SAA-2N VNA Calibration Kit

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1. Introduction

In 2021, I published an article describing the calibration standards supplied with the NanoVNA-H4 {Reeve21}. This instrument uses type SMA connectors and is supplied with SMA-Male calibration standards and an SMA-Female coupler to convert the Male standards to Female standards. I acquired the SAA-2N VNA (figure 1) in summer 2025. The SAA-2N Is advertised as electronically identical to the NanoVNA-H4 but uses type N connectors and is supplied with N-Male Calibration Standards and an N-Female Coupler. Also, the SAA-2N frequency range extends to 3 GHz compared to 1.5 GHz for the NanoVNA-H4. This article discusses my measurements of the standards and cables supplied with the SAA-2N.

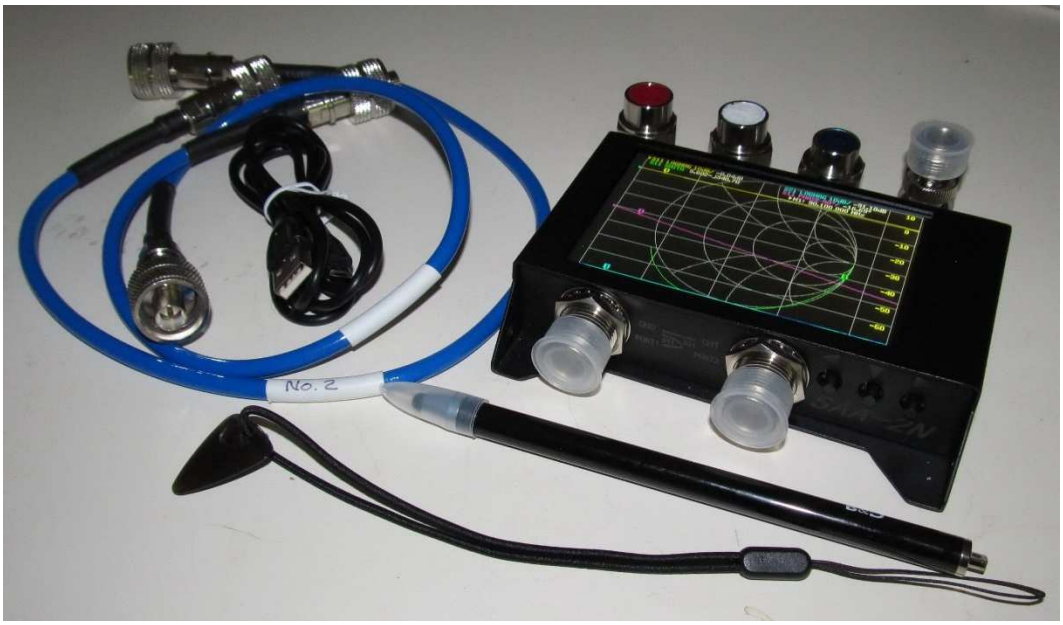


Figure 1 ~ SAA-2N VNA and accessories including two test cables and USB cable (the supplied carrying case is not shown). The Calibration Standards are above the unit at upper-right. A guitar pick and lanyard were supplied for the touchscreen, but a regular stylus has been added as shown below the unit.

2. Calibration standards

Many inexpensive vector network analyzers (VNA), such as the SAA-2N, are supplied with a 4-piece mechanical calibration kit consisting of Short, Open, Load and Thru *standards* (figure 2). The Thru is simply a female barrel connector (coupler). For calibration purposes, it is a reciprocal device called an *Unknown Thru*. When these four components are used in a calibration, it is called Short, Open, Load, Reciprocal, or SOLR. The collection of standards generally is called a Calibration Kit or simply Cal Kit.

Except as described below, the standards supplied with the SAA-2N appear to be good quality. However, because they are very low cost, no characterization data is supplied and the standards are simply assumed to be *ideal*. By ideal is meant that a Short has exactly zero impedance, no losses, no offset delay and no inductance, an Open has exactly infinite impedance, no losses, no delay and no fringe capacitance, and the Load has exactly 50 ohms resistive impedance. This is a good assumption for low frequencies.



Figure 2 ~ Type N calibration standards supplied with the SAA-2N VNA. The standards have been color-coded with fingernail polish for easy identification: Short (red), Open (white), Load (blue). The Thru standard at the bottom is an ordinary N-F coupler, which is classified as an *Unknown Thru* during SOLR calibration. The particular coupler shown here is poor quality and was discarded after it was tested (see text).

Professional VNA calibration kits are manufactured with precision connectors and are provided with characterization data, both physical and electrical. These data are based on statistics from mass production. They are not as accurate as Data-Based Standards but are well suited for ordinary measurement work. The inductances and capacitances related to the Short and Open, respectively, are provided in the datasheets and usually are given as coefficients of polynomial functions with the following forms:

$L = (L_0) + (L_1 \cdot f) + (L_2 \cdot f^2) + (L_3 \cdot f^3)$ henry and $C = (C_0) + (C_1 \cdot F) + (C_2 \cdot F^2) + (C_3 \cdot F^3)$ farad

where

f: Measurement frequency (Hz)

L_0 [H], L_1 [H Hz^{-1}], L_2 (H Hz^{-2}), L_3 (H Hz^{-3})

C_0 (F), C_1 (F Hz^{-1}), C_2 (F Hz^{-2}), C_3 (F Hz^{-3})

The inductance and capacitance coefficients are expressed as shown below. The example values are from the definitions of the Female standards in the Hewlett-Packard/Agilent 85032F type N Cal Kit and do not apply to the standards supplied with the SAA-2N, which are not known:

