

# NanoVNA

## (Version H2 / H4)

A Vectorial Network Analyser covering 50kHz to 1500MHz and a Time Domain Reflectometer

### Part 2:

Manual for the Usage from 50 kHz up to 1500 MHz and the TDR function

A) The device

B): Operation using a PC with the Software „NanoVNA - saver-v0.2.2-1.exe“(including practical examples)

C): Stand-alone operation

**Version 1.0.**

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Tett nang / Germany, May 5<sup>th</sup> , 2020

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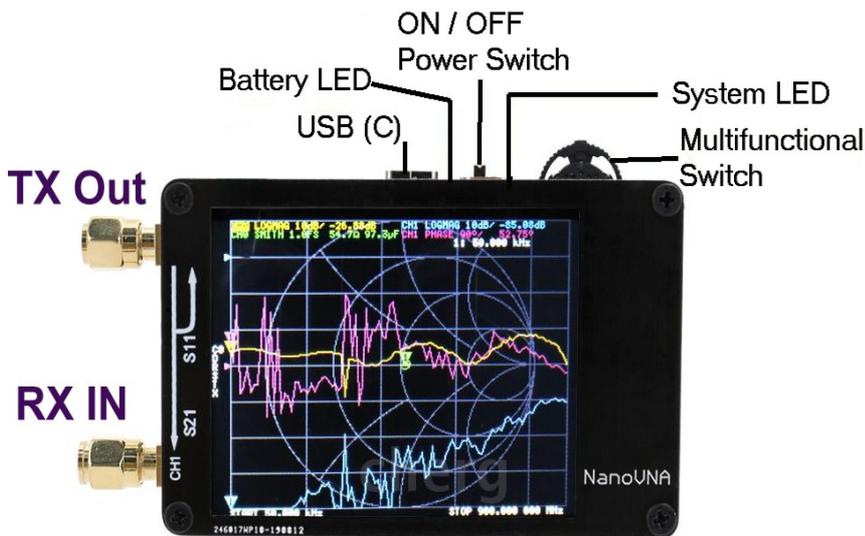
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# A):The device (with battery or power adaptor)

## 1. A short introduction to the NanoVNA-H2 or H4

The picture shows the small device of the NanoVNA H2 with the size of a cigarette packet (54mm x 86mm x 12mm) including a small LCD touchscreen (2.8 inches - diagonal). NanoVNA-H2 has a complete plastic case with top and bottom cover plate. NanoVNA-H4 is delivered with a 4.3 inch LCD touchscreen.



On the left there are two of SMA sockets: the RF input and output. **The upper socket is the transmit port (CH0) and is also the channel for S11 measurements (reflection).**

**The lower socket is the receive input (CH1) and used for transmission measurements (S21).** In the centre of the top is a USB type "C" connector. This has a symmetrical design so it does

not matter which way the USB cable is inserted. This USB port is used to supply the device with +5V and send data to a PC. The blue LED next to it serves as the "Battery LED" and lights up as soon as a supply voltage is applied.

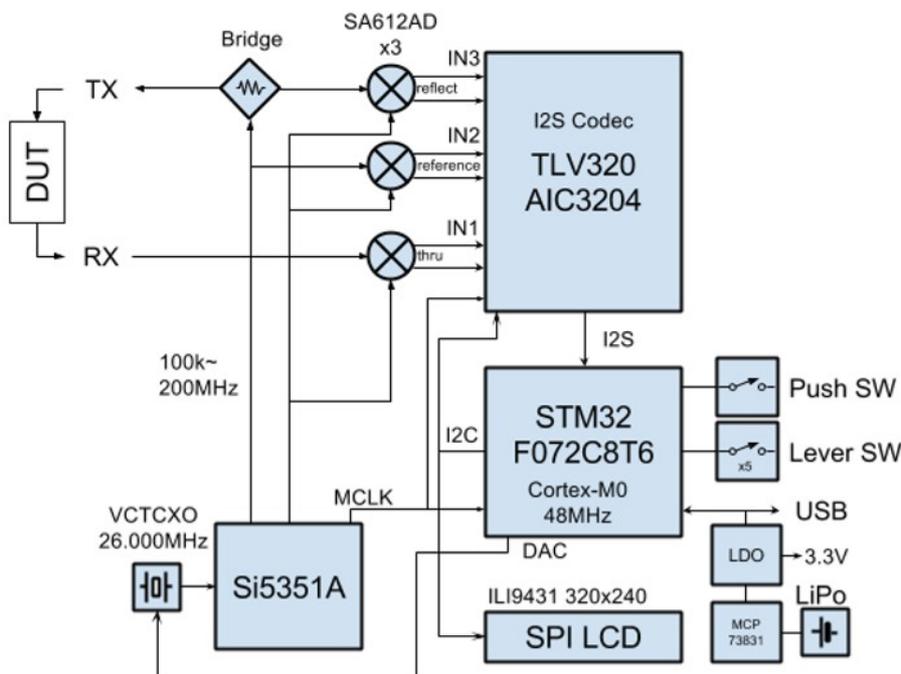
To the right is the **on / off switch** followed by a blue "System LED". It flashes on certain events or states and finally on the right there is the **Multi Function Switch ("MFS")** which has a dual function: If it is pressed after switching on it calls up the main operator menu. Because the MFS is also a rocker switch it can be used to effect the measurement results. It can move markers along the frequency axis in both directions. That is how a certain frequency of interest can be highlighted on the screen.

### The most important features:

<b>Measurement frequency:</b>	50KHz to 300MHz (50KHz to 1500MHz, extended firmware)
<b>RF output:</b>	-13dbm (maximum -9dbm)
<b>Measurement range:</b>	70dB (50kHz to 300MHz), 60dB (300MHz to 600MHz), 50dB (600MHz to 900MHz), 20...30 dB (900MHz to 1500MHz)
<b>Port SWR:</b>	<1.1
<b>Display:</b>	2.8 inch TFT (H2 version) o 4.3 inch TFT (H4 version)

<b>USB interface:</b>	USB type C communication mode: CDC (serial)
<b>Power:</b>	USB 5V 120mA
<b>Number of scanning points:</b>	101 (fixed)
<b>Display Tracking:</b>	4 traces.
<b>Markers:</b>	4,
<b>Saved settings:</b>	5
<b>Frequency error:</b>	<0.5ppm

## 2. What is inside?



There is something familiar in the block diagram:

**„It looks like the VNWA3 by Thomas Baier, DG8SAQ!“**

That is correct, the concept of the electronics (e.g. the use of a measuring bridge and mixing the fundamental frequency of a DDS oscillator in the range from 50kHz to 300MHz, then harmonic mixing for 300MHz to

600 MHz, 600MHz to 900MHz and now **also 900MHz to 1500MHz** respectively).

This is followed by calculation in the audio range of a few kHz. The software installed is very sophisticated and elaborate and is operated using menus on the small screen with submenus and further submenus.

A detailed overview of the user menu can be found in chapter C) of this manual. Take a closer look and memorise it so that you know where and how to do something without searching.

### 3. What do we need / what should we order?

If you search for this device on Ebay (input: "**NanoVNA-H**"), you get countless hits. But you should check exactly what is included with the device.

**We need:**

**a) Two short coaxial cables (normally: RG174) with SMA connectors on both ends**

**b) A USB-C connection cable to a PC**

**c) A SOLT calibration set (SOLT = Short / Open / Load / Through).** It consists of four parts:

**Short** = **Ideal short circuit** in an SMA plug

**Open** = **Ideal open circuit** in the form of an SMA plug that just has a small open tube inside.

**Load** = **Ideal SMA Termination (male) of 50Ω**

**Through** = **SMA coupling with sockets at both ends (SMA, Female to Female adaptor)**

**Important:**

To obtain the best accuracy the VNA must be calibrated. This can be carried out later but for this another SMA 50Ω termination and SMA Female to Female adaptor are required. These can be purchased on The Internet. It is also worth purchasing two particularly high quality Teflon SMA cables approximately 30cm long (e.g. from Huber Suhner). The two cable included in the kit are, unfortunately, poor quality.

Without the USB connection the power comes from the inside accumulator for ca. 4 hours, otherwise from the PC. But if you have to work outside please buy a „Power Bank“ for a Handy or a Smartphone. This will do the job for several days.

Version „H2“ is an evolution of the cheap standard version as described in part 1 of the complete tutorial. LCD Touchscreen and display are identical but

a) the installed **firmware including menu** are improved and extended

b) The hardware is also modified (**e.g. better screening of the inputs**). But the most interesting points are an **extended frequency range up to 1500 MHz and a higher accuracy**. Do not forget: you can also buy a metal case shielded version and a larger display with 4.3 inch diagonal.



You get the NanoVNA in this noble case including

- 1 SOLT kit,
- 2 SMA cables
- 1 cable USB-C to USB-A (= PC connection),
- 1 cable male USB-C to male USB-C



So the H-version looks like using the mentioned plastic case which gives more mechanical protection.

This screen appears after starting the NanoVNA and shows some information (= impressum, firmware details and so on).

It is important that now (compared to the cheap standard version) the **5. harmonic** of the fundamental oscillator can be used to extend the measuring range up to **1500MHz**.

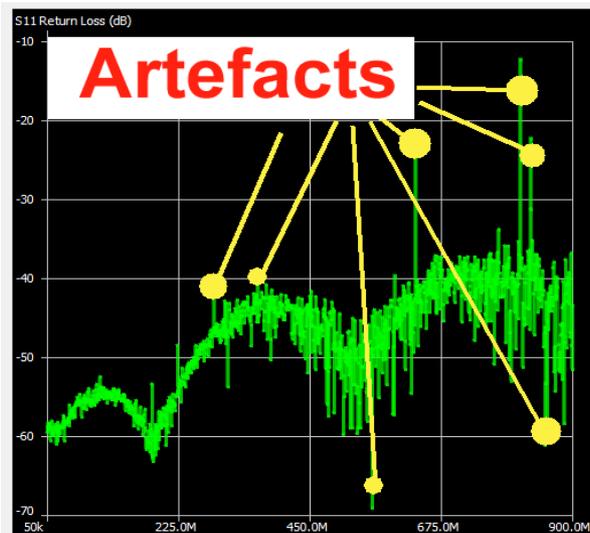
Other items:

**Build in battery**

**Usage like the the cheap standard version, but extended.**

**For the work on a PC the software „NanoVNA-saver.com v0.2.2-1.exe“ written by Rune Bromberg is used.**

#### 4. The measured results of the NanoVNA-H2 in comparison to the cheaper standard version up to 900 MHz



Even when using a lot of points and segments you will always find „artefacts“ and noise peaks.

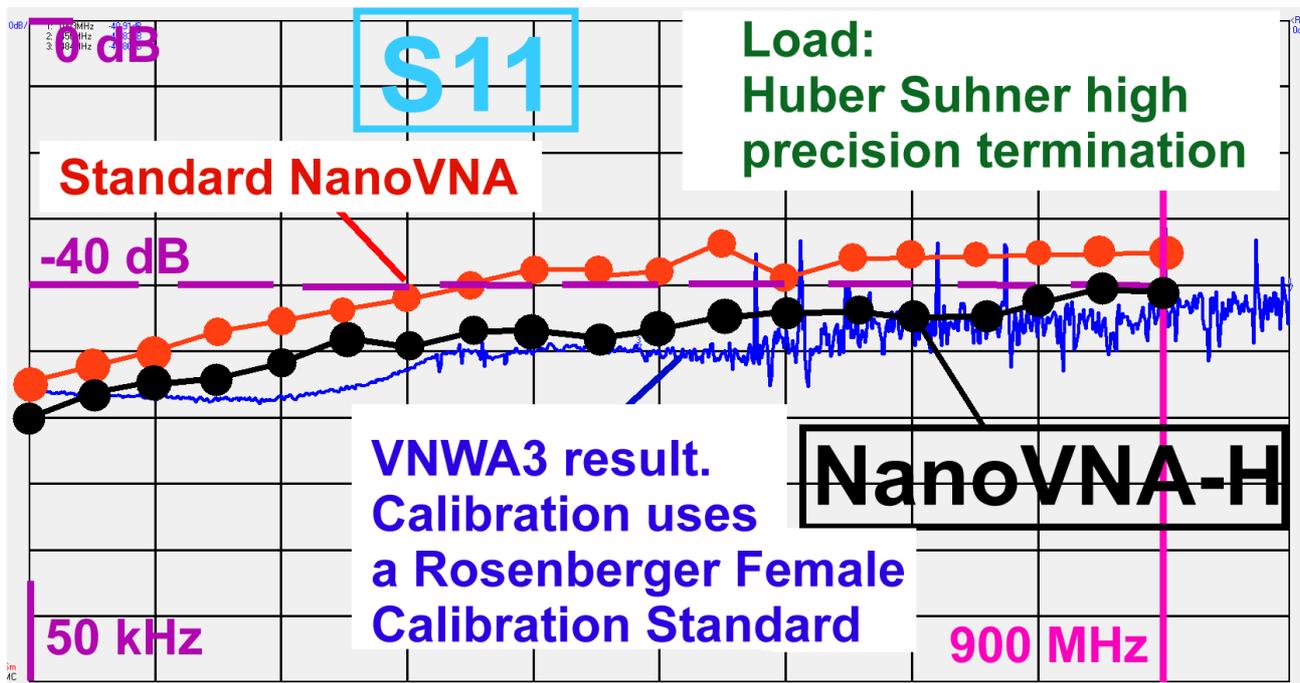
This effect cannot be avoided but reduced by an „averaged sweep“.

It is also possible to delete such peaks individually in the result file.

**But:**

noise will dramatically increase for frequencies higher than 1300MHz.....so try to stay below this value.....t

It follows a demonstration of the achieved progress of the accuracy for the S11 measurement after correct calibration (50kHz - 900 MHz / 20 segments / averaging using 3 values).



## **B): The NanoVNA-H2 on the PC**

### **5. Remember this**

If you have already and completely worked through this chapter and then switch off your PC, then this list will help you what must be done when starting for a new session.

**Start your program „NanoVNA-saver“**

**Connect NanoVNA-H2 and PC via USB C**

**Install the USB connection on the screen**

**Set sweep range and number of segments**

**Use „averaging sweep“ to reduce noise and artefacts on your diagrams**

**Load the correct Calibration File**

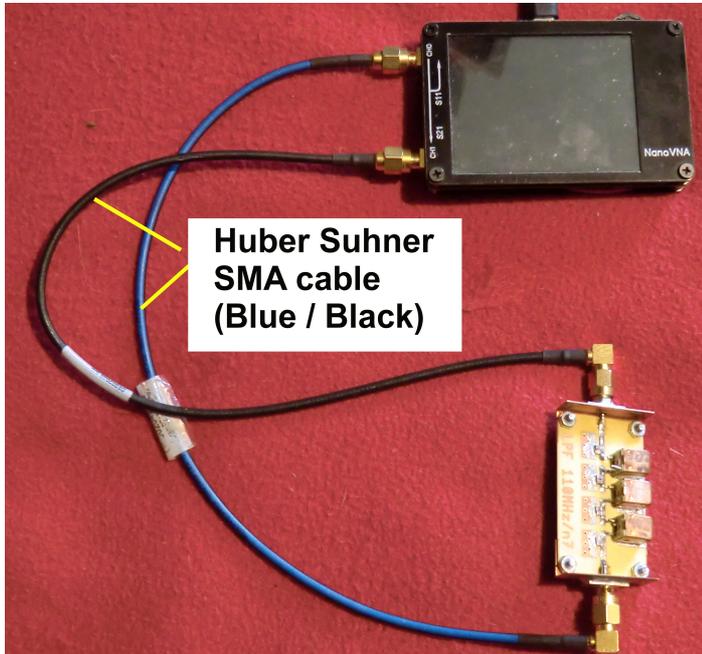
**Choose the desired diagrams**

**Sweep and wait**

**Enjoy the result**

## 6. Preparation

Unfortunately the two SMA cables included in the kit can cause trouble: not only their characteristic impedance may not be quite correct (between 52 and 54Ω instead of 50Ω when measured with a time domain reflector), but at one end the SMA connector fell off because the crimping of the plug onto the cable was poor. This means that the result of calibration often gives meaningless values.



The solution is to purchase two very high quality cables (Huber Suhner with blue black outer), these are specified up to 18GHz.

They should remain permanently attached to the NanoVNA having been fitted using an SMA torque wrench purchased from The Internet.

**(Torque = 0.45Nm).**

If that is done the reproducibility of the calibration for S11 will only have a deviation up to 0.1....0.2dB.

To find these cables:

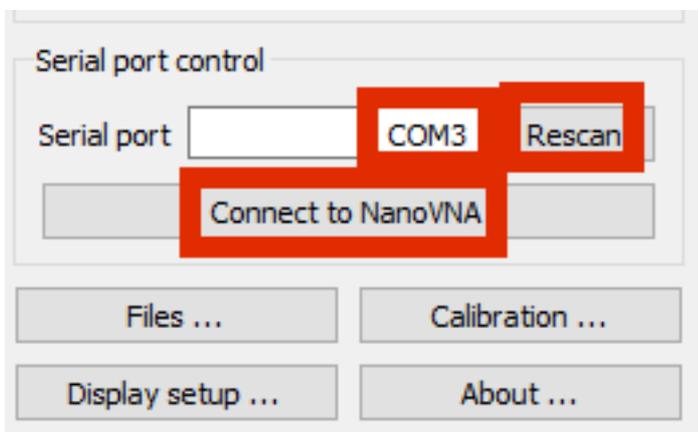
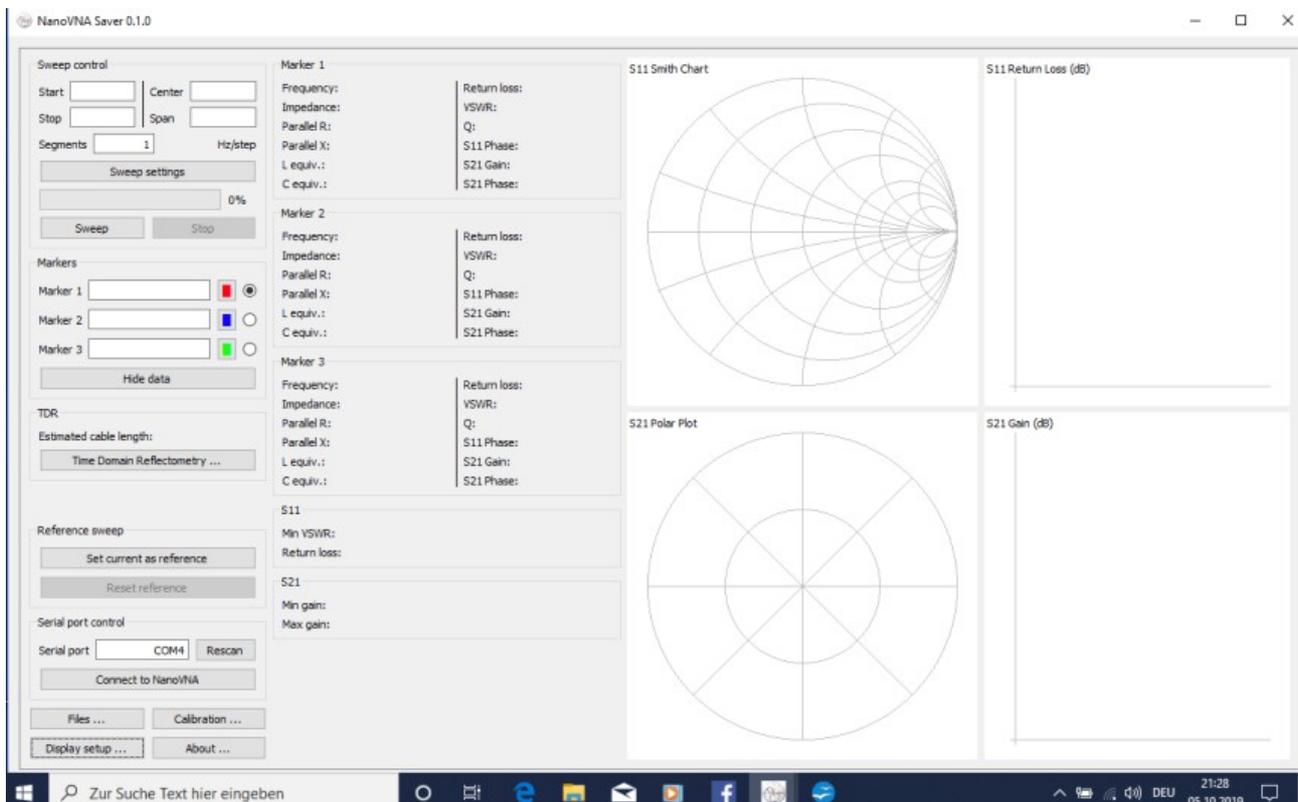
Look closely at and below all the tables at HAM flea markets to see if the cables can be found.

## 7. Starting the software

Very quickly clear result can be presented with large diagrams on a PC screen for those who have access to a PC with its constant power supply for the NanoVNA. That will be described now with help and advice from Andreas Zimmermann, DG3SAZ. **All that is required is the NanoVNA, the USB connection cable and the necessary PC program.** Once the free software is downloaded from The Internet, just switch the NanoVNA on. The most popular software is called:

**NanoVNA-saver-v0.2.2-1.exe**

It can easily be copied to a USB stick and operated from there. After starting the program, wait 10 seconds because a dark DOS Screen appears followed by this picture:

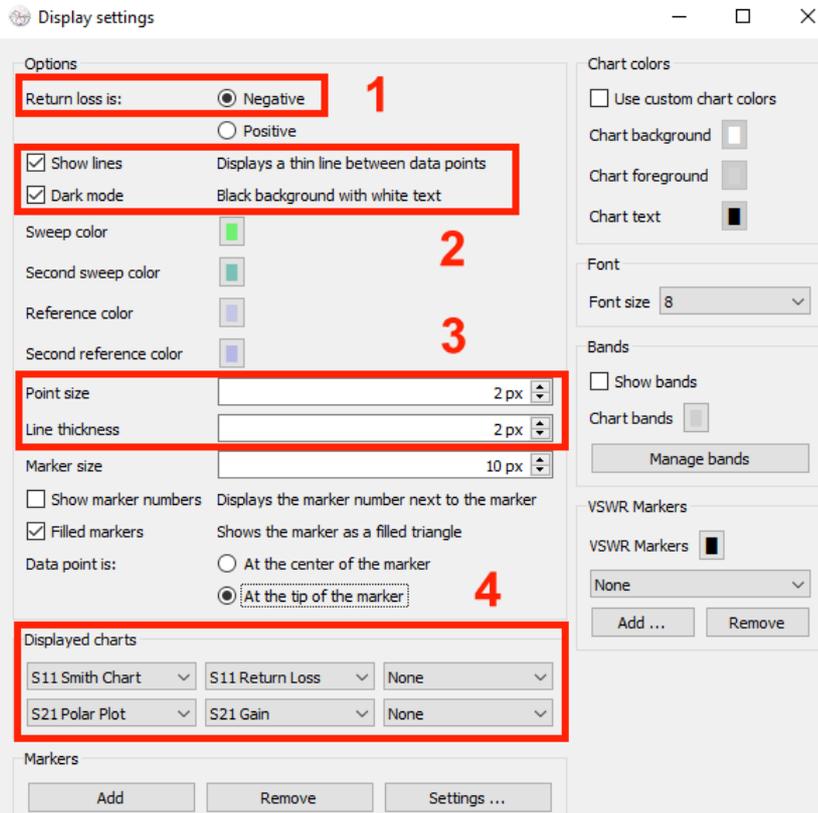


Turn the NanoVNA on and establish the USB connection to the PC by clicking on **"Connect to NanoVNA"** on the PC screen (bottom left). If necessary with rescan to make sure that the valid USB port is recognised.

