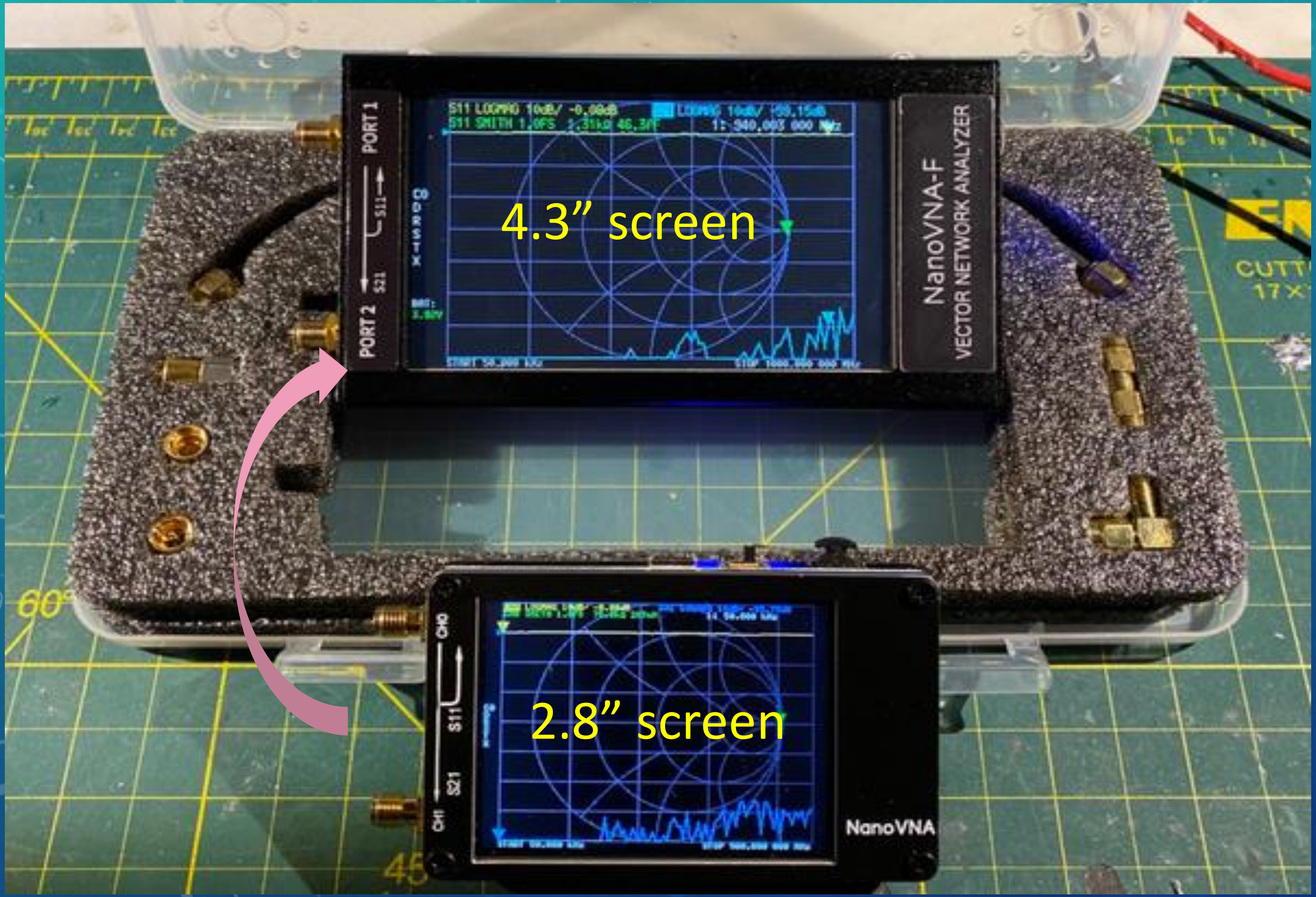
NANO VNA-F LOW COST VECTOR NETWORK ANALYZER



DAVE MOORE N7RF

KARS MEETING FEBRUARY 2020

WHAT DOES A NETWORK ANALYZER MEASURE?

