AN12810

How to use the NanoVNA for the NFC reader antenna design

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Application note
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Document information

Information	Content
Keywords	NFC, NFC antenna design, NFC antenna tuning, NanoVNA, NanoVNA Saver
Abstract	This document describes the use of the NanoVNA for the NFC reader antenna design.

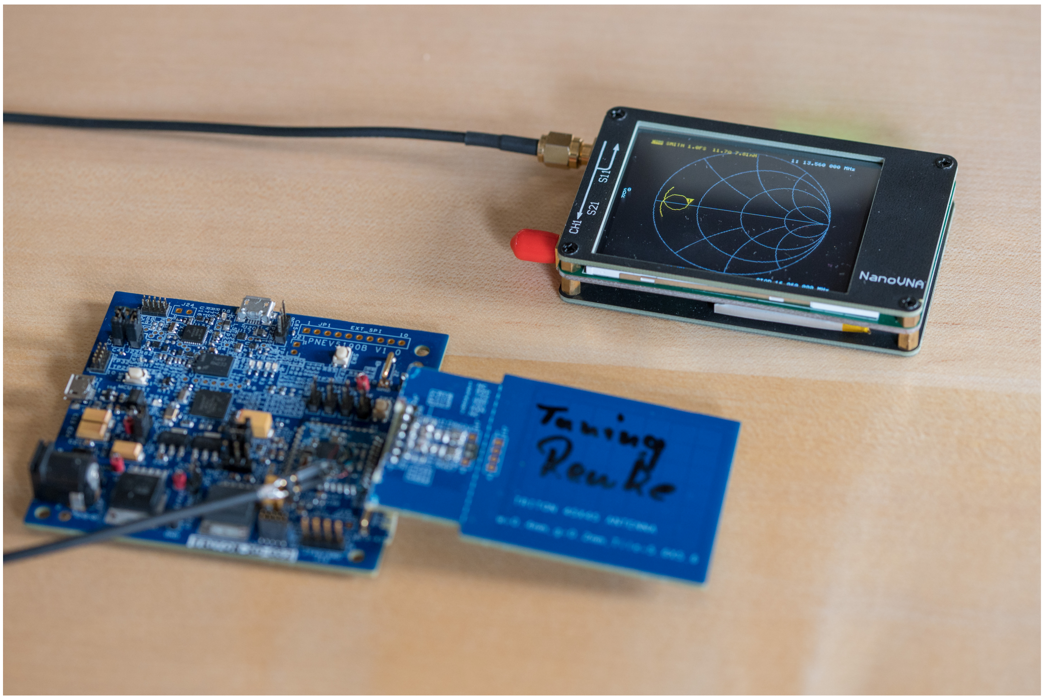
Revision history

Rev	Date	Description
1.0	20200421	Initial version

1 Introduction

Instead of using a high end impedance analyzer or vector network analyzer (VNA), there are cheaper solutions available, which can be used instead. The high end VNA (like for example, the ZVL, see [1]) allows for an easy and accurate measurement of NFC antennas. They are flexible and powerful tools.

However, even with a simple tool like the NanoVNA (see [2] and Figure 1) a very accurate measurement for the NFC antenna tuning can be done.



1. Example measurement setup

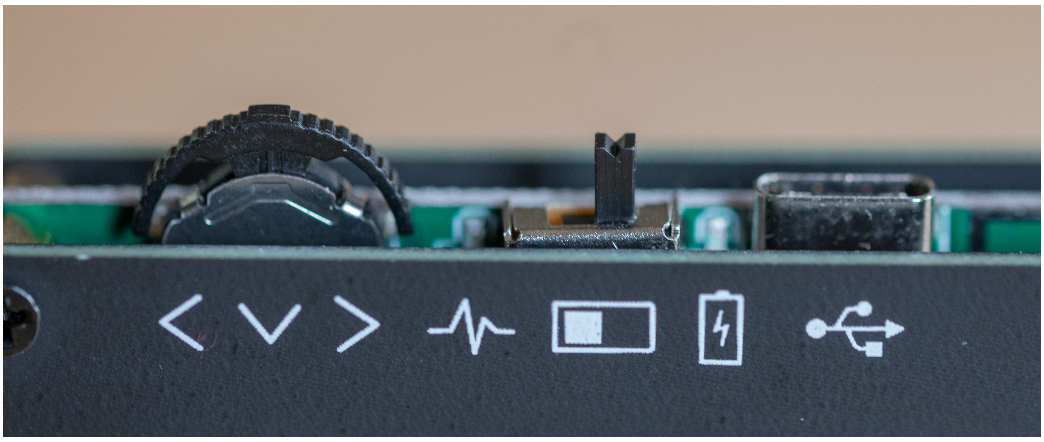
Figure 1. NanoVNA

This document describes the NanoVNA, its limitations, and how to use available PC SW to extend the measurement features of the NanoVNA for the NFC antenna design.

2 NanoVNA

The NanoVNA is easy to use. It provides touch display and a wheel / button as shown in Figure 2 to control the measurement and display settings.

The USB-C connector can be used to load the battery and to connect the NanoVNA to the PC (see [3]).



1. Select Wheel, On/Off switch, USB connector

Figure 2. Control I/O of the NanoVNA

For the NFC antenna tuning, only the S11 measurement is required and described. The S11 measurement is used to determine the antenna loop inductance (which is required to start the tuning process), and it is used to measure the tuning itself. All reference measurements use the smith chart.

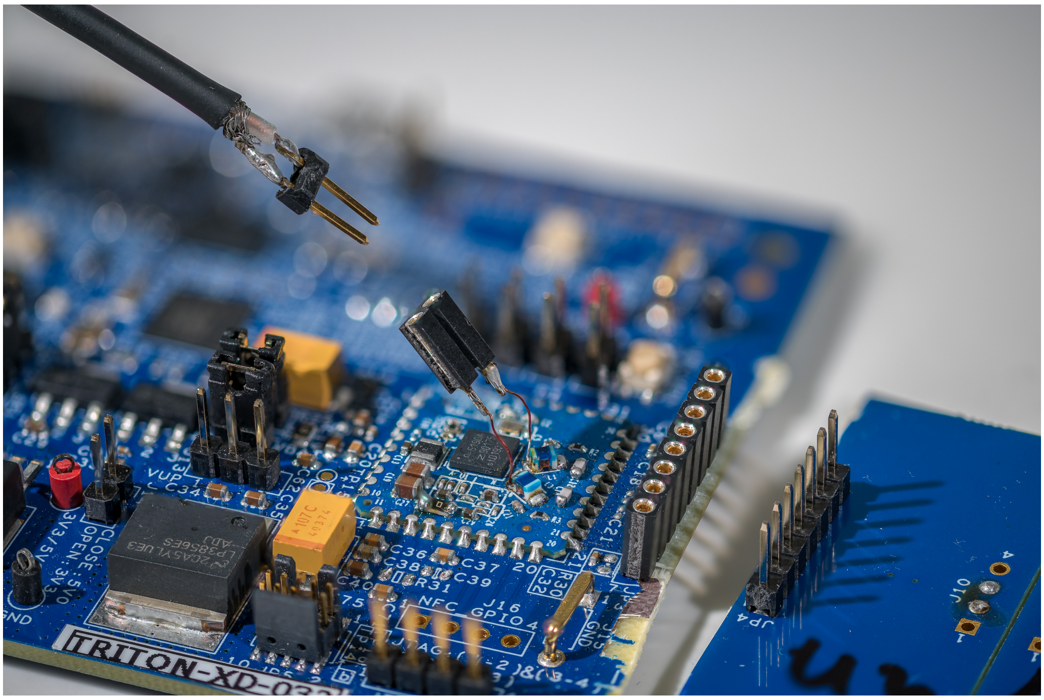
The NanoVNA can be set in such a way that it simply shows the smith chart. The marker, which should be set to 13.56 MHz allows to easily read the required data. For a proper reading and documentation, the use of a PC tool is recommended, for example, the NanoVNA Saver (see [3]).

