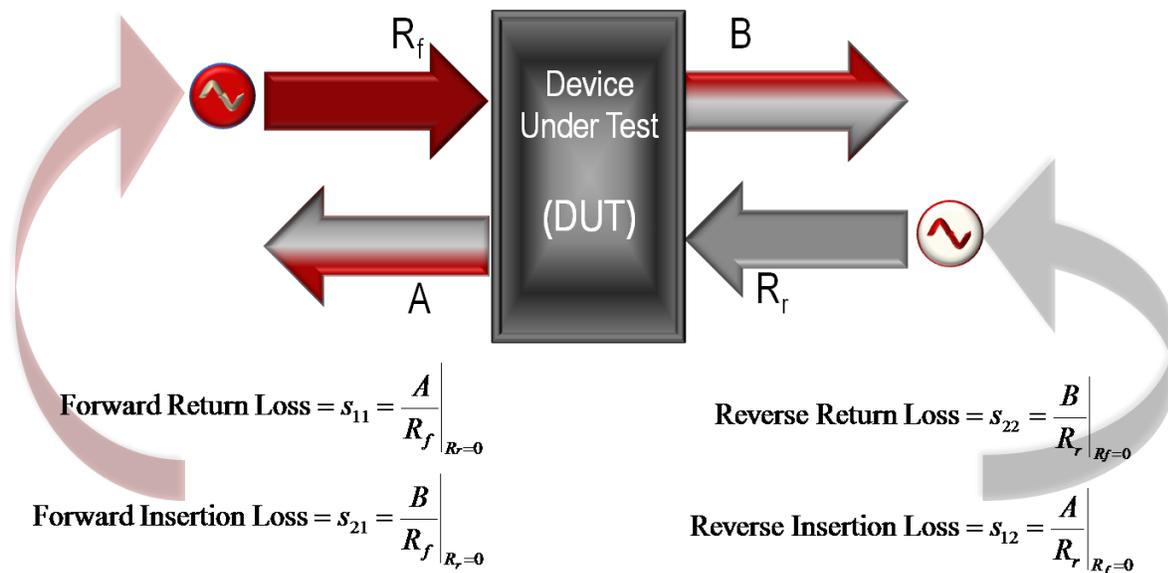
Questions

What is a VNA?

Vector Network Analyzer, VNA, is an instrument that measures network parameters of electrical networks, such as antenna or antenna system, filters, individual components, etc. The VNA sends a known signal (an electromagnetic wave of known magnitude and frequency) into a device under test (DUT), and measures how much of that wave reflects from the device (reflection) and how much transmits through the device (transmission).

The NanoVNA is a two port device. The VNA captures both magnitude and phase of reflected wave from the DUT or magnitude and phase of the wave that has passed through the DUT. When measuring one port devices, such as an antenna or individual components, the VNA transmits a signal of known magnitude and frequency from its Port 1 into the DUT and measures magnitude and phase of the reflected signal from the DUT on the same port, VNA Port 1. This known as S11.

When measuring two ports devices, e.g. filters, the VNA transmits a signal of known magnitude and frequency from its Port 1 into the DUT and measures the magnitude and phase of the signal passed through the DUT to the VNA other port, Port 2. All other "measurements" are calculated in the VNA based on measurements of the magnitude and phase of the reflected and transient signal. This is known as S21.



What can I use it for in the context of amateur radio?

- Measure VSWR (aka SWR) for an antenna and transmission lines
- Measure the characteristic impedance (Z_0) of coaxial cable
- Measure the distance along a coax until it sees a significant change in impedance. (use to check the length or look for a defect)
- Measure response of a filter (low pass, high pass, bandpass) (needs 2 ports)
- Advanced uses include Smith Chart and $R+jX$ impedance measurements

Most Hams want to use these for testing antennas. It is a good instrument for that purpose and will allow you to set it up to sweep a particular set of frequencies.

Failures in antenna system can be hard to locate. The NanoVNA can operate as a Time Domain Reflectometer (TDR) to help find the location of a fault or a bad connector.