L_0: $10^{-12} H$ $(example\ 3.3998 \cdot 10^{-12}\ H)$

L_1: $10^{-24} H\ Hz^{-1}$ $(example\ -496.4808 \cdot 10^{-24}\ H\ Hz^{-1})$

L_2: $10^{-33} H\ Hz^{-2}$ $(example\ 34.8314 \cdot 10^{-33}\ H\ Hz^{-2})$

L_3: $10^{-42} H\ Hz^{-3}$ $(example\ -0.7847 \cdot 10^{-42}\ H\ Hz^{-3})$

C_0: $10^{-15} F$ $(example\ 89.939 \cdot 10^{-15}\ F)$

C_1: $10^{-27} F\ Hz^{-1}$ $(example\ 2536.800 \cdot 10^{-27}\ F\ Hz^{-1})$

C_2: $10^{-36} F\ Hz^{-2}$ $(example\ -264.990 \cdot 10^{-36}\ F\ Hz^{-2})$

C_3: $10^{-45} F\ Hz^{-3}$ $(example\ 13.400 \cdot 10^{-45}\ F\ Hz^{-3})$

The C and L coefficients generally have little effect on VNA calibrations and measurements at lower frequencies. Similarly, the loss and offset delay have minimal effect until the standard's physical dimensions are a significant fraction (approximately 1/20th) of the wavelengths at the measurement frequencies. The wavelength in a transmission line such as a coaxial cable is found from

$\lambda = [c \cdot VF]/f$

where

λ Wavelength in transmission line (m)

f Frequency (Hz)

c Speed of light in a vacuum (299 792 458 m s^{-1})

VF Velocity Factor, ratio of the speed of light in the dielectric to c (~0.69 for PTFE or Teflon)

For example, the wavelength at 1 GHz in a transmission line with PTFE (Teflon) dielectric is

$$\lambda = [c \cdot VF]/f = [299.8 \cdot 10^6 \cdot 0.69/1 \cdot 10^9] = 0.207\ m = 207\ mm$$

With respect to this example, a standard whose length from its reference plane to the actual short or open is > 10 mm (207 mm/20) usually would not be considered *Ideal* above about 1 GHz.

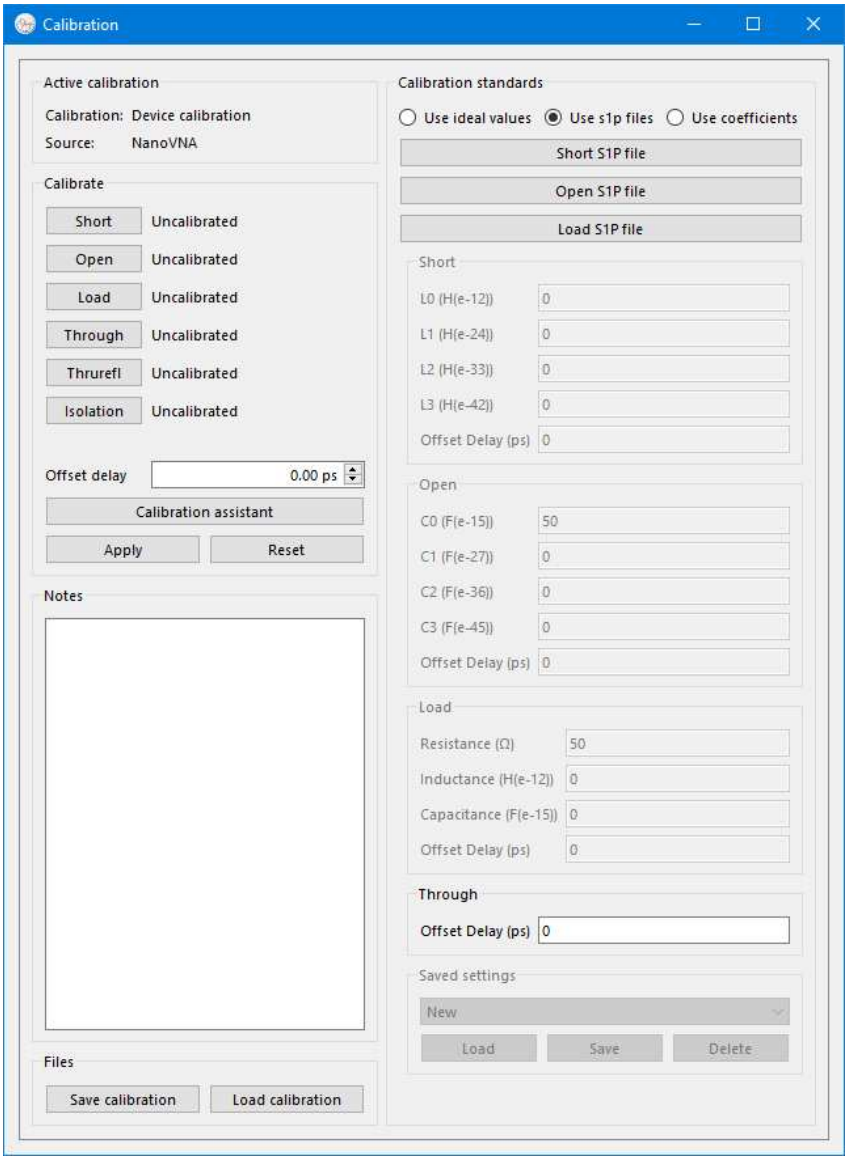


Figure 3 ~ NanoVNASaver *Calibration* settings window. The standards may be set to Use Ideal values, Use s1p files or Use coefficients, as shown in this image. If set to Use s1p files, the Load, Open and Short use measured S11 data loaded via File Explorer.