If everything works the message changes to **"Disconnect"**.

## 8. Display settings required

This menu is called up via a button in the lower left corner of the screen. Among the many possible options, four settings are important at the beginning:



**1: The input reflection S11** should be represented as a negative dB value.

**2: Thin lines should be shown between measuring points** and the diagram background should be black. (This can be changed for any colour – and the same for the curves).

**3: Point size and line width** are preset to 2 pixels. Please change if necessary.

**4: Up to 6 diagrams can be displayed** at the same time on the screen (mostly four are enough). For each individual diagram the following options can be selected:

**S11 Smith Chart**

**S21 Polar Plot**

**S11 Return Loss**

**S21 gain**

**|S11|**

**|S21|**

**S11 |Z|**

**S21 phase**

**S11 phase**

**S21 Real / Imaginary**

**S11 VSWR**

**S11 & S21 LogMag**

**S11 R + jX**

**TDR**

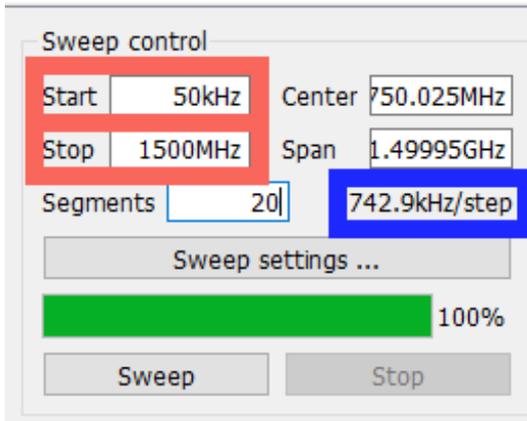
**S11 Quality Factor**

**None**

**S11 Real / Imaginary**

Please examine the rest of the options in the menu.

## 9. Sweep Settings (example: sweep from 50kHz to 1500MHz)



Start with entering the **desired start and stop frequency** in the upper left half of the screen:

**You can either enter as numbers (e.g. 1500000000), or in exponential form (e.g. 1500e6) or in well known units (kHz, MHz).**

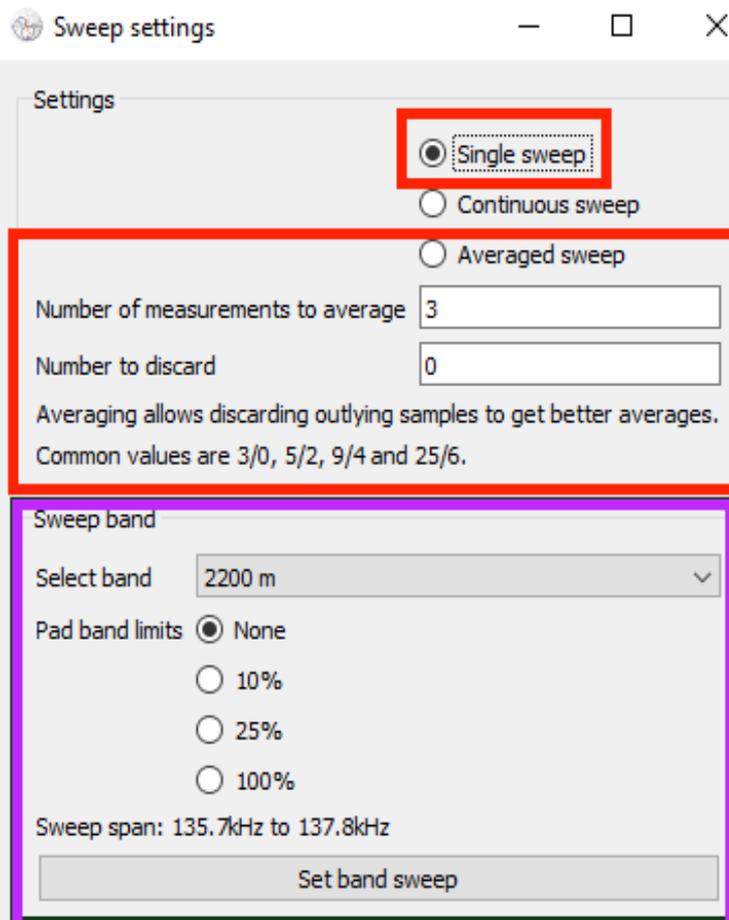
Additionally using the option „Segments“ gives a fantastic solution:

The NanoVNA itself is always **only able to divide a desired frequency range into 100 frequency steps** (= 101 points) and the sweep speed is not

variable.

**But the NanoVNA-saver software can increase the number of smaller swept segments in the desired range – every segment itself will be again divided into 100 frequency steps and thus frequency resp. measuring accuracy can be improved.**

Let us use 20 segments. This will take more calculation time but the result is really convenient. Now you find a frequency step of 742.9kHz in the blue frame.



Then press „sweep settings“:

Usually a **single sweep** is used but there is the option for a **“Continuous Sweep”**.

More interesting options are in the pink frame We can have an **averaged sweep** to reduce the effects of the **noise or artefacts**. The number of readings used to calculate the average can be chosen to improve the quality of the display.

Another clever option is to specify the **number of outlying sample to discard**. This is specified as the **measured value number followed by segment Number**.

The following values must be separated by a comma. (see the examples for demonstration in the red coloured second frame).

There is still another option:(= pink frame): It is a **collection of all Radio Amateur Frequency Bands** and if

you choose one of them, everything for a correct simulation is automatically set. Please try it out!

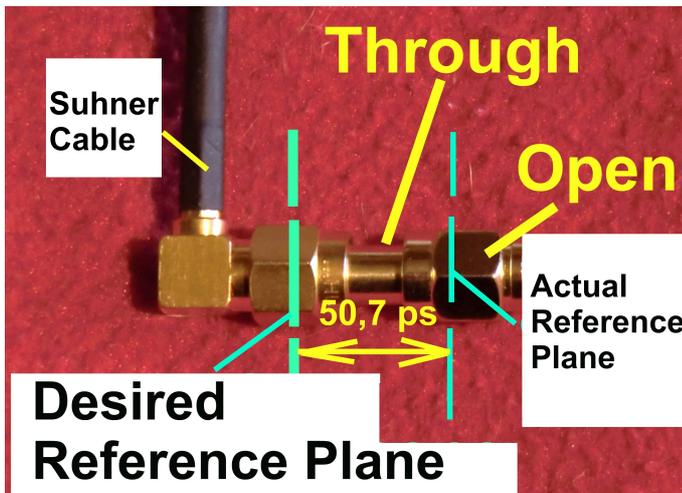
## 10. Start calibration with the calibration data

**Kurt Poulsen**, who determined the calibration data for the VNWA3 has supplied: "**Calibration data for the NanoVNA with the supplied SOLT - Calibration set**". Thanks for that!

In our case using firmly connected, high quality measuring cables with male SMA plugs specify the following values to be entered for the **three SOL-standards** (Short / Open / Load) for male SMA plugs:

<b>SHORT:</b>	<b>Delay = 51.16ps</b>	
<b>OPEN:</b>	<b>C0 = 50fF</b>	<b>Delay = 48.63ps</b>
<b>LOAD:</b>	<b>R = 49.86Ω</b>	<b>Delay = 61.59ps</b>
<b>THROUGH:</b>	<b>Delay = 50.7ps</b>	

Because the three standards (= SOL) are specified as „male“ - versions you need a „Through“ adapter (= SMA female - female) for the connection to the measuring cables with male plugs. **But this causes an additional delay of 50.7 Picoseconds** = an additional phase shift...



This is the hardware setup for the OPEN calibrating process:

The **SMA - female – female - Adapter** („Through“) shifts the actual Reference Plane to the SMA plug of the OPEN standard.

**This means a signal delay of 50.7 ps (equal to a phase shift) and the software has now to do the necessary correction for „back shifting“ to the Desired Reference Plane.**

You find the complete „Calibration Setting File“ on the next page.

### Remark:

The software wants to know the resistance value of the **LOAD standard as precise as possible.**

If you don't own a high precision measuring set for this purpose simply use the ideal value of **50 Ω. This gives a small and visible but acceptable error.**

I own an old but very accurate analogue Wheatstone Bridge. So I found my personal LOAD Standard value of **49.85 Ω for the following list.**

Calibration standards

Use ideal values

**Short**

L0 (H(e-12)) 0

L1 (H(e-24)) 0

L2 (H(e-33)) 0

L3 (H(e-42)) 0

Offset Delay (ps) 51.16

**Open**

C0 (F(e-15)) 50

C1 (F(e-27)) 0

C2 (F(e-36)) 0

C3 (F(e-45)) 0

Offset Delay (ps) 48.63

**Load**

Resistance ( $\Omega$ ) 49.85

Inductance (H(e-12)) 0

Offset Delay (ps) 61.59

**Through**

Offset Delay (ps) 50.7

Saved settings

bug fixed\_Poulsen\_02

Load Save Delete

Here comes the „Calibration standards“ list with the values to be entered:

**Step 1:**

Click „Calibration“ on the screen

**Step 2:**

Delete „Use ideal values“ (= pink frame)

**Step 3:**

Enter all data values.

**Step 4:**

Search for „New“ in the small window for the settings name, click on „Save“ and enter another name for the Calibration settings (green frame)

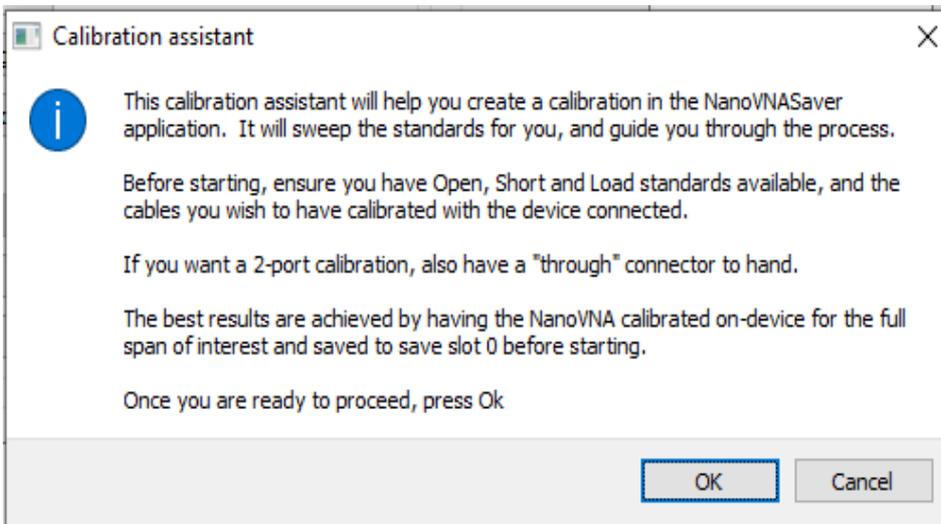
E.g.: I use **bug fixed\_Poulsen\_02**

**Step 5:**

Click on „LOAD“.to use these settings

## 11. SOLT Calibration

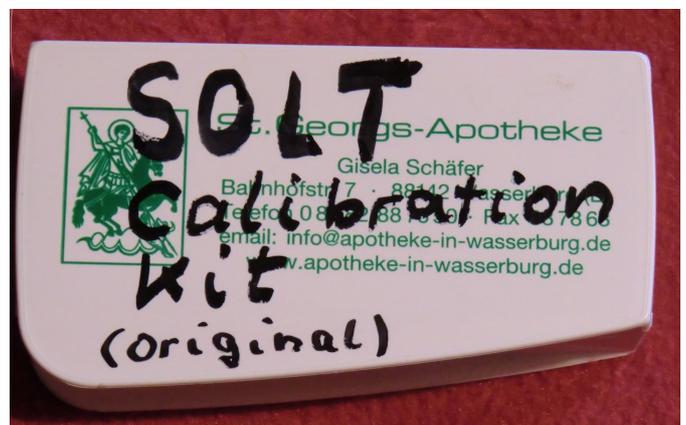
At the **middle of the Calibration Menu** you find the „**Calibration assistant**“ which guides you during the SOL calibration process for S11.



The SOLT calibration kit must be available.

The pictures show a practical tip for storing the SOLT components. It is an empty pill box that came as a small gift from my pharmacy.

The letters "S", "O" and "L" have been scratched onto the three standards using a needle.



OK starts the procedure, just follow the instructions. Please do not lose patience if it takes a long time. The green bar in the sweep field shows the progress!

The "SOL" process announces each stage (Short / Open / Load), continue with "Yes". Finally the missing calibration for S21 uses "Isolation" and "Through".

If everything is done, click on „**apply**“ to terminate the calibration process

**Important:**

**You should also save this calibration using a name to your choice.....might be that in the future more special calibrations for other frequency ranges are necessary...**

Example: my calibration file is named

**Poulsen\_Suhner 30cm\_50kHz – 1500MHz\_20Seg\_avg=3**

**But:**

**Never forget to load the correct Calibration File for your actual project when you start your PC next morning or the next time....**

And now follows a final proof to test the success of this work!

## 12. Testing the calibration quality

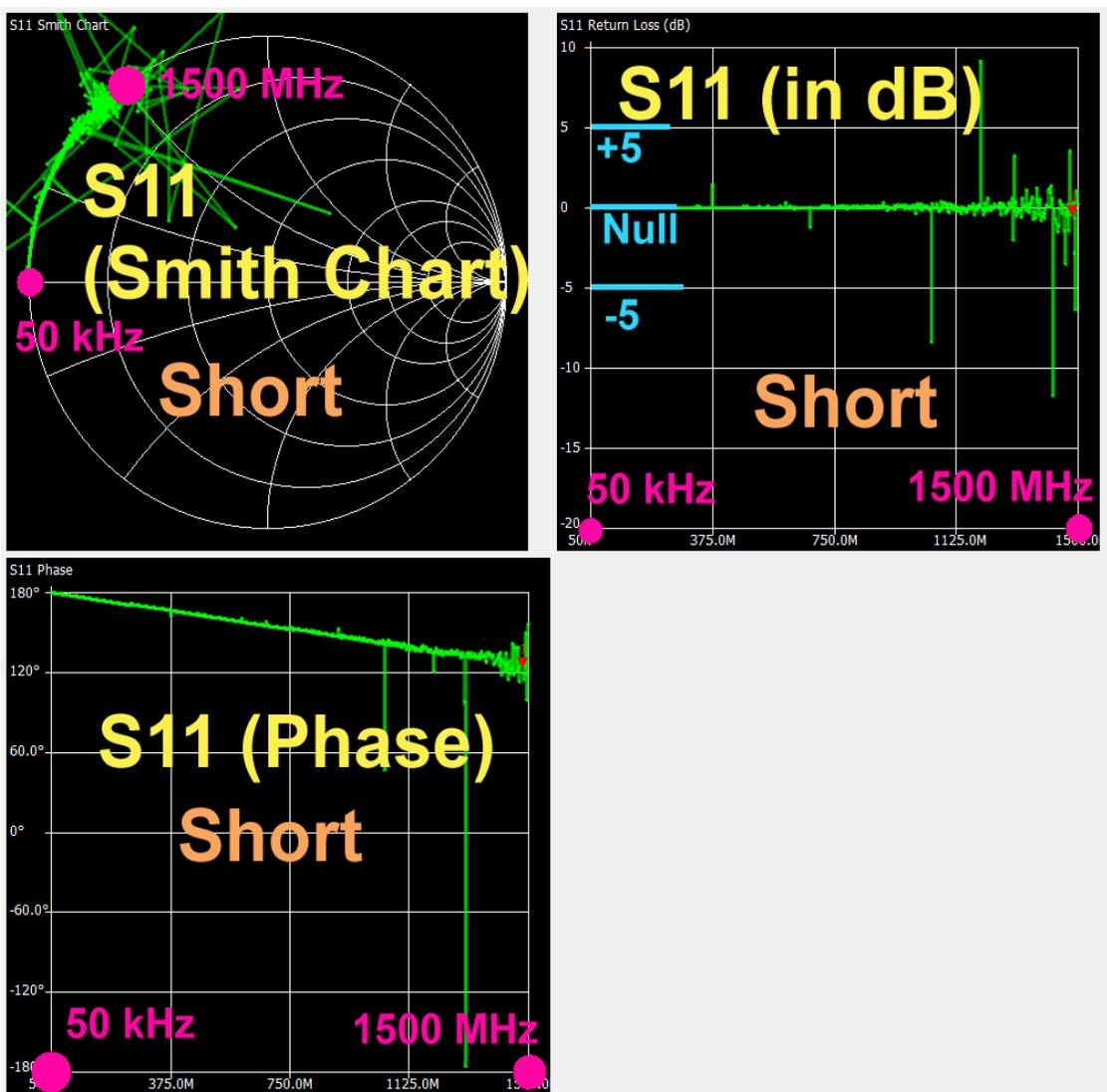
### Attention:

The curves are only reliable and reproducible if you have used a **SMA torque wrench** for every SMA connection (torque = 0.45Nm)!

Let's start with the **SHORT** standard and use all new features of software version v0.2.2.-1  
The frequency range is always 50kHz ....1500MHz.

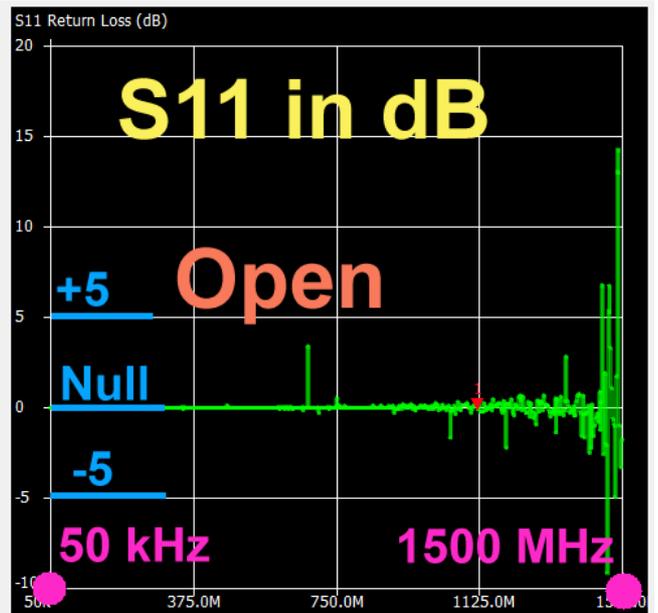
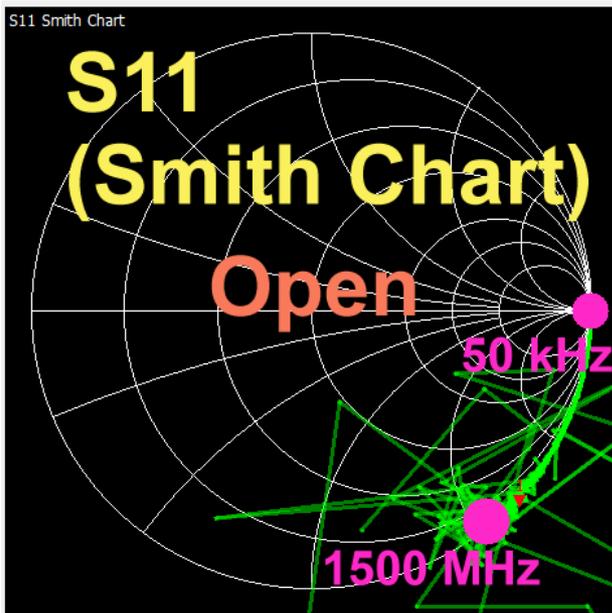
### Remark:

You can use the scroll wheel of your mouse to zoom the diagrams!



