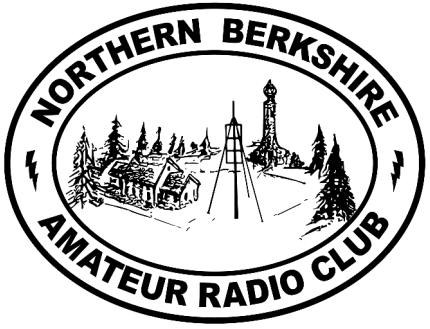
Nano VNA 101

Presented By: K1VN (with a little help from my buddy Claude AI)
With Demonstrations by: KA1SUN
October 25, 2026



What is a Nano VNA?

- What it is:
  - A small, low-cost, handheld vector network analyzer (VNA) for measuring how RF devices behave across a range of frequencies.
- What it is not
  - It is not a spectrum analyzer. Therefore it cannot be used to measure things like spurious emmisions
- What it measures:
  - Reflection (S11) and transmission (S21), which give you SWR, return loss, impedance, gain, loss, and phase.
- Why people like it:
  - Costs a fraction of a lab-grade VNA, runs on a USB or battery supply, and can be paired with a PC for logging and analysis.



Nano VNA Uses

- Antenna tuning: Measure SWR, return loss, and impedance across a frequency range to find an antenna's resonant frequency and adjust its length or matching for best performance.
- Coax cable testing: Check cable loss, estimate cable length, locate faults (opens and shorts) using time-domain features, and measure velocity factor.
- Filter characterization: Plot the passband, stopband rejection, insertion loss, and cutoff frequencies of band-pass, low-pass, high-pass, and notch filters.
- Duplexer and cavity tuning: Sweep the response of repeater duplexers and cavities to set notch and passband frequencies.
- Impedance matching: Display impedance on a Smith chart to design and verify matching networks, baluns, and ununs.
- Component measurement: Measure the value and parasitics of capacitors, inductors, and crystals, including their self-resonant frequencies.
- Amplifier and attenuator checks: Measure gain, loss, and flatness (S21) of amplifiers, attenuators, and other two-port devices.
- Transmission line and stub work: Verify the electrical length of quarter-wave stubs, phasing lines, and matching sections.
- Crystal and resonator analysis: Find series and parallel resonance and estimate motional parameters for crystal filter building.

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What are S Parameters

- S-parameters (scattering parameters) describe how RF signals reflect from and pass through a device. For a 2-port, there are four, named by output port, input port
  - S11 (input reflection): How much signal bounces back from Port 1. Relates directly to SWR and return loss. Antenna tuning lives here.
  - S21 (forward transmission): How much signal gets from Port 1 to Port 2. Shows gain (amplifiers) or insertion loss (filters, coax, attenuators).
  - S12 (reverse transmission): How much signal leaks from Port 2 back to Port 1. Indicates isolation; in passive devices it usually equals S21.
  - S22 (output reflection): How much signal bounces back from Port 2. Tells you how well the output is matched.
- Ham radio relevant examples
  - Antenna: one port, measure S11 for SWR and resonance.
  - Coax or filter: two ports, measure S21 for loss and passband, S11 for match.
  - Duplexer/cavity: S21 shows the notch and passband; S11 shows how well it's matched

S11 tells you about the match, S21 tells you about what gets through

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Measuring S11

1) Set the sweep range
    1) Choose start and stop frequencies that cover your band of interest with some margin (e.g., 13.5 to 14.5 MHz for 20 meters).

2) Calibrate at the measurement plane.
    1) Attach the cal standards to the CH0 port (or to the end of the adapter or cable you'll actually use)
    2) Run Open, Short, and Load, then Isolation (optional, leave the port terminated in 50 Ω), then Thru if you plan to measure S21 as well
    3) Save the cal to a memory slot for later recall

3) Connect the unit under test (UUT)
    1) Attach the antenna or device directly to CH0, or through the same cable you calibrated with
    2) Keep the CH1 port unused or terminated.