2.1 Preparation

The proper S11 measurement requires a proper connection and a proper calibration. The low measurement frequency range from 10 MHz to 20 MHz allows the use of a very simple but effective calibration.

2.1.1 Standard single pin row header

It is recommended to use a simple standard single pin row header for all measurements, as shown in Figure 3.



1. The 2-pin female header is connected via thin wires to Tx1 and Tx2 to protect the SMD pads.

Figure 3. Standard pin row header for all connection

The NXP NFC reader evaluation boards are prepared to cut off the antenna from the tuning circuitry and to cut off the tuning circuitry from the main board. On each side of the cutting line, there is the option to solder a standard single pin row header to reconnect the parts again.

With this simple preparation, antennas with or without tuning circuitry can be easily exchanged without soldering.

Normally it is a good solution to keep the tuning circuitry connected to the antenna loop. The major part of the EMC filter and the Rx-path connection is assembled on the main board. This part normally does not need to be changed at all. So all tuning can be done on the tuning part, which can be kept connected to the antenna.

With this concept, different antennas with different tunings can easily be connected to the main board without the requirement to solder anything.

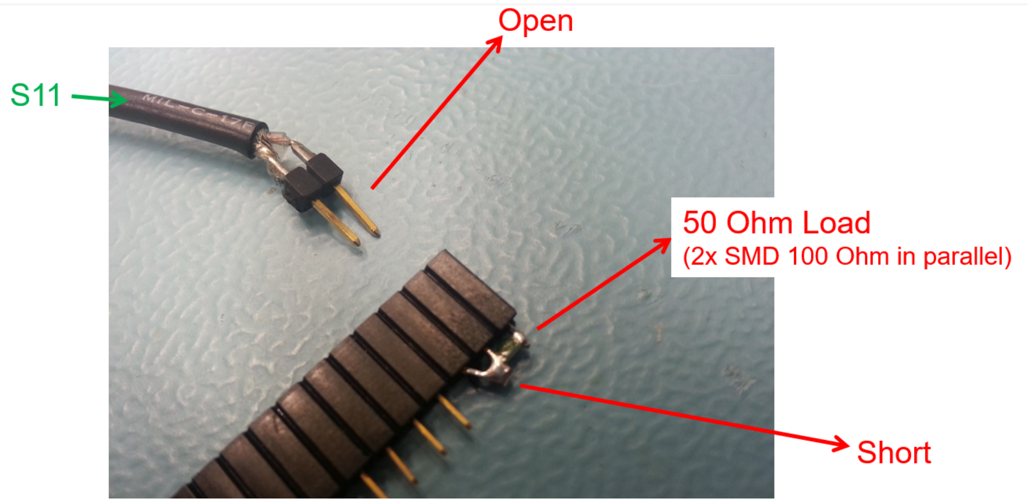
The measurement cable can be prepared with a male 2-pin row header, which allows a simple access to all measurement points:

- The antenna loop can provide a female 2-pin row header, which allows the antenna loop inductance measurement.
- The Tx1 and Tx2 pins or preferably the related L0 pads can be connected to a female 2-pin row header via thin wires, as shown in Figure 3. These short wires have an impact on the measurement, since they add some nH to the measurement. However, this impact can be kept minor, as long as the wires are very short.

2.1.2 Calibration

The S11 measurement requires a proper calibration. Some VNA tools offer a calibration and a correction. The calibration is done at the measurement port, while the correction adds some (mechanical or electrical) cable length.

For the NFC frequency range, the measurement can be simplified. A simple full 1-Port calibration (Open, Short, and Load) with a self-made calibration kit is recommended, as shown in Figure 4.



1. This typically works accurately enough for frequency <100 MHz.

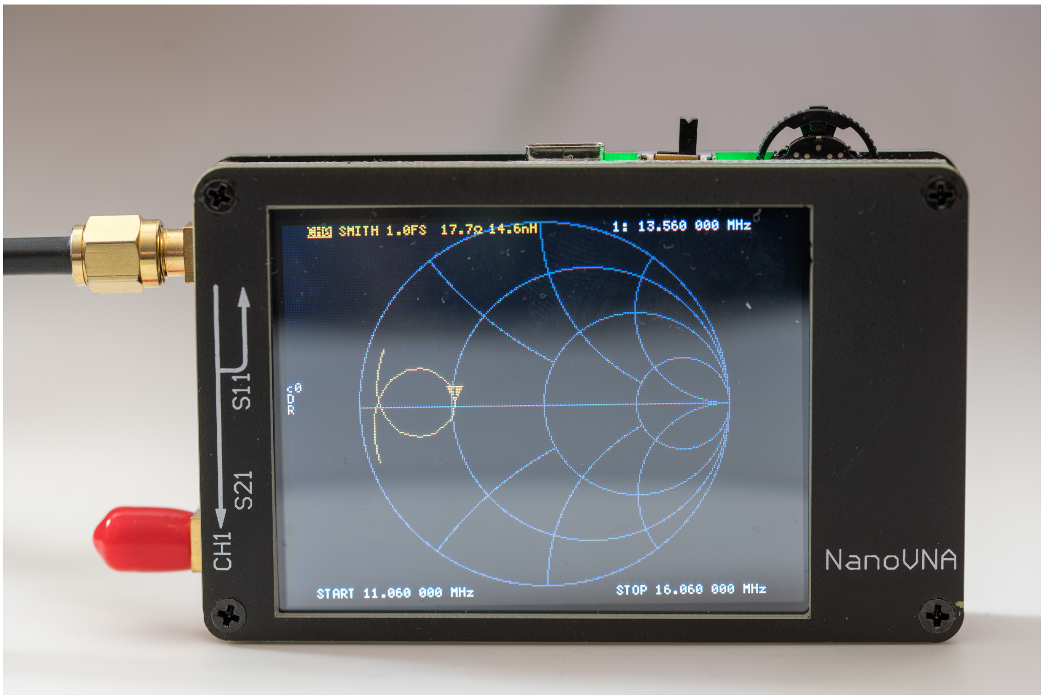
Figure 4. Self-made calibration kit

Using the standard pin row header, as described in Section 2.1.1, the calibration kit is a simple female pin row, where the short provides a short, the open provides “nothing” and the load is done with standard SMD resistor. The photograph in Figure 4 shows two 100 Ω resistors in parallel instead to achieve the 50 Ω load.

This calibration is accurate in the given frequency range, since it calibrates the measurement port in that plane, where the measurement takes place.

2.2 Stand-alone operation

The NanoVNA can be used stand-alone, as shown in Fig 5. The display is small but accurate enough to see the smith chart plot. And the marker info reads the relevant impedance data.



1. S11 showing a tuned NFC antenna.

Figure 5. Stand-alone operation

2.3 Known limitations

Obviously the number of measurement points is limited to 101. This limitation requires to either use a small sweep range (i.e. only 5 MHz) around the center frequency of 13.56 MHz. Such a small sweep range is recommended to be used in the stand-alone mode to get a proper result.

Or the PC SW allows to measure a wider sweep range in segments of 101 measurement points each. The NanoVNA Saver allows such an automatic scan in n segments, which makes it very easy to measure a full sweep from 10 MHz to 20 MHz in, e.g., 7 segments. That gives a very accurate measurement with e.g. 707 measurement in total. The segments are added into one plot automatically.