The Load standards in professional calibration kits are usually assumed to be exactly 50 ohms. Their performance is expressed in terms of Voltage Standing Wave Radio (VSWR) or Return Loss (RL). This assumption has little overall effect on the integrity of a VNA calibration. The last component, *Unknown Thru*, only needs to meet rather simple requirements because the SOLR calibration process itself determines the Unknown Thru's characteristics. Thus, it is the Short and Open standards that are most important in terms of VNA calibration.

It should be noted that the data provided with professional mechanical Cal Kits are averages that apply to thousands of manufactured units. However, for name brand Cal Kits, the statistics of both the physical and electrical dimensions are tightly controlled by design and manufacturing. If necessary, these standards may be

individually characterized at a metrology lab for additional cost but this usually is done only in demanding test and measurement work.

If the characteristic data (polynomial coefficients, delay, loss) are known, the values may be entered via the touchscreen menu into the SAA-2N. If the analyzer is used with the NanoVNASaver software (see references), the default choice is to assume the standards are Ideal (figure 3). It also can use the polynomial coefficients or the measured S-parameters of the calibration standards. If S-parameters are used, only the S11 measurements of the Short, Open and Load are needed. The accuracy of the S11 measurements must be much better than the expected accuracy of the measurements after the VNA has been calibrated with those standards.

After calibration, the analyzer calibration state may be saved for future use. Some versions of the NanoVNA-series analyzers have inherent temperature and calibration drift problems, so there is little advantage to reusing a saved calibration state with those units. However, the SAA-2N is claimed to be designed for minimum drift. My tests show the SAA-2N measurements are repeatable but I did not attempt detailed analysis.

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3. SAA-2N Standards Measurements

In this section I discuss the measurements of each standard (Short, Open, Load, Thru). I used professional test equipment for these measurements.

Measurement setup: The standards measurements were made on a Copper Mountain Technologies (CMT) S5045 VNA and associated S2VNA software from 20 kHz to 3 GHz with 1001 points. Mini-Circuits test cables with N-Male connectors were used for the interconnections. The VNA and associated cables were calibrated with a CMT ACM2506-011 AutoCal Module. The AutoCal Module has N-Female connectors on both ports, allowing them to be mated to the test cables without adapters. The SAA-2N Female standards also mated without adapters.

Port extension: To measure the SAA-2N Male standards, it was necessary to use an N-Female-to-N-Female adapter (barrel connector or coupler) in the measurements. The adapter was a Huber+Suhner p/n 31_N-50-0-2/133_N from my stock (cost 32 USD in late 2026). Any good quality (name brand) coupler could be used, not just this one. The coupler supplied with the analyzer was not used as explained below. To compensate for the shift in the calibration plane from the test cable end to the coupler end, both the manual Port Extension and Auto Port Extension functions in the CMT software were used for comparison.

For the manual Port Extension, the physical length of the adapter from reference plane to reference plane was estimated at 19.9 mm. This length is based on its measured outside length of 38.1 mm less twice the distance from an outside end to the internal reference plane of 9.1 mm (figure 4). The Port Extension delay was then determined from

$$PortExtension(s) = length\,(m)/[c\,(m\ s^{-1}) \cdot VF] = (0.0199\ m)\,/\,(299.8 \cdot 10^{6}\ m\ s^{-1} \cdot 0.69) = 96.2\ ps$$

where

PortExension	Delay setting in VNA (s)
length	Length of dielectric (estimated 0.0199 m)
c	Speed of light in a vacuum, previously defined
VF	Velocity factor, previously defined

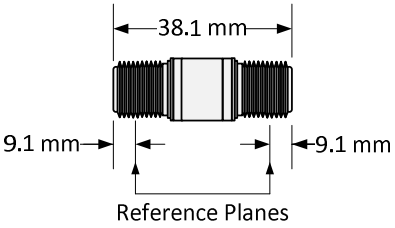


Figure 4 ~ Measured length of the Huber+Suhner p/n 31_N-50-0-2/133_N Type N Female Coupler. The distance from each end to the internal reference plane is 9.1 mm and is given in industry specifications. It is assumed the entire material between the two reference planes is PTFE but there actually is a small amount of air dielectric and a small error in the delay calculation.

After the calculated Port Extension was entered in the CMT software, the result was displayed on a Smith Chart. If the adapter was ideal, it would display a dot at the origin on the far-right of the chart but it actually showed a small trace pointed slightly downward from the origin. The Port Extension was then manually adjusted another +0.3 ps to minimize the trace, giving a total Port Extension value of 96.5 ps.

The Auto Port Extension function in the S2VNA software was used next. Auto Port Extension automatically calculates the port extension parameters by measuring a SHORT or OPEN standard, or both (if both are used, the software computes an average). I setup this function to measure the added delay as well as loss and mismatch. After regular calibration at the end of the test cable, the N-Female coupler was installed and an Open measurement was performed. This yielded a port extension value of 95.8 ps, a difference of only 0.7 ps and a fraction of a percent compared to the manual method.



Figure 5 ~ Initial reflection coefficient (S11) measurement of the SAA-2N coupler. The dip around 2.5 GHz would come and go and change shape as the coupler and connecting cables were handled. See text.

