



Nano VNA Workshop

ARRL Field Day

By Martin Buehring – KB4MG

Workshop Topics

What is a VNA anyway?

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

Basic Concepts – Common terms used

Demo 1

Calibration step.

Measure the SWR and complex impedance of various HT antennas

Demo 2

Measuring your coax cable length or change in impedance

Demo 3

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

Demo of analyzing a filter.

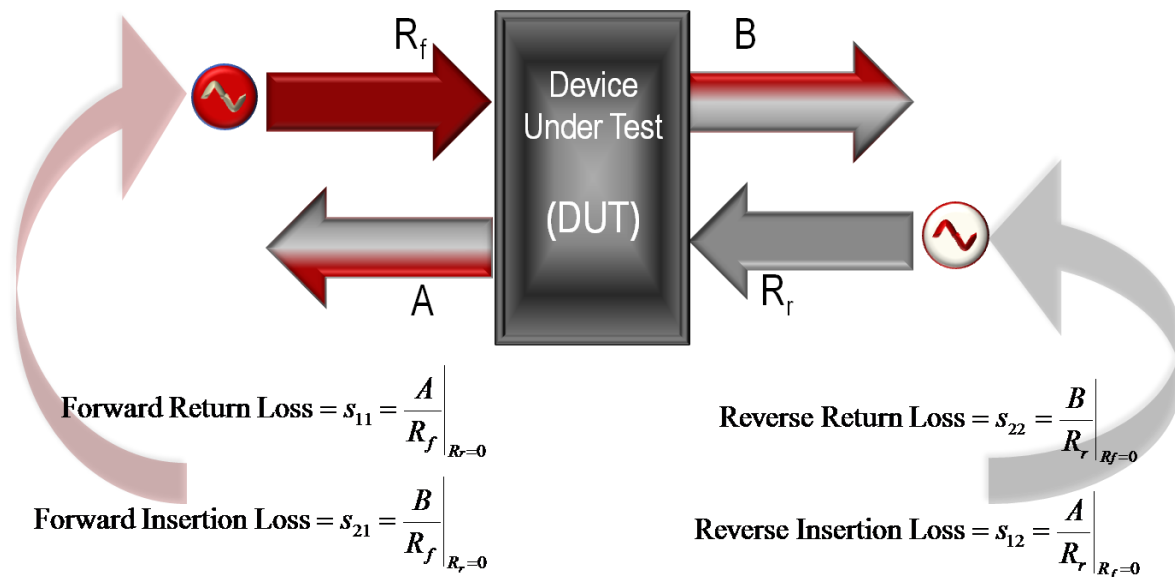
Final Notes, hints, etc

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.

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.

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.

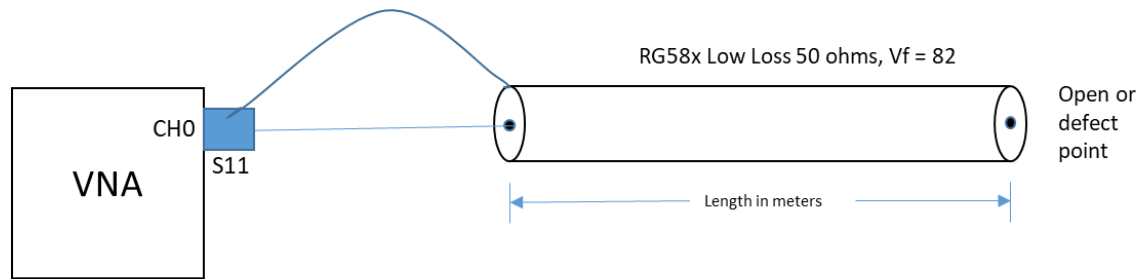
We can also measure the SWR, which we will do in Demo 1.

Field Day 2021 Learning Activity
Cherokee Amateur Radio Society

Measure length of coax

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).

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.



Measured length _____
Measured time _____
Stop Frequency _____

- 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).
- 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....

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.