- An SNA (Scalar Network Analyzer) measures amplitude only. Example: a VSWR meter is an SNA. Using your radio as a signal source, it measure the amplitude of your transmit signal going to the antenna and the amount of signal reflected back by the antenna.
- A VSWR meter measure P_{out}, $P_{reflected}$ and VSWR. How are there related ?
- The best VSWR is 1:1. This means that 100% of the signal is going to the load (0% reflected)
  - At VSWR 2:1, 11% of the power is reflected
  - At VSWR 3:1, 25% is reflected
  - At VSWR 6:1, 51% is reflected

Table I. VSWR, Reflected Power, and Γ (s11)

VSWR	Γ (s11)	Reflected Power (%)	Reflected Power (dB)
1.0	0.000	0.00	-Infinity
1.5	0.200	4.0	-14.0
2.0	0.333	11.1	-9.55
2.5	0.429	18.4	-7.36
3.0	0.500	25.0	-6.00
3.5	0.556	30.9	-5.10
4.0	0.600	36.0	-4.44
5.0	0.667	44.0	-3.52
6.0	0.714	51.0	-2.92
7.0	0.750	56.3	-2.50
8.0	0.778	60.5	-2.18
9.0	0.800	64.0	-1.94
10.0	0.818	66.9	-1.74
15.0	0.875	76.6	-1.16
20.0	0.905	81.9	-0.87
50.0	0.961	92.3	-0.35

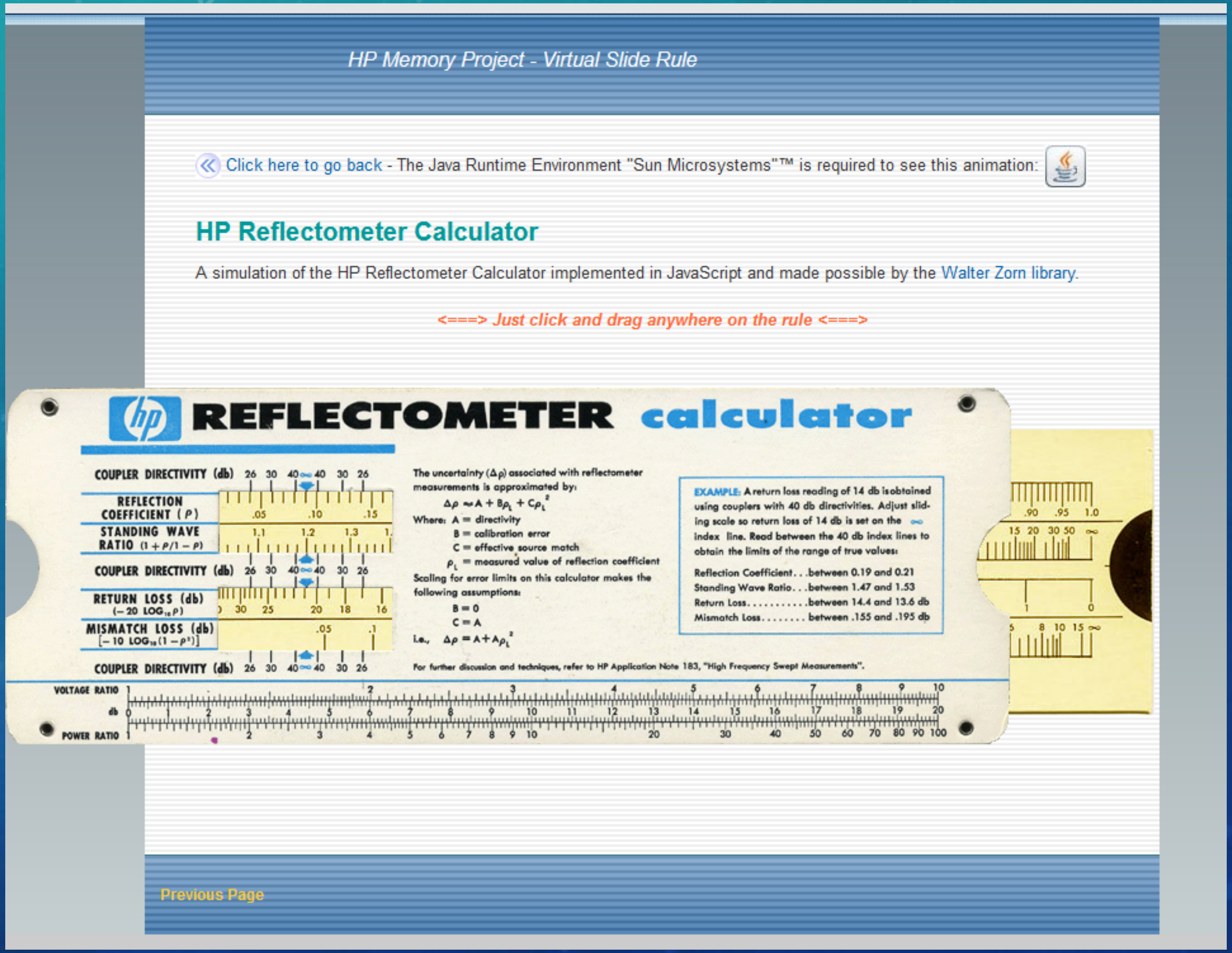
- As hams, we are always trying to keep VSWR as low as possible to put the greatest amount signal on the air.

