
The NanoVNA

Who am I?

- Trevor Clarke
- K8TRC
  - Amateur Extra
- Bona fides
  - Professional software engineer
  - Hobbyist background in digital design and audio circuits
    - Synthesizes, audio FX, and amplifiers
- When I’m interested in something I dive down the rabbithole

What are network analyzers?

- A network analyzer is an instrument that measures the **network parameters** of **electrical networks**.
  - Electrical network = circuit
- Different types of parameters
  - We’re interested in the **s**, or **scattering** parameters
- Two main varieties:
  - Scalar
  - Vector

Electrical Networks and S-parameters

- Electrical networks are portions of a circuit which are treated as a “black box” and **characterized only by their input and output characteristics**
- 1-port network has a single input/output
  - Antenna
  - A dummy load
- 2-port network has 2 pairs of input/output (4 terminals)
  - Current entering a port must equal the current leaving the other
  - Filters
  - Amplifiers
  - Transformers
  - Transmission lines

- S-parameters are a 2x2 matrix
- Defined based on **incident and reflected power** not current and voltage
- Low to medium frequency can measure I and V at the ports and do math to get S-parameters
- High frequency (UHF and higher) measure S-parameters directly

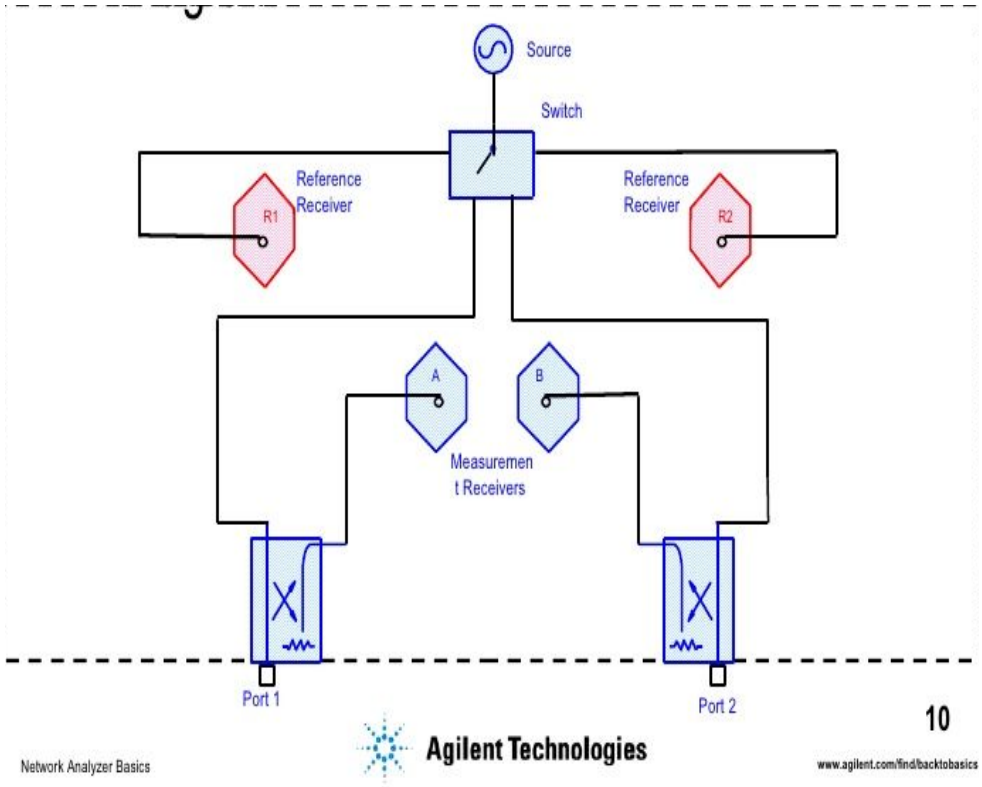
Scalar and Vector network analyzers

- **Scalar** network analyzers measure I and V **magnitude** at the ports.
- Great for VSWR and resonance measurements
- An **antenna analyzer** is a common type
- In low frequency environment, you could use a few multimeters and a signal generator