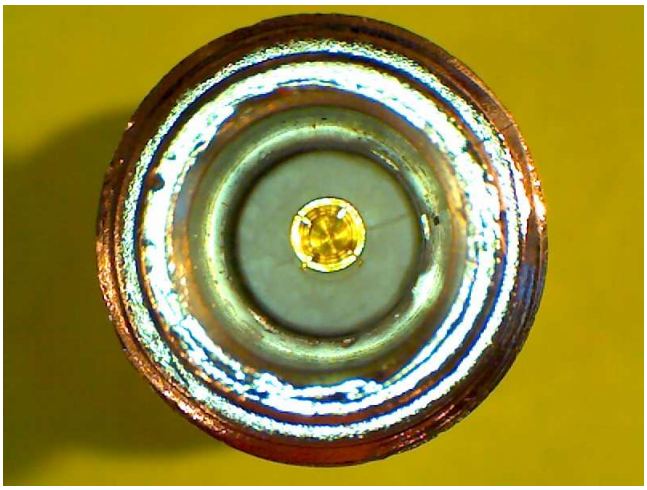
SAA-2N N-Female Coupler: The first measurement after the CMT VNA was calibrated, but before installing the Huber+Suhner adapter on the cable and setting the Port Extension, was the N-Female Coupler supplied with the SAA-2N. The coupler was a problem from the beginning. When connected to the test cable, it ideally should show 0.0 dB reflection coefficient (pure open circuit) across the frequency range. However, when first connected

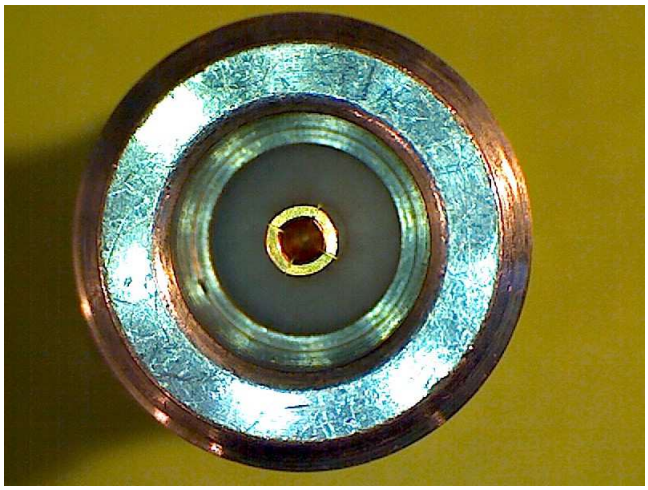
by hand-tightening on one side, it showed a dip at about 2.5 GHz (figure 5). These initial measurements were single-ended (no termination) and measured only the reflection coefficient (S11). Additional SAA-2N Coupler measurements are discussed later in this section.

The shape and depth of the dip in the reflection coefficient varied by wiggling the coupler and it would occasionally disappear. Slightly tightening or loosening the coupler changed the shape of the dip. The coupler did not show this behavior after reversing, so the problem was on one side only. Examination of the plating on the coupler outer and visible inner surfaces revealed it was poorly done (figure 6). In addition to the poor plating, there also may have been dimensional problems or possibly an internal problem with the coupler.

For comparison, the Huber+Suhner adapter mentioned above was connected in both directions with no problems whatsoever (figure 7). To avoid tainting the impending standards measurements, the supplied coupler was set aside (and eventually discarded) and the Huber+Suhner coupler was used in its place.

Figure 6 ~ Left: SAA-2N N-Female-to-N-Female Coupler shown end-on. Note the variations in the plating and finish on the end and interior surfaces. These variations could be the cause of the problems with the reflection coefficient noted in the text. Right: Huber+Suhner coupler for comparison. The plating and finish are obviously much better. The brightness variations around the concentric circles were due to the eight illumination LEDs mounted on the digital microscope.





The other SAA-2N standards were measured next. These included the Short (figure 8), Open (figure 9) and Load (figure 10). The Short, Open and Load standards appeared to be properly finished and had no obvious defects. One-path measurements, S11 and S21, also were made of the SAA-2N Coupler (figure 11) as were similar measurements of the Huber+Suhner Coupler for comparison (figure 12). The behavior of the SAA-2N Coupler was better during these measurements, although a broad dip in S11 was seen around 1.5 GHz. The measurement showed nothing unusual around 2.5 GHz as was noted above. These measurements were made for completeness only and the SAA-2N Coupler was discarded soon after.



Figure 7 ~ Initial reflection coefficient (S11) measurement of the Huber+Suhner coupler. The coupler did not show any anomalous behavior, unlike the coupler supplied with the SAA-2N.