- In contrast, a VNA (Vector Network Analyzer) is an RF test instrument that measures the amplitude and phase of RF signals. It also computes VSWR but it does a lot more. By adding phase calibration, all measurements have better accuracy.

EXPLORE RELATIONSHIP BETWEEN VSWR, RETURN LOSS AND REFLECTION COEFFICIENT

- One of the coolest slide rule calculators one could have before the dawn of desktop PCs and handheld calculators was the Hewlett Packard Reflectometer Calculator. HP sales engineers gave them out as freebies. I still have one dated 1970, and a re-print from Besser Associates dated 2003.

- They are out of print, but there is a virtual version on this web site: http://hpmemoryproject.org/pict/technics/applet/slide_rule/reflectometer.htm You can use a mouse to slide the top window back and forth and read the scale behind it.

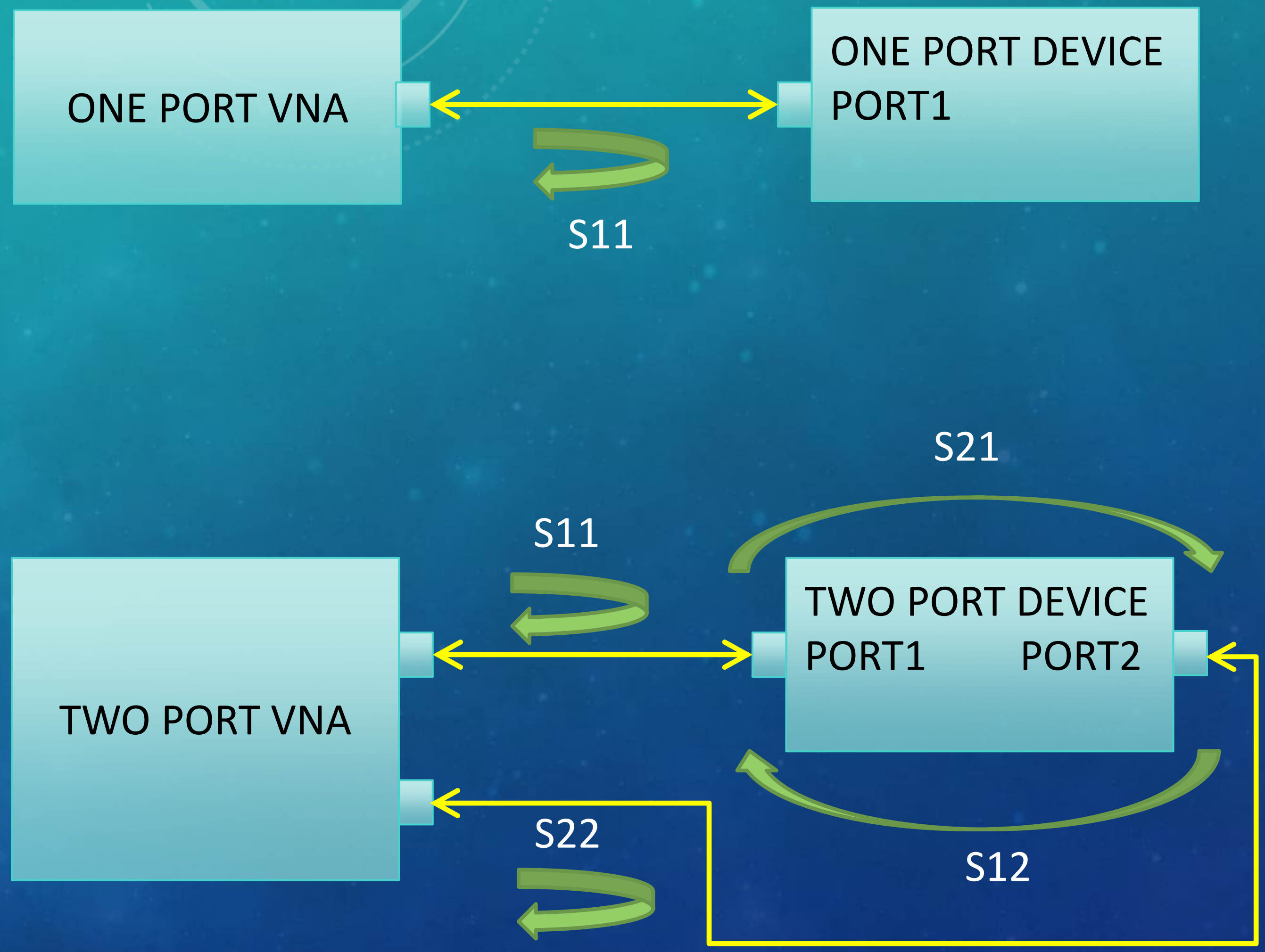


VNA TEST CAPABILITIES

- RF engineers think in terms of S-parameters. An S-parameter is simply the complex ratio of one voltage (not power) to another expressed as an magnitude and a phase. From S-parameters, we calculate a variety of other parameters.