Field Day 2021 Learning Activity
Cherokee Amateur Radio Society

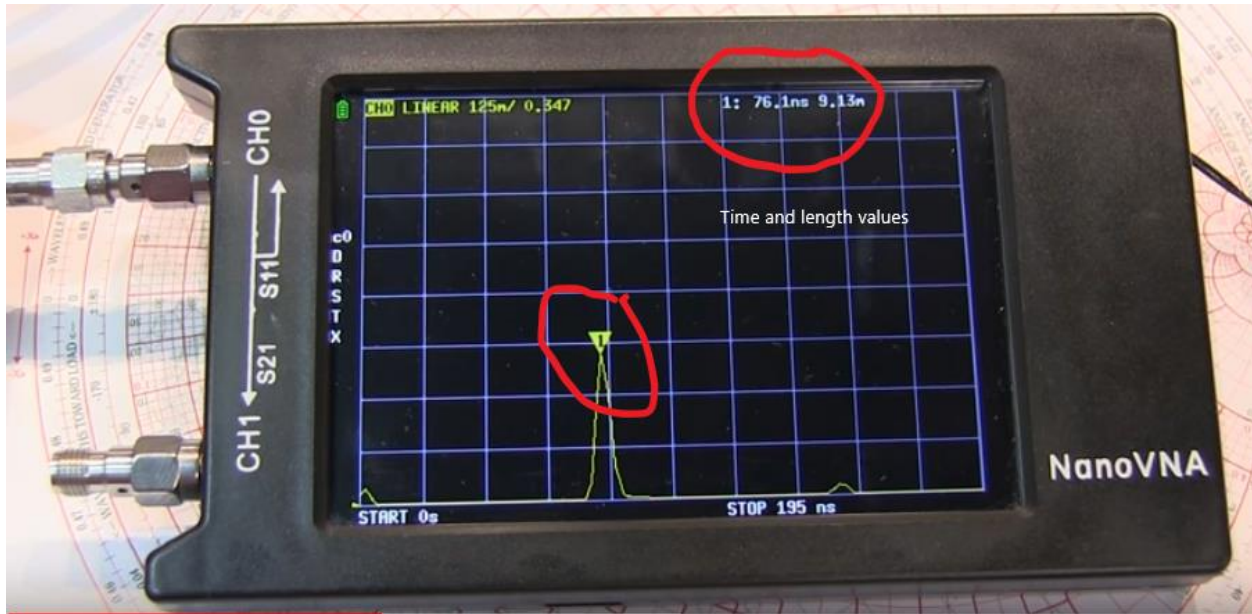
$$\text{Stop Freq (Mhz)} = \frac{5850}{\text{Max Distance}(m)} \times V_f \quad (\text{this is the decimal value, ie 80\% is 0.80})$$

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

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 Length _____m Time Delay _____nS

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

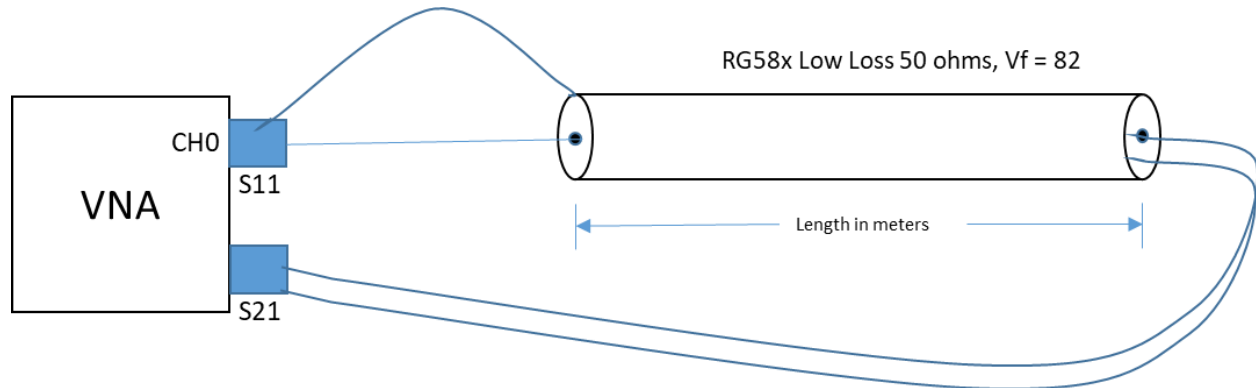
We measured _____ ns $V_f = \text{delay at C}/\text{actual delay} = 53.4ns/ \text{_____} =$

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 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?

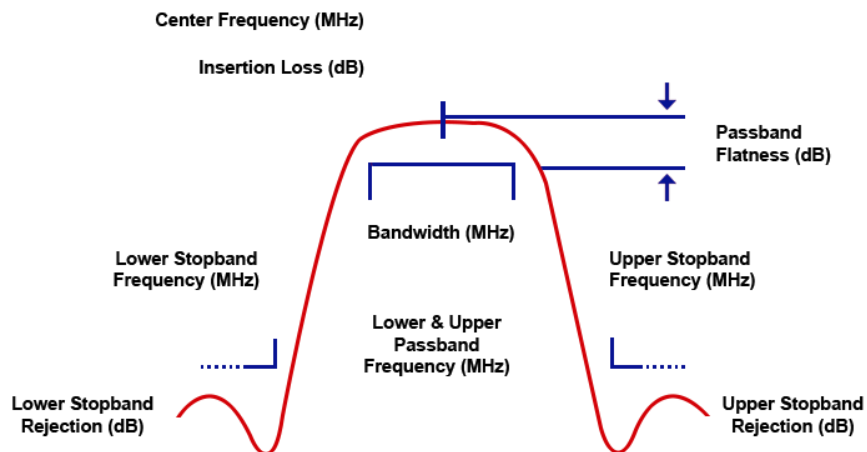
Our specs are :

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

Optional Section (As time allows)

Measure a Bandpass filter with a NanoVNA

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 profession 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.

We will measure using the NanoVNA and compare it to the datasheet.

- 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 1 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? _____
- 6) What is the attenuation (loss) at 4.0 MHz? _____

Field Day 2021 Learning Activity
Cherokee Amateur Radio Society

7) Using the 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.