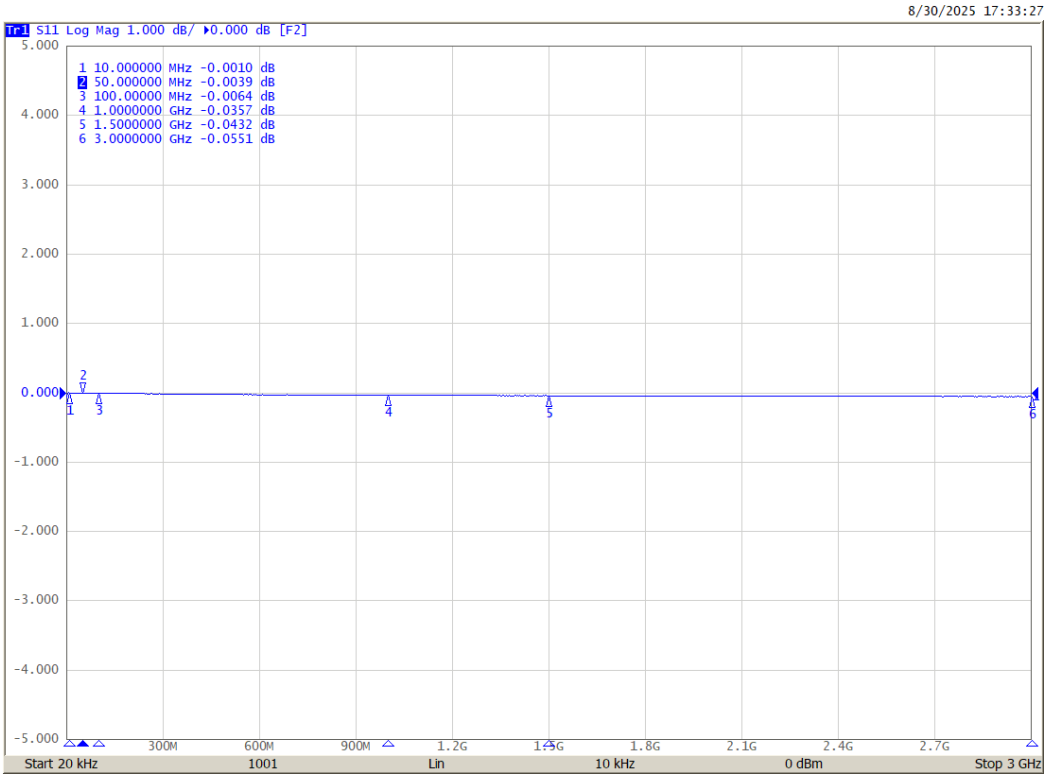


Figure 8 ~ SAA-2N Short: The reflection coefficient of an ideal short is 0.0 dB. The standard shown here is very good across the entire frequency range.

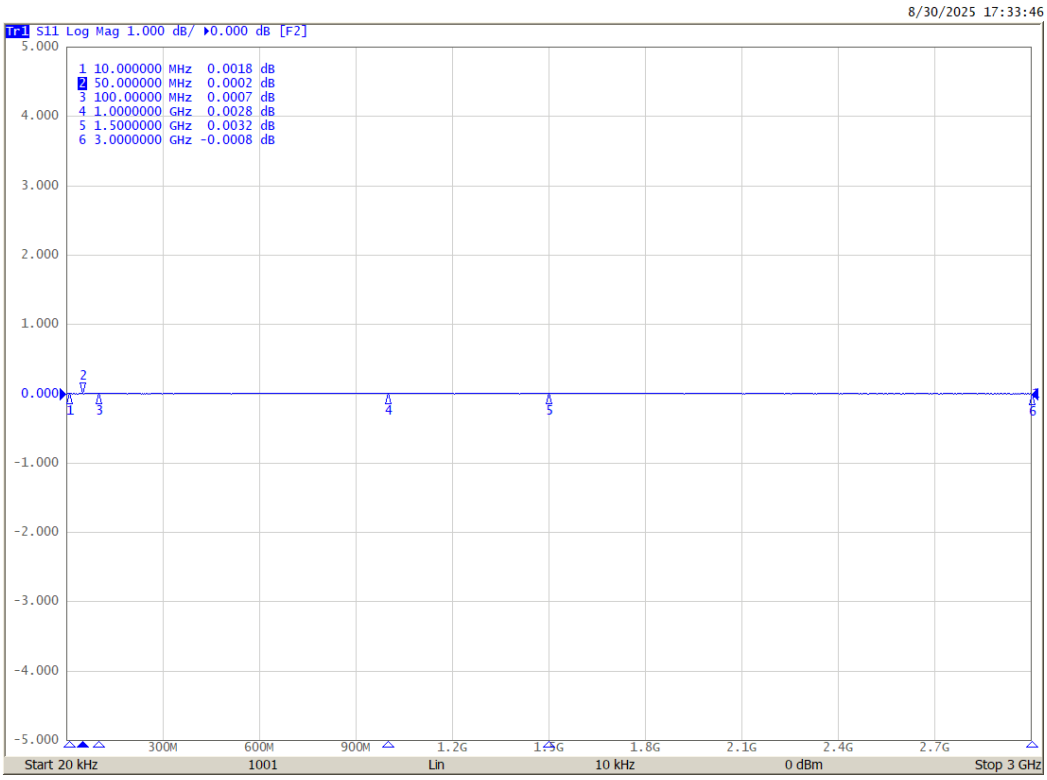


Figure 9 ~ SAA-2N Open: The reflection coefficient of an ideal Open is 0.0 dB. The standard shown here is very good across the entire frequency range.