- A one-port VNA is only capable of measuring S11, the ratio of the outgoing signal to the reflected signal from the device under test. From that, we calculate VSWR, return loss, mismatch loss, complex impedance R+jX, cable length, or distance to a cable fault (TDR).

- A two-port VNA measures S11, S21, S12, and S22. From the through-port S21/S22 measurements, we get forward and reverse gain or loss in dB, insertion phase in degrees, group delay in nanoseconds, etc.



COMMERCIAL VNAs

- Commercial VNAs commonly have 2- or 4- ports but are expandable. Custom VNAs can be configured with any number of ports and cover any frequency range up 220 GHz.

A 4-port VNA measures 16 parameters: S11, S22, S33, S44, S21, S12, S31, S13, S41, S14, S32, S23, S42, S24, S43, S34
A 20-port VNA, measures 400 parameters!

+

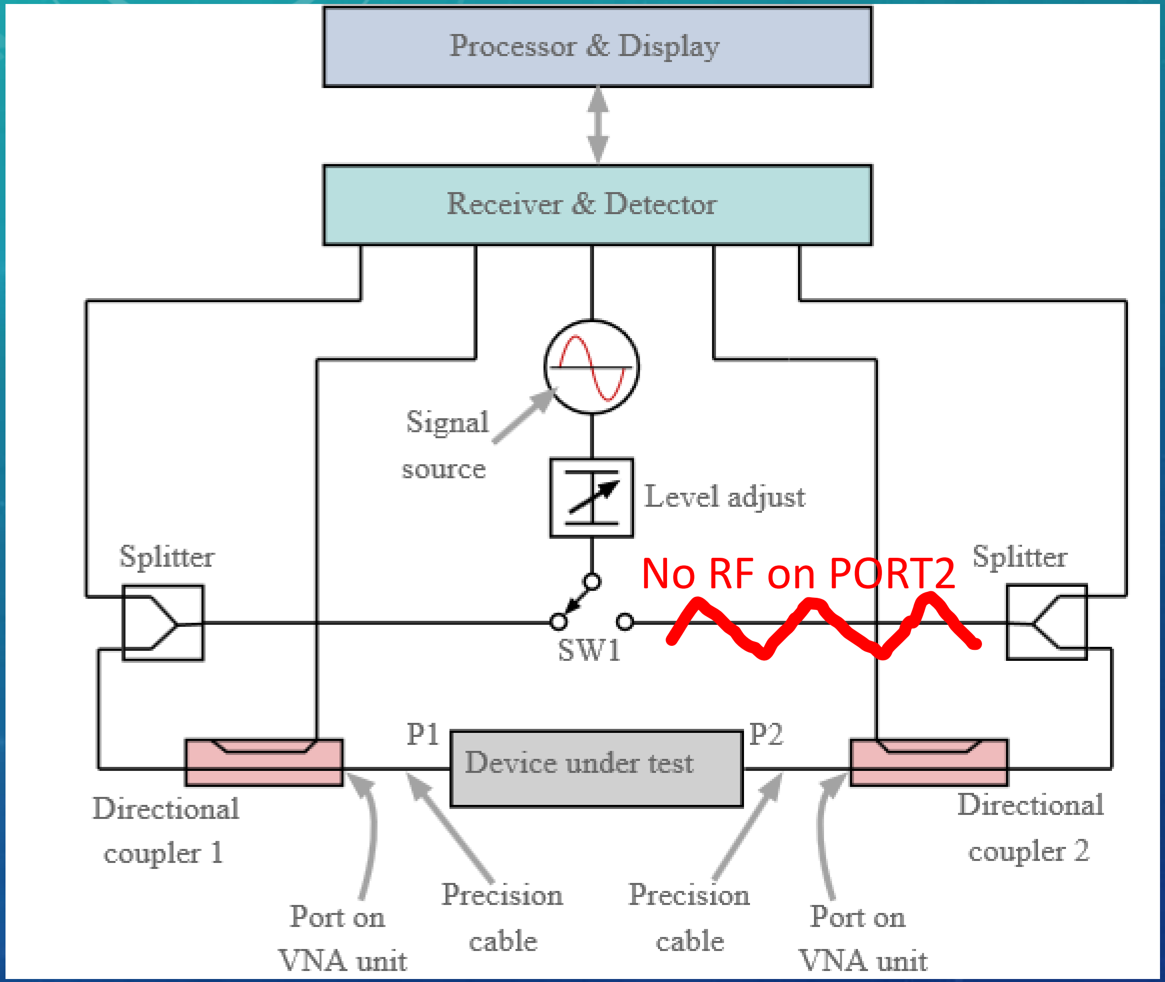
***$130 is quite a bargain for a Nano VNA!**