4) Select the S11 trace.
    1) Set the display to show S11 as Log Mag (return loss in dB) or SWR
    2) Add a Smith chart trace if you want to see impedance

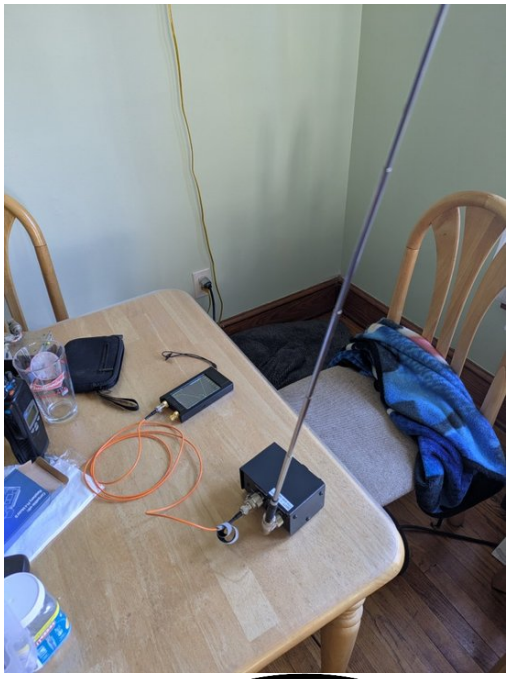
5) Read the result. Place a marker at your frequency of interest, or use the marker search to find the minimum (best match). Note the SWR, return loss, and resonant frequency.

6) Adjust and re-measure
    1) Tune the antenna or matching network, then sweep again
    2) Re-run the calibration if you change the frequency range or add or remove cables or adapters.

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Measuring S11 Example





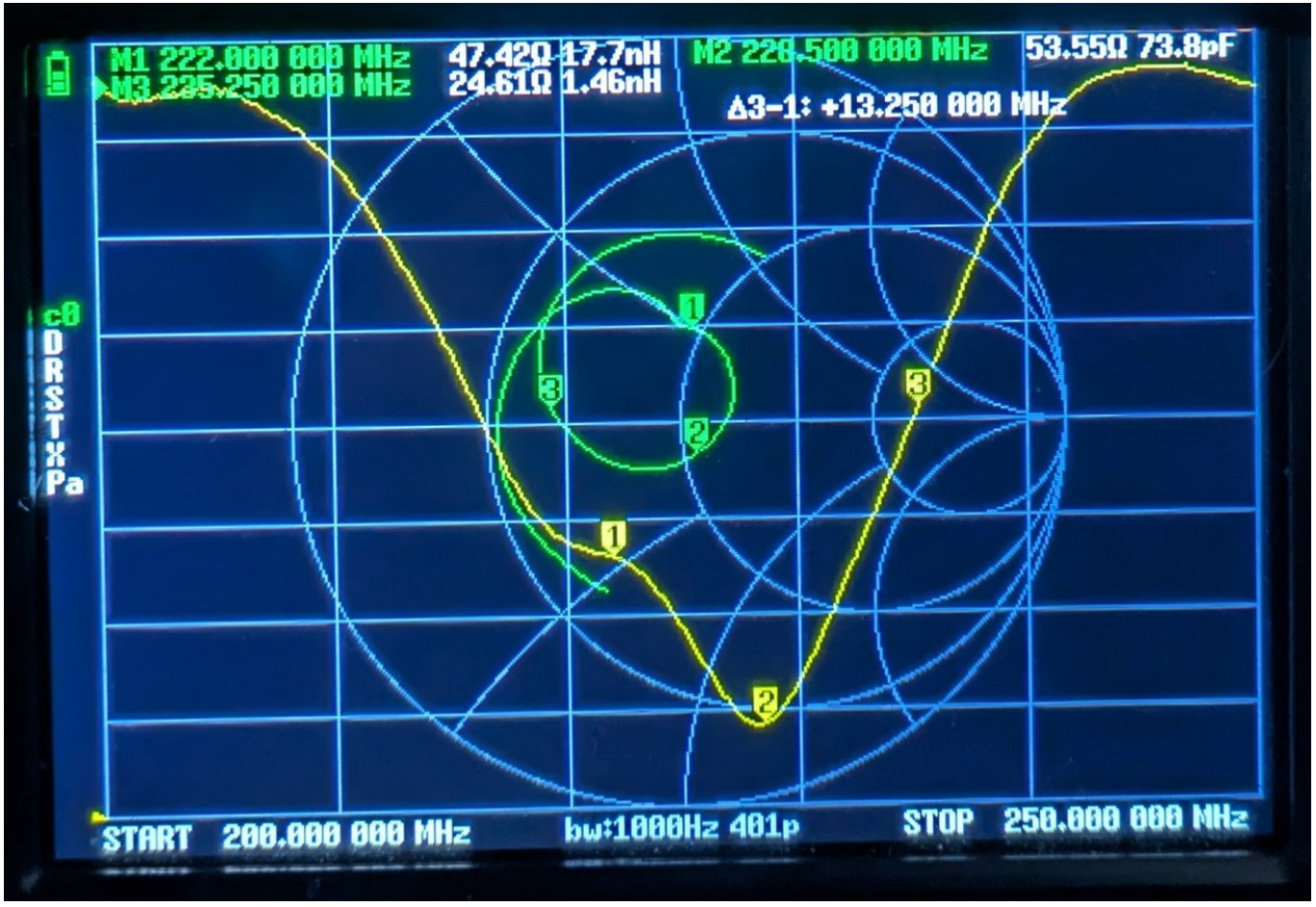
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Using the Smith Chart View

