Making measurements with a Vector Network Analyzer (VNA)

First, a disclaimer; this is not an advertisement for any specific equipment. I did not receive compensation from any of the equipment manufacturers mentioned in this article.

In recent years, many inexpensive USB-based Vector Network Analyzers have become available. These are useful tools for many RF tasks including antenna tuning, filter tuning, component values, troubleshooting and diagnosing problems with antennas, transmission lines, tuning networks, filters, connectors, and so on. I spent about $600.00 on a Libra VNA last year after fooling around with a NanoVNA for a while. I found the Libra VNA to be a step up and more in line with the more expensive units while also being intuitive and fairly easy to use. In other words, a good compromise. I have taken it on various trips; ski lifts in the winter, flights to Texas and St. Louis, etc. It is rugged, especially in the Pelican carrying case. If something does happen to it, I would be a little upset, but it won't be the end of the world either.

The Libra VNA is a two-port device that can make RF measurements from 100 kHz through 6 GHz with a maximum of 4501 measurement points and a maximum stimulus power of 0 dBm (0.001 watt). Higher stimulus power is important in situations where many RF signals are present that may interfere with the measurements being made. This is one case where a more expensive VNA with higher stimulus power may be needed. It can be powered either by the USB connection to the computer or an external power supply. It draws approximately 7 watts of power.

The software (Windows, Linux, OSX, Raspberry PI) is downloadable from Github; https://github.com/jankae/LibreVNA/releases. There are firmware updates available from GitHub as well.

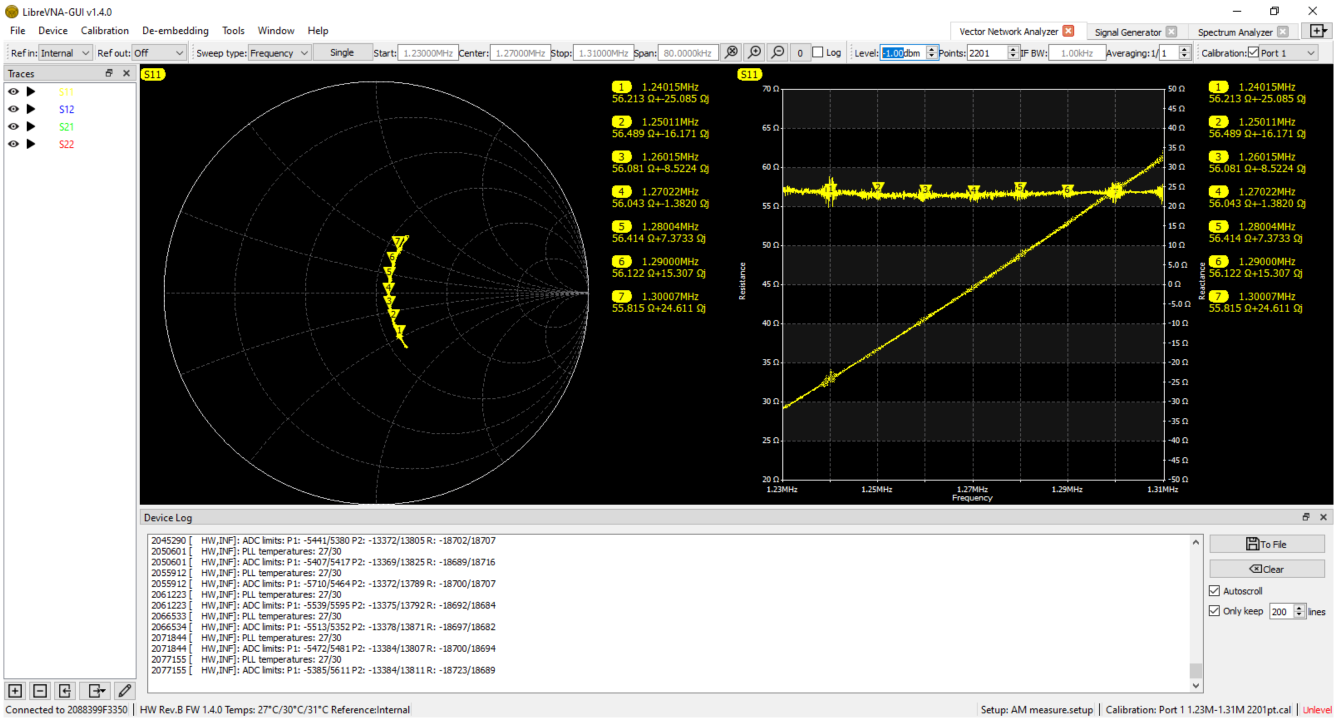
The software is slightly confusing with respect to some of the operations. There are four panels, each with a measurement window. Generally, I like either one or two panels, which is more than enough information to make a measurement or diagnosis. Each panel has a type of graph. These can be configured by right-clicking on the graph. That brings up a dialog box that allows the axis setup and measurement type.

Some technical definitions:

S – Stimulus or a small amount of RF power output.
S11 – Stimulus on port one, measurements on port one
S12 – Stimulus on port one, measurements on port two
S21 – Stimulus on port two, measurements on port one
S22 – Stimulus on port two, measurements on port two
Points – the number of measurement points across the measurement span. The more, the better for measurement accuracy. More measurement points also take longer.
Level – Power level used in the measurement. The default is -10 dBm (0.0001 Watt) and the maximum is 0 dBm (0.001 Watt). Higher power levels make the unit run warmer.
Measurement Span – the start and stop frequencies of the desired measurements.
Averaging – Averages the trace over x number of measurements.