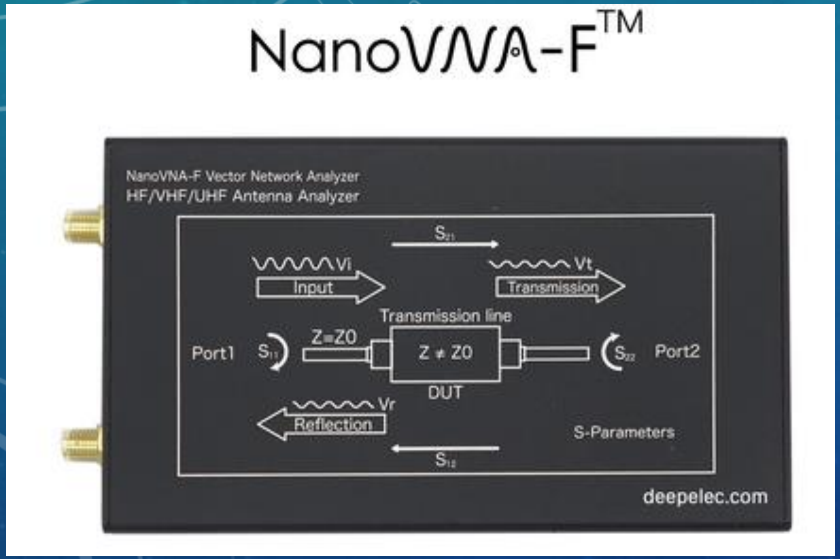
Keysight PNA Series: (4-port)
8.5 GHz: $72,745   13.5 GHz: $99,500
26.5 GHz: $126,780   67 GHz: $283,333
110 GHz: $379,946   120 GHz: $417,245

Keysight "Low Cost" SOLT Cal Standard
18 GHz type N: $2,914
26.5 GHz type 3.5mm: $3,238
40 GHz type 2.92mm: $4,050

HOW DOES A NANOVNA WORK?

- The figure at the right is a typical 2-port VNA. It contains an internal RF source, signal source routing to allow S11, S21, S12, and S22 measurements, forward and reflected RF receiver/detectors, processor to do the math, and a graphic display.
- To keep the design low cost, the NanoVNA does not provide an RF signal path to Port 2. Thus it only measures S11 (match), and S21 (gain or loss). However, we can still measure S22 and S12 by simply flipping around the Device Under Test (DUT).