1) Set up and calibrate. Set a sweep range covering your band with some margin, then run Open, Short, and Load at the measurement plane (the end of the cable or adapter you'll use). Save the cal.
2) Connect the antenna. Attach it to CH0, keeping the feedline and setup the same as during calibration.
3) Select the Smith chart. Set the display to show S11 on the Smith chart format. Add a second trace showing SWR or Log Mag so you can see the match numerically too.
4) Locate your frequency. Place a marker at your target frequency and note the resistance (R) and reactance (X) it reports. The center of the chart is the ideal 50 + j0 Ω match.
5) Read the trace.
    1) Above the horizontal centerline: inductive reactance (+jX), meaning the antenna is electrically too long, or resonant below your target.
    2) Below the centerline: capacitive reactance (-jX), meaning the antenna is too short, or resonant above your target.
    3) On the centerline: the antenna is resonant (X = 0). The R value there is the feed-point resistance.
6) Resonate the antenna first. Adjust the length until the trace crosses the horizontal centerline at your target frequency. Shorten to raise the frequency, lengthen to lower it.
7) Then fix the resistance. Once X is near zero, check R. If it isn't near 50 Ω, adjust the matching: change the feed point, add a matching network, balun, or loading, or modify the antenna geometry (height, wire angle, radial count).
8) Aim for the center. The goal is a small loop or cluster of the trace passing close to the center of the chart at your frequency. A tighter, smaller loop around the center means a wider usable bandwidth.
9) Re-measure and iterate. Make small changes, sweep again, and repeat until the marker sits near 50 + j0 Ω. Verify SWR across the whole band.

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Smith Chart Example



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Smith Chart Example (cont.)

