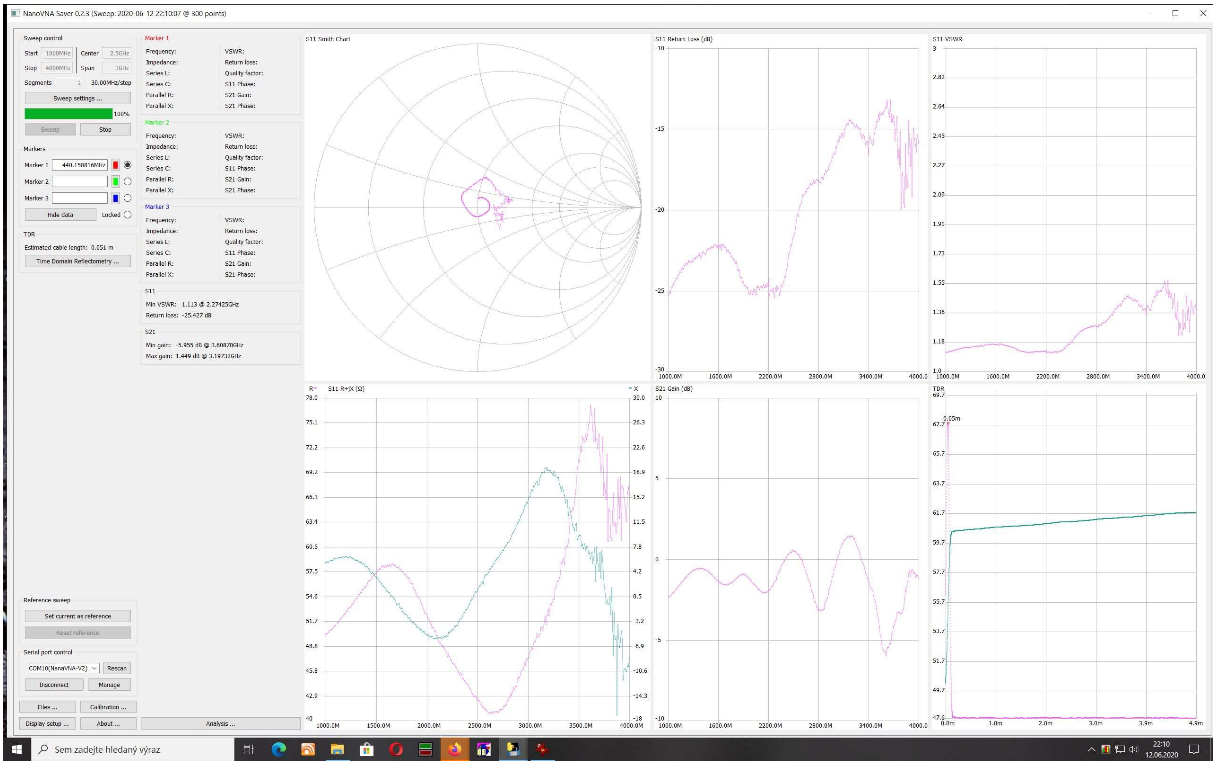
RF filter measurement with NanoVNA (V2)

One of the areas of using of the NanoVNA would be the measurement of RF high frequency filters. I would like to present easy instructions, how to achieve reproducible results, with a smallest measurement error. I recommend to use the NanoVNA Saver software.

1) *Hardware problem -NanoVNA could not measure two port circuits directly*

Although the NanoVNA has two ports, they are not identical. The port0 can measure reflections (vector reflection coefficient   or parameter s11 in two-port terminology), the port1 can measure transmission (the vector transmission coefficient S21) only. This is a root of the problem, that the NanoVNA-V2 in this setup could not be fully calibrated and possible measurement errors caused by bad matching of the port1 could not be eliminated.

The measurement of the of the matching of the port1 of the NanoVNA-V2 shows increase of reflections above 2GHz raising over -20dB, so the port1 does not represent ideal perfect match any more, and this fact contradict the method of scattering parameter measurement in principle, which is defined by use perfect matched measurement ports (by hardware or virtually by use of calibration method).



Fortunately, this issue could be quite easily improved when inserting a more precise attenuator in front of NanoVNA (6dB to 10dB is enough). This improves the port1 matching, but decreases the sensitivity of the port1 of the NanoVNA and consequently the s21 measurement dynamics.