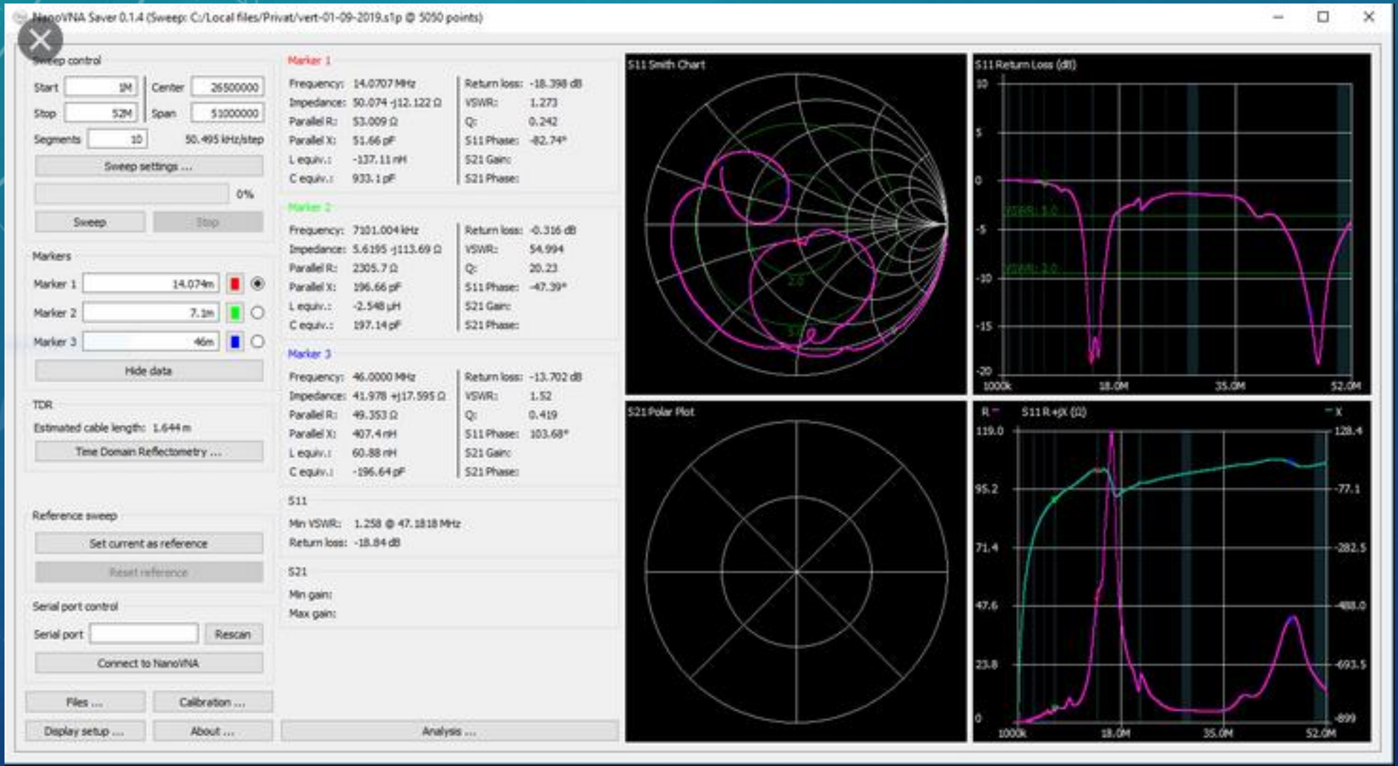


NanoVNA-F Versions

- Link to purchase at Amazon. May also be available on eBay
  https://www.amazon.com/gp/product/B0816QXCX1/ref=ppx_yo_dt_b_asin_title_o04_s00
- Price on Tuesday was $130.99. I paid $139.99 a few weeks ago.
- As sold currently: (1000 MHz coverage): Version 0.0.4
- Upgrades on line:
  - 0.0.5:   Extends frequency scan to 1500 MHz
  - 0.1.0:   Fixes minor bugs and adds TDR to measurement list (came out this past weekend)
- I upgraded mine to 0.0.5, then to 0.1.0. Upgrading is easy. Method described on groups.io blog page.
  - 0.1.0 version comes up in Chinese, but new menu map on groups.io shows how to fix it
  - https://groups.io/g/nanovna-f
- A custom text field can be inserted on VNA start screen (ie, your call letters, etc.)
  - 10 characters in earlier versions
  - 44 characters in version 0.1.0

NanoVNA Saver Windows GUI

- Allows data capture in several formats. Latest version is 0.2.2.
- GUI requires a certain USB-serial port driver to talk to the VNA using the cable provided. It is an STM32 VirtualComPort driver. It appears to be available online from a number of sources. Thanks to Ben Koerner for installing mine.
- Problems: Window does not scale correctly to monitor settings (wants a really high resolution monitor?); Changing sweep range causes error message “Sweep out of range” for no apparent reason. Axes also do not scale well.