CAUTION! When using the NanoVNA to test an outdoor antenna, it is important to first discharge any built up charge it may have from static electricity. The coax cable can act like a capacitor and store this charge. If you connect your NanoVNA, it can blow out the sensitive front-end electronics.

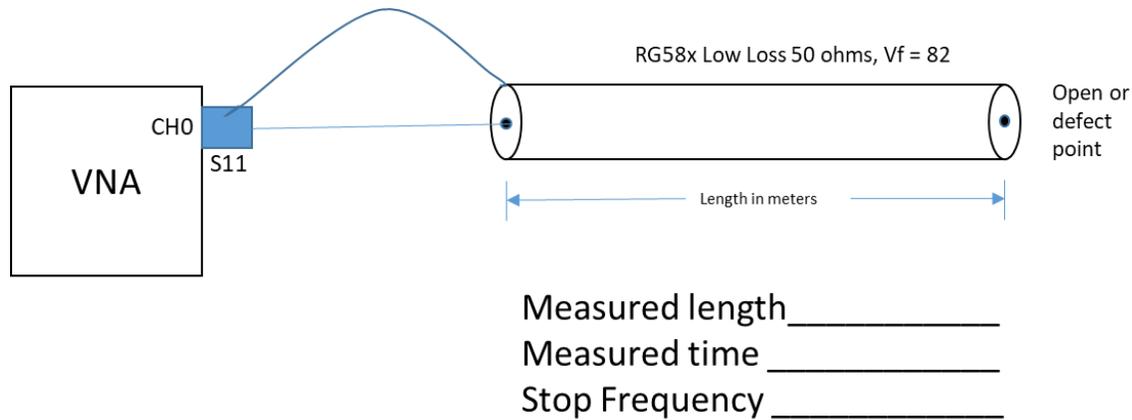
Activity 1: Measure length of coax and losses at various frequencies

Length

Theory – If we put a pulse on the coax with the opposite end open, it will be reflected back to the VNA port, which is looking for Return Loss signals. This reflected signal, knowing the velocity factor, will tell us the length of the coax (electrically speaking). The physical length can vary by a number of inches.

We can measure the time it takes to make a round trip on the coax and knowing the Velocity factor, we can calculate the length.

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- 1) Know the type of coax (ie RG8x, RG8u, etc) [DX Engineering Low Loss DXE-8XDB050 with BNC connectors]

- Gas injected foam dielectric cable, 16 AWG center, 19 strands 29 AWG shield
- Loss for 100ft is 1.4dB @ 30Mhz
- Velocity Factor is ~82% (data sheet) , because it is foam type dielectric

- 2) Connect the coax to the NanoVNA with the needed adapter(s). (BNC to SMA)
- 3) Display -> Turn on Trace 0 for Channel 0.
- 4) Add one marker, if not already on (triangle shape with number)
- 5) In Display -> Format -> More-> Linear (for a linear graph)
- 6) In Display -> Transform -> Transform ON
- 7) In Display -> Transform -> Low Pass Impulse (which give you just a pulse output)
- 8) In Display -> Transform .-> Velocity factor (Vf) enter 82 x1 (which means 82% of C – speed of light)
- 9) In Stimulus -> Start 50KHz
- 10) In Stimulus ->Stop (what to put here?) It depends....

With NanoSaver Software:

- 1) Select the Time Domain Reflectometer – opens small window
- 2) Set the velocity factor as Semi-solid PE (vf = ~84%) Close enough.
- 3) Electrical length is shown in meters and feet.

Because the NanoVNA only has limitations on the length it can measure. To get the best results we have to determine what Stop Frequency to enter.

- Higher Frequency = shorter the distance range
- Lower Frequency = longer distance range

Estimate the length of the coax. We will use this to set the stop frequency.