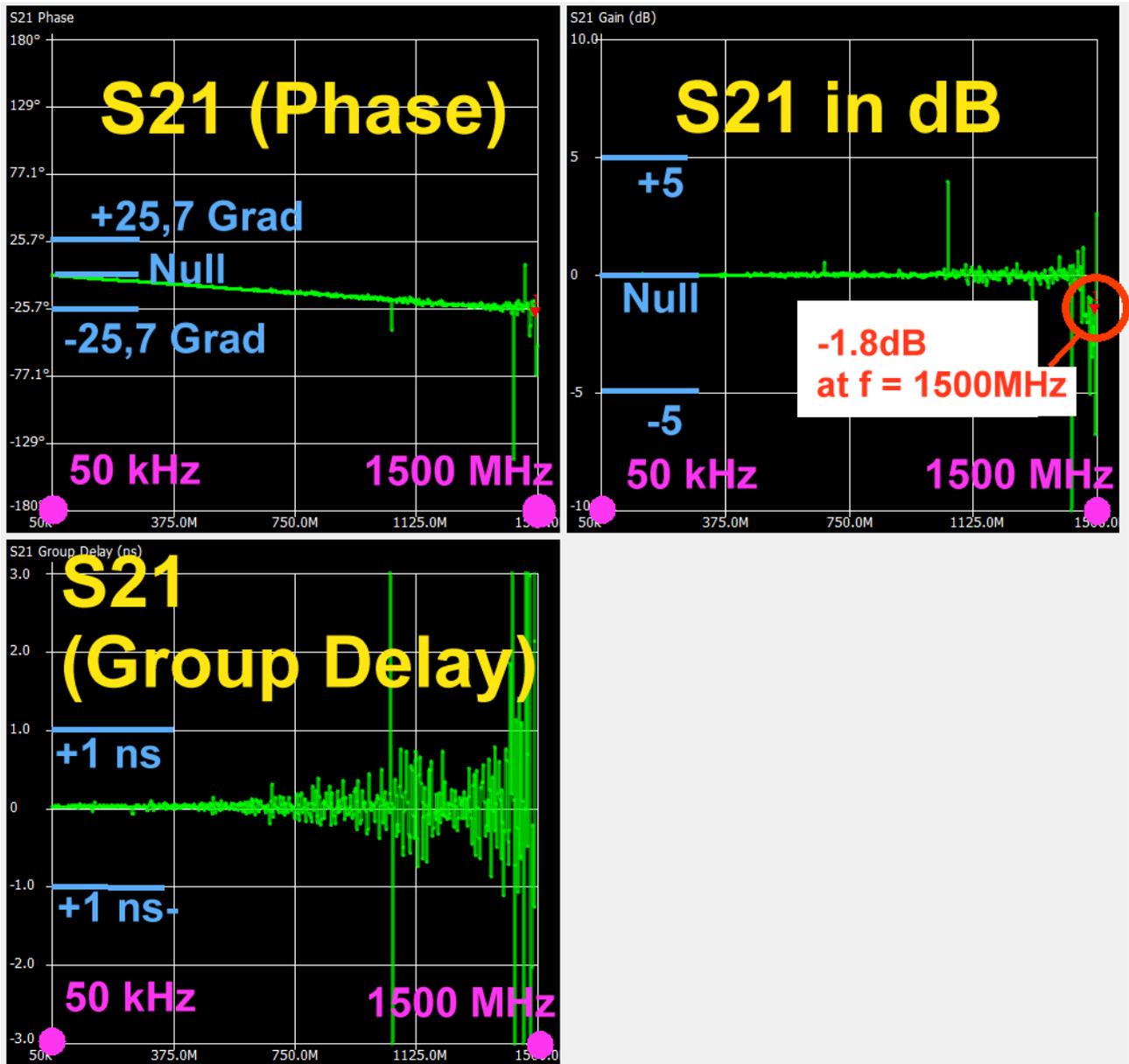
Not so bad....but the noise is starting at 1300MHz....

Now the OPEN-Standard from 50 kHz to 900 MHz:



OK....but the noise in the highest range...

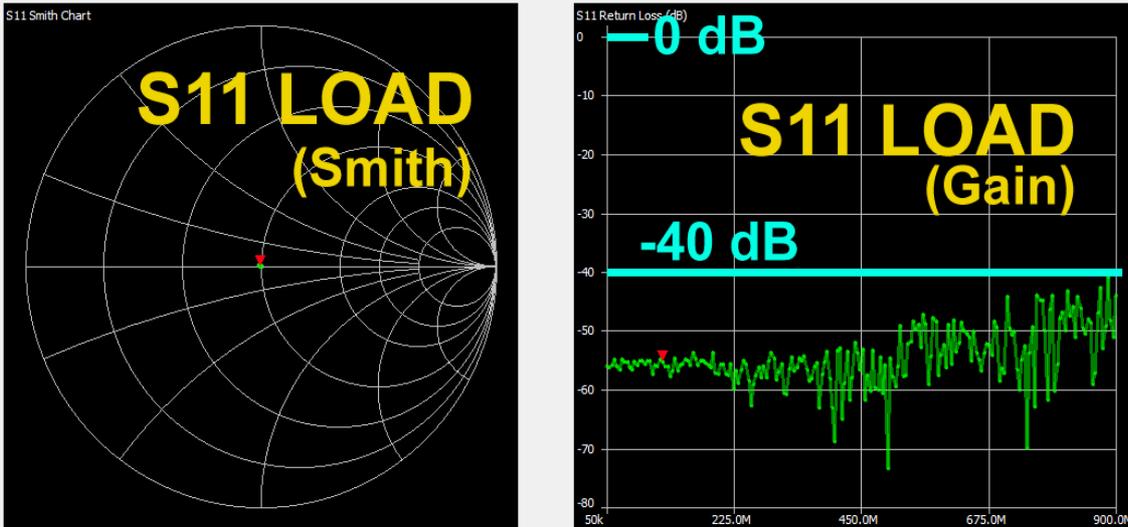
The two Huber Suhner measuring cables are now connected together via the **Female Female Through adapter** to get **S21**:



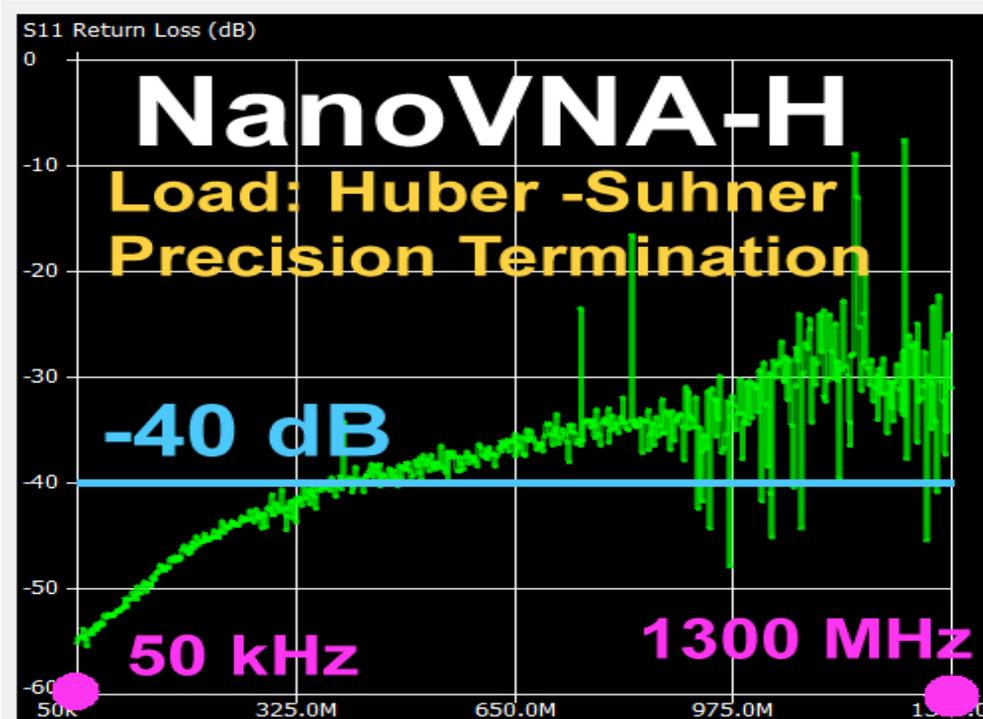
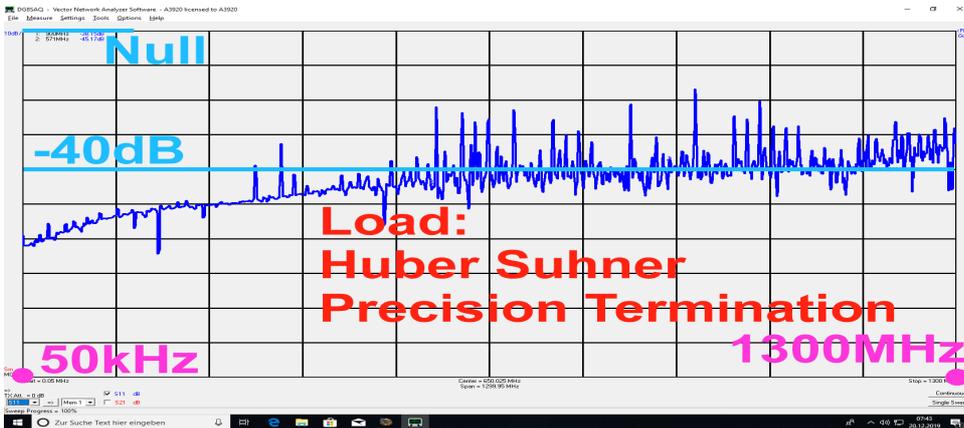
OK....but the noise at  $f = 1500\text{MHz}$ ...

(Sweep settings are: 50kHz ..1500MHz / 5 segments / averaging = 3)

At last: the reflection coefficient **S11** of the **LOAD** standard:

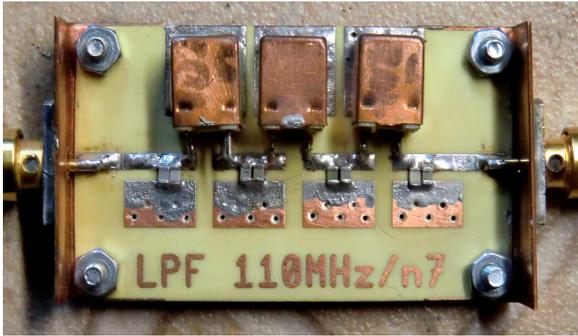


Now compare the quality of the NanoVNA to the well known VNWA3 regarding the **S11** values of a Huber Suhner High Precision Termination:



Remark:  
When testing in the frequency range up to 12 GHz you'll know at once why the Huber Suhner is the favorite solution and not the LOAD Standard supplied with the kit (...but Suhner is more expensive...).

### 13. Testing a 110 MHz - Lowpass Filter



The SMA sockets are soldered to two bended copper sheets. Thus the central conductor of the socket touches the central Microstrip Line and is then soldered. This gives a transition with low reflection.



This is **S11** for the 50kHz to 1500 MHz frequency range. The **passband** can be identified without any efforts (= low reflection) and in the **stop band** we get a **total reflection with S11 = 0 dB**

**S21** decreases after leaving the pass band down to -80 dB. But even up to 900 MHz the maximum value is -38 dB (= minimum stop band attenuation)

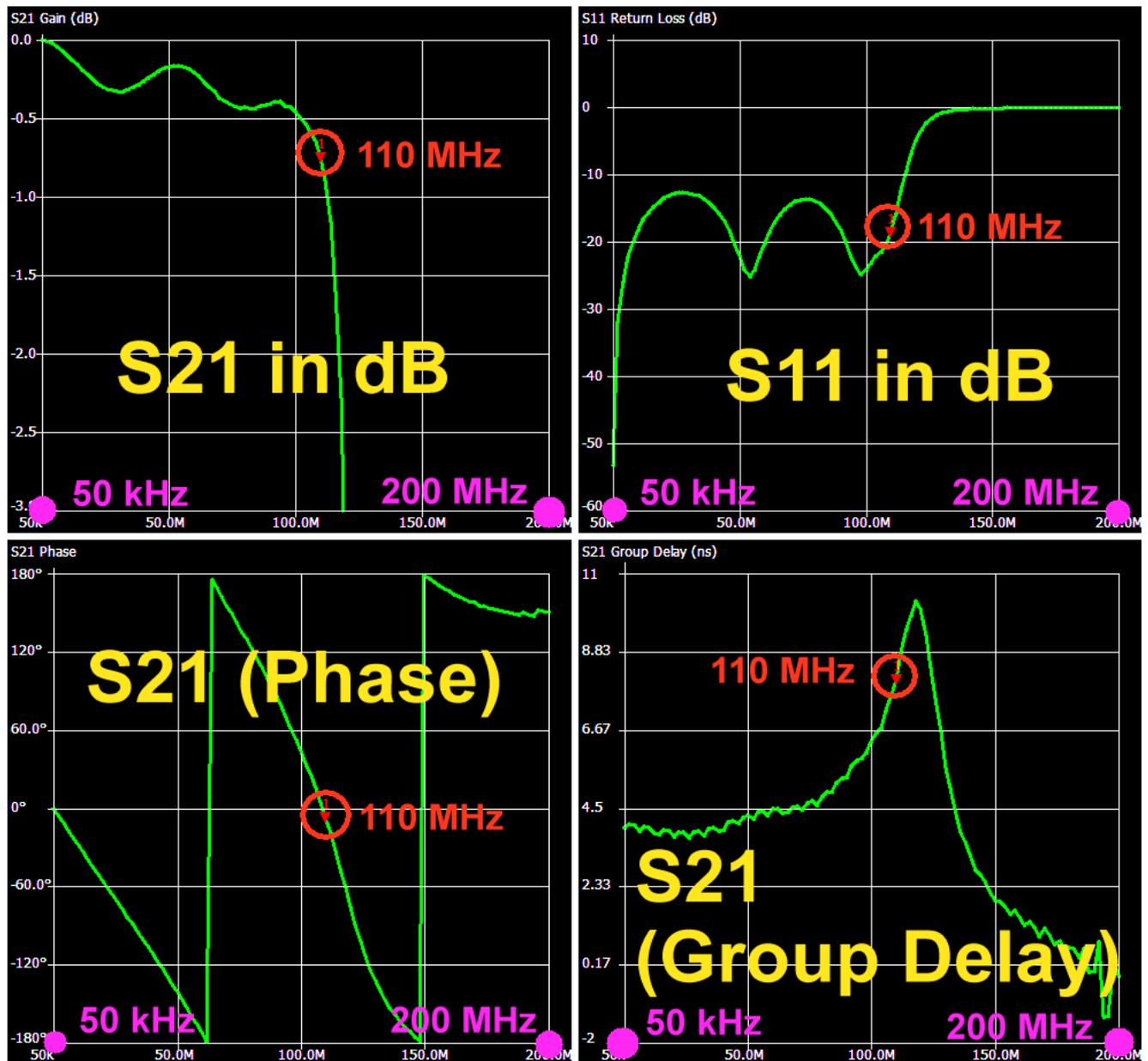
The decrease of the stop band attenuation at rising frequencies is caused by self resonant effects of the used parts.

## 14. Attenuation and Group Delay in the Pass Band of the LPF

If you want to see these features: do a right click on the S21 gain diagram and open „Frequency Axis“ to reduce the frequency span to **50kHz ...200MHz**.

Afterwards right click once more on the diagram and choose „Data Axis“. Set the data axis range to 0....-1 dB-

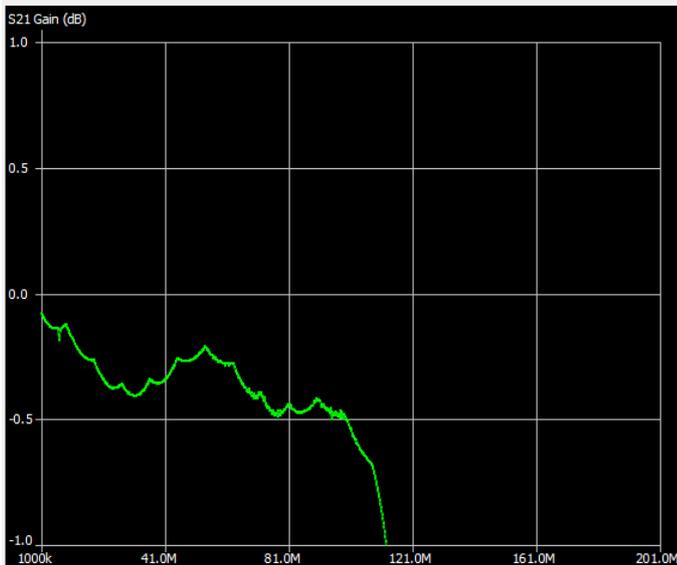
Add Marker 1 set to  $f = 110\text{MHz}$ .



## Warning:

Never change the span of the frequency axis by entering new values for start or stop frequency followed by a new sweep **without a new calibration procedure!**

Otherwise:



In this case you could lose the SOLT calibration if you do not exactly hit the saved frequency values in the calibration file.

So the screen will look like this in such a case!

## Remember:

You can save five independent calibrations in the registers c0...c4 on the NanoVNA board itself.

But if you work with the NanoVNA -saver software you can create and save on the PC as many calibrations as you like.

The „original calibrations c0...c4“ of the board are frozen and you have again access to them when disconnecting the board from the PC and using the Recall - command.

## 15. Markers

**Marker 1** (below the Sweep Menu) has been activated for a frequency of **100 MHz**. Use the mouse (= drop and drag) for shifting to other frequencies in a diagram.

Marker 1	
Frequency:	99.8956 MHz
Impedance:	54.1 +j2.211 $\Omega$
Admittance:	54.19 +j1326.0 $\Omega$
Series R:	54.1 $\Omega$
Series L/C:	3.523 nH
Series L:	3.523 nH
Series C:	-720.58 pF
Parallel R:	54.19 $\Omega$
Parallel L/C:	2.113 $\mu$ H
Parallel L:	2.113 $\mu$ H
Parallel C:	-1.202 pF
VSWR:	1.094
Return loss:	-26.985 dB
Quality factor:	0.041
S11 Phase:	27.11°
S21 Gain:	-0.471 dB
S21 Phase:	44.64°

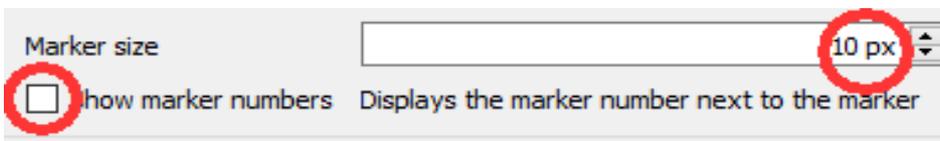
Up to three Markers can be used independently.

Enter the frequency and choose the colour of a marker. At once this marker is display on all curves.

At the side of the sweep menu you find this list of all marker properties which can be displayed.

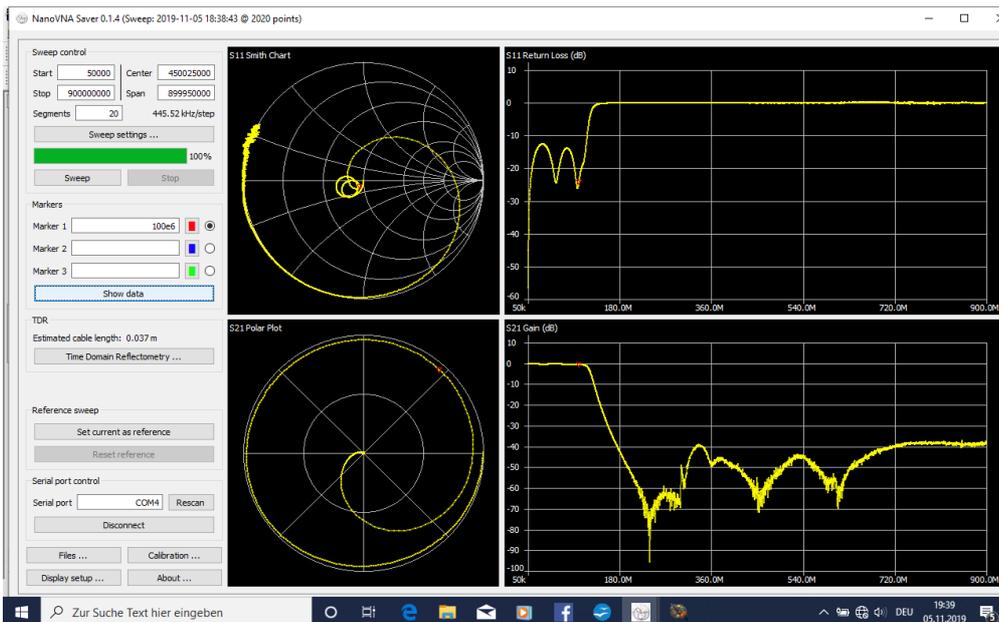
a) When entering a marker frequency the programm chooses the nearest adjacent frequency which

can be found in the calibration file (for instance: entering **100 MHz** gives a frequency value of **99,8956 MHz** in the marker list)



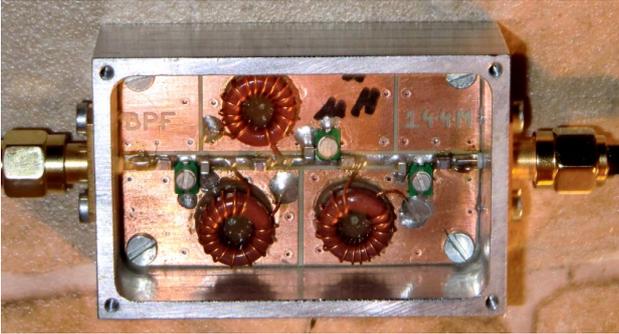
b) Marker size, colour, number and type can be set on the marker menu and on „Display settings“

settings“



c) If you hit „hide data“ the marker property list disappears and all 6 diagrams can be displayed.

## 16. A Bandpass Filter for 10.7 MHz



That is it!  
A Chebchev BPF with a centre frequency of 10.7 MHz, realised with Amidon ferrite ring cores ( $Q = 150$ ).

The Aluminium case is milled.

### Step 1:

Generate a SOLT Calibration File for a frequency range of **5 MHz to 15 MHz** using **20 Segments**.

### Step 2:

Save this file under a new name, e.g.:

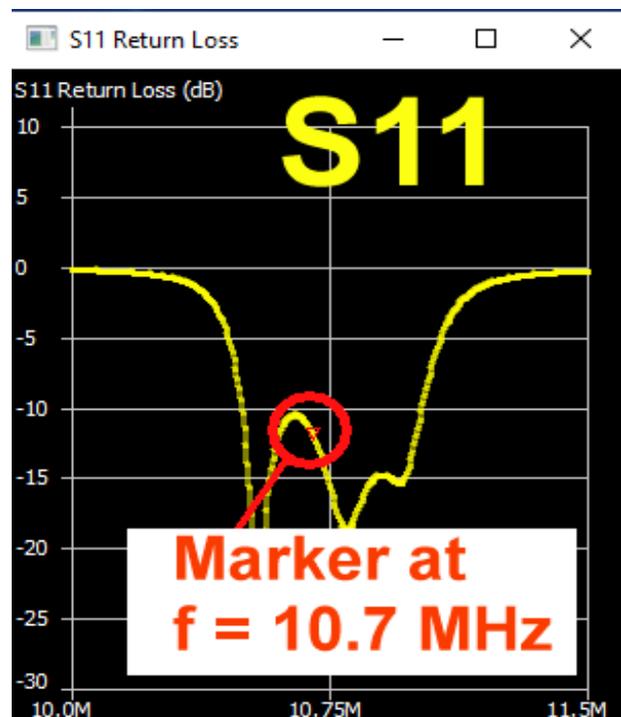
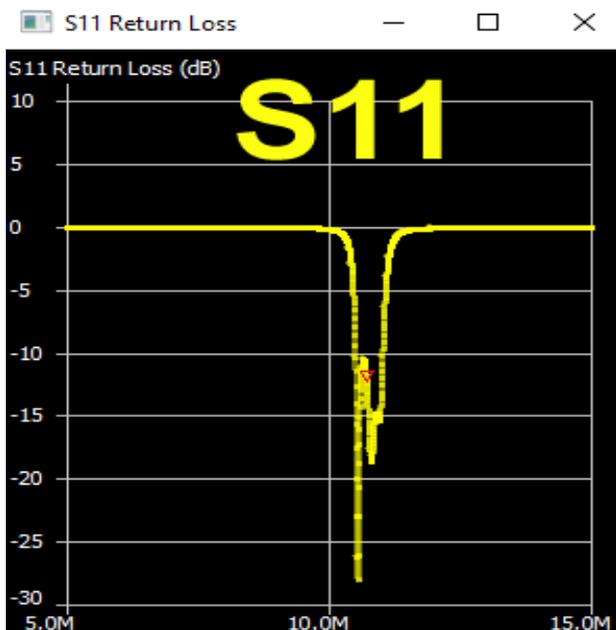
„Suhner 30cm\_Poulsen\_5M-15M\_20Seg“

and load it.