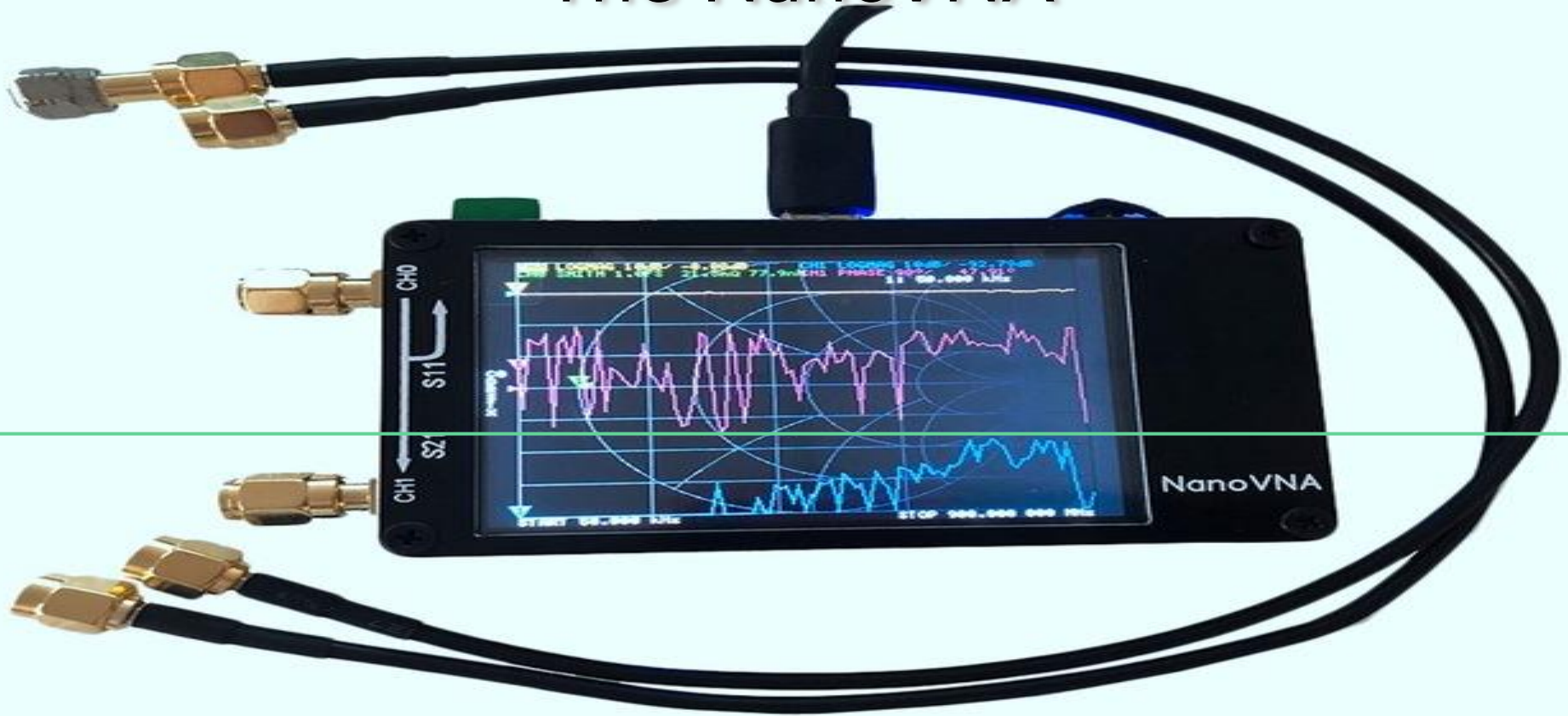
- **Vector** network analyzers (VNA) often measure S-parameters directly and they measure **magnitude and phase** (complex values)
- Complex values are needed for some applications
  - Complete characterization of linear networks
  - **Design of matching circuits**
  - **Device modeling**
  - Time-domain characterization
  - Vector-error correction

VNA hardware

1. Signal generator sends a signal out a port
2. Reference receiver measure the outbound signal
3. Measurement receivers on each port measure the reflected and transmitted signal
4. Compared to the reference to make measurements
5. Repeat on the second port



The NanoVNA



What is it?