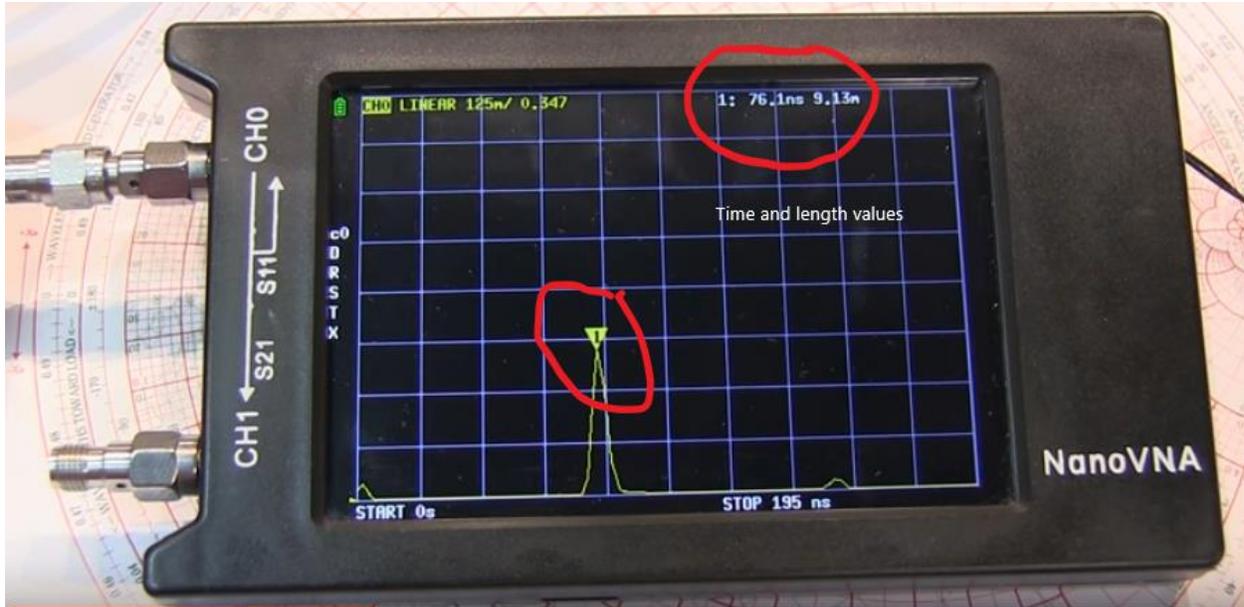
$$\text{Stop Freq (Mhz)} = \frac{5850}{\text{Max Distance}(m)} \times \text{Vf} \quad (\text{this is the decimal value, ie 80\% is 0.80})$$

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$$\text{Stop Freq} = \frac{5850}{25m} \times 0.82 = 191 \text{ Mhz} - \text{ Lets round down to } 190 \text{ MHz}$$

Note: The marker, if moved to the end of the trace, would tell you the maximum length range.

- 11) Look at the trace and do a Display -> Search -> Maximum to get the max value of the pulse.
- 12) The display shows the length in meters and the round trip time (typically in nS).



NanoVNA Display for cable length

NanoVNA Measured Length _____ m _____ Feet

Sanity Check

C = speed of light = 299,792,458 m/s

To travel 16m would take $16m/299,792,458m/s = 53.4 \text{ e-9}$ or 53.4ns

We measured _____ ns $V_f = \text{delay}(C)/\text{actual delay} = 53.4ns/ \text{_____} = \text{_____}$

Why is it longer than the physical length?

The clue is in the propagation speed. In free space a line with length = 1m would introduce a delay of $t_d = 1/c_0 = 3.333nS$.

When, due to dielectric material (as in a coaxial transmission line), the propagation speed is less (about $0.66*c_0$), this line (with physical length of 1m) would show a delay of. In our case $.82*c_0$

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$$T_d = 1/(0.82 * c_0) = 4.06 \text{ nS}$$

This is more delay, so electrically spoken; this line appears to be longer.

Based on $l_e = t_d * c_0$, the dielectrically filled line has an electrical length of:

$$e.l. = t_d * c_0 = 4.06 \text{ nS} * 3e8 = 1.21 \text{ m.}$$

So electrical length is the physical length of a line with propagation speed c_0 that behaves the same as the actual line.

Note that unterminated lines have somewhat more electrical length, even when corrected for the propagation speed of the actual line. This is because of the capacitive fringing at the unterminated end.