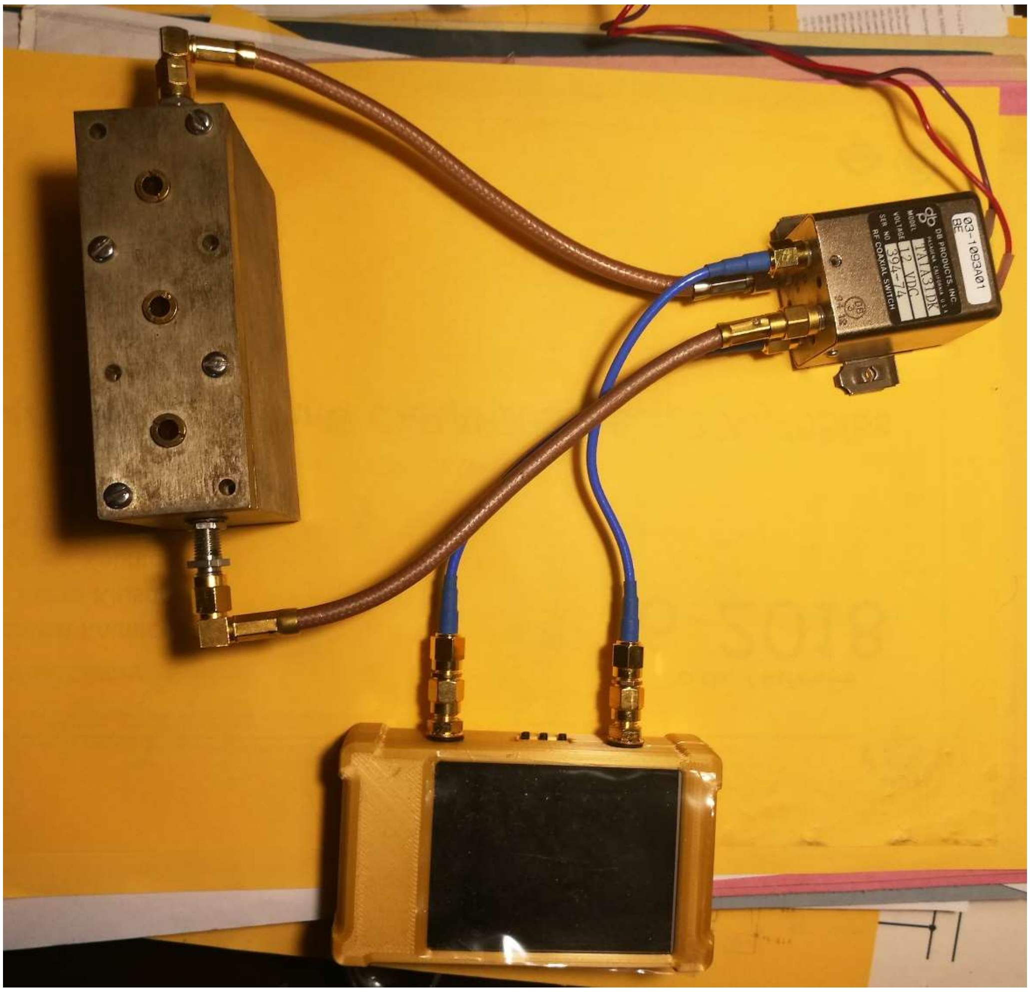
A simple rule (mostly valid for scalar systems) says, that in case of measuring circuits the overall measurement matching system errors should be at least that 10dB better that measured circuit. On the other hand, the low-cost microwave cables, connectors etc in most cases hardly achieves better matching values than -20dB in the GHz ranges. The matching error multiplies by cascading, so to reach -20dB in circuit port matching adjustment value is enough.

2) Using of transfer switch (relay) to measure the two-port circuit from both sides

The problem when measuring different RF circuits requires the knowledge of their matching from both sides. This problem grows, when measuring and adjusting filters, as far as the adjusting filter very often influences the matching on both sides, so in professional VNA the both S11 and S22 matching could be measured simultaneously. This could not be achieved with NanoVNA. The way of manually re-screwing the circuit is time consuming and leads very fast to wear of the fragile SMA connectors and bad measurement reproducibility. For regular measurement it is annoying and unusable.

As it was proposed on Youtube, groups IO and so all, the easiest way is to use RF Transfer switch. This part is having 4 RF connectors and unique by its design and switching properties the measured object can be measured from both sides without need of any reconnecting of the measured circuit. The even better is, that (by my experience) the switch is symmetrical, so even after switching of the switch the calibration of the NanoVNA could be still used and phase is the same. The bad news is, that the price of the used microwave transfer switch on Ebay is about 50USD or more, so it costs as the NanoVNA (V2) itself.