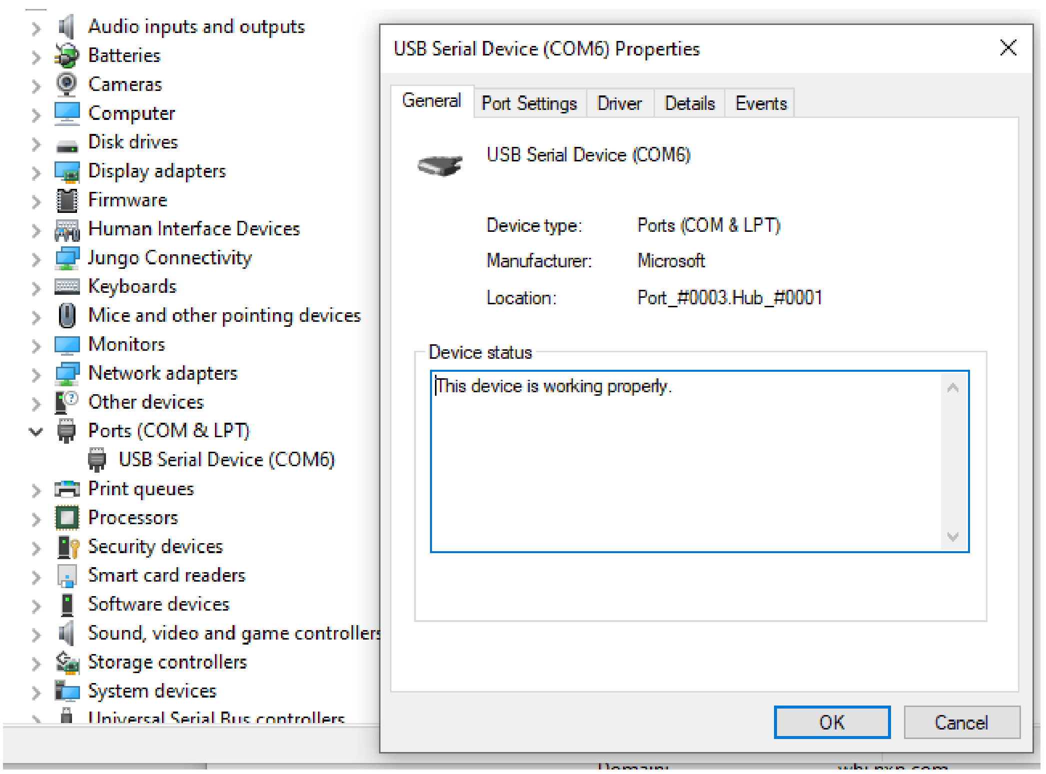
The display size and the related resolution are limited, too. However, the display is very clear and good enough to read and judge the results. And then the data can be retrieved via USB to any other platform. So in case of the use of NanoVNA Saver, there is no limitation in resolution anymore.

3 NanoVNA Saver

There are several open source SW tools available to drive and read the NanoVNA. Here in this document the NanoVNA Saver has been chosen (see [3]).

3.1 Driver

There is no driver installation required in MS WIN10. The NanoVNA automatically connects as “USB Serial Device”, as shown in Fig 6.



1. No driver installation is required in WIN10.

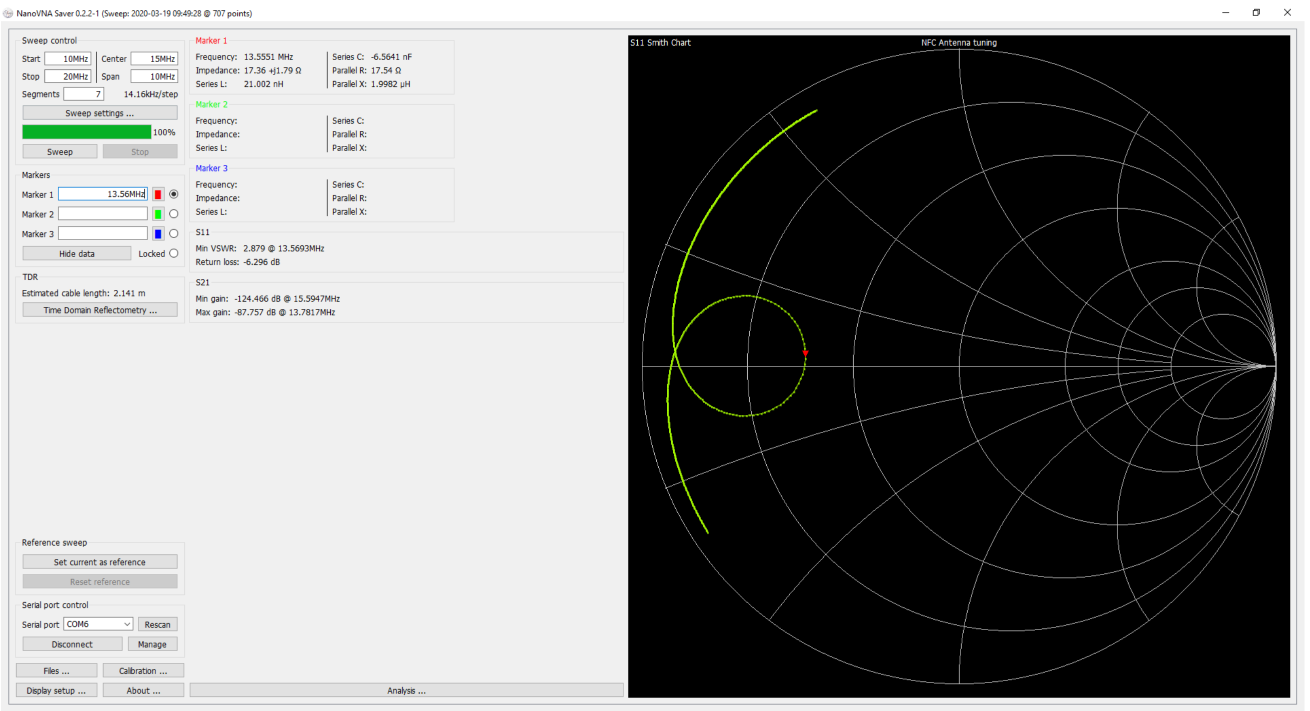
Figure 6. Standard USB driver for WIN10

3.2 NanoVNA Saver installation

The NanoVNA Saver can be downloaded from [3]. It is licensed under version 3 of the GNU General Public License, and comes without any warranty.

The Fig 7 shows a measurement result with a sweep from 10 MHz to 20 MHz with 707 measurement points, plotted in the smith chart.

There is no installation required, the SW simply can be started after download. It takes a few seconds, when started, before the full screen shows up. The SW is available for Microsoft Windows, Linux and MacOS.



1. Smith Chart Plot in “Dark mode”

Figure 7. Screenshot of the NanoVNA Saver

It makes sense to set the marker to 13.56 MHz.

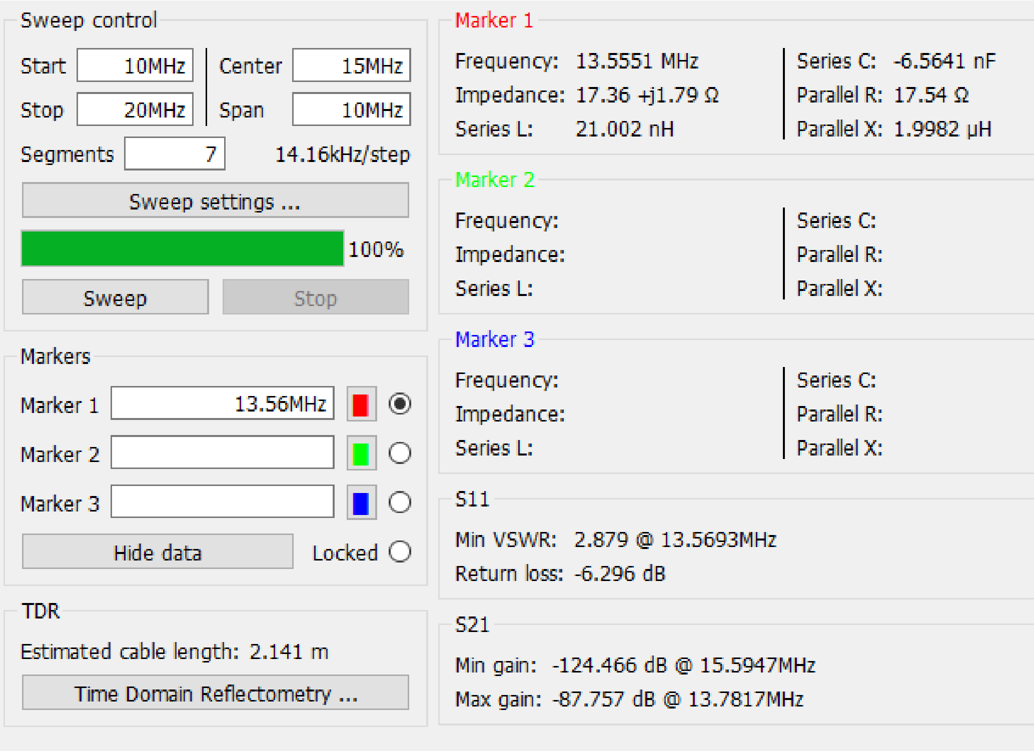
The screenshot shows a sweep based on 7 segment, resulting in 707 measurement points, from 10 MHz to 20 MHz.