### Step 3:

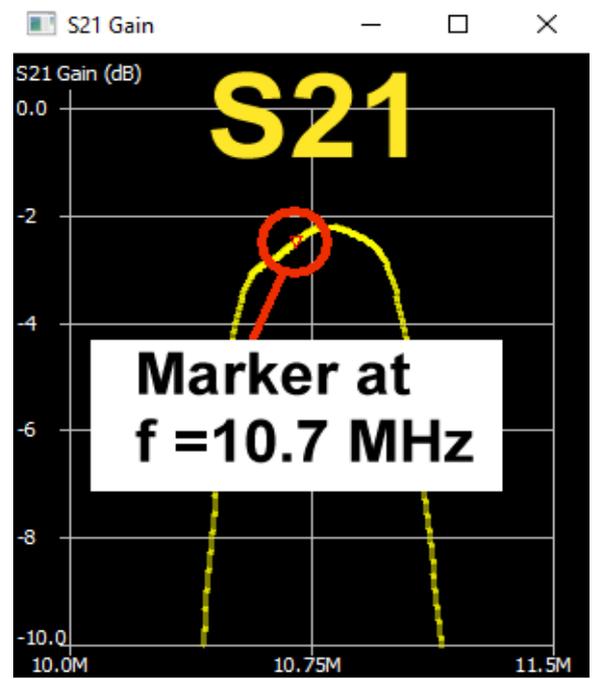
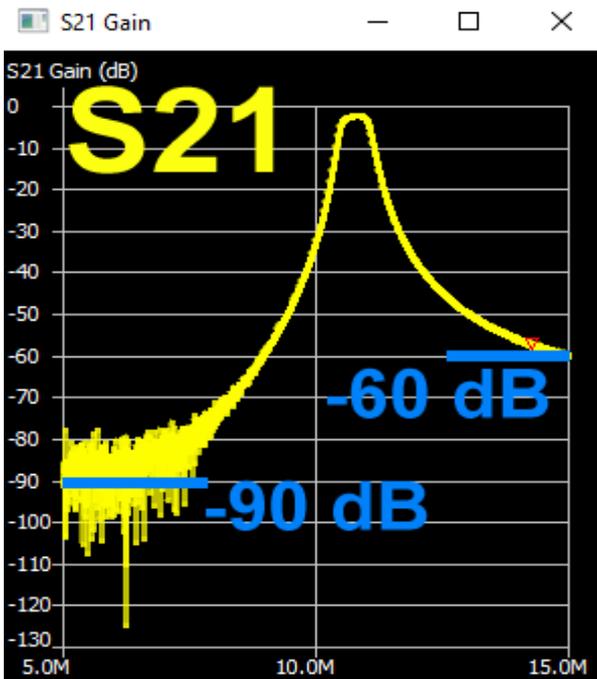
Start a sweep from **5 MHz up to 15 MHz** using **20 Segments** and add **Marker 1** for **10.7 MHz**

### Result for S11



The left illustration uses a frequency range from **5....15 MHz**, the right one from **10...11.5 MHz**

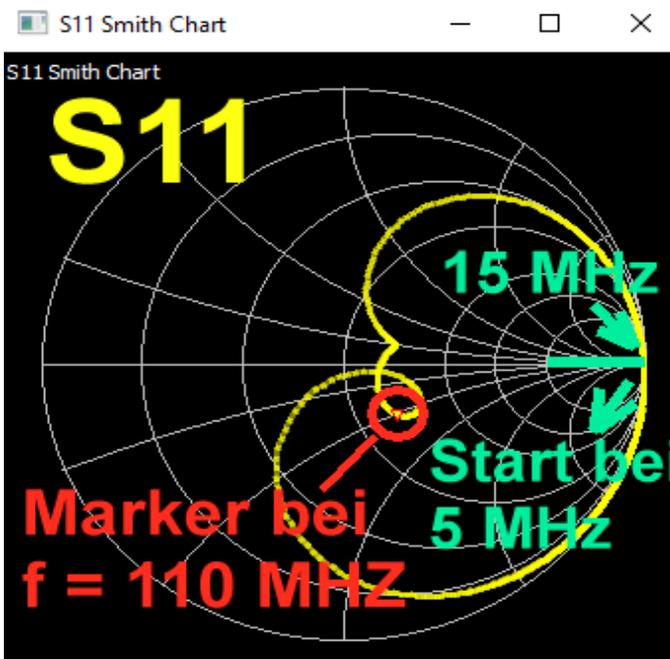
The same procedure for S21:



The left illustration shows a remarkable **stop band attenuation of -90 dB for  $f = 5$  MHz** and **-60 dB for 15 MHz**.

In the right illustration you see the pass band with a minimum attenuation of **2.1 dB at  $f = 10.9$  MHz**. (..it is true: the alignment procedure should be repeated and improved...)

In a Smith Chart you get nice loops when presenting **S11 of the pass band** and you can **easily demonstrate this**:



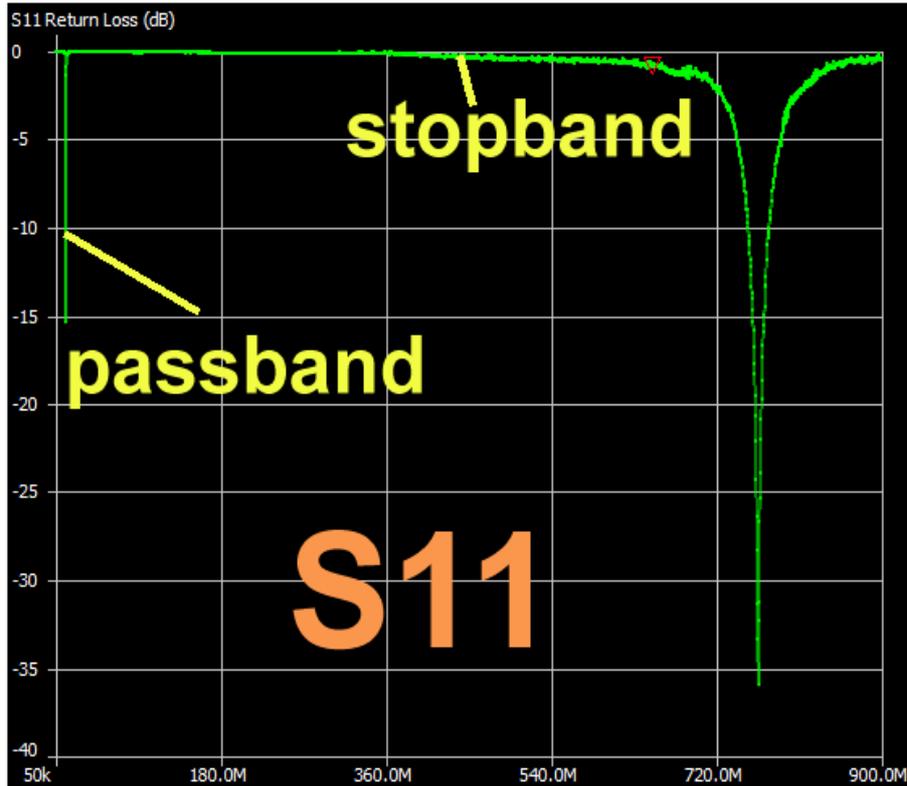
The curve starts at  $f = 5$  MHz at the point

**5 MHz / +1**  
(= right end of the horizontal axis).

Then the curve turns like a watch pointer and ends at the **same point**

(+1 for 15 MHz)

Now a special S11 and S21 test:



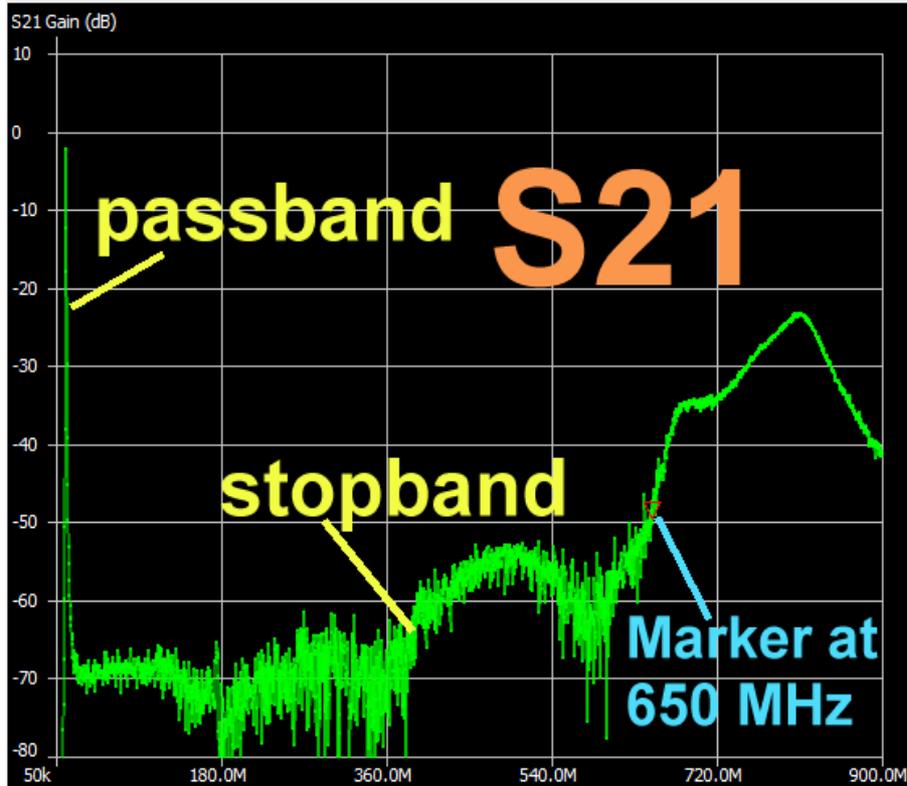
Please load the Calibration File for the range

50 kHz up to 1300 MHz

and sweep up to 900MHz.

This gives an overview of the stop band attenuation S21 and the wide band reflection S11.

S21 is below -50 dB up to 650 MHz.



The rest is a problem caused by self resonant effects of the parts.

## 16.1. Automatic Analysis

Really fine because you automatically get all parameters of a filter after a sweep.  
We want to have a look at the 10.7 MHz Filter from the last chapter. But pay attention to work through the preparation in the correct manner.

### Step 1:

Do a **SOLT calibration with a higher resolution for a reduced frequency span**. My new Calibration File is applied and saved as

**Suhner 30cm\_Poulsen final\_50k - 50MHz\_20 Seg\_avg = 3**

This file contains the following information:

**Suhner cables, length = 30cm**

**Calibration settings = newest version from Kurt Poulsen (see last chapter)**

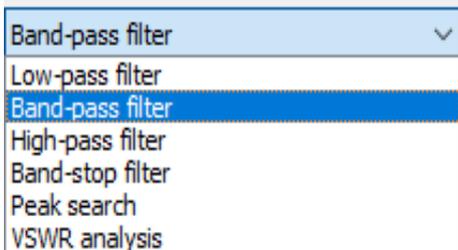
**Sweep range from 50kHz to 50MHz**

**Sweep range divided into 20 Segments**

After opening „**Sweep settings**“ the „**Averaging Sweep using 3 values**“ was selected.  
**This reduces the influence of noise**

### Step 2:

**A sweep from 9.5 MHz to 10.5 MHz with 20 Segments is used.**



### Step 3:

Open the menu „**Analysis**“ (at the middle of the lower border of the screen) and delete „**Run automatically**“.

Then choose „**Band-pass-filter**“ on the left menu.

Now mark „**Run automatically**“ again

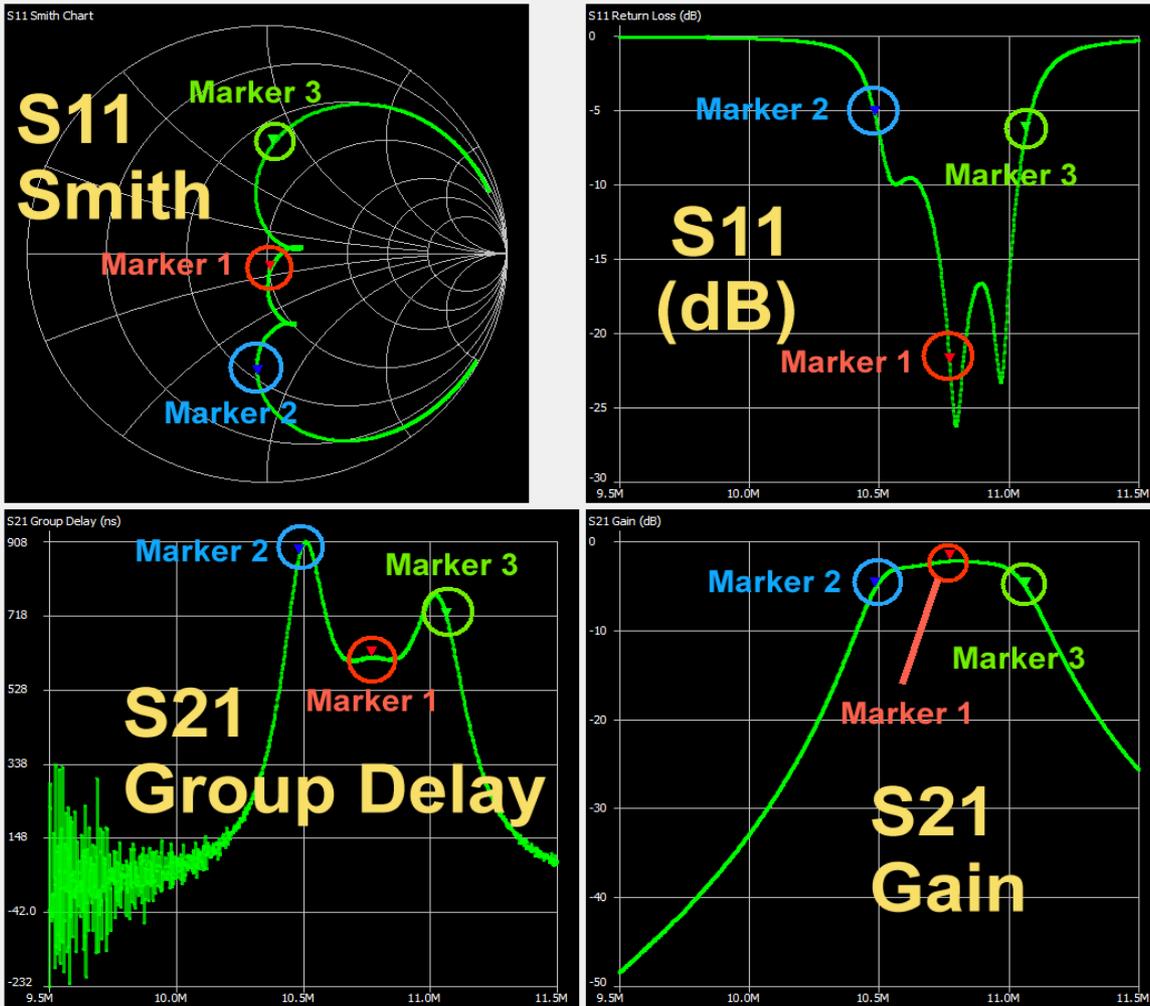
### Step 4:

**Set Marker 1 at the centre frequency of 10.7MHz.**

### Step 5:

**Start the sweep.**

This ist the result:



All details shown in the left hand window are described on the following page:

„1“ = Marker frequencies.

„2“ = Marker 1 indicates the exact **centre frequency** (10.771488MHz) with a gain of S21 = -2.207dB

„3“ = Marker 2 gives the **lower corner frequency** (10.485MHz). S21 has decreased by 3dB and is now -5.207 dB

„4“ = Marker 3 gives the **upper corner frequency** (11.065774MHz). S21 has decreased by 3dB and is again -5.207dB

„5“ = Minimum value of VSWR (1,103 or S11 = -26.227dB at 10.7962MHz)

Maximum value of S21 = -2.185 dB at f = 10.8002MHz

Minimum value of S21 = -48.421 dB at f = 9.50190MHz

The screenshot displays a software interface for signal analysis, divided into several sections:

- Sweep control:** Includes fields for Start (9.5e6), Center (10.50MHz), Stop (11.5e6), Span (2.00MHz), Segments (10), and a sweep rate of 1.980kHz/step. A green progress bar shows 100% completion. Buttons for 'Sweep' and 'Stop' are present.
- Markers:** A table lists three markers with their respective frequencies and colors:
 

Marker	Frequency	Color
Marker 1	10771488	Red
Marker 2	10485028	Blue
Marker 3	11065774	Green
- Analysis Results:** Three panels provide detailed parameters for each marker:
  - Marker 1:** Frequency: 10.7724MHz, Impedance: 50.94 -j7.94 Ω, Admittance: 52.18 -j334.8 Ω, Series R: 50.94 Ω, Series L/C: 1.8607 nF, Series L: -117.31 nH, Series C: 1.8607 nF, Parallel R: 52.18 Ω, Parallel L/C: 44.129 pF, Parallel L: -4.9464 μH, Parallel C: 44.129 pF, VSWR: 1.171, Return loss: -22.052 dB, Quality factor: 0.156, S11 Phase: -78.75°, S21 Gain: -2.207 dB, S21 Phase: -20.69°.
  - Marker 2:** Frequency: 10.4850MHz, Impedance: 26.14 -j39.2 Ω, Admittance: 84.94 -j56.63 Ω, Series R: 26.14 Ω, Series L/C: 387.23 pF, Series L: -595.03 nH, Series C: 387.23 pF, Parallel R: 84.94 Ω, Parallel L/C: 268.04 pF, Parallel L: -859.60 nH, Parallel C: 268.04 pF, VSWR: 3.309, Return loss: -5.418 dB, Quality factor: 1.5, S11 Phase: -94.08°, S21 Gain: -5.256 dB, S21 Phase: 124.97°.
  - Marker 3:** Frequency: 11.0658MHz, Impedance: 33.03 +j40.36 Ω, Admittance: 82.34 +j67.39 Ω, Series R: 33.03 Ω, Series L/C: 580.48 nH, Series L: 580.48 nH, Series C: -356.36 pF, Parallel R: 82.34 Ω, Parallel L/C: 969.25 nH, Parallel L: 969.25 nH, Parallel C: -213.42 pF, VSWR: 2.804, Return loss: -6.48 dB, Quality factor: 1.222, S11 Phase: 86.89°, S21 Gain: -5.219 dB, S21 Phase: -162.06°.
- TDR:** Shows 'Estimated cable length: 0.0 m' and a button for 'Time Domain Reflectometry ...'.
- Reference sweep:** Includes a button for 'Set current as reference'.
- Summary:** A red box highlights S11 and S21 parameters:
  - S11:** Min VSWR: 1.103 @ 10.7962MHz, Return loss: -26.227 dB
  - S21:** Min gain: -48.421 dB @ 9.50190MHz, Max gain: -2.185 dB @ 10.8002MHz

More information can be found when opening the „**Analysis**“ Menu:



## Sweep analysis



### Select analysis

Analysis type Band-pass filter

Run analysis

Run automatically

### Analysis

Band pass filter analysis

Please place Marker 1 in the filter passband.