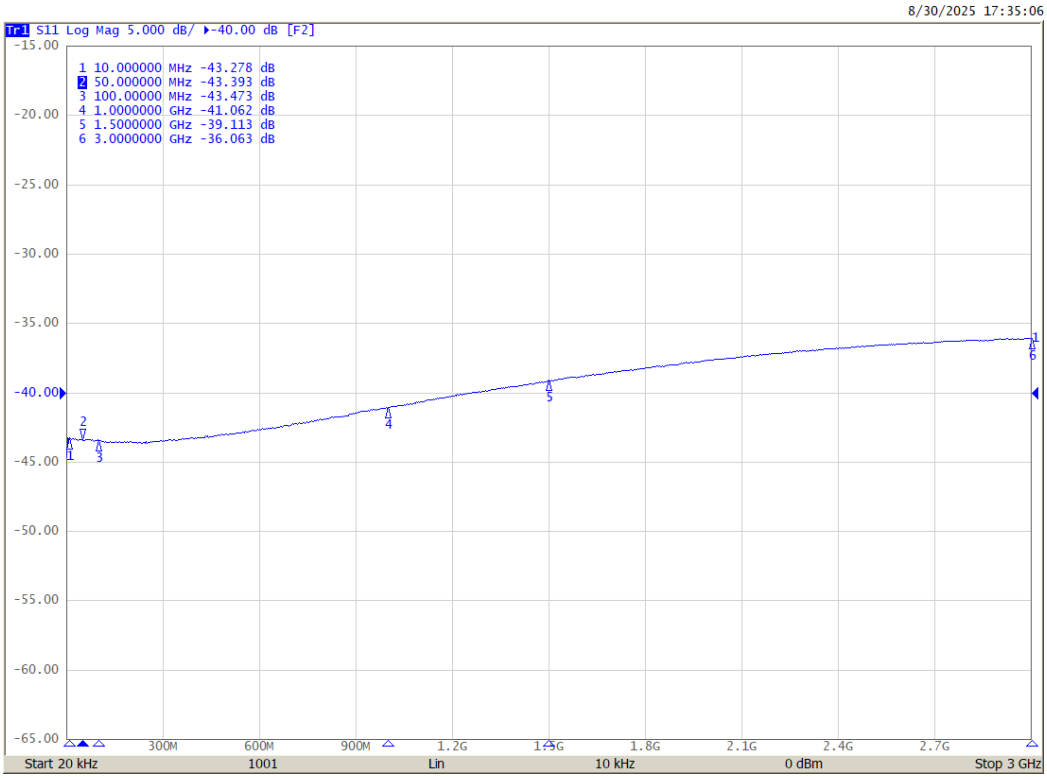


Figure 10 ~ SAA-2N Load: The reflection coefficient of an ideal Load is –∞ dB. The standard shown here is better than –39 dB up to 1.5 GHz and then decreases slightly to about –36 dB at 3 GHz. These are equivalent to 1.02 and 1.03 VSWR, respectively.

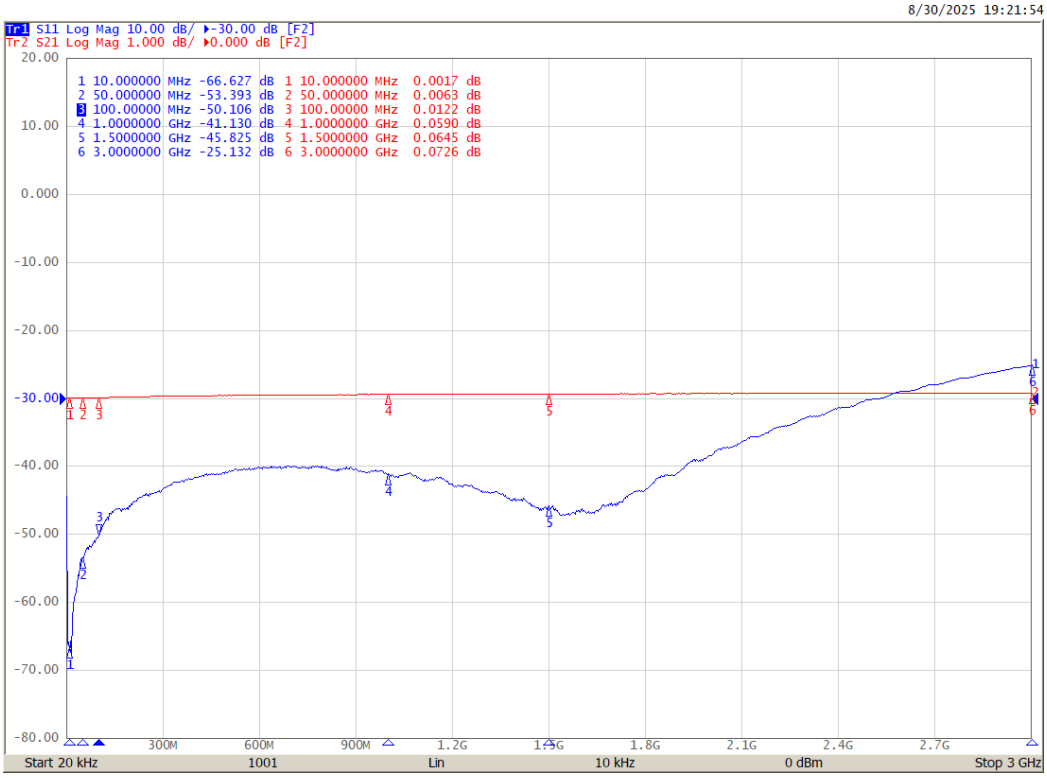


Figure 11 ~ SAA-2N Coupler: Reflection (S11) and transmission (S21) coefficients of the original coupler. Note that the reflection coefficient (blue trace, S11) has a dip at 1.5 GHz, nowhere near the dip seen in previous measurements. The vertical scale in this image is tied to the S11 measurement. Refer to the Markers for S21 measurement. The measurements use a different scale factor as shown in the upper-left corner.