3.3 Recommended settings

Here some recommended settings are listed. These settings work fine especially for the NFC antenna tuning.

3.3.1 General settings and info

The Fig 8 shows the general settings, as they can be set in the main window, and all the info that is shown besides the smith chart.



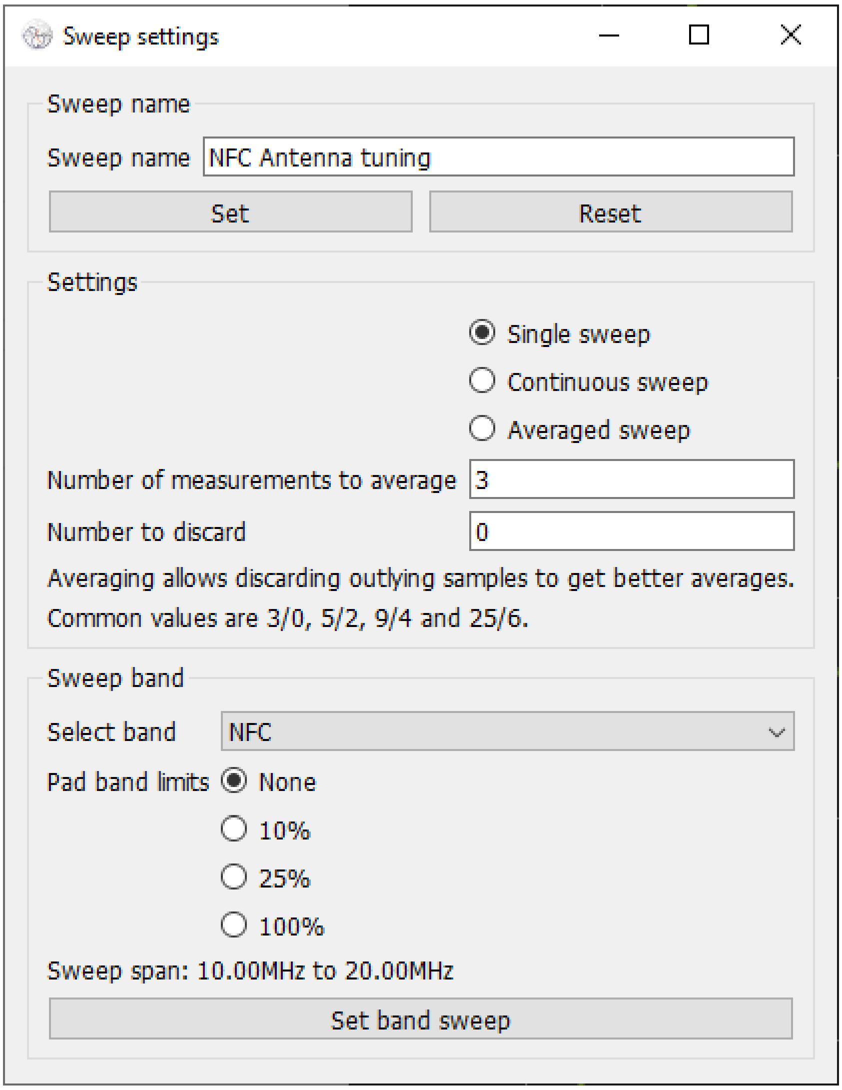
1. This is part of the main window.

Figure 8. General settings and info

Normally a single marker is sufficient.

3.3.2 Sweep settings

The Fig 9 shows the Sweep settings.



1. The NFC band had been defined and set before in the Display settings.

Figure 9. Sweep settings

The single sweep is good enough and faster than the averaging. It is recommended to increase the number of measurement points **with multiple segments** rather than enable the averaging.

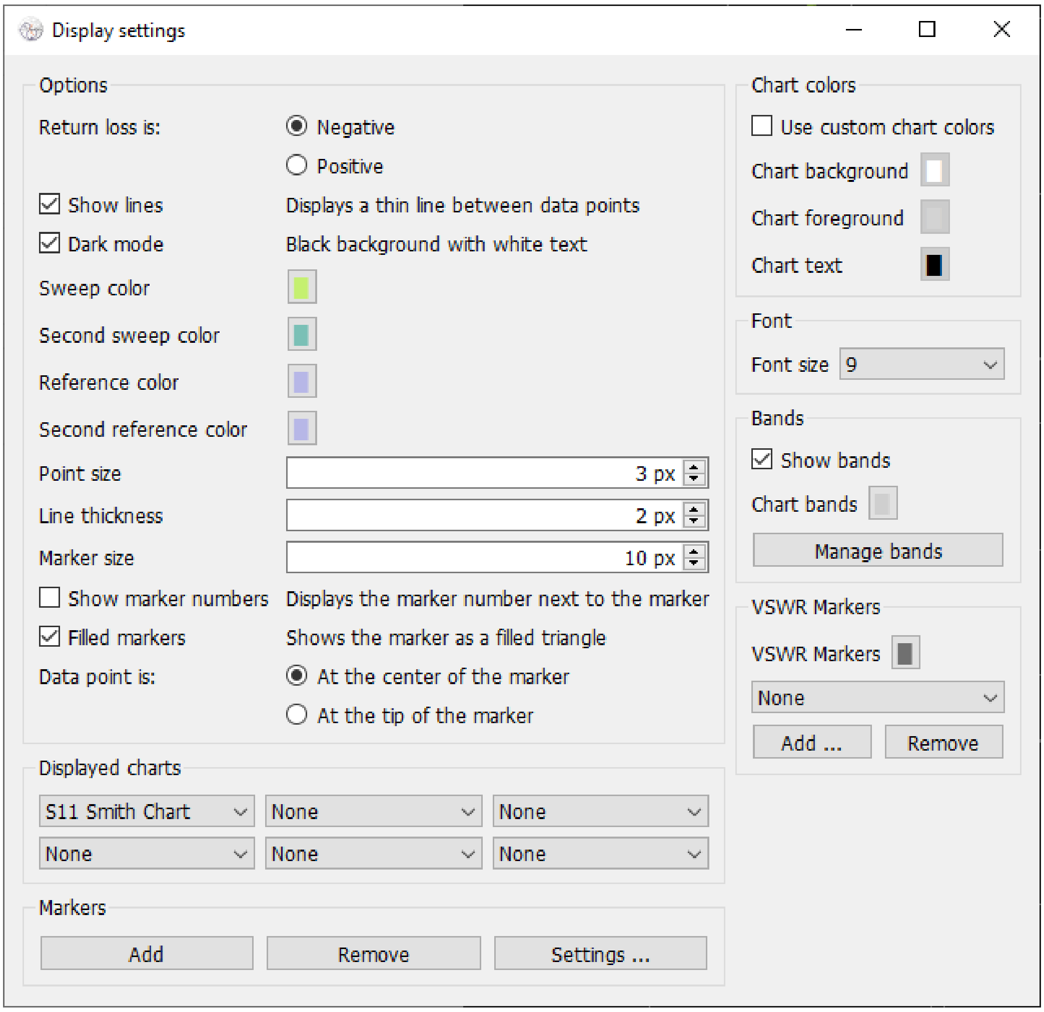
The "NFC" band had been defined and set before in the Display settings. It defines the Start frequency of 10 MHz and the Stop frequency of 20 MHz. Any other band with any other name can be defined there.

A Sweep name can be entered, which then is shown in the top of the smith chart.

Note: In the stand-alone operation, a smaller sweep range makes sense. In the stand-alone operation only a "single segment" with 101 measurement points is used, so it makes sense to reduce the sweep range to e.g. +/- 2.5 MHz around the 13.56 MHz.