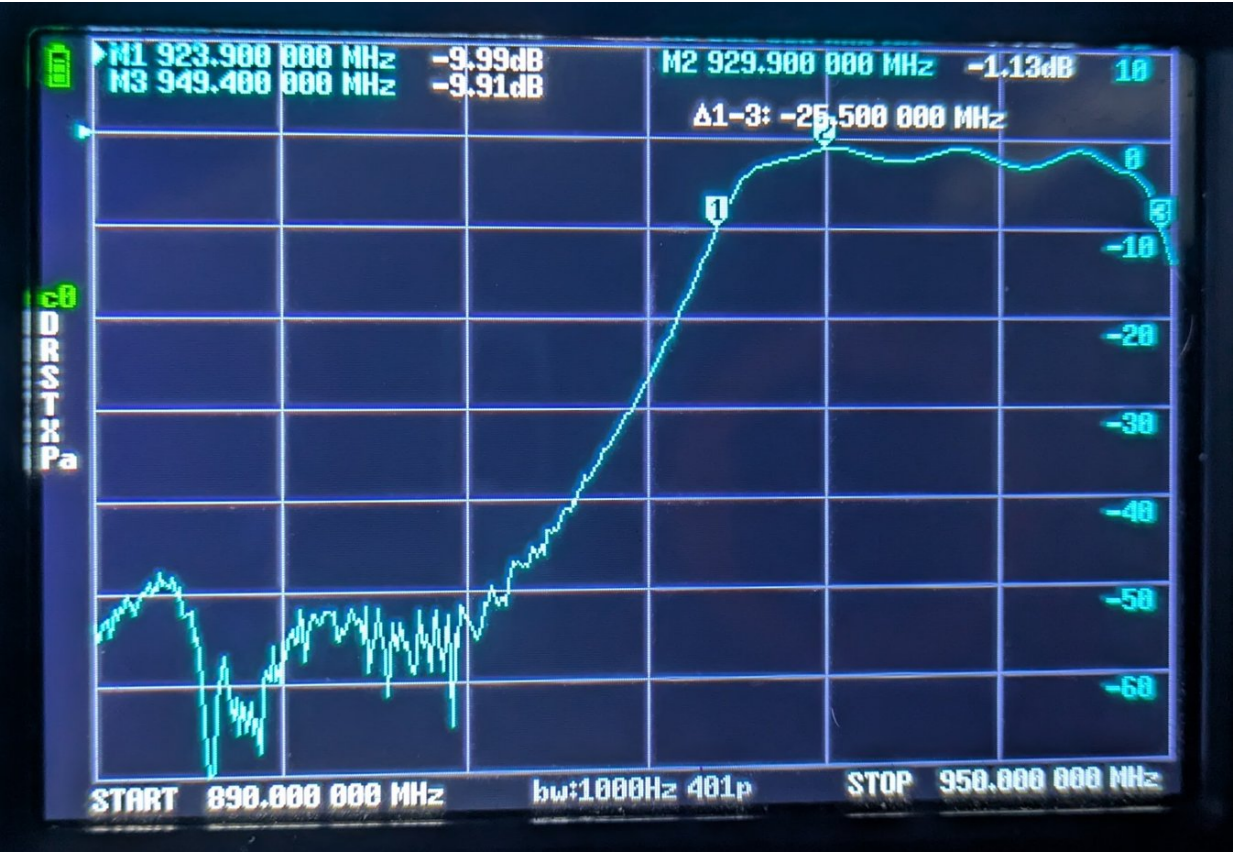


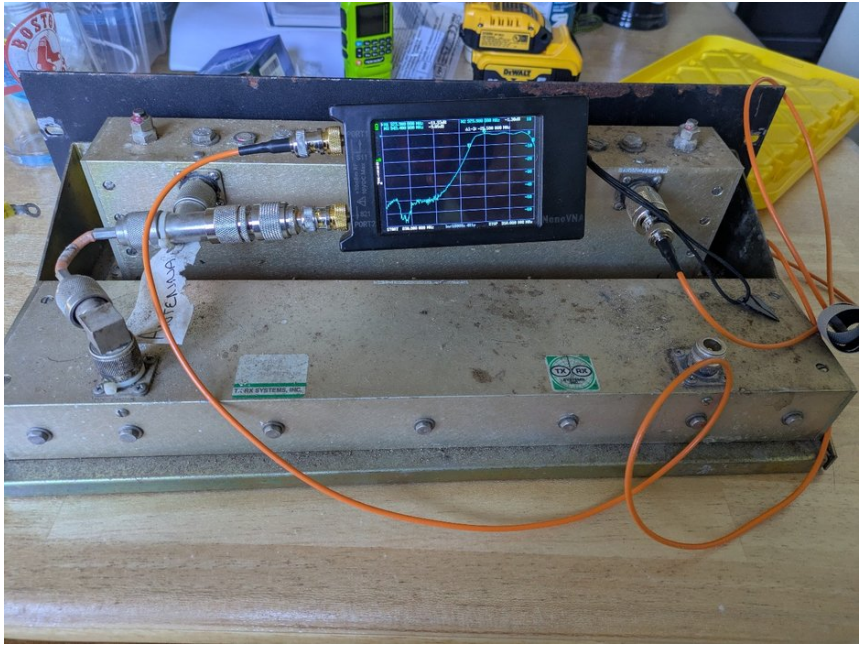
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Measuring S21