Likely the easiest type of measurement to understand is the VSWR curve. This is typically an S11 measurement. The graph is set up to show the frequency on the X-axis and the VSWR on the Y-axis. A similar measurement that shows somewhat more detail is the return loss, or as this software calls it "Magnitude." This is a measure of the radiation efficiency of the antenna system. Return loss shows exactly which frequencies are being radiated (the loss) vs which frequencies are being reflected back (the return).

For AM tower measurements, Resistance and Reactance values are required to file an FCC license. This is also an S11 measurement. This can be done in two different panels, as the trace color cannot be changed, and having both on the same plot is confusing. For the ultimate in RF goodness, the Smith Chart cannot be beaten. The Smith chart shows resistance, reactance, and phase rotation. Ideal for tuning and making symmetrical sidebands around an AM carrier frequency.

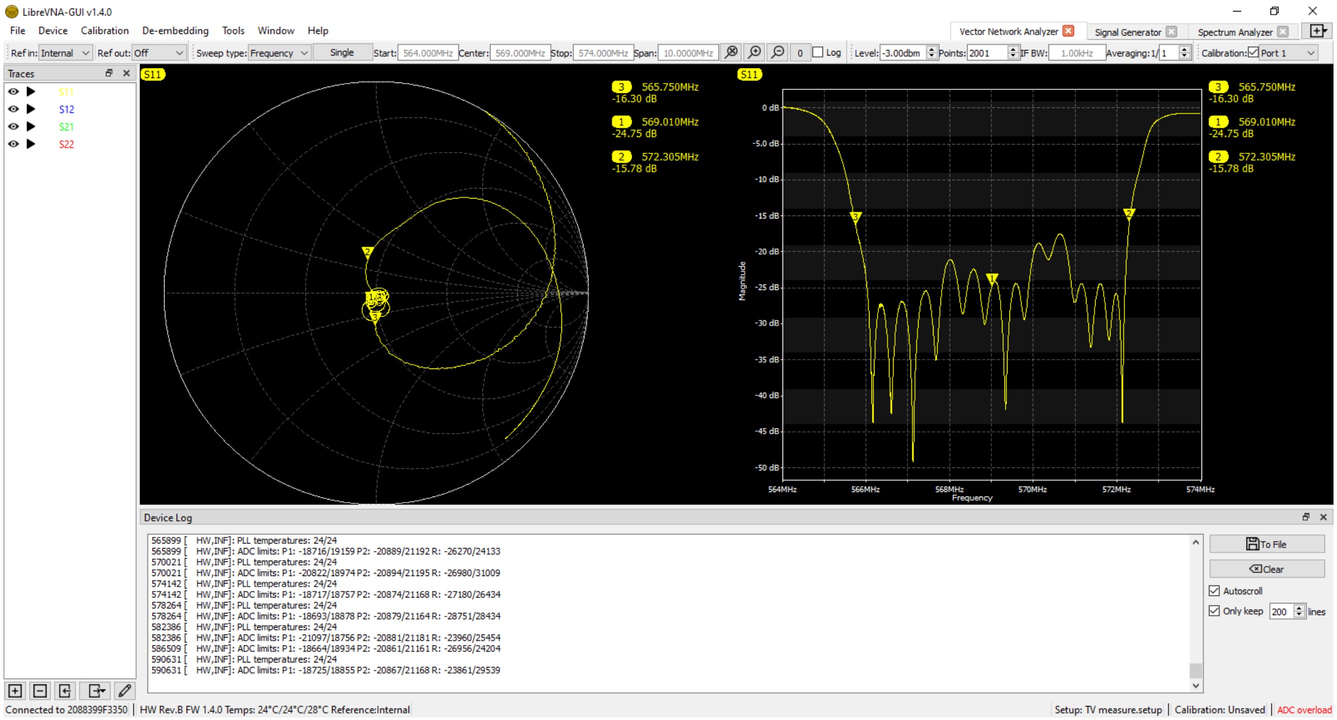


Also, in the dialog box is the ability to drop a marker or two, which can demonstrate a carrier frequency or the span of a signal across its occupied bandwidth. This measurement is on the input of an AM ATU that needed a touch-up. I placed markers every 10 kHz. It shows the resistance is a little high which can be tuned out at the transmitter. The reactance crosses the 0 mark at the carrier and the sidebands are symmetrical around the carrier frequency. In short, this should be a pretty good-sounding AM station.

With every measurement, the VNA should be calibrated for its measurement bandwidth. Includes all cables, adapters, and any other part of the transmission system not actually being measured. Calibration is essential because it normalizes the measurement cables and connectors. Prior to making any measurements, the minimum calibration should be SLO (Short, Load, Open). If any S12 or S21 measurements are being made, then both ports need a SLOT (Short, Load, Open, Through, or Port-to-Port) calibration and a port isolation calibration must be completed. Port-to-port isolation requires a load on both ports.

As with any piece of sensitive test equipment, care must be taken not to connect either port to a high signal level. It is very easy to damage the front end of one of these units. Therefore in areas where there are high RF levels, it is good to start with an attenuator connected to the measurement port. The output level may need to be adjusted to overcome the attenuator.

As with any computer-based piece of equipment, software and firmware updates may be released to fix bugs, security issues, or add features.



Another use, verifying the bandpass of a TV channel filter connected to a UHF slot antenna. The FCC requires channel mask filters to keep the digital TV signals within their assigned 6 MHz bandwidth. Part of a TV proof of performance is measuring the filter, then looking at the signal with a spectrum analyzer. The shoulders are required to be -40 dB below the carrier. Prior to turning up a new antenna and filter, it is a good idea to sweep the system and make sure that it is tuned correctly, otherwise high VSWR may damage the RF devices in the power amps. Once it is on the air, most exciters have a precorrections function, which needs to be initiated to get the best performance out of the transmission system.