3.3.3 Display settings

The Fig 10 shows the Display settings.



1. These settings are not default.

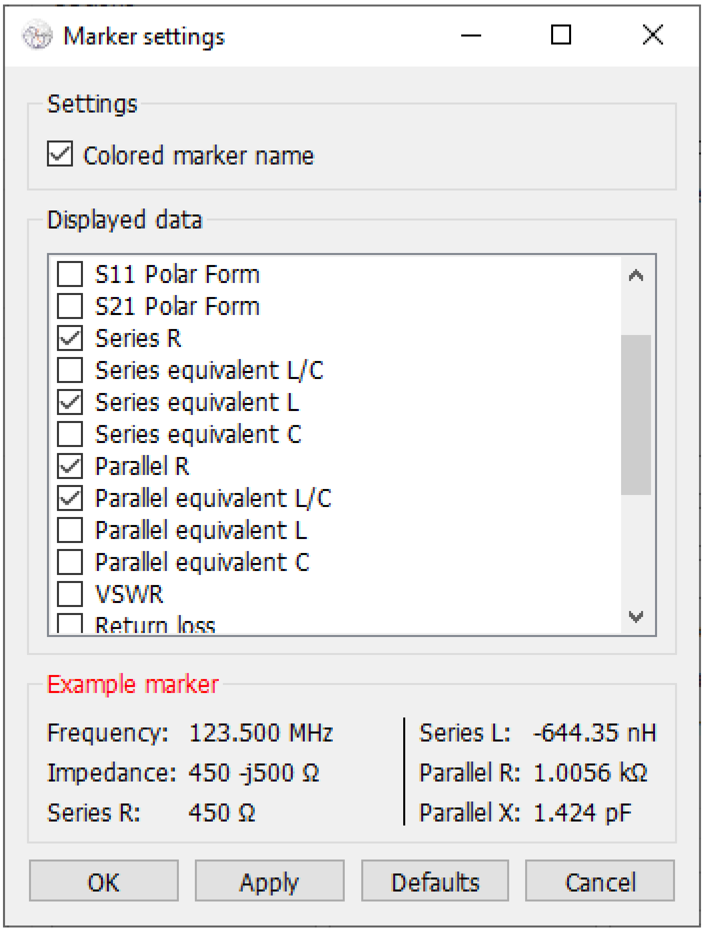
Figure 10. Display Settings

In the Display settings colors and the look & feel can be defined. It is recommended to disable all traces except the first one, which should be set to “S11 smith chart”.

In the sub menu <Manage bands> the available frequency bands can be edited. In this menu, it might make sense to define the “NFC” band.

3.3.4 Marker settings

The Fig 11 shows the most relevant data settings for the marker(s) for the NFC antenna design.



1. A useful selection of data for NFC antenna tuning.

Figure 11. Marker settings

For every marker, the NanoVNA Saver shows some related data, if needed. For the NFC antenna tuning, the selected data is useful.

4 NFC antenna design with NanoVNA

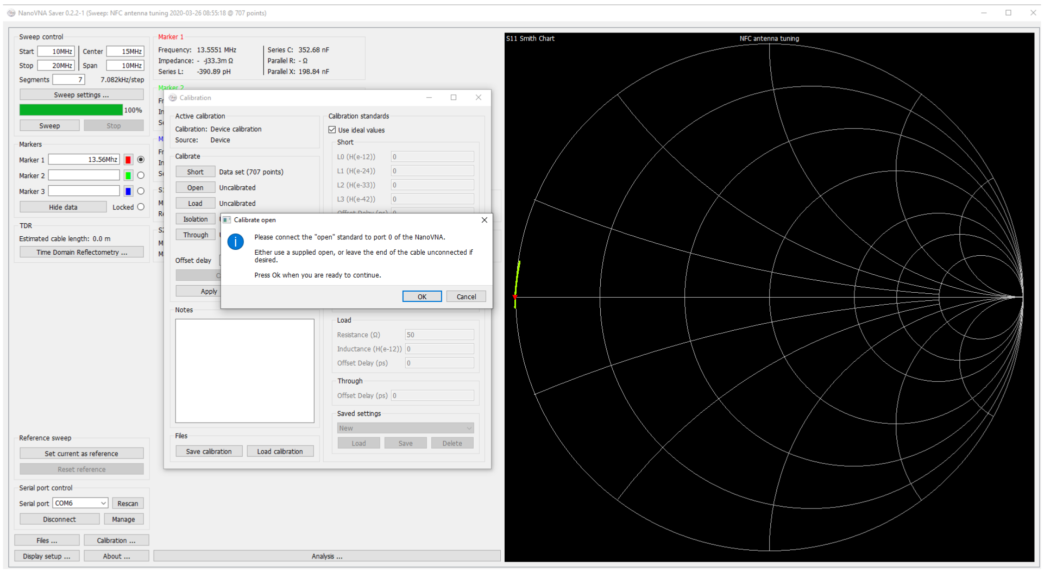
The NFC antenna design is done in the same way as described in the related application notes (see [4], [5], [6], and [7]). The following sections show a comparison of measurement results between a reference measurement, done with a ZVL from Rohde & Schwarz (refer to [1]) and the NanoVNA.

4.1 Measuring the antenna loop

Before measuring anything, it is required to calibrate the setup and check the calibration. The easiest way to perform a 1-Port calibration with the NanoVNA is to use the Calibration assistant of the NanoVNA Saver. It is required to make all relevant settings upfront:

1. Set the measurement start and stop frequency, for example, from 10 MHz to 20 MHz.
2. Set the number of segments to get a proper resolution, for example, 7.
3. Set a marker to 13.56 MHz.

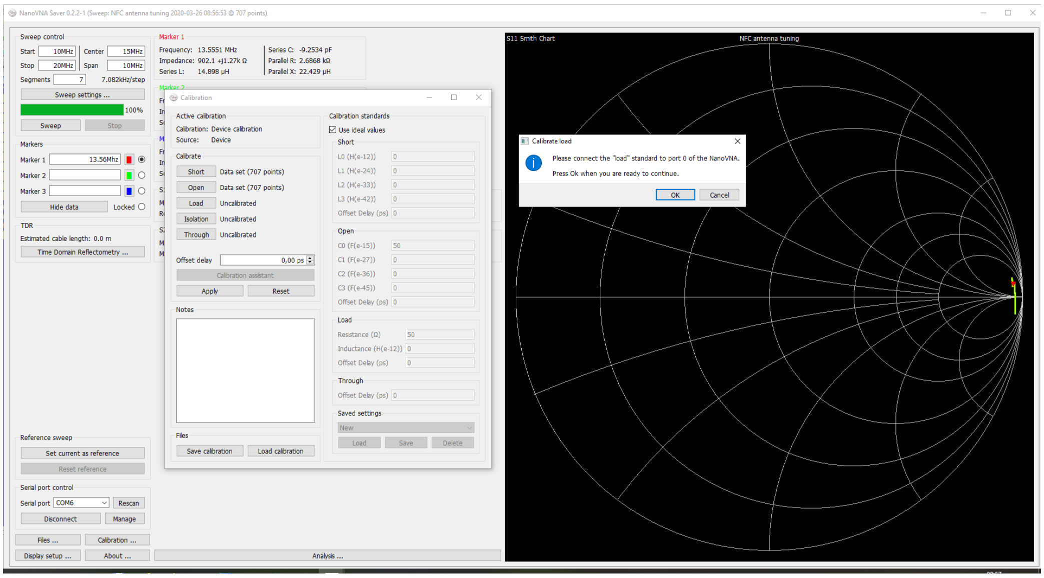
Figure 12 shows the calibration of a short: the smith chart indicates the uncalibrated measurement, using the calibration short.