VNA CALIBRATION

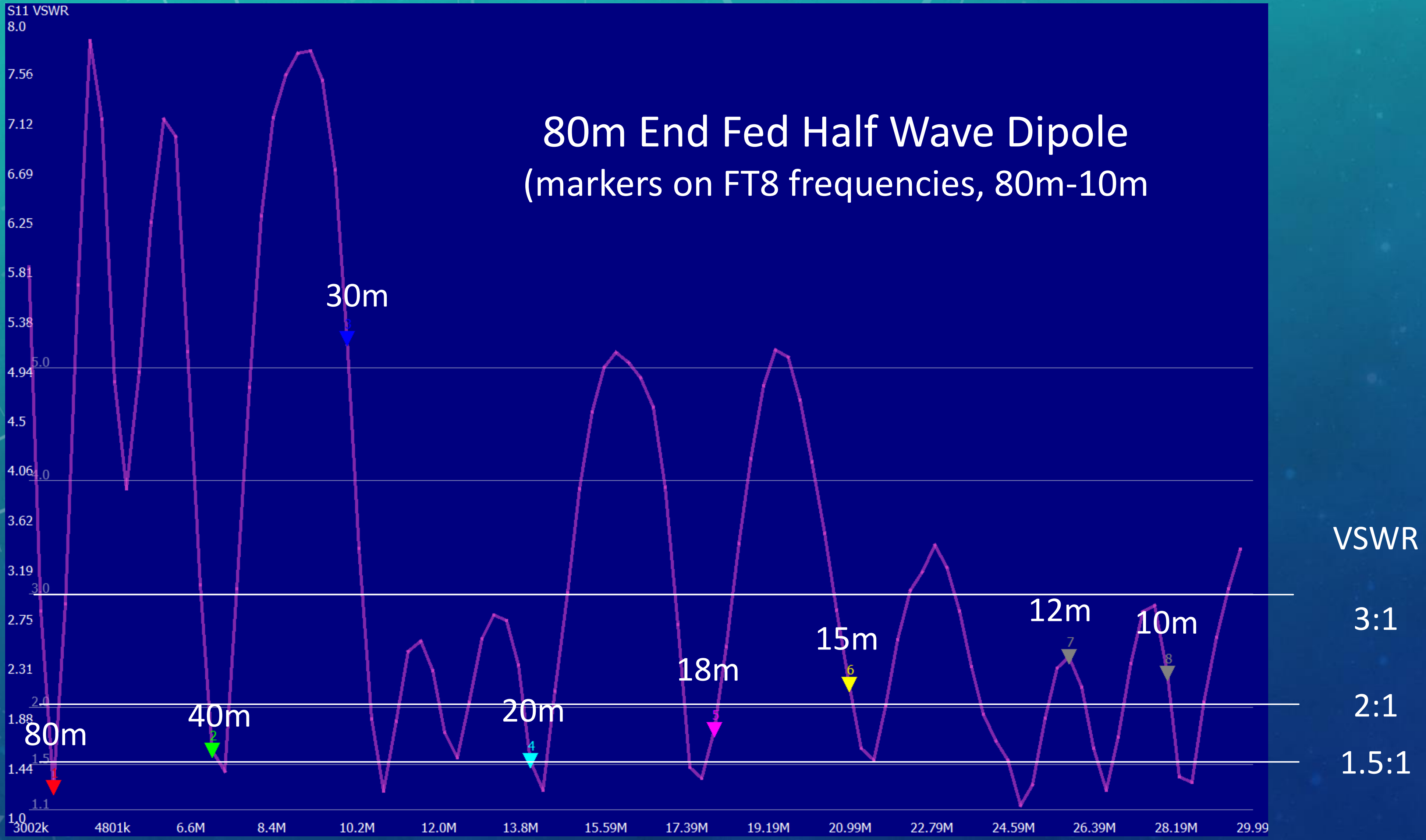
- Remember that a VNA not only measures signal amplitude, but it also measures phase relative to its internal RF source. In order to measure the true impedance or time delay or cable length (etc.) of a test item, we first must establish a phase/amplitude reference plane. This is done with a procedure called an SOLT calibration (Short, Open, Load, Through).
- Procedure:
  - Set a wide frequency span in the STIMULUS menu, say 1-1200 MHz
  - Go to CAL menu and connect OPEN standard to Port 1.
  - Use a stylus to select the OPEN tab. The VNA will beep and the tab lettering will invert color to indicate that the cal step is complete.
  - Repeat for SHORT and LOAD standards.
  - With the LOAD still attached to Port 1, press the ISOLATION tab
  - Disconnect LOAD standard, and connect short coax jumper provided between Port 1 and Port 2.
  - Press the THROUGH tab. Then press DONE. Remove the short coax jumper.
- What happens now? You have set the measurement reference plane to Port 1. The VNA will measure true complex S-parameters relative to this location.
- What if it isn't convenient to attach a load directly to the Port 1? The reference plane can be extended with a length of coax cable. Repeat the CAL procedure by attaching CAL standards to the end of a convenient length cable connected to Port 1. The reference plane will then exist at the end of the cable instead of at Port 1.
- Amplitude Only: if all you care about is VSWR or frequency response then reference phase is not important (amplitude only). You can still calibrate at Port 1, then attach your antenna coax to measure VSWR, or attach a filter with short coax sections and measure response, etc.