- VERY inexpensive VNA
  - Many commercial options are $1000s or $10 000s or more
  - Existing hobbyist options are still $100s
- Open source and open hardware design
- Recently, many Chinese manufacturers have been selling pre-built devices
  - Cost about **$50**!
- Up to 450 MHz with up to 900 MHz using 3rd harmonic frequency
  - Latest firmware can go to about 1.5 GHz but signal quality suffers with each harmonic
- Signal generator only routes to 1 terminal
  - Can only measure S_{11} and S_{21}
  - If your device is fairly static, you can reverse the connectors and measure S_{22} and S_{12}
- **Measurements are quite good for the price**

What can it do? (without a computer)

- Perform SOLT calibration
- Measure 2-port S-parameters
- 2 independent plots (overlaid)
  - VSWR
  - Magnitude
  - Phase
  - Smith chart
- Use marker to get plot values at specific frequencies
- Change the frequency range
  - You only get 101 points across the selected range so narrowing it will give you better precision

What can it do? (with a computer)

- Different tools available
  - Use NanoVNA Saver application or smartphone client
  - Use a terminal or Python to program your own tools
- Customize plots
- Increase resolution through multiple overlapping scans
- Directly work with S-parameters (math stuff)
- Save S-parameters to a file for use in modelling software
- Automatically calculate matching networks
- Calculate transmission line length
- Compare two traces
- ...

Getting started

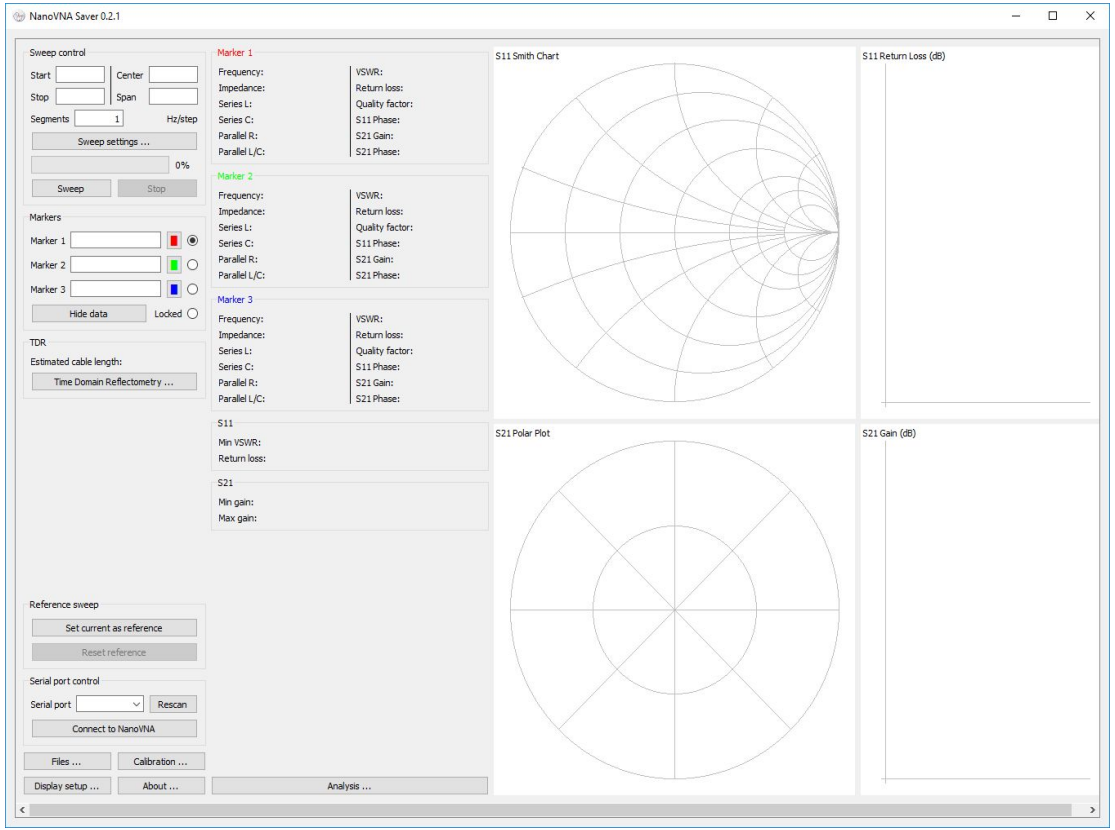
Update your firmware! Many of the Chinese builds especially, are out of date.