1. The calibration with Short was done, and the next calibration step is requested.

Figure 12. Calibration with Short

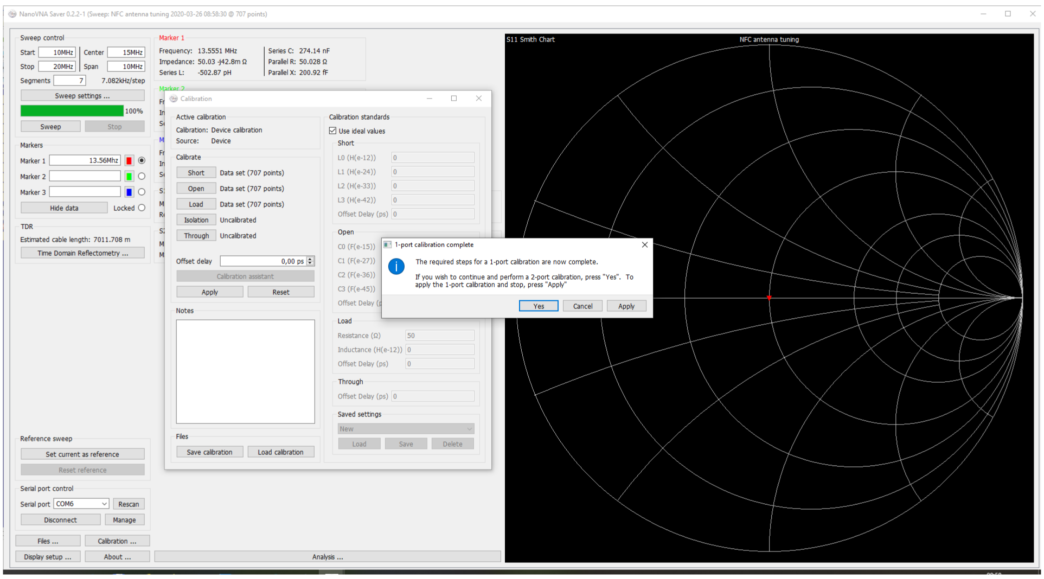
Figure 13 shows the calibration of an open: the smith chart indicates the uncalibrated measurement, using the calibration open.



1. The calibration with Open was done, and the next calibration step is requested.

Figure 13. Calibration with Open

Figure 14 shows the calibration of a load: the smith chart indicates the uncalibrated measurement, using the calibration load.



1. The calibration with Open was done, and the calibration is completed.

Figure 14. Calibration with Load

The 1-Port calibration is done now, and it can be applied. Afterwards the calibration should be checked, measuring the Open, Short and Load again: now they must return a single dot in the related position of the smith chart, as shown in Figure 15, Figure 16, and Figure 17.