Result: Analysis complete (1010 points)

Center frequency: 10.7715MHz

Bandwidth (-3 dB): 580.746kHz

Quality factor: 18.55

Bandwidth (-6 dB): 685.828kHz

Lower side:

Cutoff frequency: 10.4850MHz (-3.1 dB)

-6 dB point: 10.4374MHz

-60 dB point:

Roll-off: 463.356 dB / octave

Roll-off: 1539.234 dB / decade

Upper side:

Cutoff frequency: 11.0658MHz (-3.0 dB)

-6 dB point: 11.1233MHz

-60 dB point: 12.2939MHz (derived)

Roll-off: 370.049 dB / octave

Roll-off: 1229.276 dB / decade

## 16.2. Set Sweep as Reference

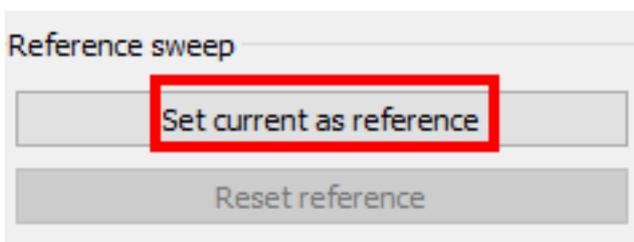
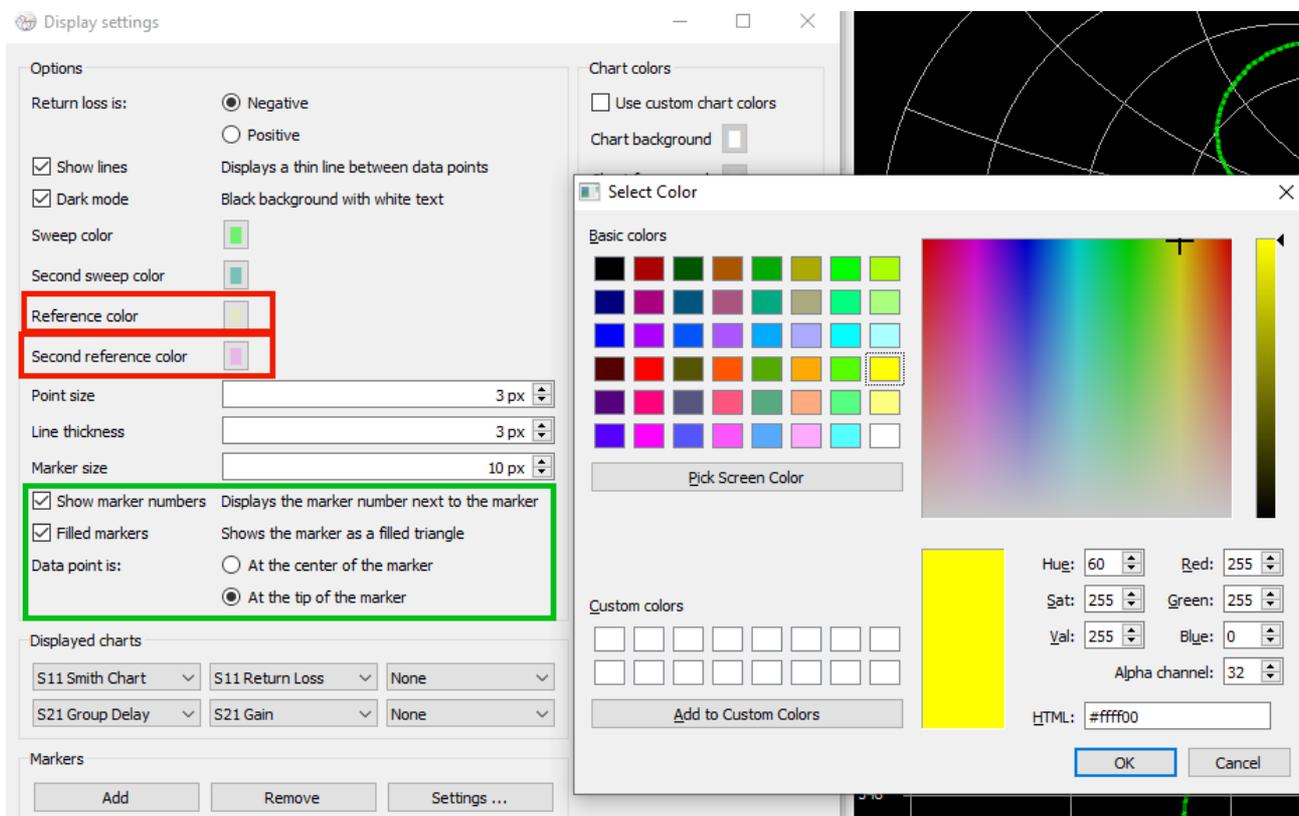
If you do that, then the next result will be shown together with the first ( but with another colour). So you can compare and recognise any variation.

### Step 1:

(Red frames). If you use a dark background for your diagrams you should first change to a **bright colour for the reference sweep (Yellow or Pink)**. Default is „Dark Blue“ and this does not work very well on a black screen...

Remember the content of the green frame:

**Here you can modify a lot of marker properties (show marker number / hollow or filled triangle / marking the data point by the center or the bottom of the triangle)**



### Step 2:

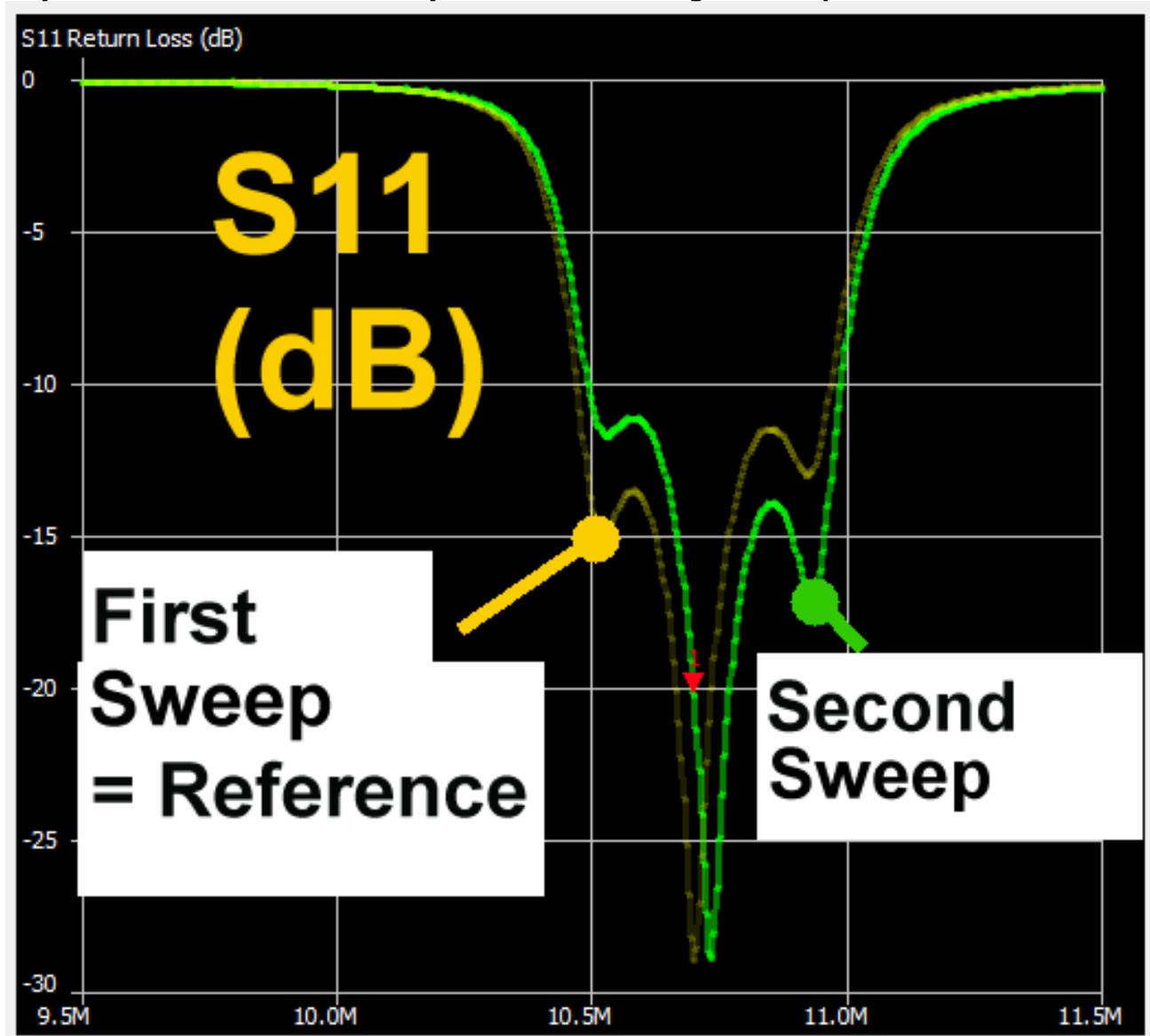
Sweep and tab on

**Set current as reference**

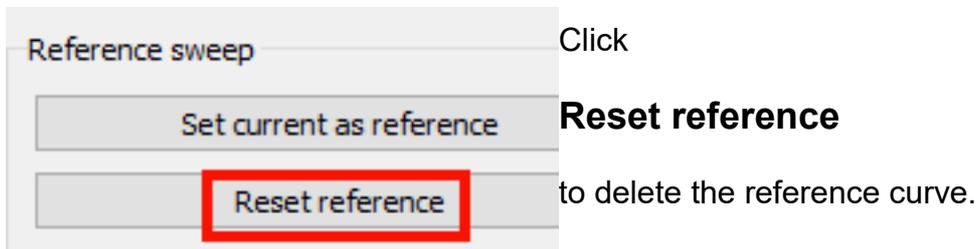
(In the lower left half of the screen)

**Step 3:**

**After the first sweep I have misaligned the BPF slightly followed by a new sweep. Any differences caused can always be best seen using the S11 presentation:**



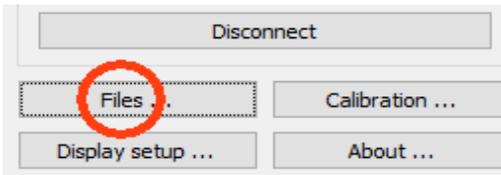
If you want to terminate this option:



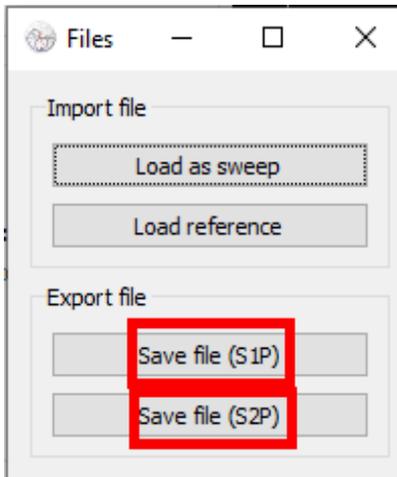
Personal remark:

The sweep speed is too low for „real time alignment of a good or misaligned filter“ and cannot be changed or increased. So the reference sweep option is better used for final testing of production filters against a good reference filter.

### 16.3. Saving the Touchstone Files generated



Open the „Files“ menu at the left lower edge of the screen....

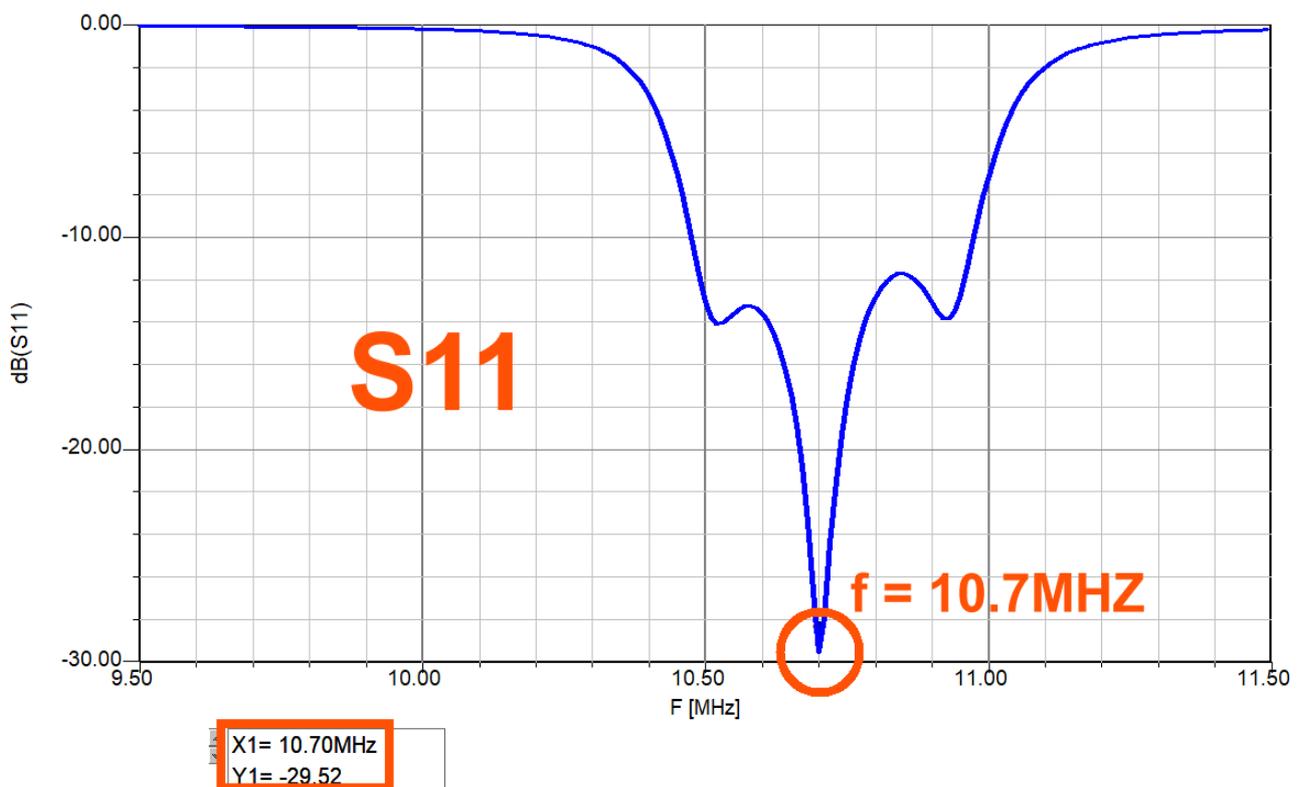


....then export and save at first the S1P File, followed by the S2P File.

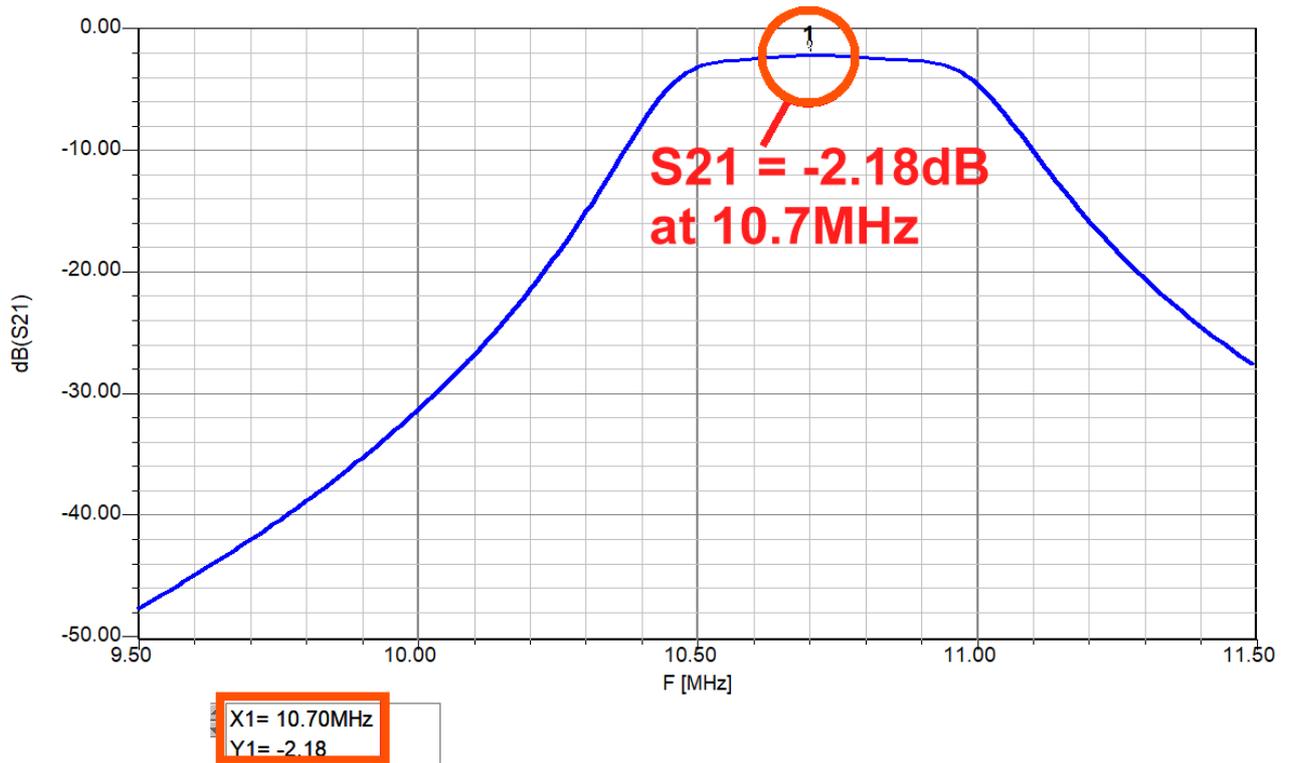
Give a name and choose a folder for saving.

After a new align procedure of the filter:

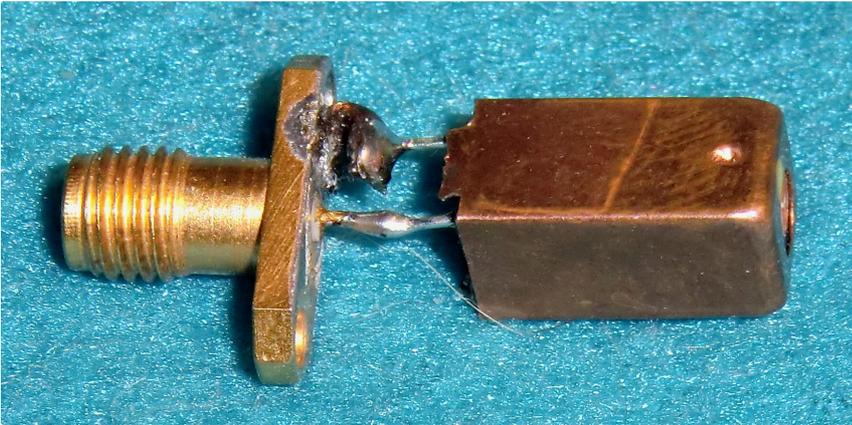
This is a **test simulation with the saved S11 file using the software „Ansoft Designer SV“** which can be free downloaded from my homepage ([www.gunthard-kraus.de](http://www.gunthard-kraus.de))



This is the S21 result:



## 17. Properties of a shielded filter coil



See the preparation:  
The coil (= an older Neosid version) is soldered to a SMA socket and then connected to the male SMA adaptor at the end of the Suhner cable connected to channel CH0 of the NanoVNA.

What we want to know:

a) R and X for the frequency range from 50 kHz up to 100 MHz

b) Quality factor  $Q = f(f)$  for this range

c) Exact values of inductance „L“, quality factor „Q“ and series resistance „R“ at a frequency of  $f = 30$  MHz

Now a correct Calibration file (e.g. 50 kHz ...900 MHz) must be loaded and the sweep started.

Here come the results:

a) R and X = f(f)



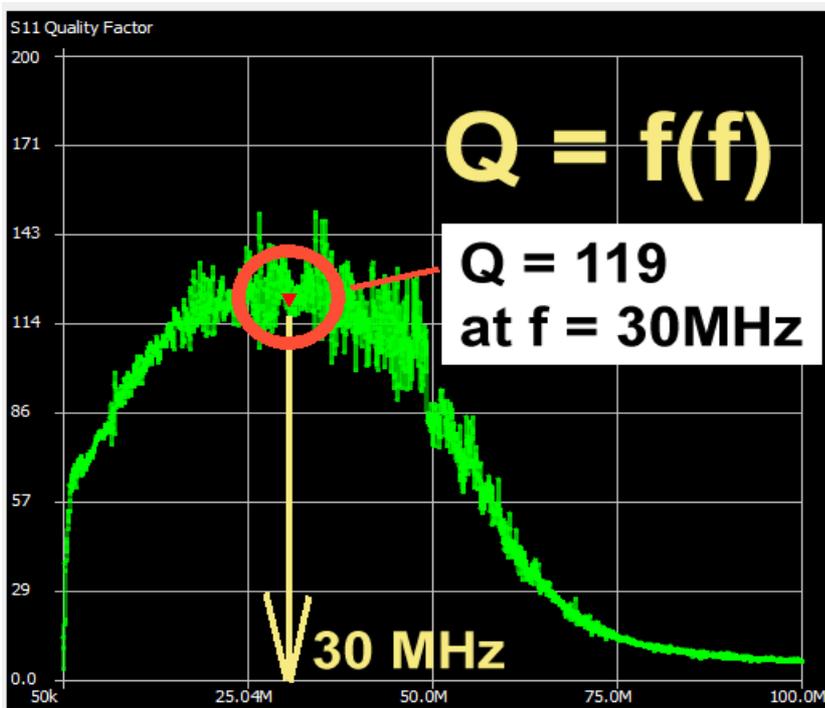
The inductance value L starts to increase at 50 MHz. (X curve is rising)

But the losses (= R curve) are exploding at frequencies higher than 50 MHz.

Due to these effects the Quality factor Q

must show a maximum

b)  $Q = f(f)$



The maximum value is  $Q = 119$  at  $f = 30$  MHz

Marker 1	
Frequency: 30.6929MHz	Parallel L: 992.48 nH
Impedance: 1.606 +j191.4 $\Omega$	Parallel C: -27.092 pF
Admittance: 22.8k +j191.4 $\Omega$	VSWR: 487.19
Series R: 1.606 $\Omega$	Return loss: -0.036 dB
Series L/C: 992.48 nH	Quality factor: 119.1
Series L: 992.48 nH	S11 Phase: 29.28°
Series C: -27.092 pF	S21 Gain: -89.908 dB
Parallel R: 22.8k $\Omega$	S21 Phase: -75.65°
Parallel L/C: 992.48 nH	

c) In the Marker 1 window you find all interesting values for  $f = 30$  MHz:

$R = 1.606 \Omega$

$L = 992.48$  nH

$Q = 119.1$

## 18. Ferrite Rod Antenna for VLF Experiments

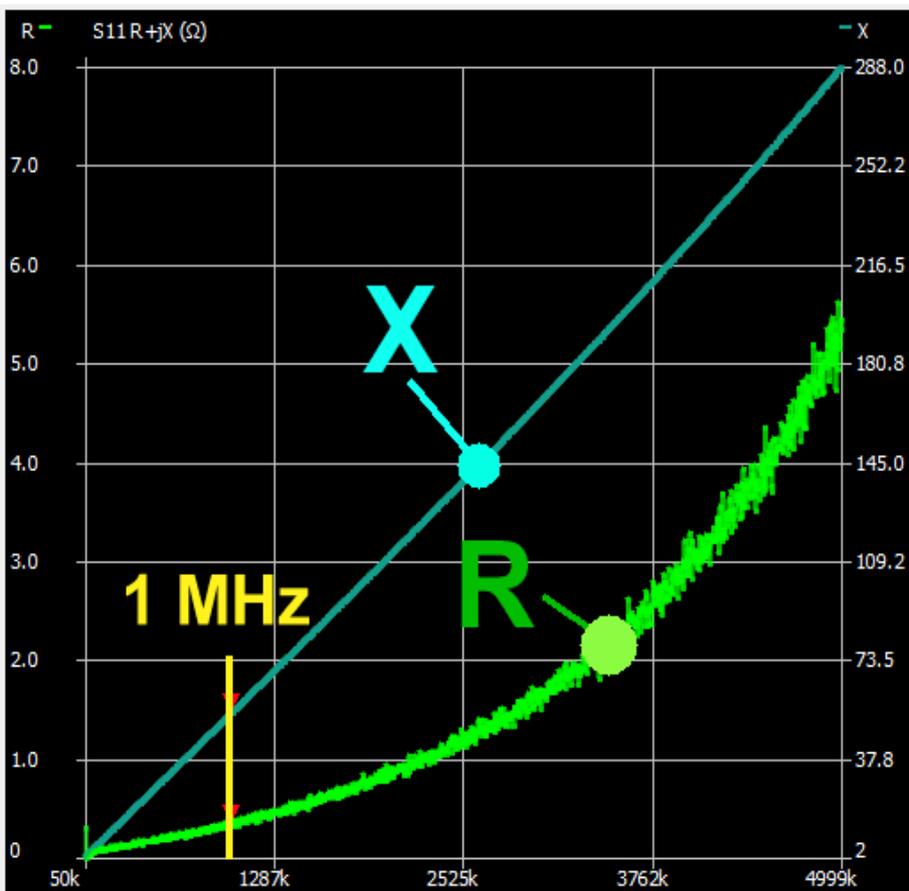
These antennas came with old valve radio sets and are a good choice for Very Low Frequency (= VLF) experiments in the range of a few Hertz up to 150 kHz or so. There you find signals of Submarine Communication, the „Schumann Resonances of the Globe“, Time and Frequency Standard Transmissions like DCF77 and so on.