Latest version as of **19 December** is **0.5.4-20191210**

1. Download **dfu-util**
2. Download firmware
3. Select menu Config->DFU (needs recent firmware)
    a. If it's an old firmware Jumper BOOT0 pin at powering device, see NanoVNA github for instructions
4. `dfu-util -d 0483:df11 -a 0 -s 0x08000000:leave -D build/ch.bin`

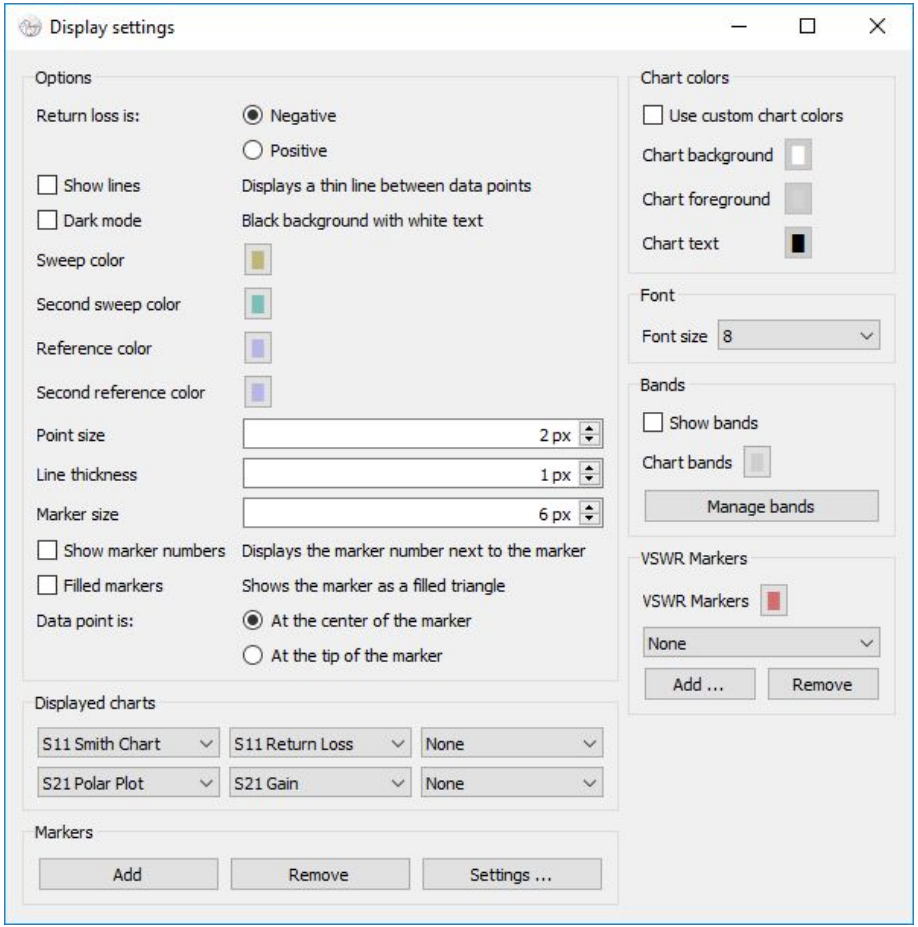
NanoVNA Saver

1. Written in Python (multiplatform)
2. Active community and updates
3. Pretty intuitive interface
4. Powerful analysis tools