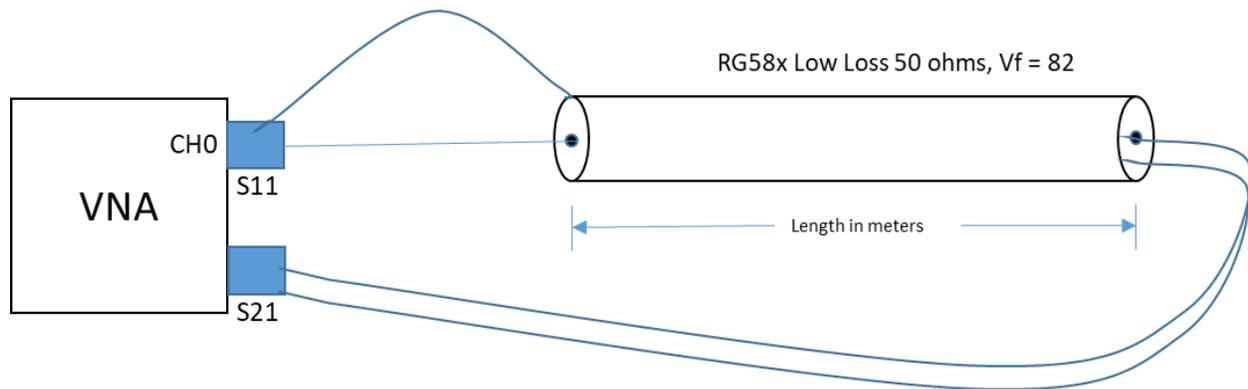
If you express the electrical length in wavelength, you can say
electrical length = (physical length)/(wavelength IN trans.line)

Part 2: COAX LOSSES

Guiding equation is $Z_0 = \sqrt{\frac{L}{C}}$ Where Z_0 = Impedance, $\sqrt{\frac{L}{C}}$ is cable loss

There are some good YouTube videos that show this measurement.

It requires the two port VNA configuration shown below.



If we measure this RG8x coax for use for VHF and UHF, what do you think we will find?

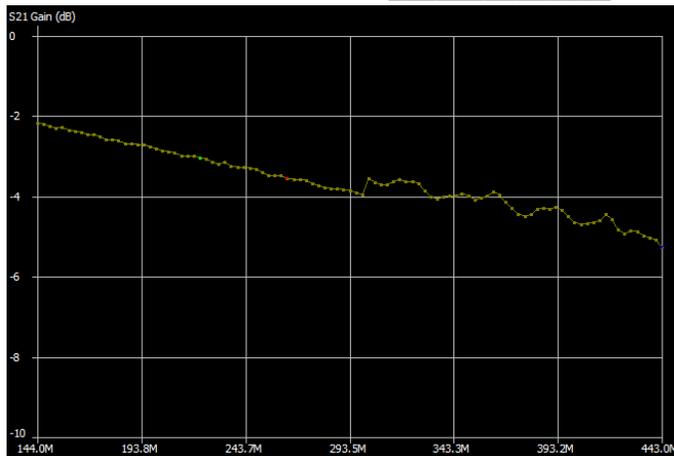
Our specs are :

- DX Engineering Low Loss DXE-8XDB050 with BNC connectors – 50 ohms Characteristic Impedance
- Gas injected foam dielectric cable, 16 AWG center, 19 strands 29 AWG shield
- Loss for 100ft is 1.4dB @ 30Mhz

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- Velocity Factor is 82%

- 1) Connect the coax like the figure with it making a loop between the S11 and S21 ports. The VNA transmits a signal of known magnitude and frequency from its Port 1 into the coax, and measures the magnitude and phase of the signal passed through the coax to the VNA other port, Port 2.
- 2) Use Trace 1 set to Log/Mag for Channel 1. This must be channel 1 because this is the through port S21. In VNA Saver set to display the S21 Gain plot and S11 Return Loss
- 3) Set Start Frequency to 120 MHz (ie below the 2m band), set Stop Frequency to 500 MHz
- 4) Losses will be shown in dB at the range of frequencies we set.
- 5) What is the loss at 144MHz ? _____
- 6) What is the loss at 443 MHz? _____ How much power is lost?