You can determine every property of such a ferrite rod using your NanoVNA.

Simply use 10 turns of enameled copper wire (diameter = 0.5 mm), connect the two ends to an SMA socket and connect it to the NanoVNA.

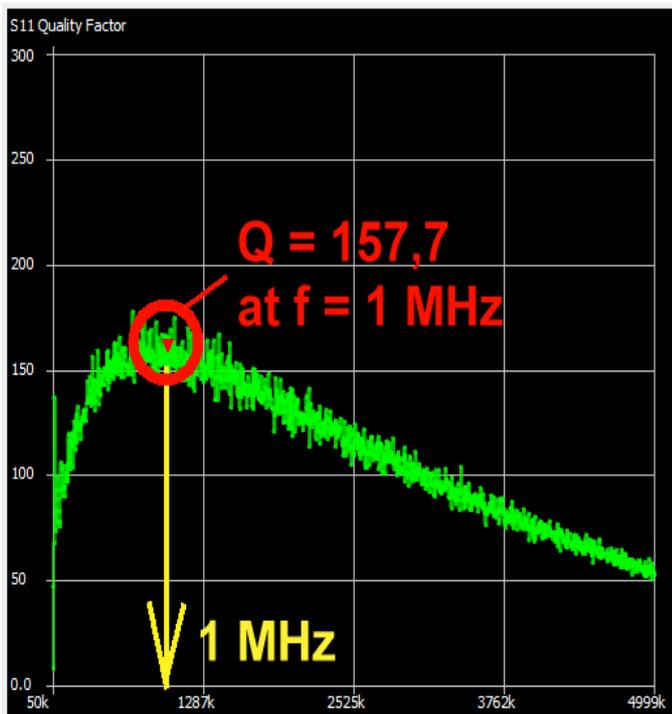
At first create a new **Calibration File** for the frequency range from **50 kHz up to 5 MHz and 20 segments**. Save this file under a new name and load it.



Now sweep **S11** and examine **R** and **X** for this frequency range.

**R** is low up to **1...1.5 MHz**. Then follows an exponential rise. This will dramatically reduce the quality factor **Q**.

(Now you recognise that 0...1600 kHz was the used frequency range of the antenna when operating in a MW radio)



The decrease of Q in the upper range is presented in this diagram.

But Q = 157.7 at f = 1 MHz is a good result...

Marker 1	
Frequency: 1.00151MHz	Parallel L: 8.6244 μH
Impedance: 0.344 +j54.27 Ω	Parallel C: -2.9282 nF
Admittance: 8559.0 +j54.27 Ω	VSWR: 316.485
Series R: 0.344 Ω	Return loss: -0.055 dB
Series L/C: 8.6244 μH	Quality factor: 157.7
Series L: 8.6244 μH	S11 Phase: 85.31°
Series C: -2.9282 nF	S21 Gain: -80.696 dB
Parallel R: 8559.0 Ω	S21 Phase: -9.18°
Parallel L/C: 8.6244 μH	

Marker 1 at f = 1 MHz delivers all interesting information.

Using

**L = 8.6244 μH** and **N = 10** turns

gives an „AL-factor“ of  $AL = L / N^2 = 8622.4 \text{ nH} / 100 = 86.22 \text{ nH}$

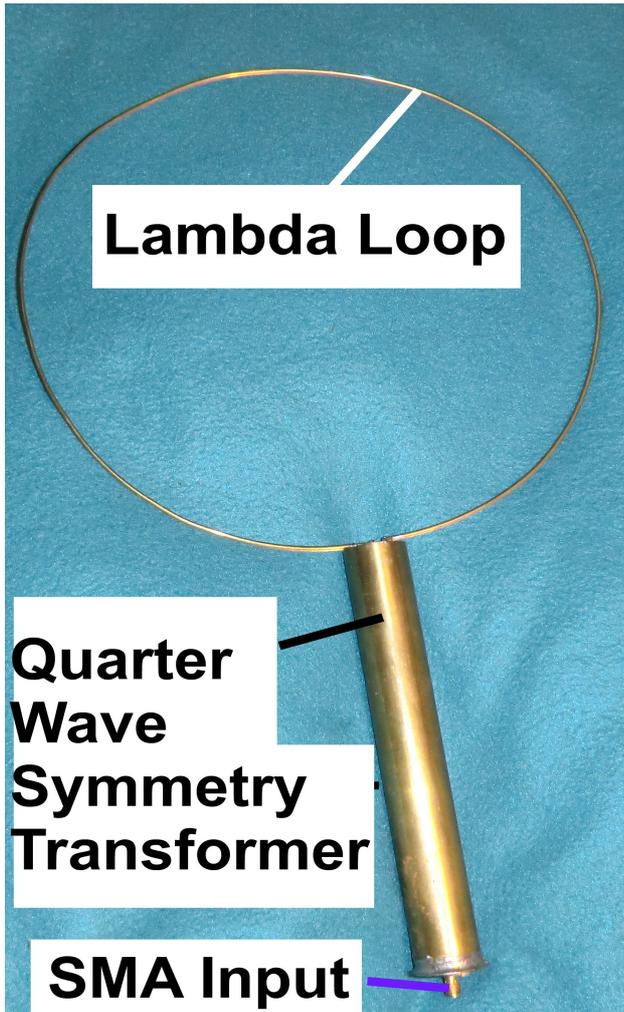
**Attention:**

Due to fringing effects of the magnetic flux the inductance for **other turn values** will vary and not strictly follow the formula

$$L = AL * N^2$$

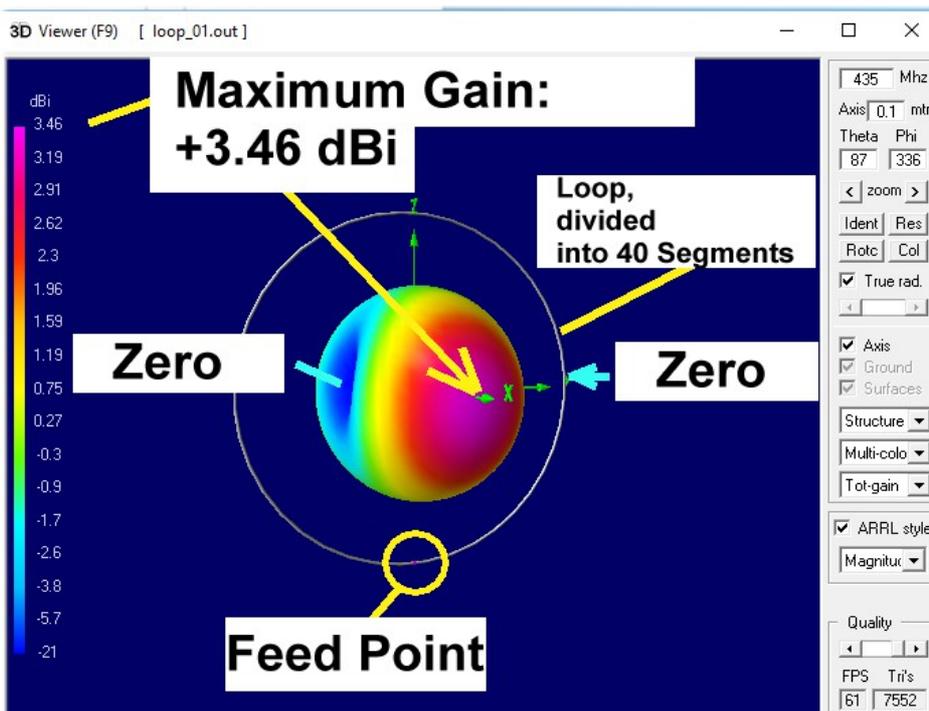
It is better to choose the turns given by the formula for a desired inductance and to test the result with your NanoVNA. Then do a correction of the turn number and measure again.

## 19. Lambda Loop Antenna for the 70cm - Band



This antenna consists of a wire with a diameter of 2mm and a length equal to the wavelength of a signal with  $f = 433 \text{ MHz}$  ( $\lambda = 693 \text{ mm}$ ). The wire forms a circle (diameter = 220 mm).

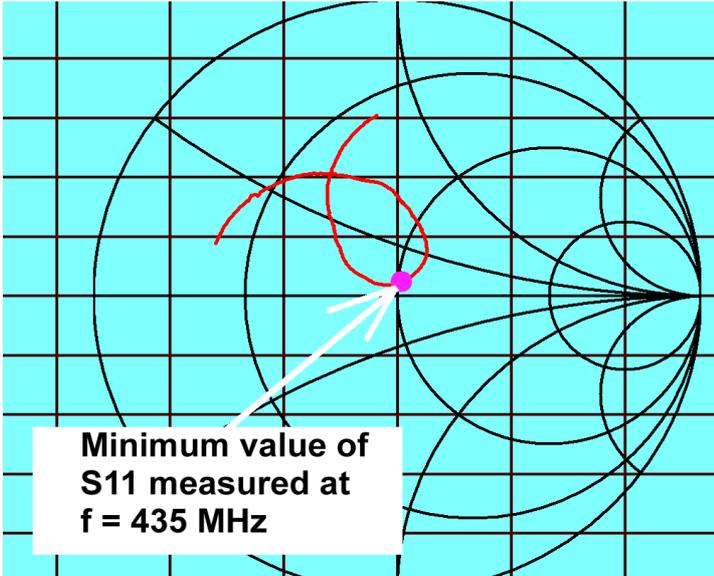
We need an impedance matching transformer which includes symmetric output for the antenna but unsymmetric operation at the SMA input socket. This is done by an arrangement using quarter wave coaxial lines.



This is a 4NEC2 simulation of the 3D radiation pattern.

Maximum gain is approx. 3.5dBi.

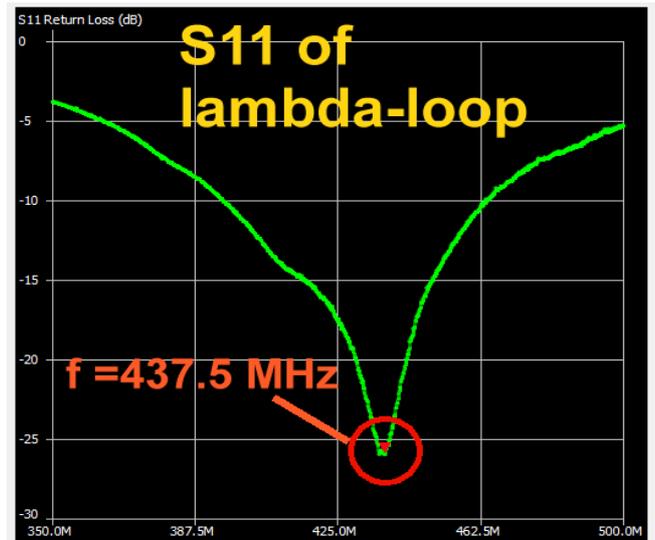
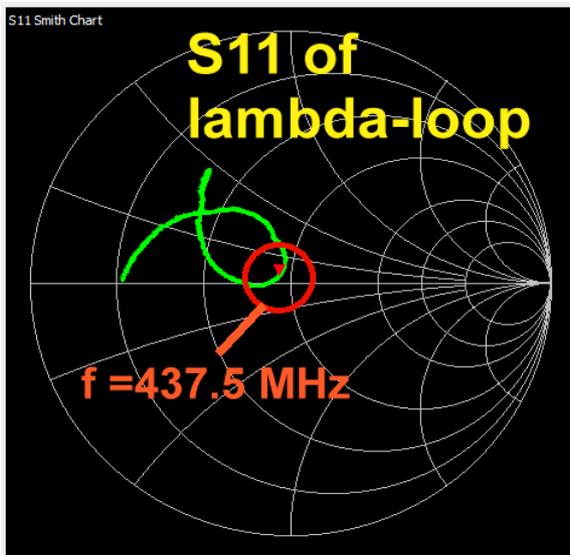
**Measured S11 at the Input Socket:**



**Result for the VNWA3.**

It is the same as for a professional measuring set (hp8410B + hp8620 +hp8745A)

**Results for the NanoVNA (f = 350.....500 MHz):**



Marker 1	
Frequency: 437.562MHz	Parallel L: 319.14 nH
Impedance: 45.77 +j2.394 Ω	Parallel C: -414.56 fF
Admittance: 45.9 +j877.4 Ω	VSWR: 1.107
Series R: 45.77 Ω	Return loss: -25.895 dB
Series L/C: 870.77 pH	Quality factor: 0.052
Series L: 870.77 pH	S11 Phase: 149.05°
Series C: -151.93 pF	S21 Gain: -55.417 dB
Parallel R: 45.9 Ω	S21 Phase: -23.4°
Parallel L/C: 319.14 nH	

**Marker 1 is the source for further information at 437.5 MHz**

## 20. Low Pass Impulse Response: NanoVNA-H2 as a Time Domain Reflectometer

### 20.1. Fundamentals of S Parameters

The NanoVNA-H2 is a test set to measure S Parameters (= reflection S11 resp.. transmission S21) in the **Frequency Domain**.

A generator signal coming from **channel CH0** feeds a cable connected to the input of an object („Twoport“) to be investigated. This signal running on the cable, named „**Incident Wave Uinc1**“, meets the input and a part of the energy (**reflected wave** = **echo** = **Ureflected1**) is travelling back to the generator. A measuring bridge at CH0 **separates the echo from the incident wave** and the NanoVNA calculates the ratio

**Ureflected1 / Uincident1**

which is as „**LOG / MAG**“ in **dB form** well known as „**Input Reflection S11**“. The output of the Twoport is terminated by the characteristic system impedance (normally = 50 Ω).

**Input „CH1**“ feeds a receiver for the same frequency and so the „**Forward Transmission S21 in dB**“ can be measured and indicated if the output of the Twoport is connected to channel CH1 and the ratio

**Uout1 / Uincident1**

is calculated and expressed in „**LOG / MAG**“ as in **dB form**.

If you now interchange input and output jack of the Twoport, the „**Output Reflection S22**“ and the „**Reverse Transmission S12**“ are measured and calculated as above.

Measuring at different frequencies gives the famous **S Parameter File** (mostly saved in **Touchstone** format).

### 20.2. From the Frequency Domain to the Time Domain

You get the same total amount of information about a One- or Twoport – whether you are measuring the properties and characteristics either in the frequency domain or in the time domain. Conversion from one to the other domain is done by the Fourier Transform.

**Both methods are simply the both sides of the same coin and with some mathematical efforts you can jump from one side to the other.**

The NanoVNA-H2 regards only the **Input Reflection S11** and calculates interesting details using this technique.

In the frequency domain the NanoVNA measures „step by step“ in a segment with 101 points (= 100 frequency spans). The result is the S11 file in this frequency range.

**But**

**alternatively using a Dirac impulse at the input would produce the same result and S11 file.** This is why this impulse contains all frequencies with the same spectral density

and you cannot distinguish between the S11 results of the two methods.

This means when converting the **measured S11 result** (delivered by the step by step measurement of the NanoVNA\_H) using the **Inverse Fast Fourier Transform gives the exact echo**

## Ureflected = f(t) in the Time Domain:

Now you'll find the location of anomalies like open end, short circuit etc. in this echo (depending on the cable's length).

If you want to know more about this theme please read the **Anritsu Application Note**

### Time Domain Measurements using Vector Network Analyzers

on The Internet. Also the Online Help for the **VNWA3 (from Tom Baier, DG8SAQ)** is very useful when reading the chapter „**Time Domain Measurements**“.

## 20.3. How to measure a cable length using the NanoVNA and the NanoVNA-saver software

### 20.3.1 Fundamentals

#### Questions:

- a) Which relation exist between the sweep range and the maximum of the indicated cable length?
- b) Which **sweep range** is necessary to indicate the **correct length of a very short or a very long cable**?
- c) Where can I find the **maximum frequency step**? I need it for the Inverse Fast Fourier Transformation (IFFT).
- d) What is the relationship between **the maximum frequency step** and the **indicated maximum cable length**?
- d) Where can I find the **cable properties**? (= material, cable velocity....)?

#### Answers:

The NanoVNA measures at **101 points** in the choosen frequency range. This gives **100 frequency steps**.

**Example:**

A sweep from 1MHz up to 101MHz gives a step width of  
 **$(101\text{MHz} - 1\text{MHz}) / 100 = 1\text{MHz}$**

This equates a time step of  **$1 / 1\text{MHz} = 1\text{ }\mu\text{s}$**  (= measuring time slot)

But if you want to see the echo produced by the end of the cable the echo needs the same time to travel back to the generator. Thus only

**$1\text{ }\mu\text{s} / 2 = 500\text{ns}$**

can be used for the measuring task.

**The NanoVNA-saver software reduces this value of 500ns to the half = 250ns**  
(...perhaps to avoid aliasing errors?).

If a Teflone cable is used then you have to take into account a cable velocity factor of 70% and with the well known relationship between light speed, time and distance you get a „maximum range for the indicated cabel length“ of

<b><math>0,7 * (3*10^8 \text{ meters per second}) * 250*10^{-9}\text{sec} = 52,5 \text{ m}</math></b>
---

Let us test this at once....

## 20.3.2. Test Project

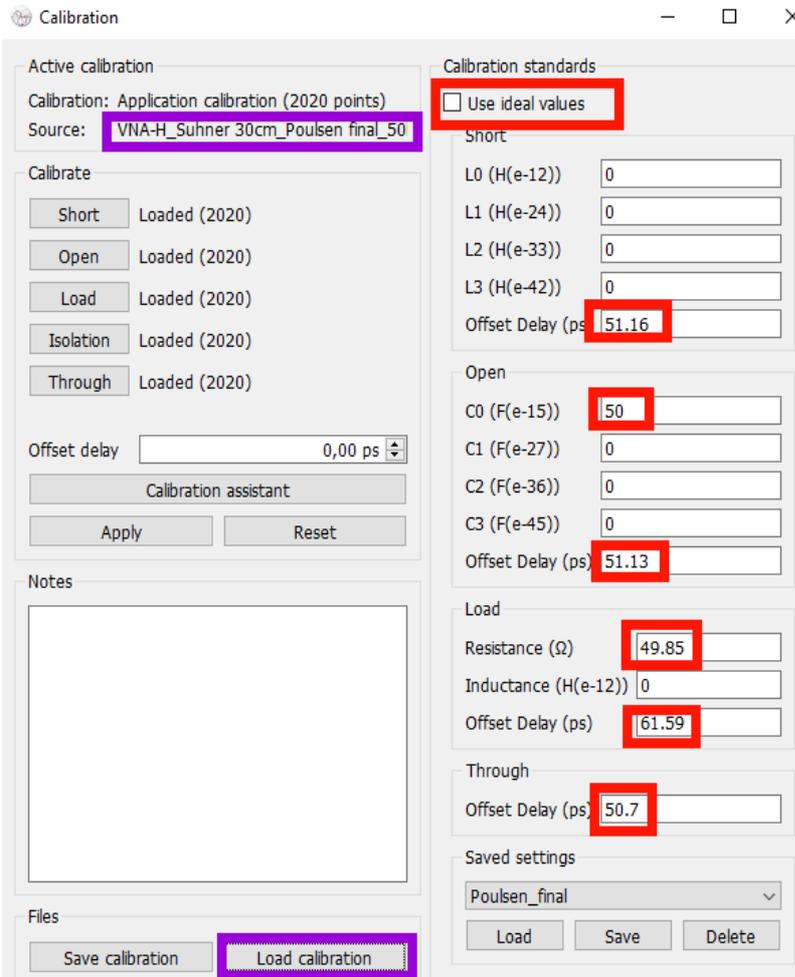
### Step 1:

Connect NanoVNA-H2 and PC via a USB-C-cable. At channel CH0 the Huber Suner cable with a length of 30cm is fixed.

Connect a SMA Teflon cable with a length of ca. 30 cm as test object to channel CH0.

Start the software „NanoVNA-saver-v0.2.2-1.exe and switch on the NanoVNA-H2.

Open the USB connection between the PC and the NanoVNA on the PC screen.



### Step 2:

Open „Calibrate“ and load first the **Calibration Standard**.

My version is called „**Poulsen\_final**“ and should be well known (...see the left illustration).

Then a **calibration file** must be loaded (= pink frames). The version up to 1500MHz got the name

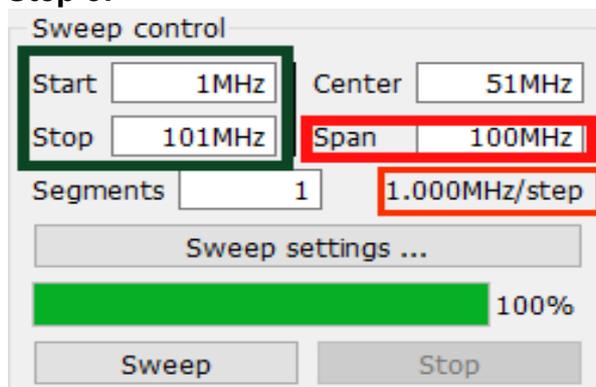
**VNA\_H\_Suhner 30cm\_Poulsen final\_50k - 1500M\_20Seg\_avg=3**

**Huber-Suhner SMA cable with a length of 30 cm is permanently connected to CH0 (..using the correct torque) and the SMA plug at its open end is the reference plane for the calibration.**

The calibration runs from 50kHz

up to 1500MHz using 20 segments and averaging = 3

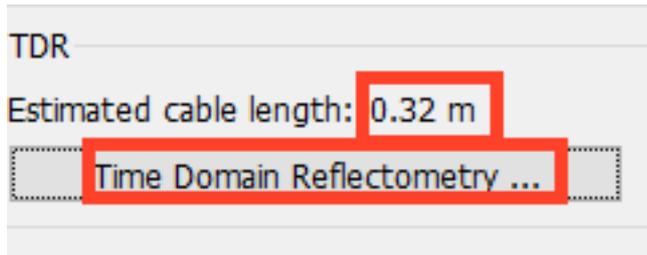
### Step 3:



A start at  $f = 1\text{MHz}$  and a stop at  $101\text{MHz}$  is now entered (= green frame).