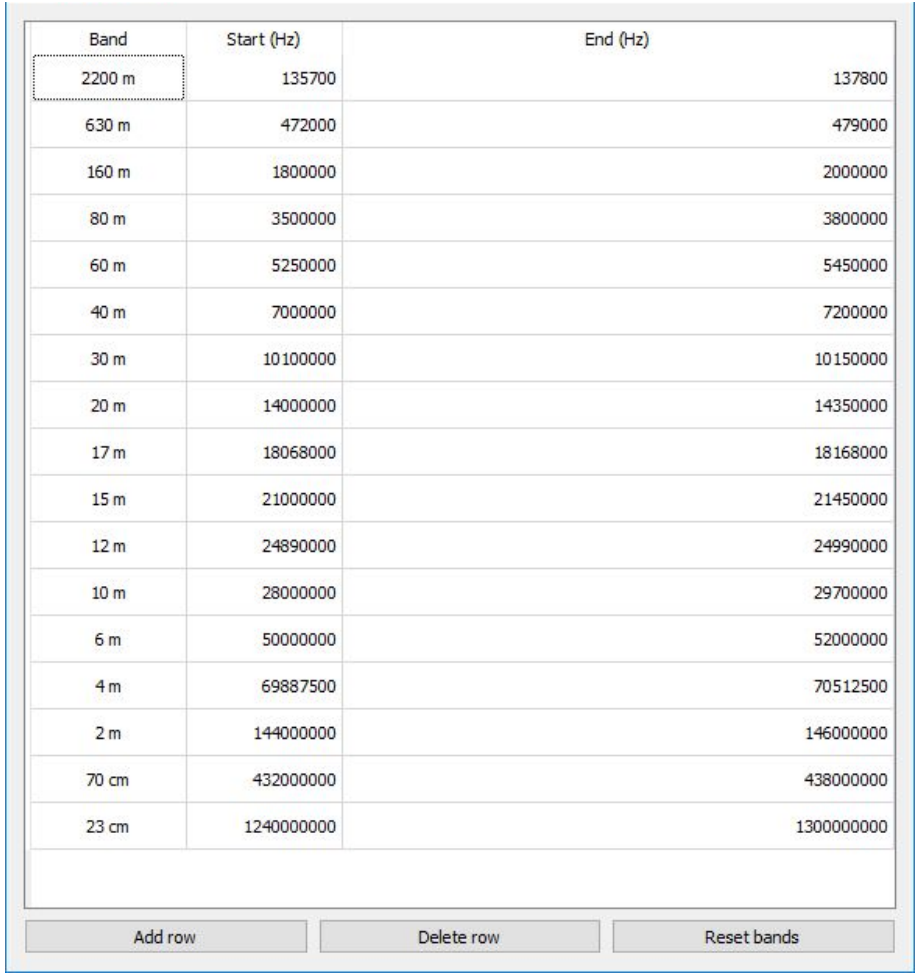
Setup NanoVNA Saver

1. Download and install v0.2.1
2. Set **Display setup**
   a. **Show lines** checked
   b. Fix band ranges with **Manage bands**



Band Presets

1. By default, these are wrong for the US
2. Make sure you update them before using the presets.
3. Add your own presets such as a 2m through 70cm or a full-range sweep.