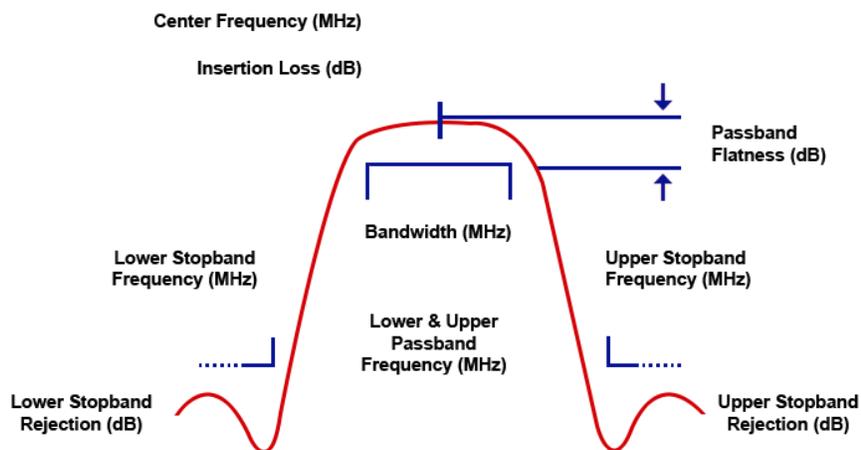
- 7) _____
- 8) Change the Stop Frequency to 40 MHz and read the loss at 30MHz. How does that compare to the datasheet? _____
- 9) Would you use this coax for a UHF station? _____

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Return Loss, R (dB)	Reflection Coefficient, Γ	Voltage Standing Wave Ratio (VSWR), r
0	1.000	∞
1	0.891	17.391
2	0.794	8.724
3	0.708	5.848
4	0.631	4.419
5	0.562	3.570
6	0.501	3.010
7	0.447	2.615
8	0.398	2.323
9	0.355	2.100
10	0.316	1.925
11	0.282	1.785
12	0.251	1.671
13	0.224	1.577
14	0.199	1.499
15	0.178	1.433
16	0.158	1.377
17	0.141	1.329
18	0.126	1.288
19	0.112	1.253
20	0.100	1.222
21	0.089	1.196
22	0.079	1.173
23	0.071	1.152
24	0.063	1.135
25	0.056	1.119
26	0.050	1.106
27	0.045	1.094
28	0.040	1.083
29	0.035	1.074
30	0.032	1.065
∞	0	1.000

Activity 2: Measure a Bandpass filter with a NanoVNA (time allowing)

Bandpass filters are used to reject a range of frequencies and pass others within the “band” of choice. The figure below shows what the perfect response curve would look like. We will use the NanoVNA to see the “real-world” response.



The filter we are measuring is a product from Low Band Systems and has a datasheet supplied by the vendor that shows the response curve measured on a professional grade VNA. This filter is for the 80 meter band and rejects signals outside that band as well as limits transmission of signals outside the band.

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We will measure using the NanoVNA and compare it to the datasheet. Make use of NanoSaver free software or on the NanoVNA screen.

- 1) Connect the coax the filter box between the S11 and S21 ports. The VNA transmits a signal of known magnitude and frequency from its Port 1 into the filter, and measures the magnitude and phase of the signal passed through the filter to the VNA other port, Port 2.
- 2) Use Trace 1 set to Log/Mag for Channel 1. This must be channel 1 because this is the through port S21.
- 3) Set Start Frequency to 2 MHz (ie well below the 80m band), set Stop Frequency to 30 MHz, near the end of the HF band.
- 4) To get a better look at the pass band set the stop to be 10MHz, just beyond the 40m band.
- 5) What is the attenuation (loss) at 3.5 MHz? _____ at 4.0 MHz? _____
- 6) What is the attenuation (loss) at 10MHz? _____
- 7) Using the NanoVNA Saver PC software, look at the response curves. The Figure here shows what it would look like. Notice the sharp response curve and almost flat response in the 80 meter band. How do these compare to the datasheet from LBS?