The following picture shows my testing setup, when measuring 2,4GHz microwave filter for QO-100 satellite. To keep the symmetry, it is necessary to have the cables from the measured circuit to the transfer switch with the same length.



My measurement procedure is following:

1)calibrating the NanoVNA for two-port measurement in the desired frequency band (in my case between the right angle SMA cables) with SOLT method.

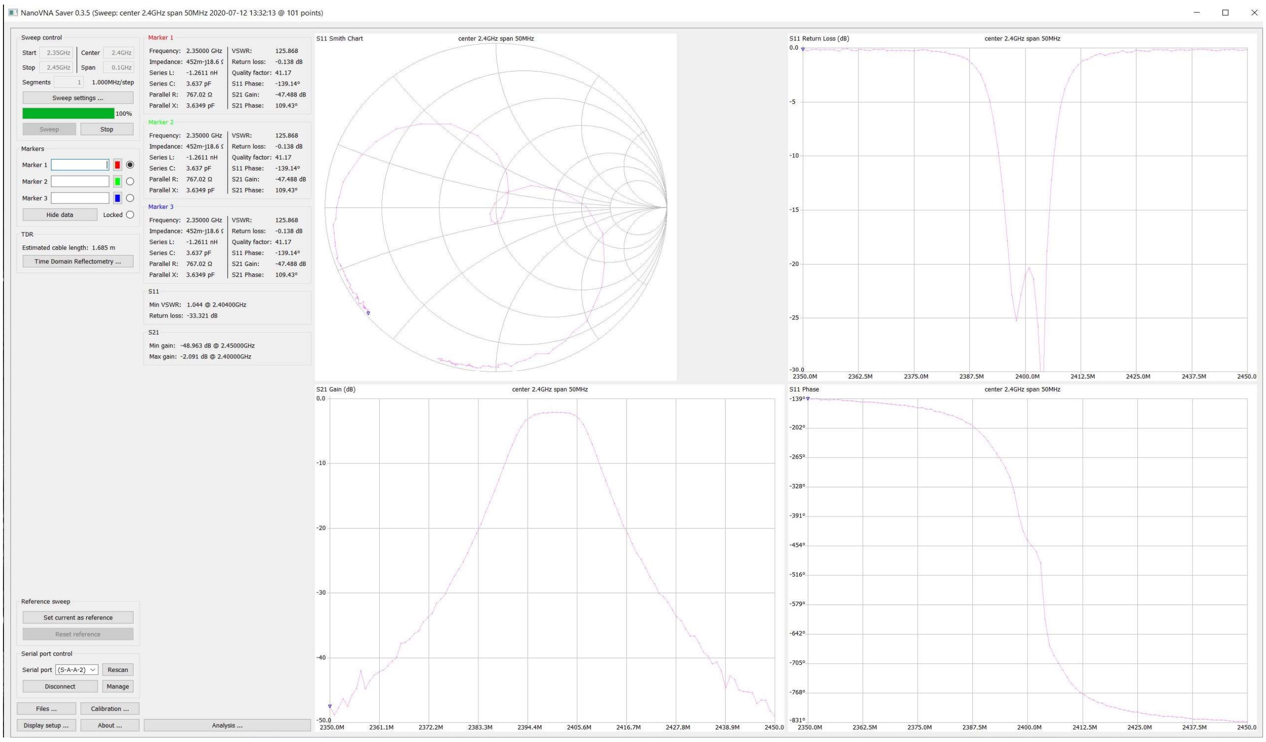
2) inserting the measured/adjusted circuit

3) measuring the circuit with its port0 connected to port0 of the NanoVNA and port1 of the circuit connected to receive port1.