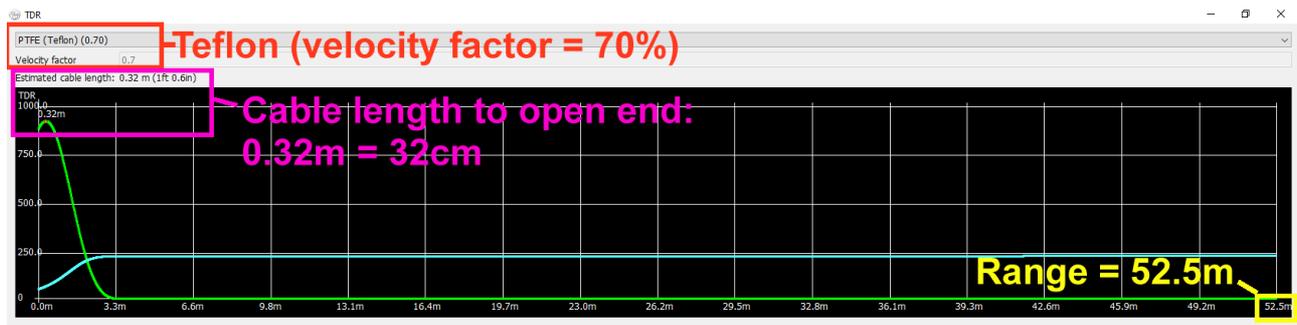
Using only 1 segment we get a **span of 100MHz** and a **step size of 1MHz / step**.

Now click on „Sweep“.



**Step 4:**  
Then a click on „Time Domain Reflectometry“ starts the Inverse Fast-Fourier Transformation (= IFFT)....

...and the following result is presented (= green curve):



At first the properties of the Teflon cable must be set (red frame).

The maximum of a cable length to be displayed is **52,5 m**

The maximum of the echo appears after a cable length of **32cm**.

(Remark:

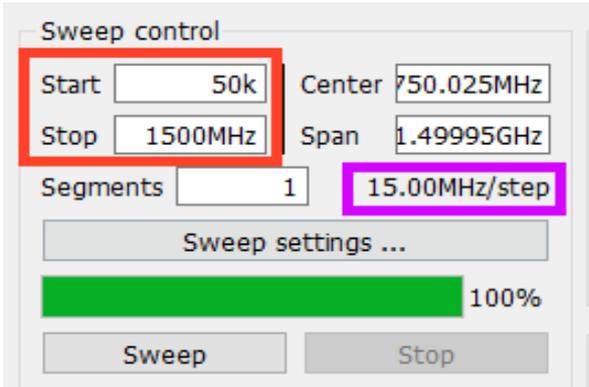
Open end or short circuit at the cable's end give the same result: a peak).

The real measurable mechanical cable length is exactly **30cm**. Where does the difference come from?

Reason:

The software starts to measure at the reference plane in the middle of the male SMA plug on the Huber Suner cable's end. But a through adapter (female - female) is inserted at this point between the two cables and adds its electrical length to the result. Now we try to measure its mechanical length using the NanoVNA-H2.

### 20.3.3. Reduction of the range maximum for short cables



An easy task:  
 Increase the frequency step as much as possible. This gives the smallest inverse value and this is the smallest time step.  
 If we use a frequency range from 50 kHz up to 1500MHz and only 1 segment, we get appr. **15MHz / step**.

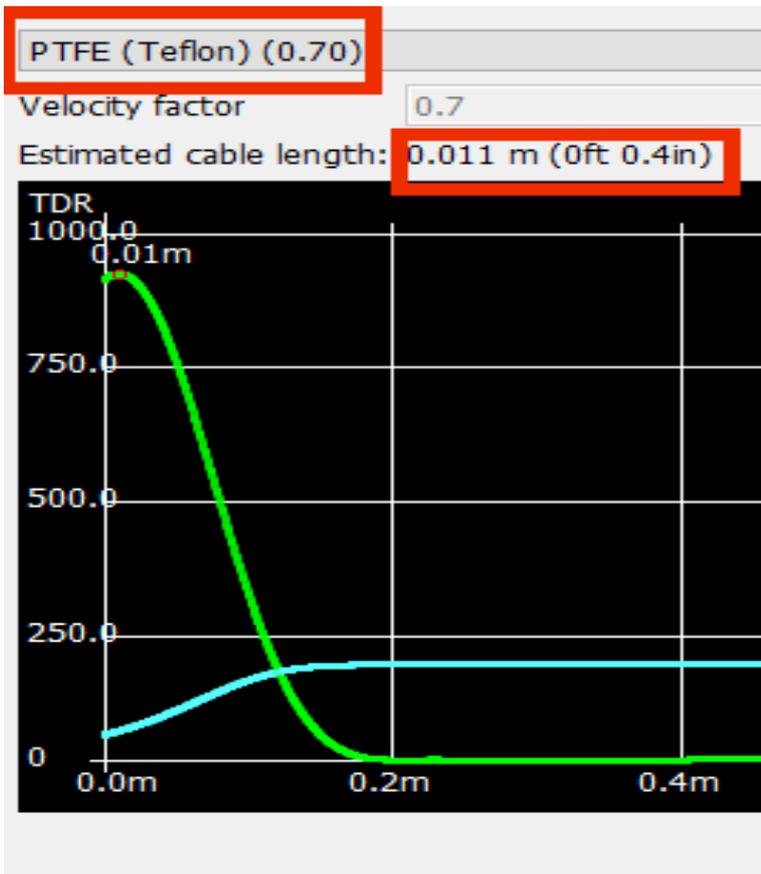
But check whether a calibration file (valid up to 1500MHz) is loaded.

Dismantle the Teflon cable and the Through adapter. Then start the the sweep and afterwards the IFFT.

Result for the now open ended Huber- Suhner cable fixed on CH0:

**distance = 0,002m = 2mm**

**It seems that this effect is caused by the „open end extension“ of the SMA-Plug.**



If now the Female Female Through Adapter is screwed on again, we get a cable length of **11mm**.

**This gives an adapter length of 11mm - 2mm = 9mm**

(The measuring range is now 3.5m).

The total indicated length (= adapter + test cable) was 320mm. So we can now calculate the „true mechanical cable length“ to

**320mm - 9mm = 311mm.**

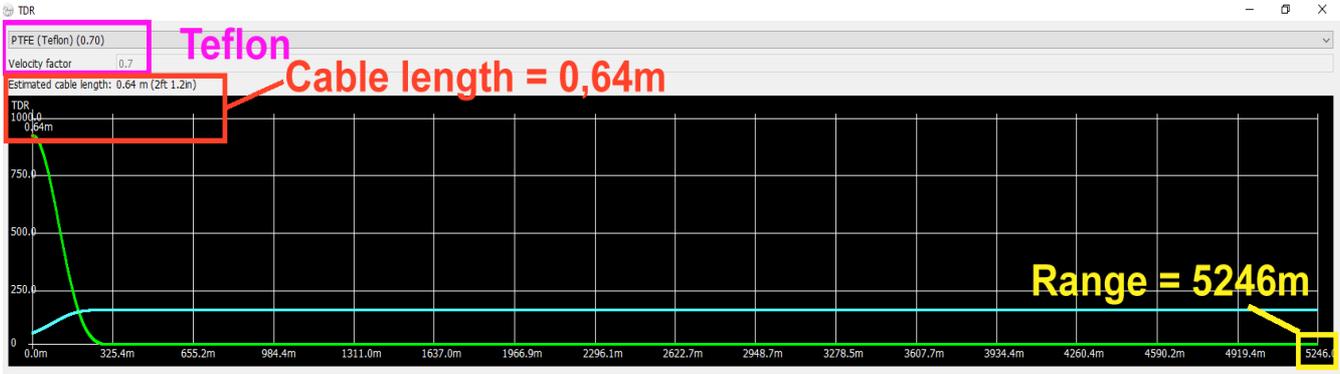
That is what we wanted to know...

### 20.3.4. How can we test very long cables?

Due to the formula „frequency step = 1 / time step“ we need the greatest time step und thus a **small step in the frequency range**.

**Example:**

We use a sweep from 1MHz up to 2 MHz with 1 segment. This gives a frequency step of 10kHz.



The result of 0.64m =640mm is inaccurate (...result too near toZero). The range rises up to **5246m**.

Finally we start a new trial with a greater span (1MHz up to 20MHz / 1 segment):



An indicated cable length of

**337mm - 9mm = 328mm**

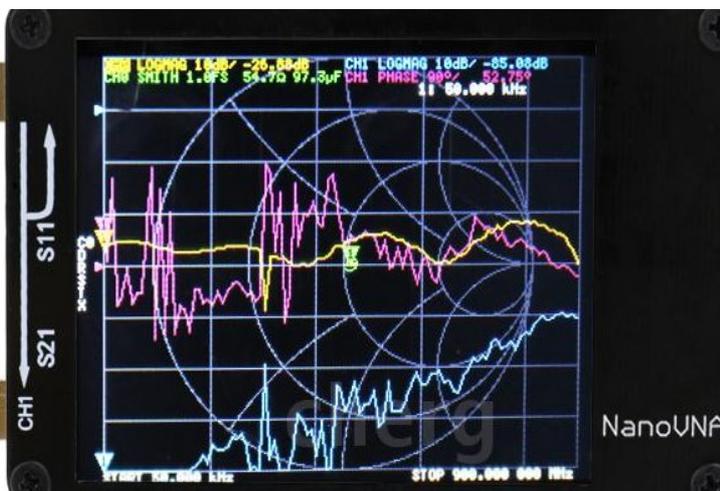
is not so bad for the new maximum range of 276m....

## C): Standalone operation

### 21. Familiarisation with the H2 - device

First, make sure that both RF inputs are open and switch on. If the battery is missing power the NanoVNA -H2 via the USB cable supplied connected to a laptop or PC. The computer must be turned on to provide the +5V we need for a power supply.

Unfortunately, nothing happened for me, no LED lit after switching the power switch on and the screen remained dark. This signalled the first rework because the USB C socket on the board was poorly made so that when the cable was plugged in there was no contact. It was reworked carefully by bending the tiny PCB inside the socket until it was exactly central AND the metal sheath of the shield ensured a snug fit for the plug. Do not forget to test that turning the plug through 180 degree also makes contact.



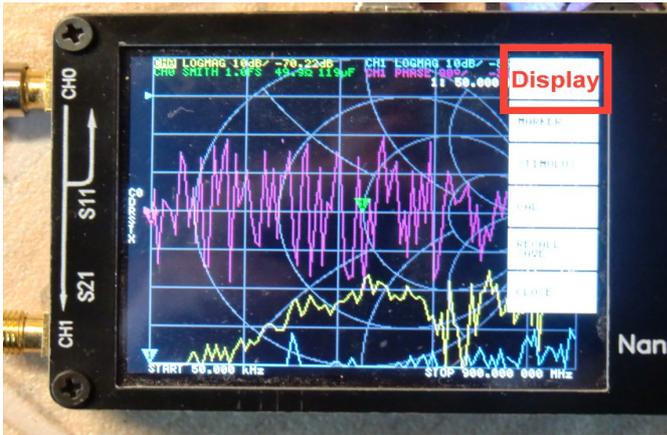
Now it really shows life (the Battery LED flashes blue).

**Fit the LOAD resistor on the TX output (Channel 0).**

As shown in the picture, **three differently coloured curves and a Smith Chart** are displayed on the NanoVNA screen.

The corresponding information text is tiny with this small screen size but everyone has to see how they gets along with it (I've been working for a long time, for example, soldering using a stereo magnifier).

## 22. The first successful measurement: LOAD properties



Leave the LOAD resistor on the TX port and tap on the screen with your finger or a "stylus" ("Stylus" = pen with rubber cap or a pencil fitted with small eraser).

This opens the main operator menu on the right edge of the screen giving access to the four curves by tapping on **"Display"** then on **"Trace"**. Select the purple curve first and tap **"OFF"**. In the same way the blue curve at the bottom of the display can be removed.

The screen should now only show S11 in the Smith Chart and Cartesian form from 50kHz to 900MHz.



Now press the **Multi Function Switch (MFS)** to the right and hold it there. The marker moves from the start at 50kHz towards the higher frequencies. Try  $f = 468\text{MHz}$ , it will show 468.042MHz. The display has a scale on the left hand side with 10dB divisions as well as the top "Zero dB point".

The S11 data ("LOGMAG") for the Cartesian curve fluctuates around -47dB. But it will only be the result for the very first measurement displayed.

The Smith Chart only shows one marker for such a small reflection this is in the centre of the chart ( $50\Omega$ ). The corresponding series connection for the input impedance at 468MHz is shown on the top, far right as:

**49.5  $\Omega$  in series with 1.7 to 4 Nanofarads**

No wonder there is such a big spread. With such small voltage levels and the noise that can be seen. Because this noise increases with frequency it is better to use the middle of the S11 curve to estimate from the Cartesian diagram.

**Task:**

**Move the marker (by pressing the MFS to the left) to 144MHz and determine the S11 values there.**

(Solution: S11 = -37,2 dB / R = 49,7  $\Omega$  in series with ca.- 800pF)

## 23. The sweep options

The main menu has an option "**Stimulus**". When this is chosen there are the following options:

- a) Using "**Start**" and "**Stop**" we sweep over the chosen range
- b) Using "**Centre**" and "**Span**" we select a certain centre frequency as well as a span around this centre frequency
- c) Using "**CW Freq**" a fixed frequency is used.

Finally there is the option to switch between "**Pause**" and "**Sweep**"

### 23.1. Start-stop - operation

101 frequency points are always used. If the range of **460MHz to 470MHz** is required:

**Step 1:** Open the "Stimulus" menu

**Step 2:** Tap on "**Start**" followed by a tap on the **right edge of the box showing the displayed frequency (right bottom corner of the screen)**. This will open a small keyboard to enter the new starting frequency as "**460.0M**"

**Step 3:** Do the same again for the **stop frequency** but enter "**470.0M**"

Finished!

### 23.2. Centre / Span operation at 465MHz

**Step 1:** Open the "**Stimulus**" menu

**Step 2:** Tap on "**Center**"

**Step 3:** Enter the frequency "**465.0M**"

**Step 4:** Tap on "**Span**"

**Step 5:** Enter the frequency "**5M**"

**Step 6:** Check if it the sweep starts at **462.5MHz** and stops at **467.5MHz**

### **23.3. CW operation at 465MHz**

**Step 1:** Open the “**Stimulus**” menu

**Step 2:** Tap on "**CW Freq**"

**Step 3:** Enter the CW frequency “**465M**”

**Step 4:** Check the result on the screen

,

## 24. Calibration

### Important:

Everything practised so far would not provide accurate results and would be **meaningless without a prior calibration.**

**So if the frequency range changes, calibration should be carried out IMMEDIATELY!**

What does calibration involve:

a) A maximum of **five different calibrations (C0 to C4)** can be stored.



b) The currently active calibration will be shown in the middle of the left hand display border displayed as shown in the picture.

**At switch on the data from C0 is automatically used**

When the device is purchased a **factory calibration can be found in C0 from 50kHz to 900MHz**. With the maximum possible number of frequency points being 101 it is very coarse (step size about 9MHz). In addition it was not done with the "SOLT" (SOLT = Short / Open / load / through).components therefore it is **not perfect fit**.

**The first thing to do is a basic calibration of the NanoVNA-H2.**

If you want to make measurements over a narrower frequency range (e.g. an antenna or bandpass filter), then **extra calibrations are required** with the results stored in one of the memory locations C1 to C4. These can be selected next time the associated frequency range is used and the calibration data will be setup automatically.

Before a practical example is explained take a closer look at the information on the left side of the screen. This should be checked before taking an important measurement to make sure that everything is activated. When the NanoVNA is switched on the data in memory C0 is used to activate "Error Terms" stored from a previous calibration determined. These are:

- C0** (default calibration data)
- D** (Directivity)
- R** (Reflection tracking)
- S** (Source Match)
- T** (Transmission Tracking) X (Isolation)

Note:

This topic is explained well in the Application Note

### **NanoVNA RF Calibration Considerations and Procedure**

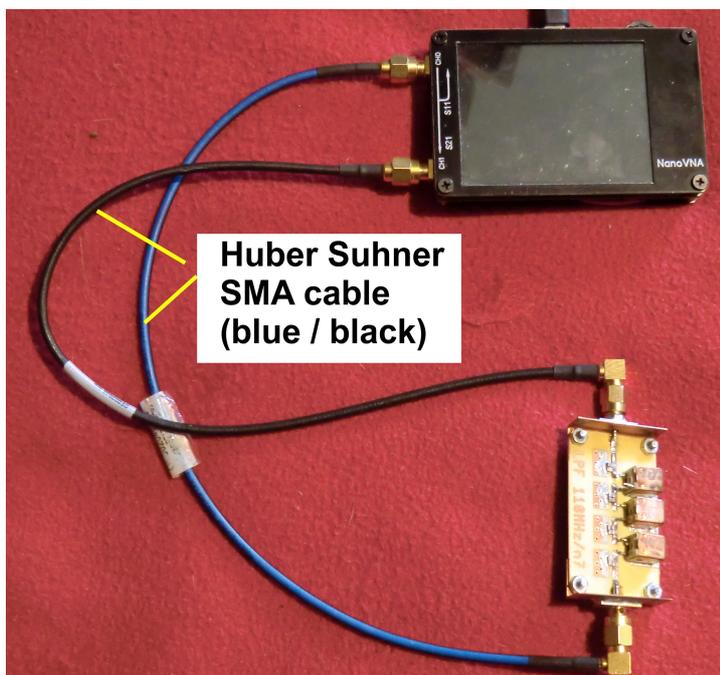
This can be found on The Internet. It is worth downloading!

## **25. Using measuring cables**

The SMA sockets on the NanoVNA should always be protected from damage using one of these two options (changing a socket on the board in case of damage is a very delicate mission):

a) Fit an **SMA Male to Female adaptor** onto each socket using the suggested torque (torque spanners are available on The Internet). This means that the measuring cables only come in contact with these adaptors that would be easy to change if required.

b) As already mentioned, the **two SMA cables included in the kit** can cause trouble. Not only is their characteristic impedance not quite correct ( $54\Omega$  instead of  $50\Omega$  as measured with a time domain reflectometer) and an SMA connector just dropped off one of mine!. This was because the crimping of the plug onto the cable was poor. The result of calibration is often meaningless until this is known



The solution is to purchase and to use **two very high quality cables (Huber Suhner with blue black outer), they are specified to 18GHz**. They should be permanently attached to the NanoVNA.

They can often be found by looking under all the tables at the HAM Radio flea markets.

## 26. SOLT calibration (50kHz to 1500MHz) for C0 memory

1) Start the NanoVNA\_H2 and permanently connect the SMA cables to the two RF ports (CH0 and CH1). Check the correct torque of 0.45Nm.

2) Open the main menu (tap the screen) and select "DISPLAY" followed by "TRACE". Select the yellow curve "TRACE 0" and then "SINGLE". Select "BACK". then tap on "FORMAT" then "LOGMAG"

3) Do the following actions for Trace 1: BACK / DISPLAY / TRACE / TRACE 1 then FORMAT and LOGMAG



Then the screen should look like this screen shot.

CH 0 = yellow curve = S11

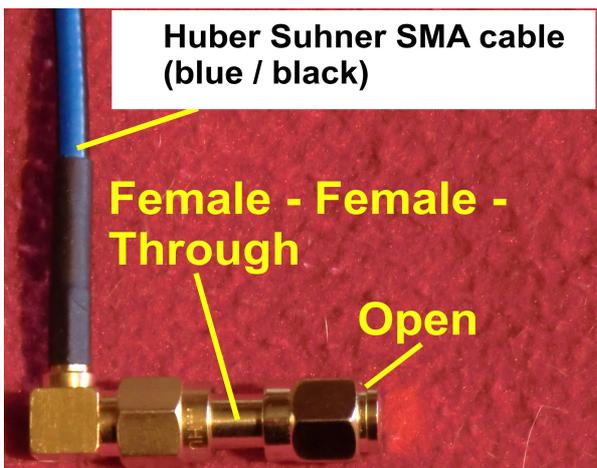
CH 1 = blue curve = S21

4) The **Start - Stop** settings required are:

### 50kHz to 1500MHz

5) Start the calibration process with a reset so that all old calibration data is deleted: From the main menu (begins with "DISPLAY") tap **CAL** then tap on **RESET**.

6) The **CAL** menu also contains **CALIBRATE**, tap that option.



This opens a list that starts with **OPEN**. Attach the **SMA OPEN** calibration standard to the end of the cable connected to CH0 using the **Female to Female** coupler.

Tap on **OPEN** to start the calibration process. The next step continues with **SHORT** highlighted in green. Replace the "**OPEN**" standard with the "**SHORT**" standard and tap on **SHORT**. The next step continues with **LOAD** highlighted in green. Replace the "**SHORT**" with the "**LOAD**" standard and tap on **LOAD**.

**Attention for the next calibration step:**

**The manual recommends that, if possible, both inputs CH0 and CH1 should be terminated at the cable ends by 50 Ω.**

**This requires another Female to Female SMA adaptor and another terminator for CH1. This is the only way to get the last one little bit of accuracy.**

The next step continues with **ISOLATION** highlighted in green. For this CH0 and CH1 should be terminated with 50Ω. Then tap on **ISOLATION**.

=====

The last step is **THROUGH** highlighted in green. For this the terminators are removed and both cable ends are connected using the **Female to Female adaptor**. Then tap on **THROUGH** to complete the calibration process.