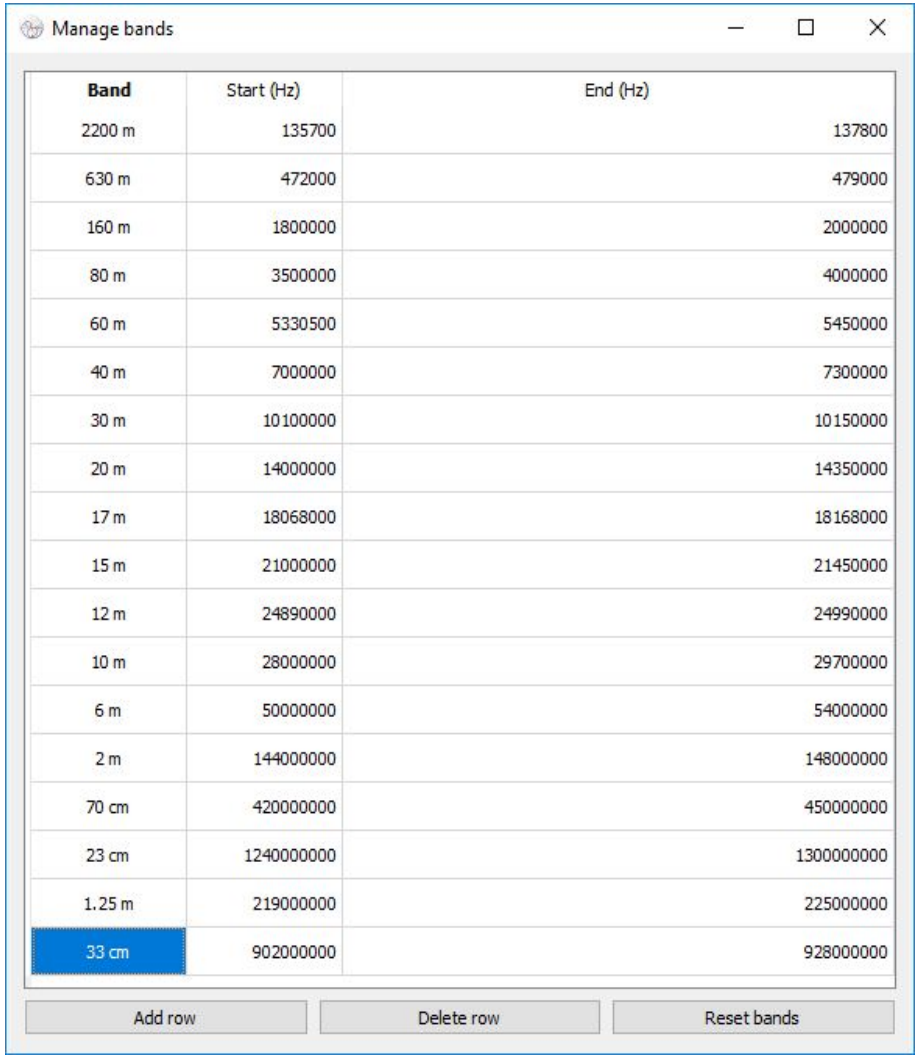


Band	Start (Hz)	End (Hz)
2200 m	135700	137800
630 m	472000	479000
160 m	1800000	2000000
80 m	3500000	3800000
60 m	5250000	5450000
40 m	7000000	7200000
30 m	10100000	10150000
20 m	14000000	14350000
17 m	18068000	18168000
15 m	21000000	21450000
12 m	24890000	24990000
10 m	28000000	29700000
6 m	50000000	52000000
4 m	69887500	70512500
2 m	144000000	146000000
70 cm	432000000	438000000
23 cm	1240000000	1300000000