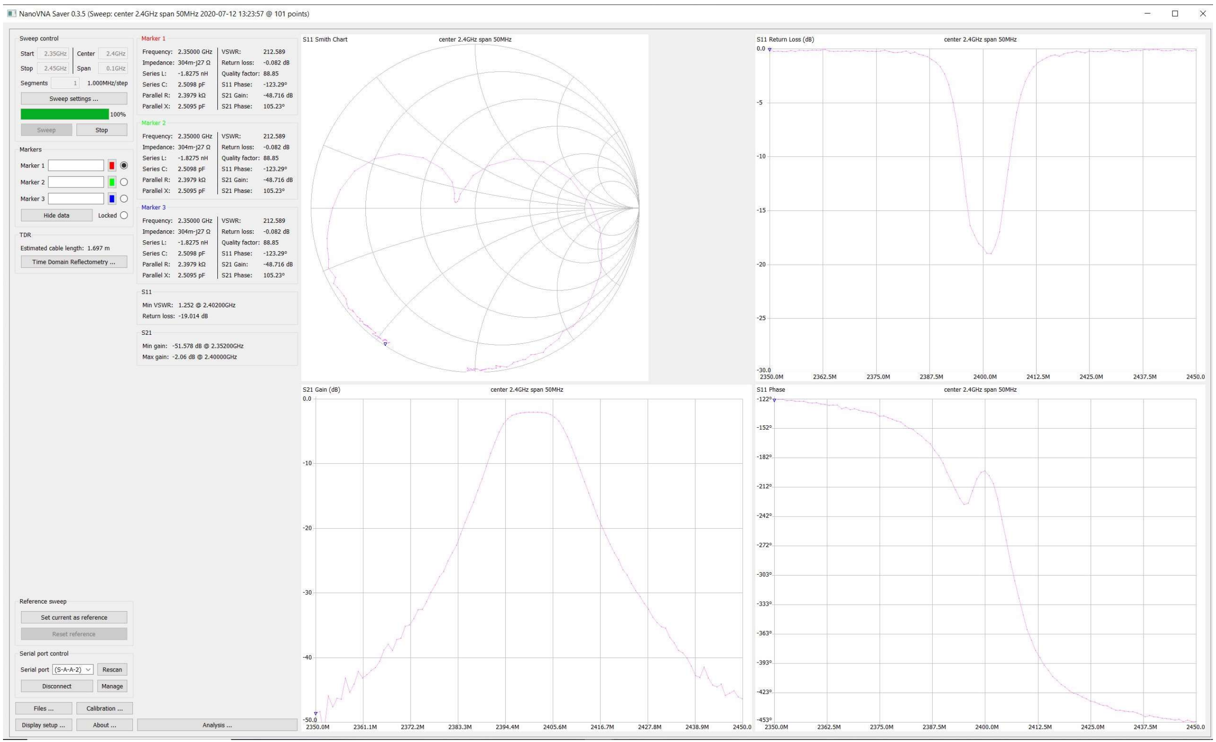
4) by manual switching of the transfer switch the connection is reversed, so port1 of the circuit is connected to port0 of the NanoVNA and port0 is connected to port1 of the NanoVNA.

In my case the transfer switch is non-latching, and due to current 0.35A from 12V in can be quite hot after time, so I recommend to use pulse latching switch when possible.

By use of that method a very good results can be achieved. The following pictures shows the results:



Measurement with transfer switch reversed (ports of the filter are reversed):



There are slight differences between those pictures due to different matching on both sides of the filter. The S21=S12, so both must be the same.

3) Points to improve

The greatest problem with NanoVNA V2) in comparison to professional vector network analyser is its low measurement speed. Even the oldest analogue microwave HP8410 system, which was the ancestor of all of the modern VNAs had the capability to measure (=stay locked) with about 10ms for a whole frequency sweep of few GHz. The high sweep speed of all RF analysers is important when adjusting circuits such as filters, to have a fast response on display when adjusting and not to tire the eyes. In case of digital display, the sweep time could be higher, my opinion is to have around 5-10 sweeps per second is a good value, but 1 sweep per second is very slow, you have to wait for the reaction and the adjustment work is cumbersome.

In case of using NanoVNA the sweeps are in the range of seconds. When using NanoVNA or similar PC software, the number of points per sweep can be selected, but when going below 101 points per sweep, the curve begins to be rough and inaccurate.

I will be very happy, when the sweep time will be improved, but I understand the limitations of the hardware, but every millisecond of improvement will be greatly appreciated.

Other question is to modify the hardware of the NanoVNA to create a full two-port analyser without the need of switching the circuit polarity by the transfer switch.

Usable links:

https://www.youtube.com/watch?v=HYlQHwDb9fA https://groups.io/g/NanoVNA-V2/topic/making_a_bench_instrument/75228503?p=,,,20,0,0,0::recentpostdate%2Fsticky,,,20,2,0,75228503

https://www.ducommun.com/pdf/RFCoaxialSwitchCatalog_120215.pdf

Version 1

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