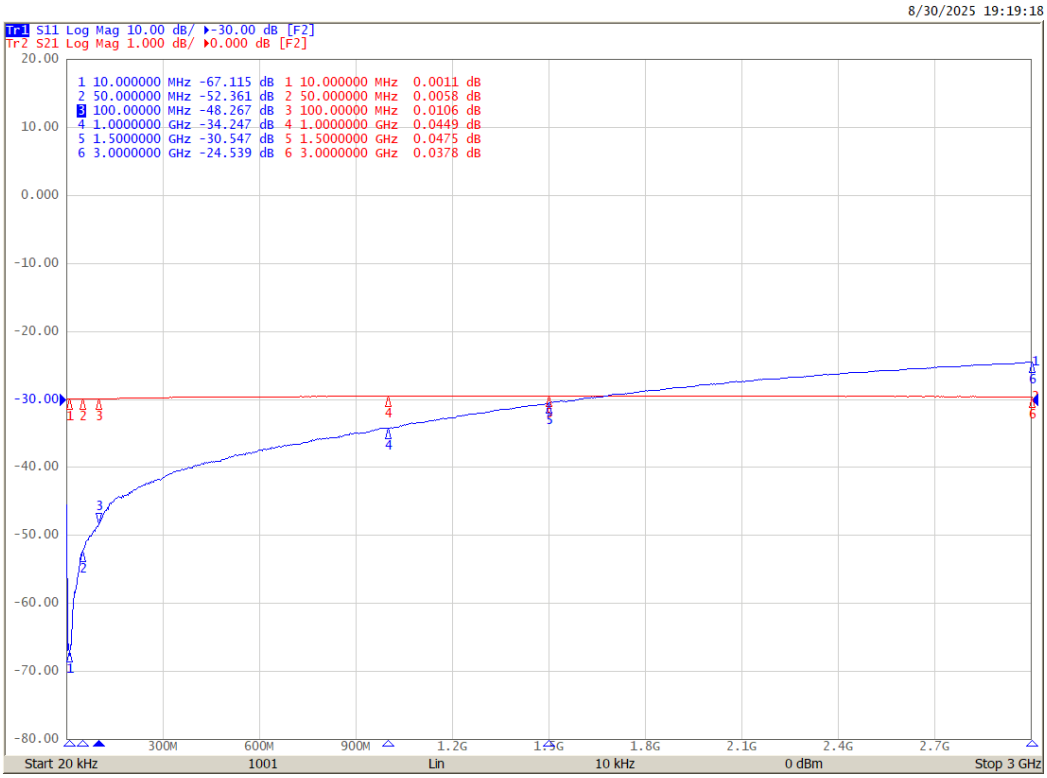


Figure 12 ~ Huber+Suhner Coupler: This coupler was measured for comparison with above. The measurements produced a more realistic plot of S11 but about 7 dB worse at 1 GHz compared to the SAA-2N Coupler. As above, the vertical scale is tied to the S11 measurement. Refer to the Markers for S21 measurement. The measurements use a different scale factor as shown in the upper-left corner.

4. Test Cable Measurements

The jackets of the two test cables supplied with the SAA-2N are labeled *RG142-PUR* and are 0.5 m long. RG-142 cables have PTFE dielectric (0.69 VF). Their length corresponds to a full wavelength at 414 MHz and 1/2-

wavelength at 207 MHz. The N-Male connectors on each end are similar in construction to PL-259 UHF connectors with a loose nut over the body (figure 13). This type of construction is far different than normally seen in commercial and industrial type N connectors. Unlike the SAA-2N Coupler, the plating and finish on the cable connectors had good appearance. The Huber+Suhner coupler previously described was used to adapt the cables to the test cables on the CMT analyzer, and Port Extension was enabled.



Figure 13 ~ The type N-Male connector on the right is installed on the test cables supplied with the SAA-2N. Note that the nut portion is not captive as it is in commercial connectors; it is loose and has been pushed back over the body exposing the ferrule around the connector's center pin. Measurements of the test cables did not indicate any specific problems with the connectors. The type N connector on the left is on a Mini-Circuits test cable and is shown for comparison. It is color coded for identification. The nut turns easily but has only a very small amount of fore and aft movement on the connector body.

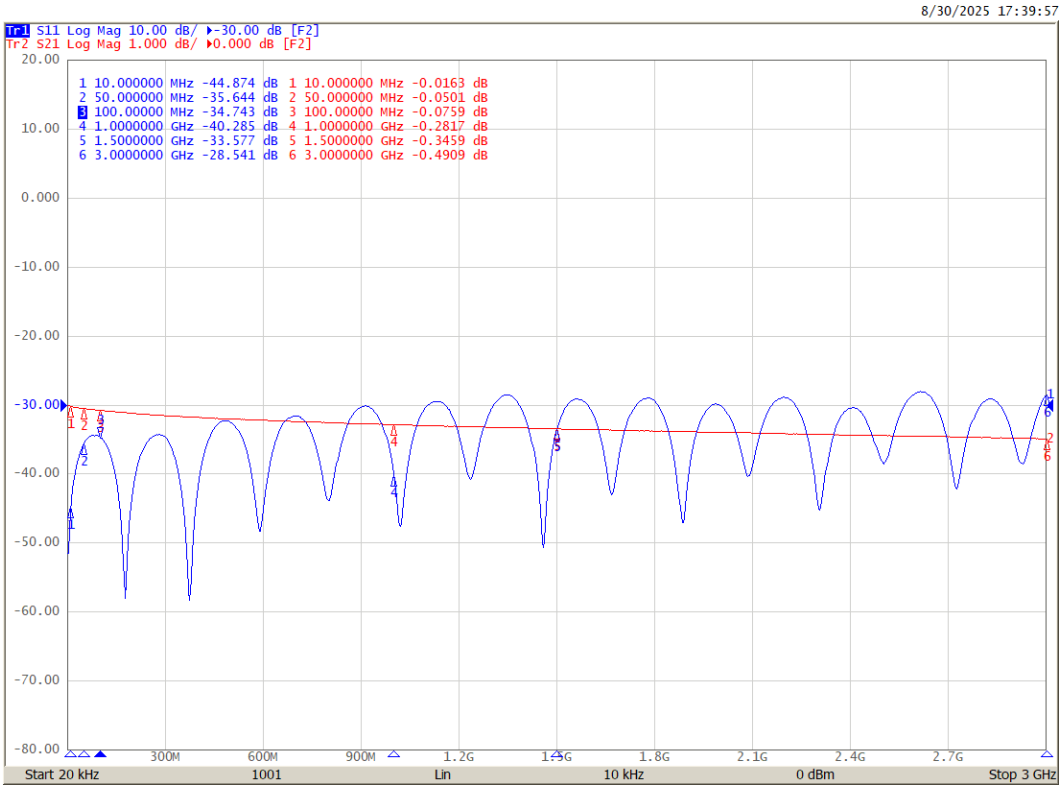


Figure 14 ~ SAA-2N Test Cable No. 1: Note the reference positions are different for the two parameters, S11 and S21. These are shown in the upper-left corner of the image. The left vertical scale is shown for S11 (blue trace) with the reference at –30 dB and 10 dB/div. The scale for S21 (red trace) has a 0 dB reference and 1 dB/div.