USES AROUND THE SHACK

- Sweep any ham band up to 1300 MHz.
- One port measurements (S11):
  - "Cantenna" or other dummy load (VSWR vs frequency)
  - Antennas (VSWR vs frequency)
  - Coax cable length (TDR)
    - Table of standard coax types built in to software!
  - Coax cable distance to fault (TDR)
  - Components (inductance, capacitance, resistance)
  - Home brew RF circuits (impedance matching aid)
  - Tuned circuits/loop antenna (find resonances)
- Two port measurements (S11, S21) :
  - Bandpass/lowpass/highpass/notch filters (frequency response)
    - Filters for Field Day!
  - Repeater duplexer (insertion loss, isolation)
  - Attenuators (return loss and insertion loss vs frequency)
  - Low power RF amplifiers (gain, reverse gain, return loss vs frequency)
- Signal source – can be set to a single CW RF frequency

DEMO, FIRMWARE 0.0.5

N7RF ANTENNA FARM



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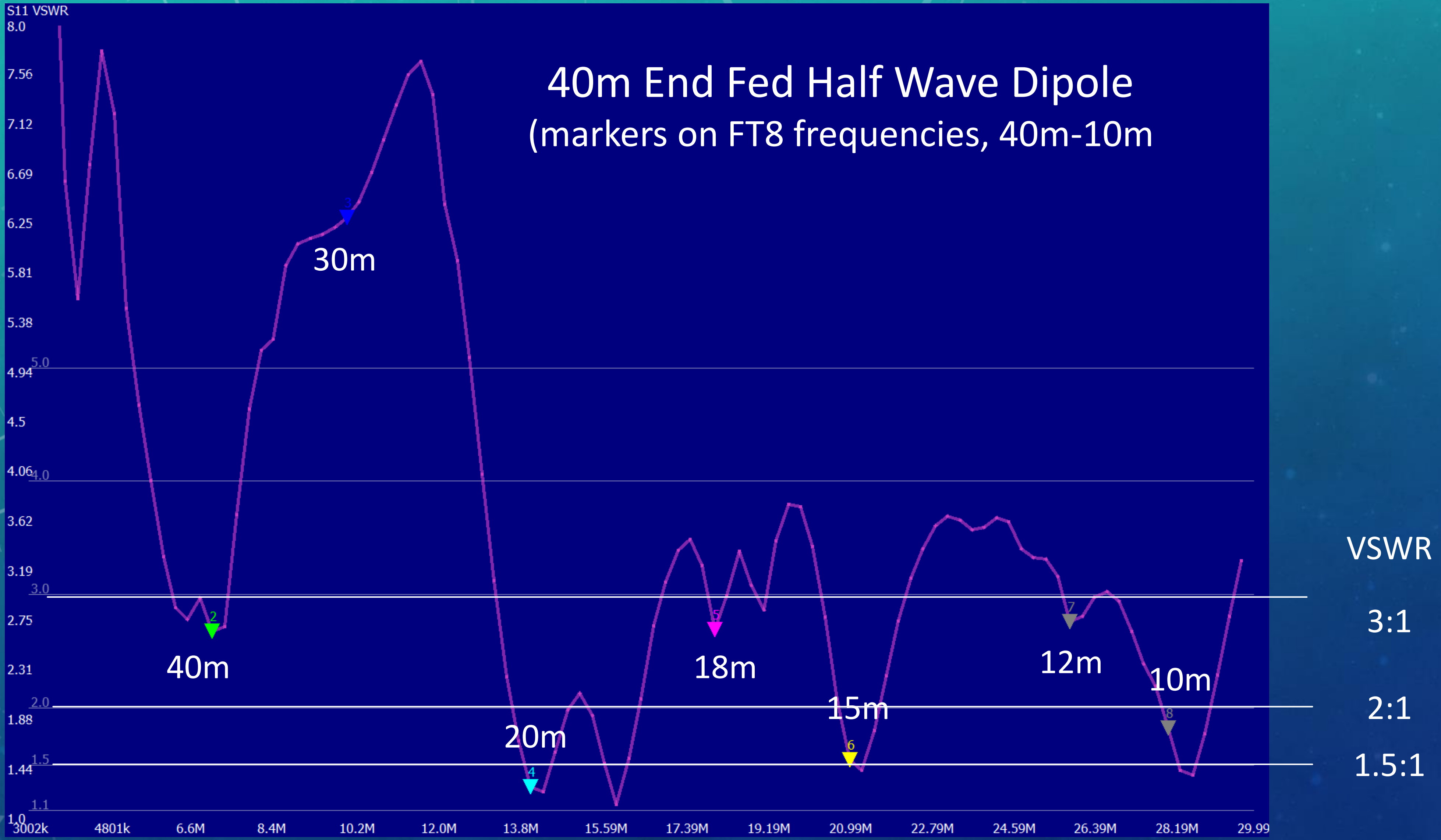

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