Add row | Delete row | Reset bands

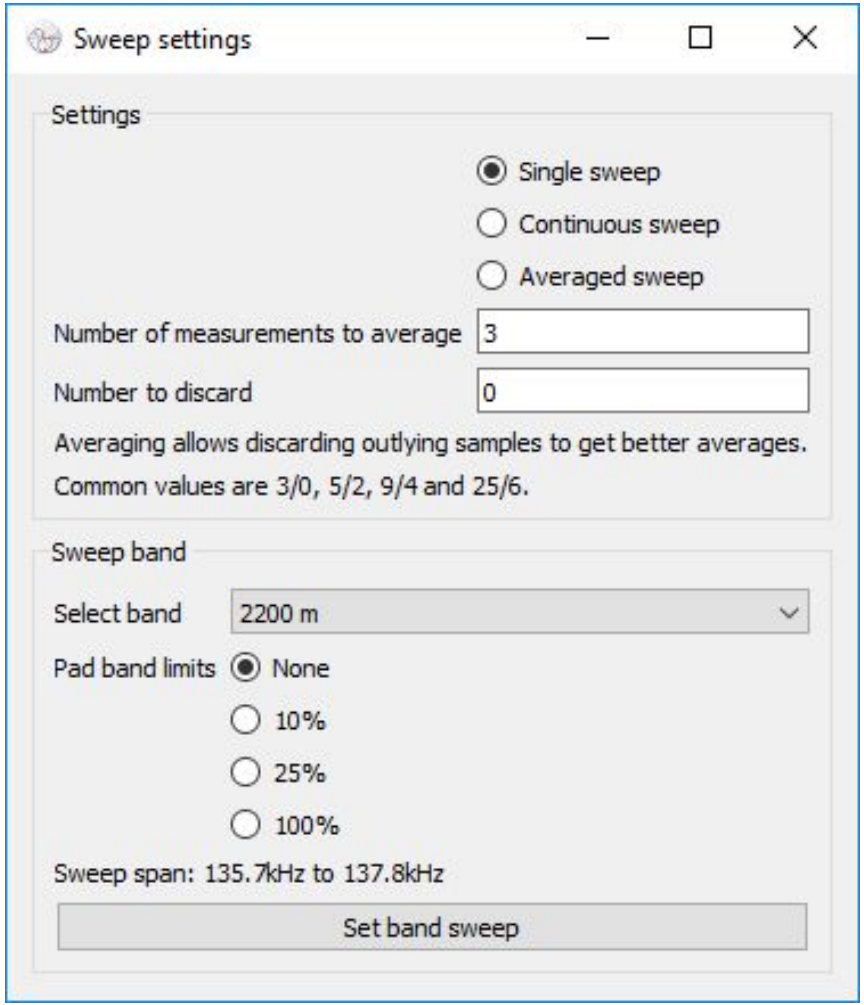
Updated Band Presets

1. Fixed for US band limits through 23 cm



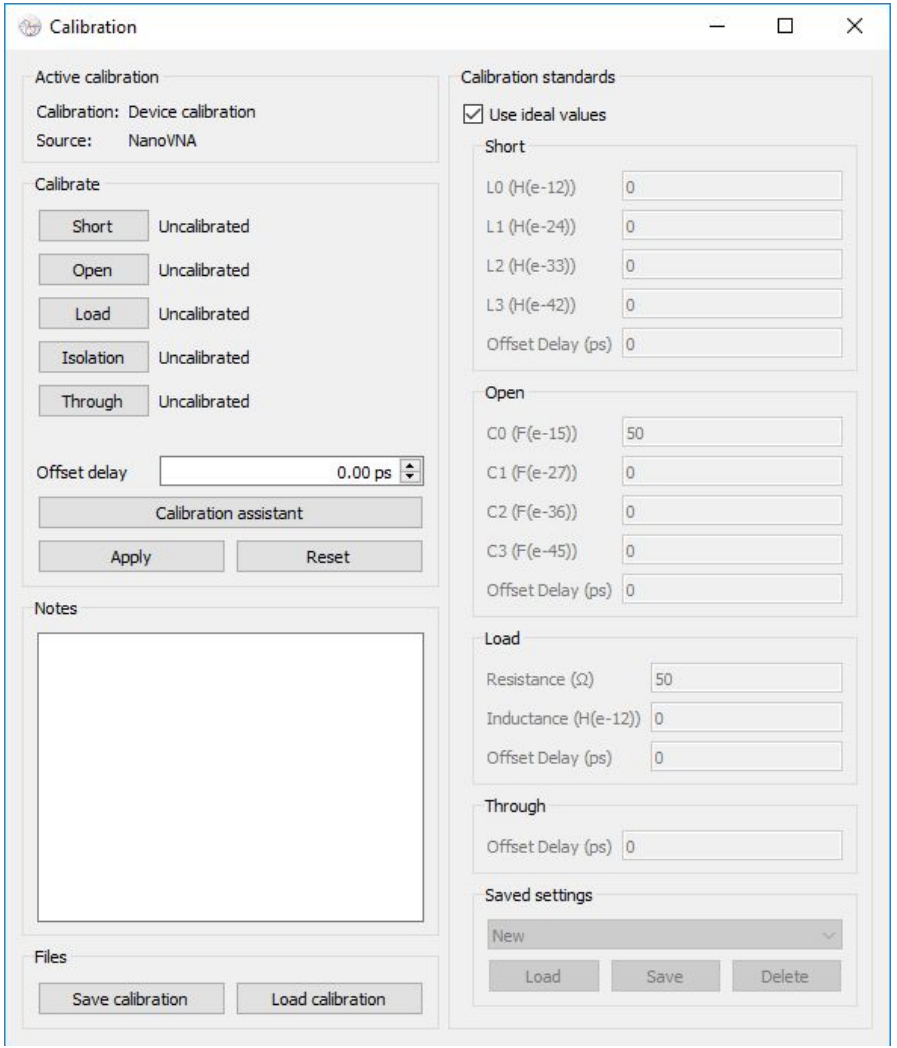
Sweep Settings

1. Select the frequency range
2. Select **single** to collect each time you push the button
3. Select **continuous** so see a constantly updating sweep, this can be slow.
4. Select **averaged** and adjust **Number of measurements** and **Number to discard** to help increase SNR



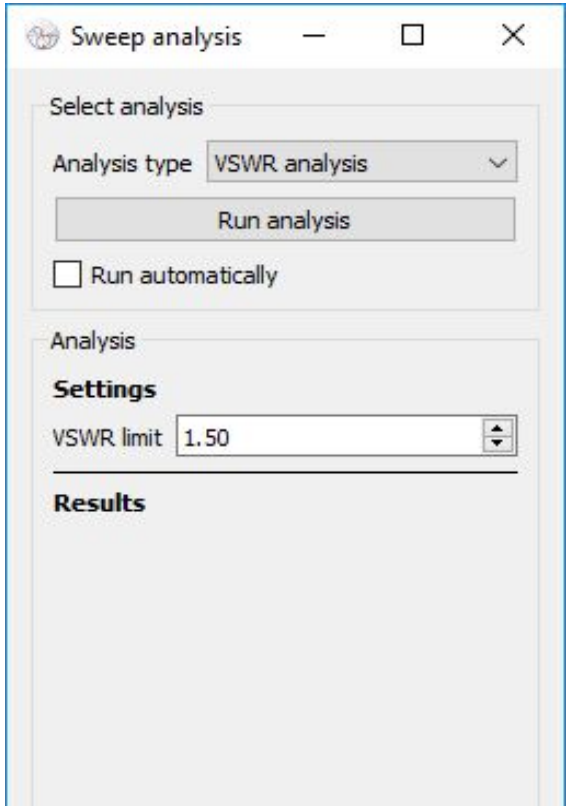
Calibration

1. Calibrate when changing connectors or band range. You can save and load calibrations, but I usually do a fresh one whenever I start using the device.
2. **Calibration assistant** does everything you need for the type of reading you want.
3. If you get a better, characterized set of calibration standards, configure their values.
4. **Offset delay** can help adjust for an uncalibrated connector or adapter.



Sweep Analysis

1. After collecting a sweep you can perform various analyses.
2. Find **Low-pass**, **High-pass**, **Band-pass**, or **Band-stop** filter parameters by adding a marker in the passband
3. Search for **peaks** and **valleys** in VSWR, Resistance, Reactance, and Forward Gain
4. Find frequency ranges which are below a specified **VSWR**. This is good for determining what bands an antenna is tuned to.



Impressions?

- I’ve been very impressed with the tool. It’s a great value and a great tool for HAM use.
  - Get one of these instead of a <$200 antenna analyzer
  - Get one of these if you build radios
  - Just get one, you’ll find uses you’ve never thought about
- Other members surveyed have similar conclusions

References

1. NanoVNA homepage https://nanovna.com
2. NanoVNA github https://github.com/ttrftech/NanoVNA
3. NanoVNA Saver https://github.com/mihtjel/nanovna-saver
4. Tutorial for NanoVNA Saver https://zs1sci.com/blog/nanovnasaver/
5. NanoVNA Articles on RTL-SDR.com https://www.rtl-sdr.com/tag/nanovna/
6. Purchase NanoVNA
    a. AliExpress
    b. eBay
    c. Lots of other vendors (I usually stick to AliExpress, eBay, Amazon, Banggood)