1) Set the sweep range.
    1) Choose start and stop frequencies that cover the passband and some of the stopband of your device (e.g., 140 to 150 MHz for a 2-meter filter).
2) Calibrate.
    1) Run Open, Short, and Load on CH0, then Isolation with both ports terminated in 50 Ω, then Thru by connecting CH0 directly to CH1 with the same cables or adapters you'll use for testing.
    2) Save the cal to a memory slot.
3) Connect the UUT
    1) Attach the input of the device to CH0 and the output to CH1, using the same cables you calibrated with.
    2) Check connector gender and use adapters only if they were part of the calibration.
4) Select the S21 trace
    1) Set the display to show S21 as Log Mag (dB)
    2) Optionally add a phase or delay trace
5) Read the result. Place markers at the frequencies of interest. Note insertion loss in the passband, rejection at the stopband or notch, and the -3 dB points for bandwidth.
6) Check the match
    1) Optionally view S11 at the same time to confirm the device is well matched at its input.
7) Adjust and re-measure
    1) Tune the filter or cavity and sweep again
    2) Recalibrate if you change the sweep range or the cable setup.

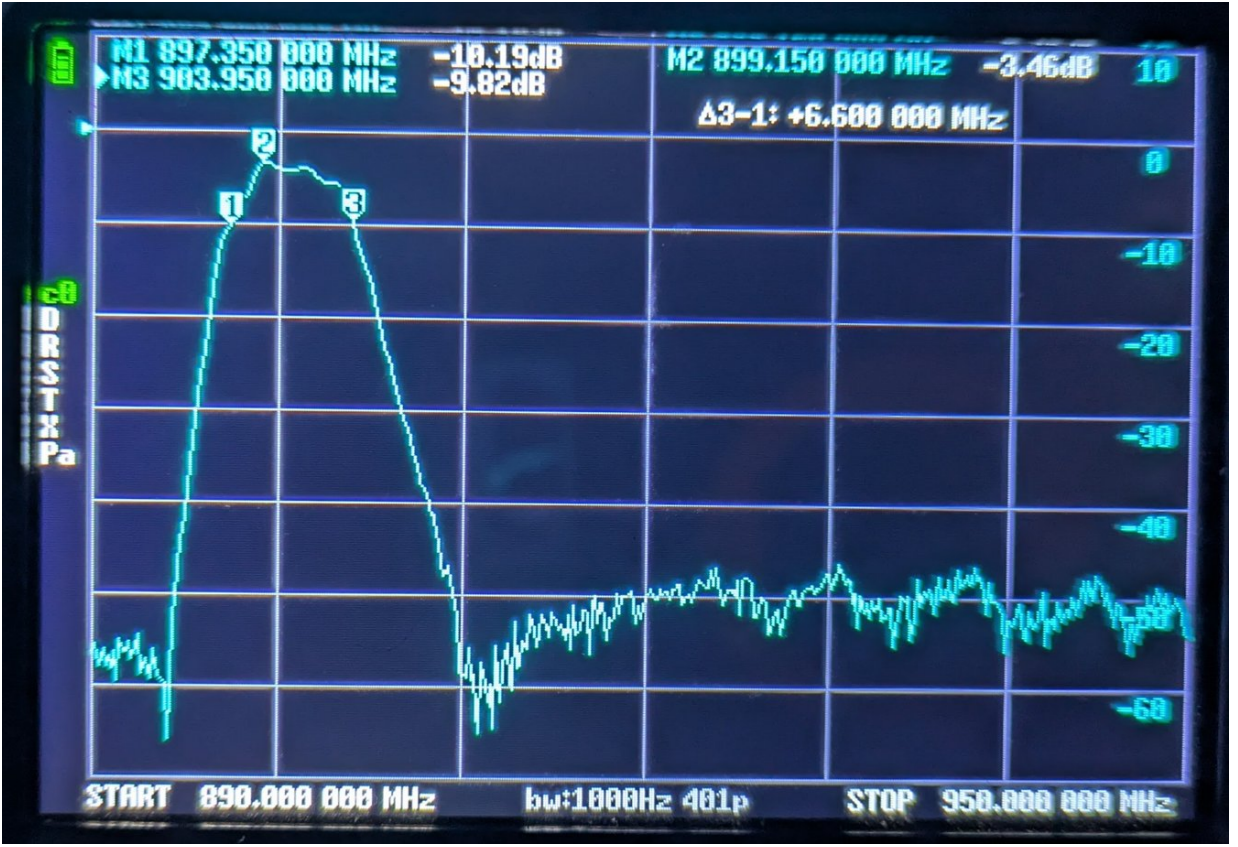
Measuring S21 Example