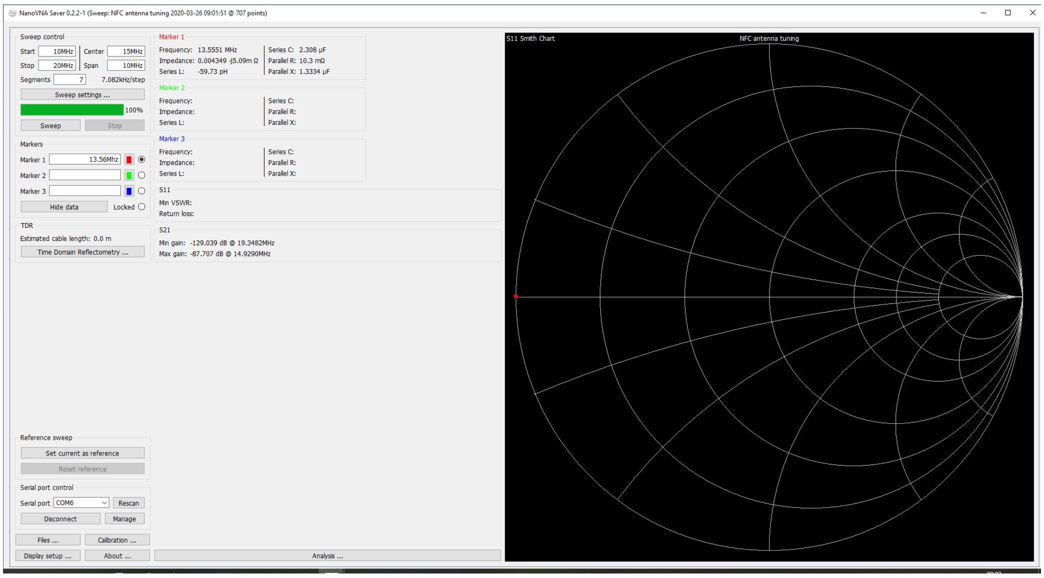


Figure 15. Measuring the short

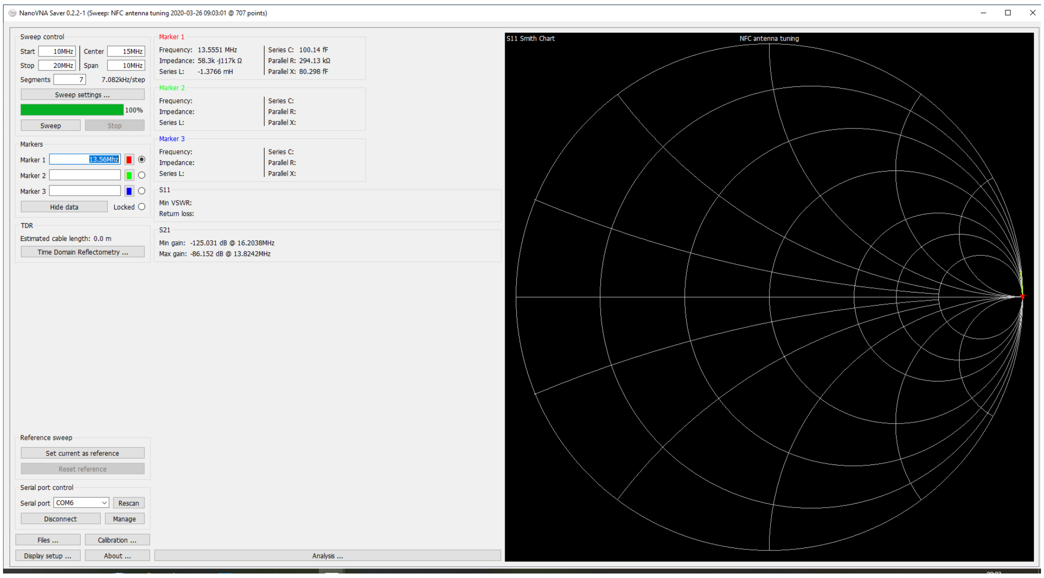


Figure 16. Measuring the open

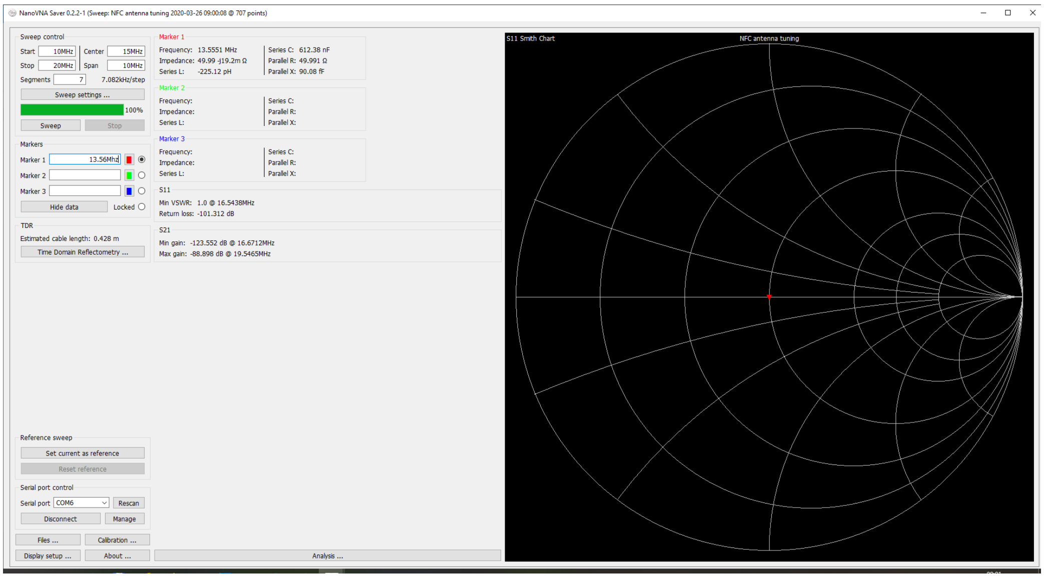
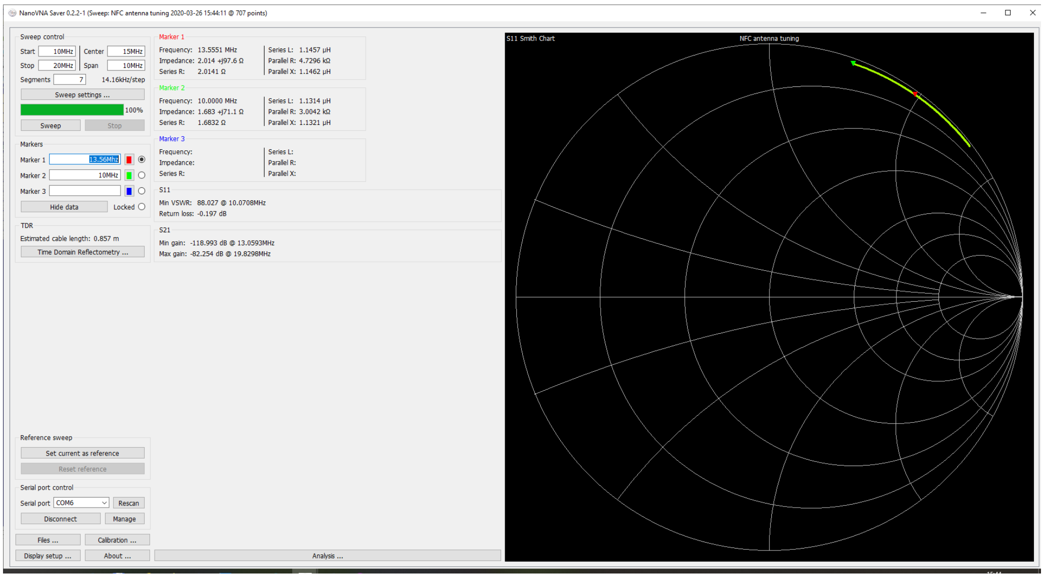


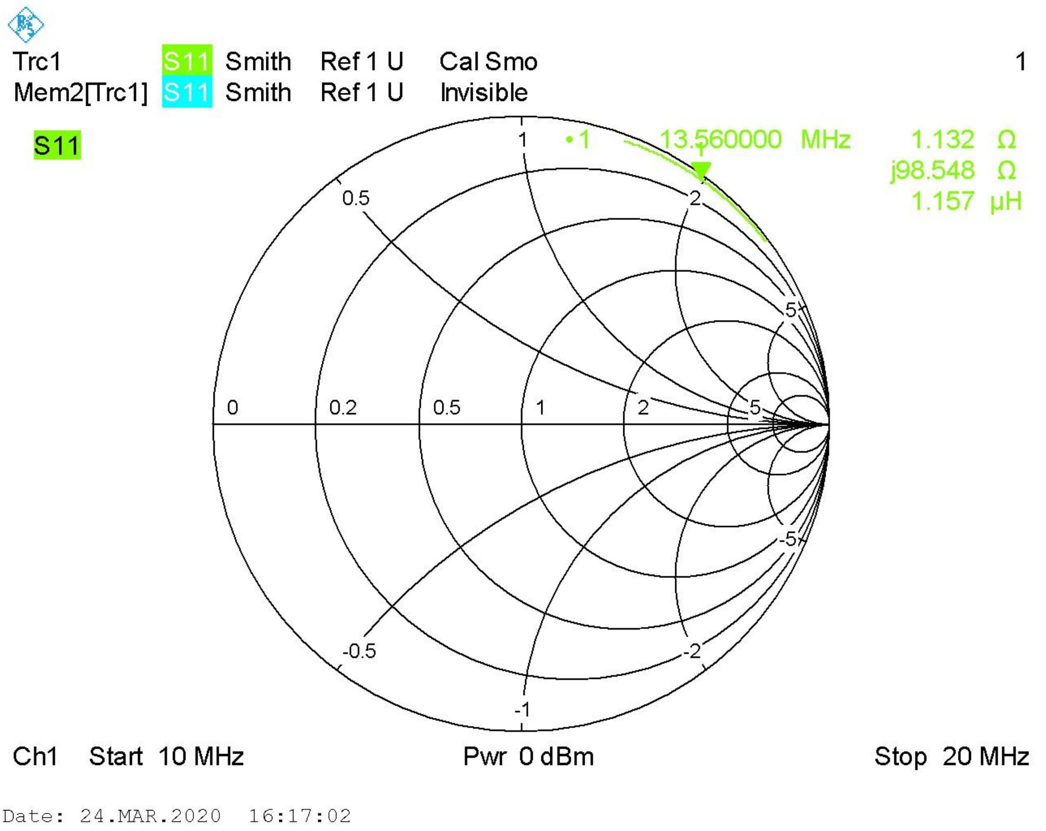
Figure 17. Measuring the load

Now the measurement can start. Figure 18 and Figure 19 show the same measurement with NanoVNA and with ZVL.



1. Lant = 1.15µH + j 2Ω

Figure 18. Measurement of the antenna loop with NanoVNA



1. Lant = 1.16µH + j1.1Ω

Figure 19. Measurement of antenna loop with ZVL

In both measurements, the inductance and series resistance can be directly read from the marker.

4.2 Measuring the tuning impedance

The same comparison is done with the complete antenna tuning circuitry, as derived in [7].

The Fig 20 shows the antenna tuning circuit with the simulation result in Fig 21.

The Fig 22 shows the S11 measurement result measured with the NanoVNA, the Fig 23 the same measured with the ZVL. The results both are good, i.e. the NanoVNA demonstrates a good enough performance for the NFC antenna tuning.