=====

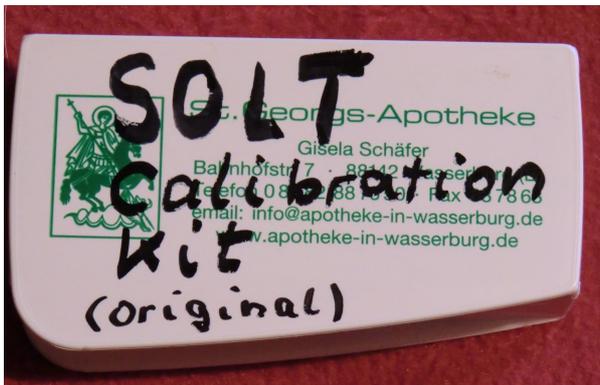
Finally tap "**DONE**" and store the result in **memory C0** with "**SAVE 0**". Now accurate measurements can begin.

To be absolutely sure, look at the left edge of the display to see if it shows the following:

**C0 D R S T X**

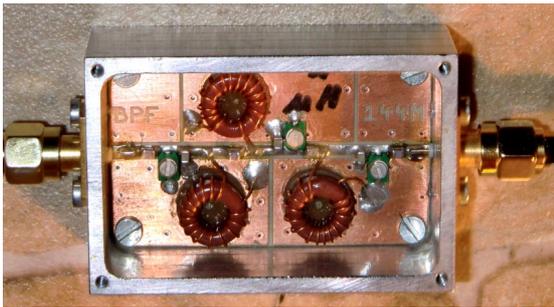
Then everything is OK.

Finally a practical tip for storing the SOLT standard kit:



The empty pill box came as a small gift from my pharmacy. The letters "S", "O" and "L" have been **scratched on the standards using a needle**.

## 27. Example: A Chebyshev - low pass filter with $f_g = 110\text{MHz}$ and $N = 5$



Since the current calibration is from 50kHz to 1500MHz this is a good object to measure. The picture shows the test piece. It is a printed circuit board with SMA connectors attached using right angle copper sheets. The inner conductors of the SMA connectors form a low reflection connection on the central microstrip.

After „Power On“ of the NanoVNA we find a calibration from 50kHz to 1500MHz in C0 and the measuring procedure starts automatically. Please open the TRACE-Menu and set only Trace 1 (= yellow curve, shows S11 in LOG / MAG format) and Trace 2 (blue curve, shows S21 in LOG / MAG format) active.

**Set the span to a start at 1MHz and a stop at 300MHz. Now you can see all the details of the Low Pass Filter.**



**Remark:**  
Click on the display and shift the frequency marker to 120MHz by using the rocker function of the Multifunction Switch.

Now you find all information about the properties at 120MHz on the upper edge of the screen.t

### **Attention:**

The calibration runs from 50kHz up to 1500MHz but only 101 measuring points are used. This gives a frequency span of 15MHz.

So if you want to investigate details in the passband (= below 100MHz) you should start a new calibration – only for this frequency range and save this calibration in C1. Then you can recall it in the future for other projects.

## 28. Low Pass Impulse Response / Low Pass Step Response

This is a difficult and complex theme but the following application note (from Anritsu) explains very good:

### Time Domain Measurements using Vector Network Analyzers

(to be found on The Internet). A good choice is also the **VNWA3 online help** written by Tom Baier, DG8SAQ. See the chapter „Time Domain Measurements“).

We have already used the **Low Pass Impulse Response** during chapter 18 and worked with it under the software „NanoVNA-saver“. This gives a fine result presentation on the PC screen. But working with the **Low Pass Step Response is still missing**.

But in the **NanoVNA-H2 version both options are already integrated in the firmware and can be used via the menu. In this case prefer to use the H4 modell with the 4 inch display – the usage is easier...**

This is the fundamental difference between the two methods:

If you send an **impulse** into the input of a cable then the echo shows a **maximum at a short circuit or an open end**. The exact distance of this anomaly in meters is displayed on the screen but you can also shift a cursor along the curve .

If you send a **voltage step** into to input of a cable the echo will show a high interesting property: when shifting the cursor along the cable: the **local impedance will be displayed at every cable length**.

### 28.1. Test Procedure for the NanoVNA-H2 (Low Pass Impulse Response)

#### Step1:

Start the NanoVNA-H2 without a PC (= **stand alone** option) and check whether the **calibration „C0“ is loaded**. Normally under „C0“ a **frequency range from 50kHz up to 1500MHz** is prepared and used.

#### Step 2:

Check whether the **Huber Suhner presicion SMA cable is connected to the transmitting port C0** and tightend with the correct torque (0.45Nm). For this case the C0 calibration is **valid up to 1500MHz** an you find „**C0 D R S T X**“ at the left edge of the screen.

Reference Plane is now the middle of the male SMA plug at the open end of the Suner cable.

**Step 3:**

Call up the start menu and choose „DISPLAY“ followed by „TRACE“.

**Step4:**

We need only Trace 1 (yellow curve for S11) and Trace 2 (green curve showing a Smith chart). Delete the other curves.

**Step 5:**

Connect first the Female Female SMA Adaptor to the open end of the Suhner cable.and then a Teflon SMA test cable to the adaptor

**Step 6:**

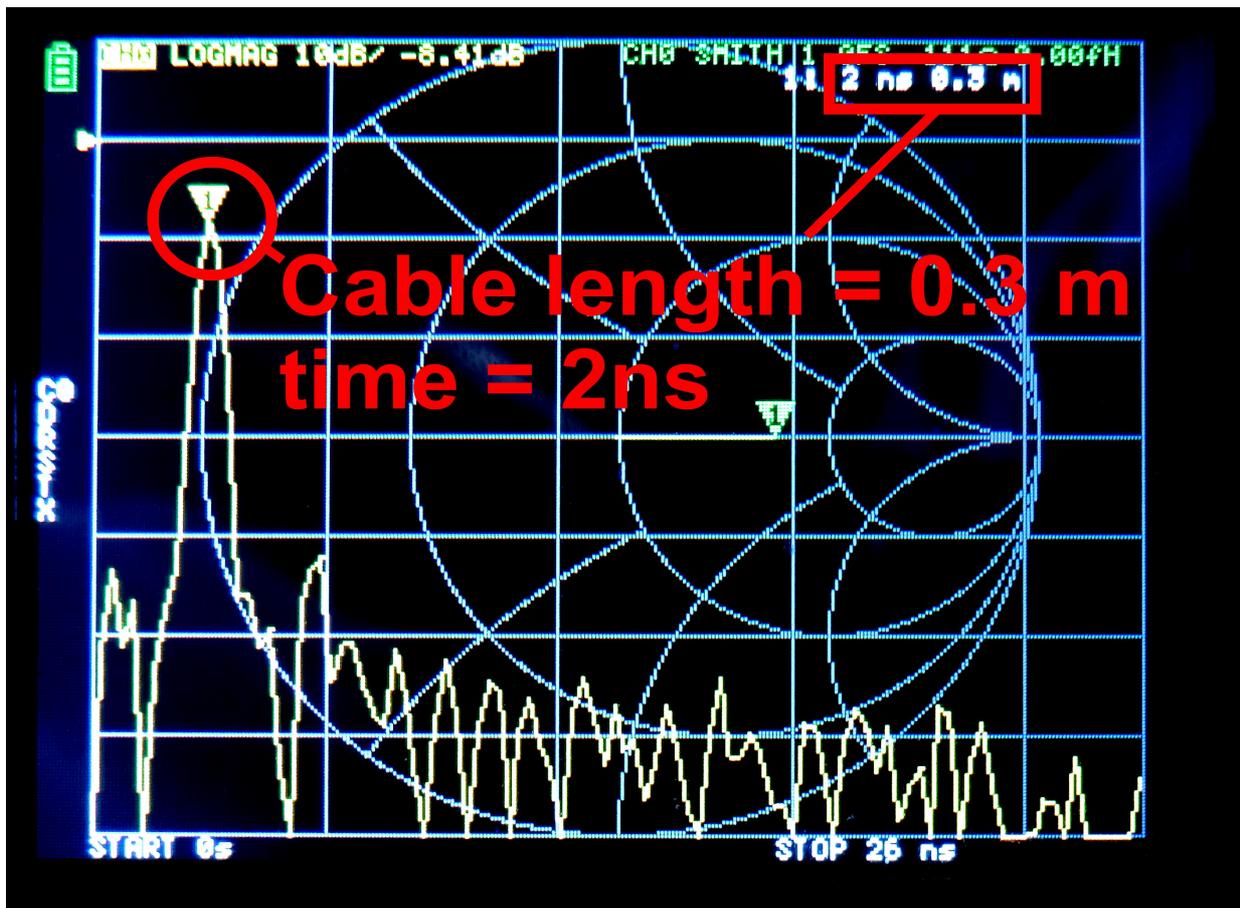
In the menu list (which must begin with „Trace“) type on „TRANSFORM“, followed by „LOW PASS IMPULSE“. Then press „TRANSFORMATION ON“ (= top field)

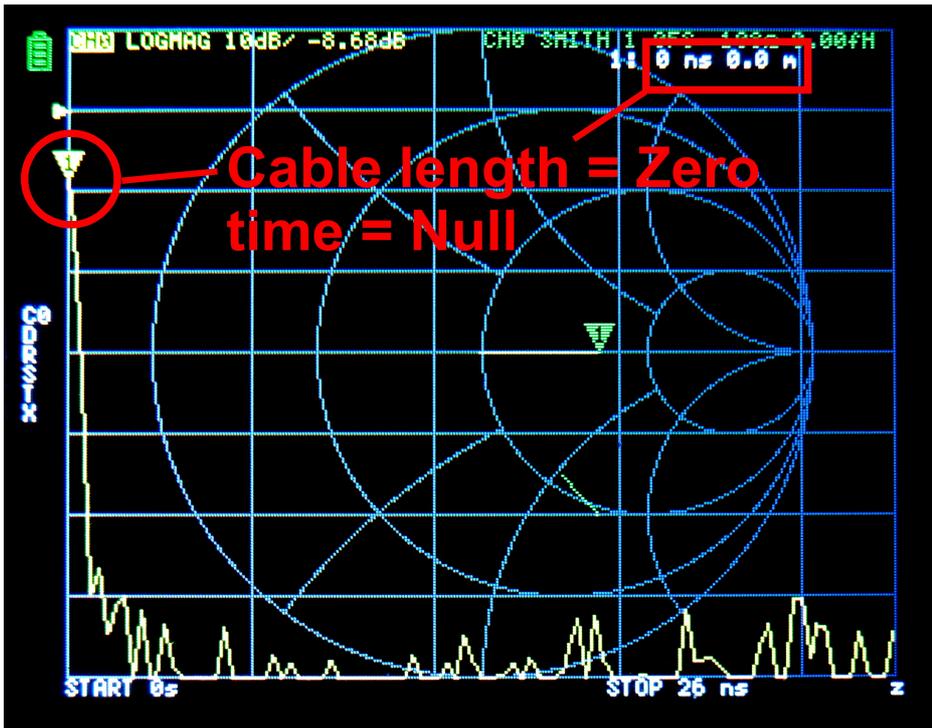
**Step 6:**

What you can see is only valid for „Air“ as dielectric.

So type on „VELOCITY FACTOR“ (= bottom field). Then you must enter the velocity factor in percent. Type „70“ for Teflon, followed by „x1“.

Now you get the result by moving the cursor to the top of the peak on the curve. This gives a cable length of 0.3m (= 2 Nanoseconds).

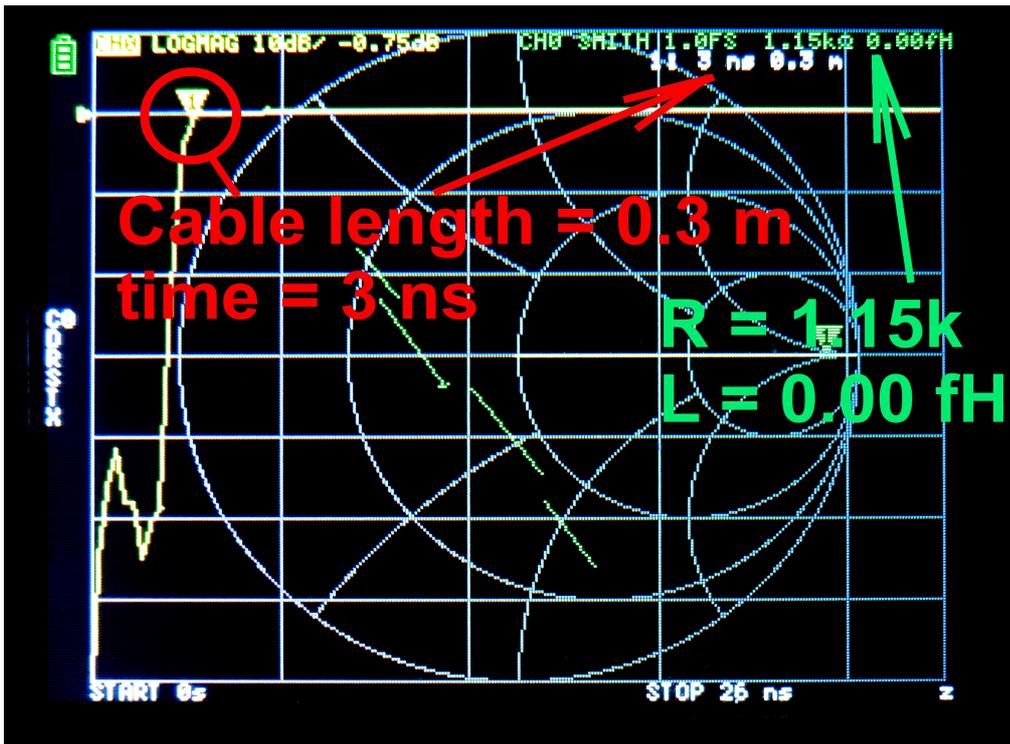




Step 7:  
 Screw off the adapter  
 and the test cable to see  
 whether the Reference  
 plane is now running  
 exactly through the  
 center of the male SMA  
 plug at the open Suhner  
 cable end!

It does....

## 28.2. Test Procedure for the NanoVNA-H2 (Low Pass Step Response)



Connect the adapter and the test cable again to the Suhner cable.

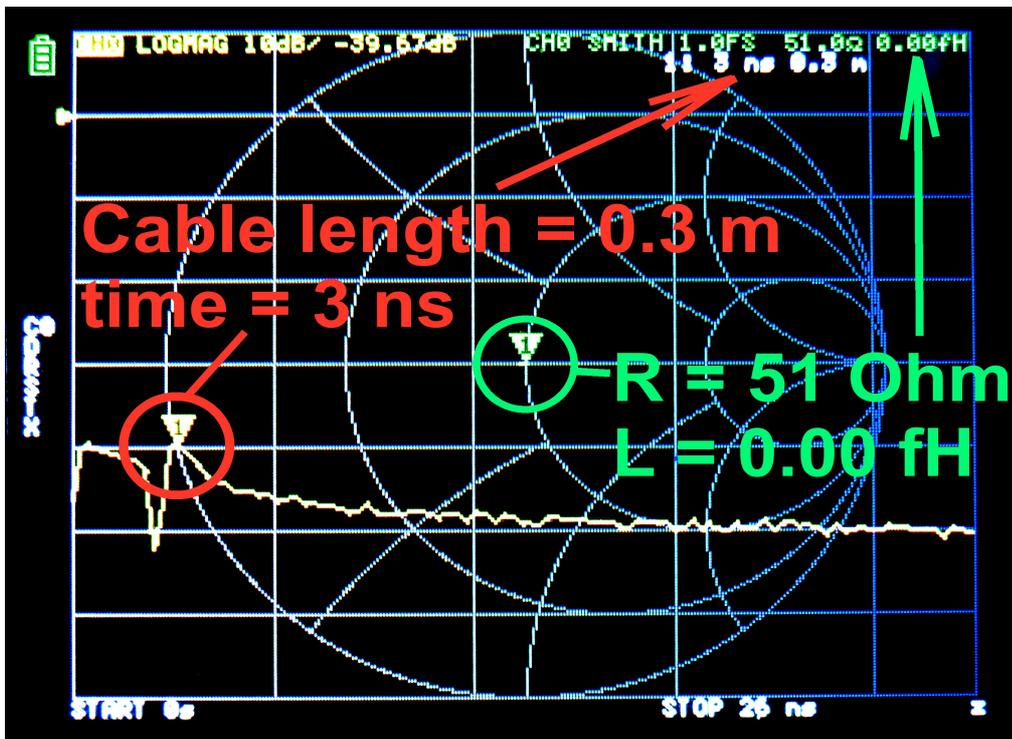
Open the TRACE menu and tab on „TRANSFORM“.

Choose now „LOW PASS STEP“

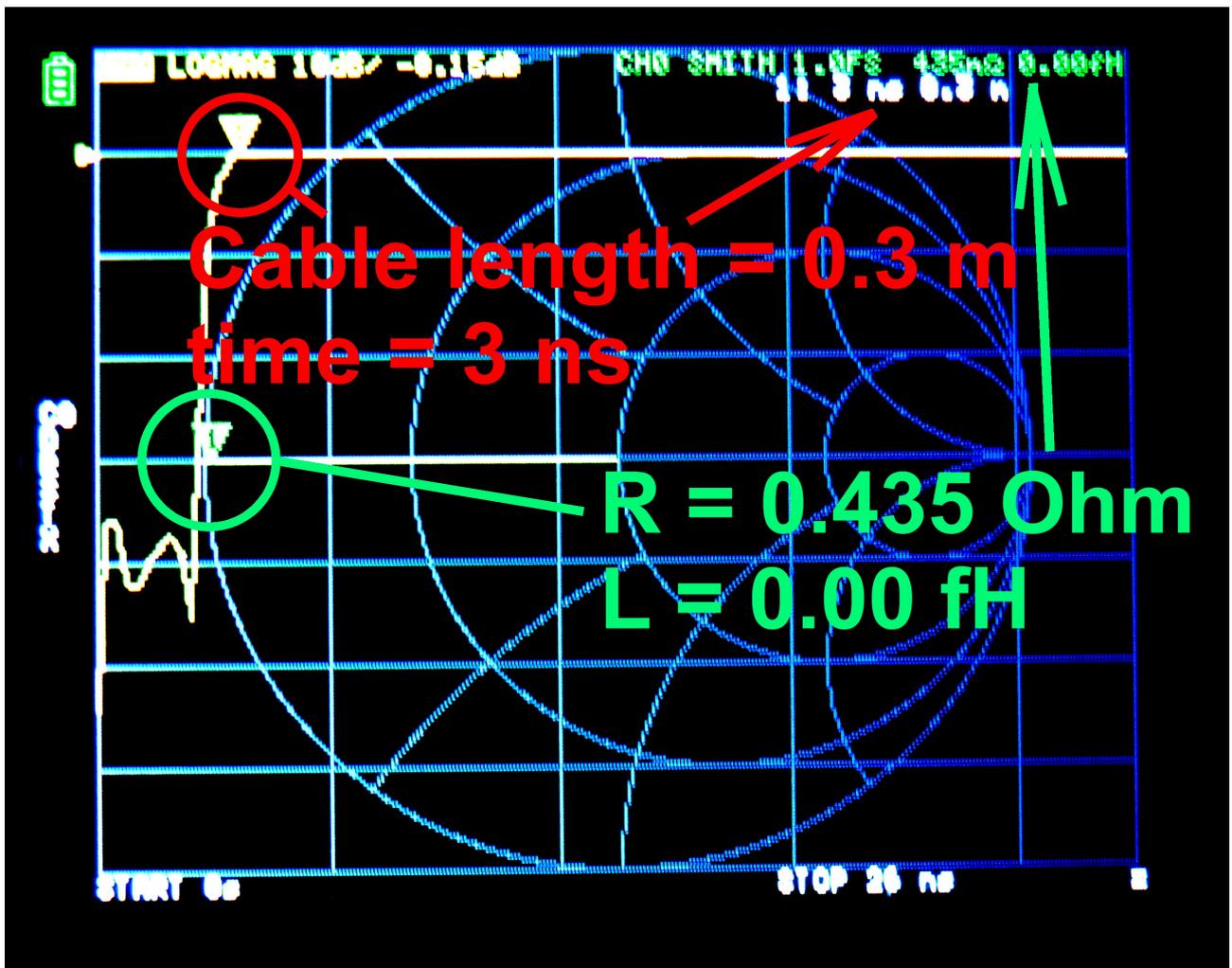
This is the same result als produced by a true Time Domain Reflektometer!

After 3 Nanoseconds (cable length = 30cm) the curve is jumping up to the „Open End Status“ with and open end impedance of 1.15kΩ (= green information at the upper edge of the screen)

And so the Step Response looks like if the end of the test cable is terminated by 50Ω:



:Finally: a short circuit at the end of teh test cable:



435mΩ at the cable's end.....this is really a short circuit.....

## 29. Conclusions (good / bad / changes ...)

It is great: a **small, handy device with sufficient accuracy** for practical use.

**Cheap price.**

**With a battery** very handy for 4 hours of outdoor measurements directly on antennas.

**Saves** up to three older 19 inch devices (like hp8410 / hp8745 / hp8620) on the work bench.

**High frequency stability** (0.5ppm). Absolute frequency accuracy approximately 2.5ppm

**With a USB connection and the free software (NanoVNA-saver v0.2.2.-1.exe)** from The Internet a PC can be used very comfortably to control the device and display the results on elaborate diagrams. It behaves like a big machine.

**Then comes "Well, yes ...."**

**Very small screen** with even smaller font size. Touch screen operation is not easy with a finger but better with a stylus. Better operation using the **H4 version (= display with 4.3 inch diagonal)** or a PC and the program "**NanoVNA-saver-version-v0.2.2-1.exe**".

**In standalone operation** there are **only 101 measuring points**: This makes measuring filters difficult so careful consideration is needed for the sweep range selected. (this is no longer a criticism when using a PC and the NanoVNA-saver software)

The **Micro USB C connector** on the board is **a bit wobbly** and at first mine was unreliable. It required rework but works now fine.

The **SMA cables** supplied had a **wide tolerance (52....54Ω instead of 50Ω)** and were **poorly crimped**. In fact one connector fell off! High quality Teflon cables or if necessary, Semirigid cables are recommended as replacements.

**Menu navigation using the NanoVNA screen** is now **significantly improved in comparison** to the cheap standard NanoVNA version. But using a PC and the NanoVNA-saver software is more comfortable....

The **Multi Function Switch (MFS)** is a somewhat delicate device and requires very gentle use.

**SOLT calibration data is not included with the purchase. This is now available for PC operation using the NanoVNA Saver software (thanks to Kurt Poulsen) as described in Part B).**