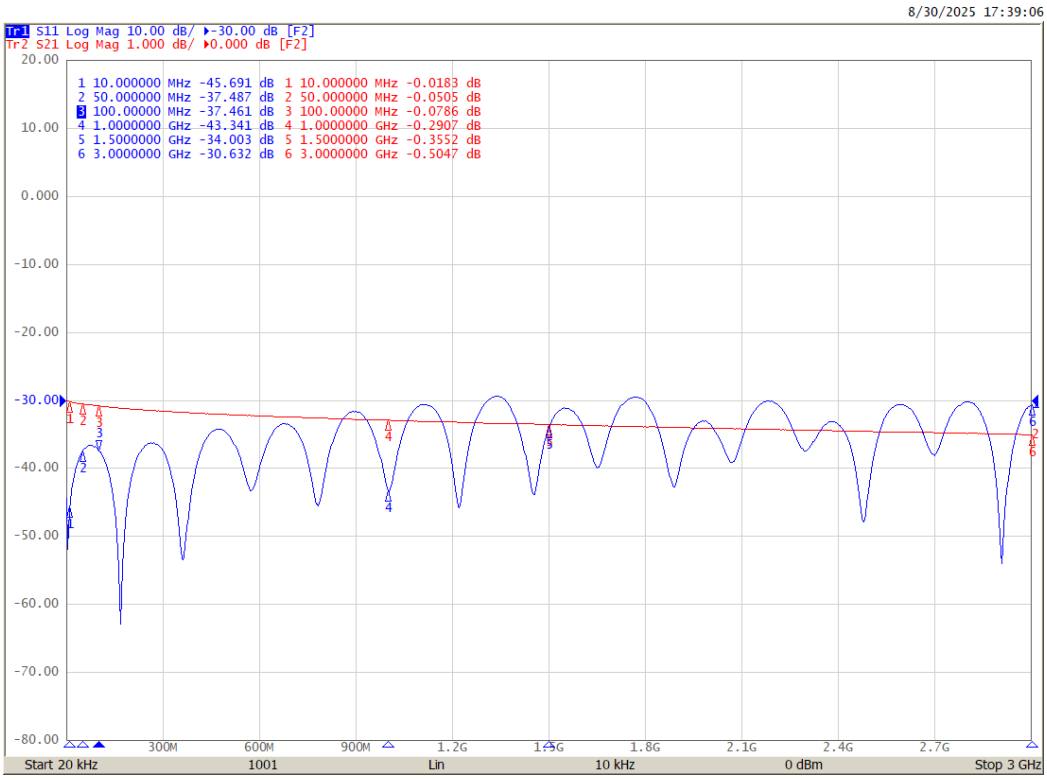


Figure 15 ~ SAA-2N Test Cable No. 2: Note the reference positions are as described in the previous figure. The left vertical scale is shown for S11 (blue trace) with the reference at –30 dB and 10 dB/div. The scale for S21 (red trace) has a 0 dB reference and 1 dB/div.

The measurements included the reflection (S11) and transmission (S21) coefficients (figures 14 & 15). The reflection coefficient measurements show ripple, which indicates an impedance mismatch. In the measurements shown here, the frequency spacing between maximums or minimums of the ripple is between 200 and 214 MHz, which is very close to what was found above to correspond to a 1/2-wavelength in the 0.5 m long cable. The difference between the measured and calculated 1/2-wavelength probably is due to the assumed dielectric velocity factor in the calculation.

The measured reflection coefficients (S11) are better than approximately –28 dB across the 3 GHz frequency range. The calculated insertion loss (RFCalc), which is equivalent to the transmission coefficient S21, is 0.45 dB at 3 GHz and quite close to the measured losses of 0.49 and 0.5 dB. The plots for the two cables are very similar. Some variations (fractions of a dB) were noted while moving the cables around during measurements, so these cannot be considered high quality test cables but are usable in static applications. No phase measurements were made.

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5. Conclusions

The N-Female Coupler supplied with the SAA-2N was found to be worthless and was replaced with a name-brand coupler. It is possible the defective coupler was an anomaly, but buyers should closely examine all connectors immediately after receiving an SAA-2N, or any inexpensive VNA for that matter.

On the other hand, the calibration standards appear to be quite good. The test cables supplied with the SAA-2N showed some instability when moved around during measurements. Their insertion loss is acceptable at approximately 0.5 dB at 3 GHz and their return loss is better than –28 dB throughout the SAA-2N frequency

range. The type N connectors on the test cables have unusual construction but this does not appear to impair their use over the measurement frequency range.

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6. References

NanoVNASaver https://nanovna.com/?page_id=90

{Reeve21} Reeve, W., nanoVNA Calibration Standards, 2021: https://www.reeve.com/Documents/Articles%20Papers/Reeve_nVNA_CalStd.pdf

{RFCalc} https://abrind.com/coax-cable-rf-calculator/

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