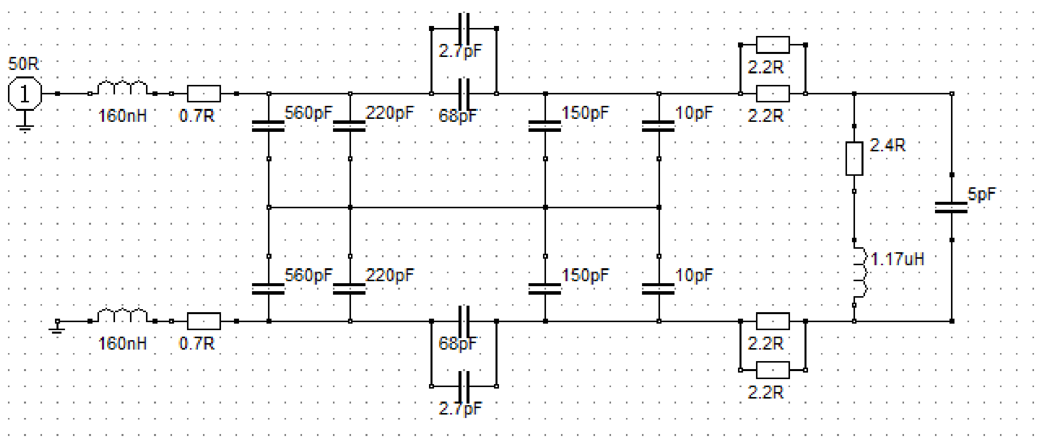


Figure 20. Antenna tuning circuit in RFSIM99

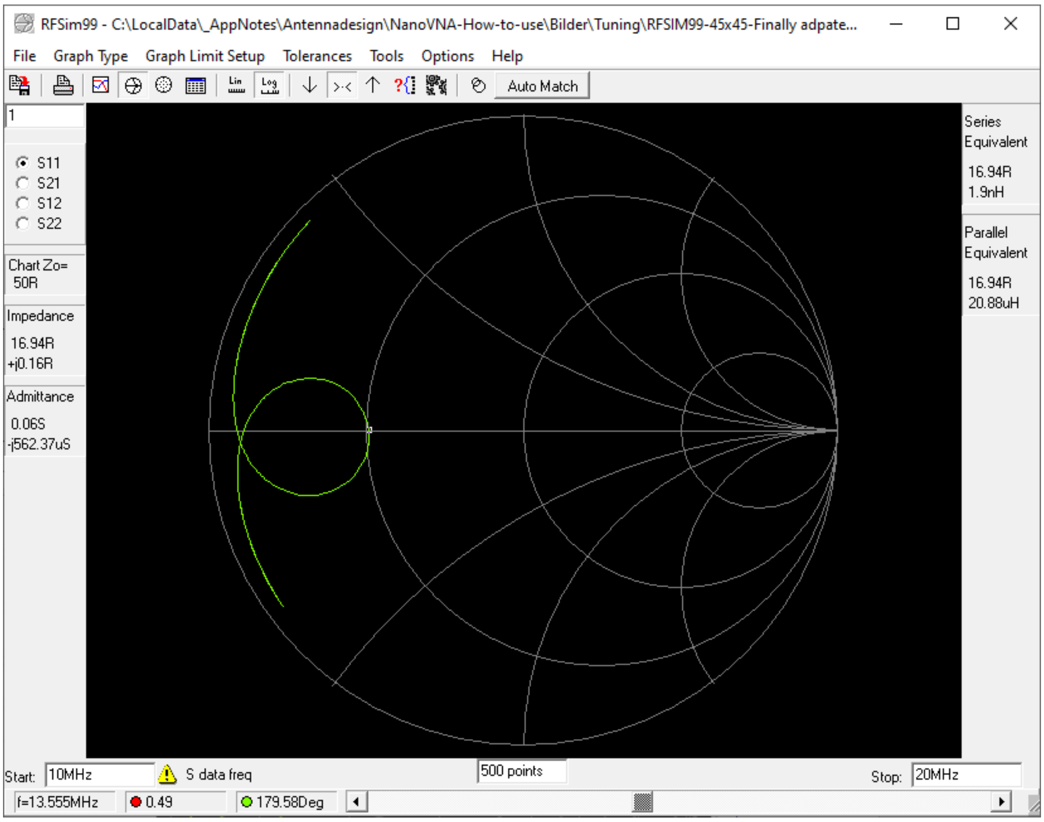


Figure 21. Smith chart of simulation result in RFSIM99

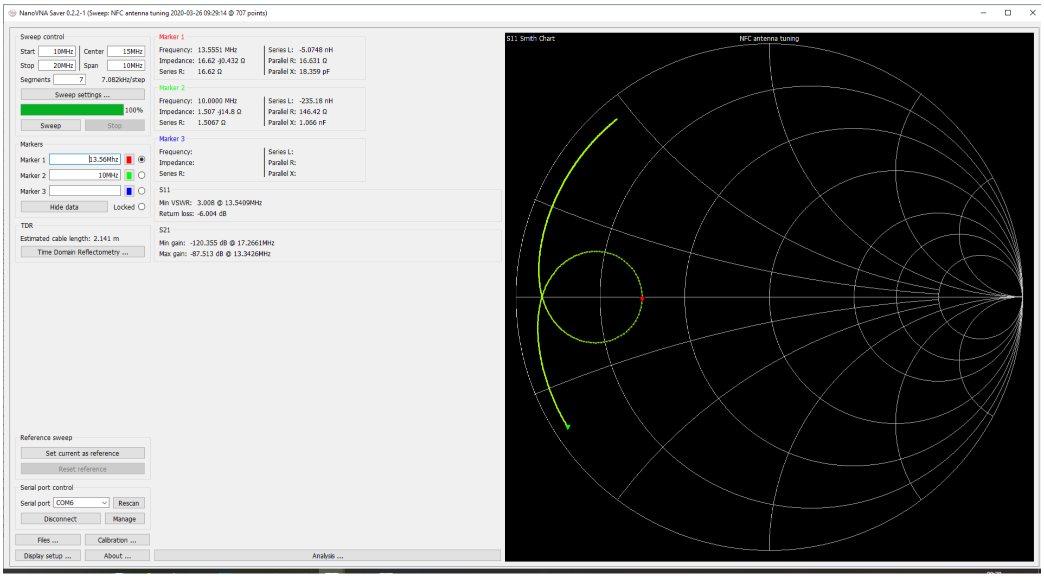


Figure 22. Measurement with NanoVNA

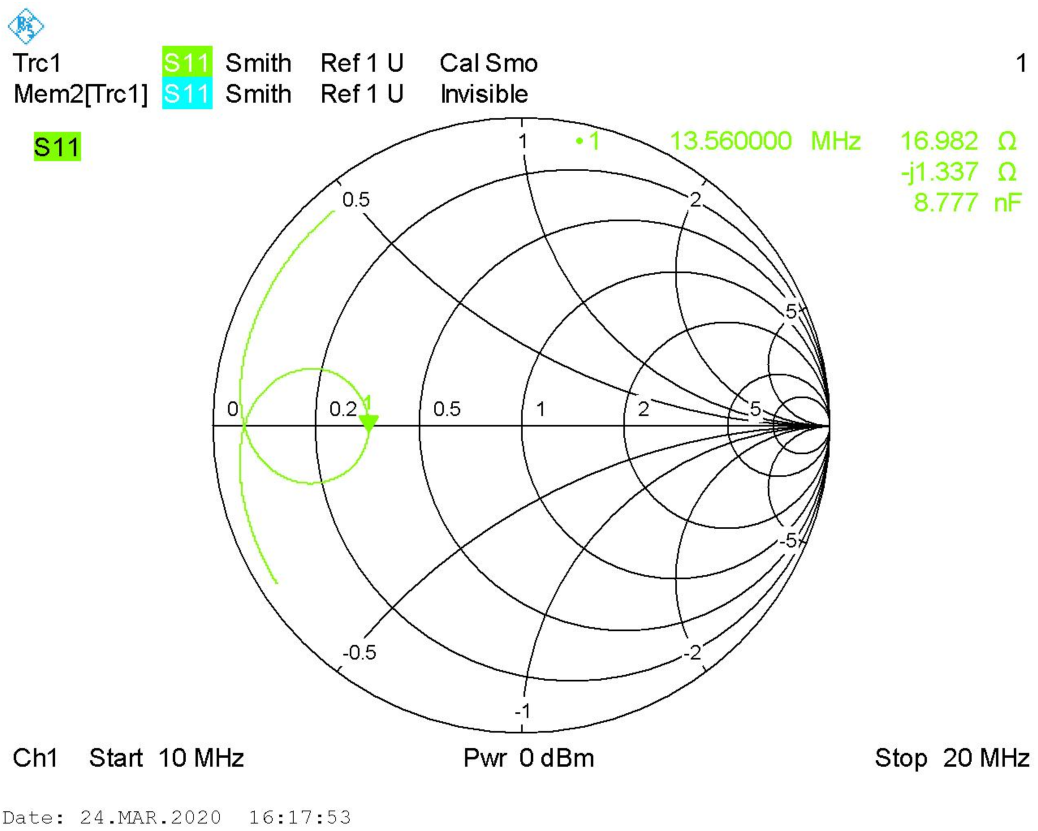


Figure 23. Measurement with ZVL

5 References

[1] R&S®ZVL Vector Network Analyzers: www.rohde-schwarz.com

[2] NanoVNA: https://nanovna.com/

[3] NanoVNA Saver: https://github.com/mihtjel/nanovna-saver

[4] AN11019 CLRC663, MFRC630, MFRC631, SLRC610 Antenna Design Guide: https://www.nxp.com/docs/en/application-note/AN11019.pdf

[5] AN11740 PN5180 Antenna design guide: https://www.nxp.com/docs/en/application-note/AN11740.pdf

[6] AN11706 PN7462 family Antenna design guide: https://www.nxp.com/docs/en/application-note/AN11706.pdf

[7] PN5190 antenna design guide: will be available at www.nxp.com

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