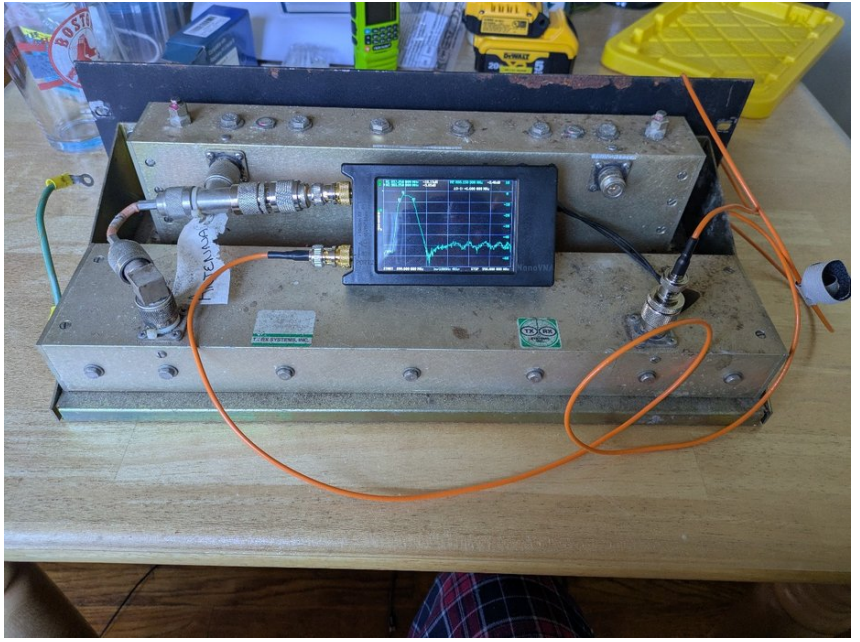




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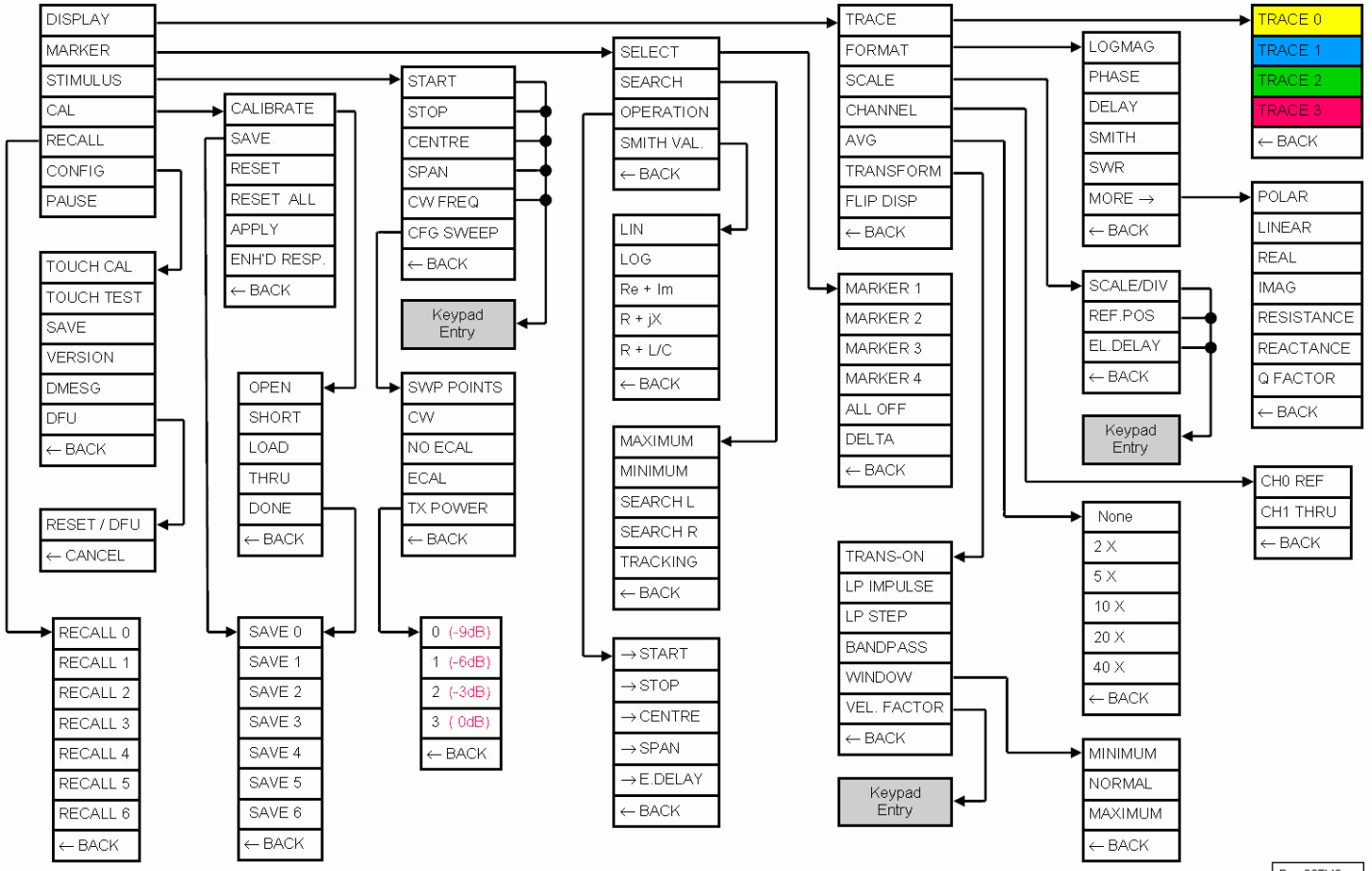
Measuring S21 Example





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NanoVNA V2 (S-A-A-2) menu system (FW 20201013)



Note:- NanoVNA V2 now always loads Calibration data stored in memory location C0 at start-up.

By: G3TMG
20th Oct 2020
Issue 1.1

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Other Advanced Topics

- Time Domain Reflectometry
  - Cable length measurements
  - Cable Defect Analysis
  - Velocity Factor Measurement
- Designing Matching Networks
- Ferrite Characterization

