How to check the calibration and accuracy of the VNWA using the T-Check Software
1. **T-Check Software from R&S and how to install**
2. **How to generate S2P files from VNWA for use by T-Check Software from R&S**
3. **How to calibrate the VNWA and test the Calibration / Accuracy within VNWA**

The T-Check software from Rohde & Schwarz is freeware to use and thus allowed to upload to VNA/VNWA Yahoo forum's. this information received Januar 2010 from Rhode & Schwarz R&D Department in Denmark on Management level. Of course all right are reserved R&S and for personal use.

The whole purpose of using C-Check is to control how good your SOL standards are and how accurate they are reflected in the Settings/Calibration Kit and provided the SMA Tee Adapter and testcables are loosless then the result will reflect the quality of the VNWA, both with respect to Source impedance of the TX port and the input impedance of the RX port, and also with respect to performance of the calibration procedure (Full 5,6 or 12 term corrections) for the software.

In addition the T-Check software is a nice tool as a supplement to the VMWA software, which can perform the same function – See later how – and has the benefit of indication for quality, by colour bands, like **Good** (0- 10%) – **OK** (10-15%) – **Poor** (15-25%) of the accuracy on the readout.

An Rohde & Schwarz Application note no 1EZ43_OE with the Title
T-Check Accuracy Test for Vestor Network Analyzers Utilizing a Tee-junction
provides the theoretical background.

T-Check Software from R&S and how to install:

In the following is a small guide how to install and use the Software:

The content of uploaded zip file named T-Check_HD_Install.zip is contaning a floder of same name which is installed on the harddisk in the C Root or in your Download folder. By opening the folder T-Check_HD-Install folderand by clicking on the Setup.exe the program will be installed.
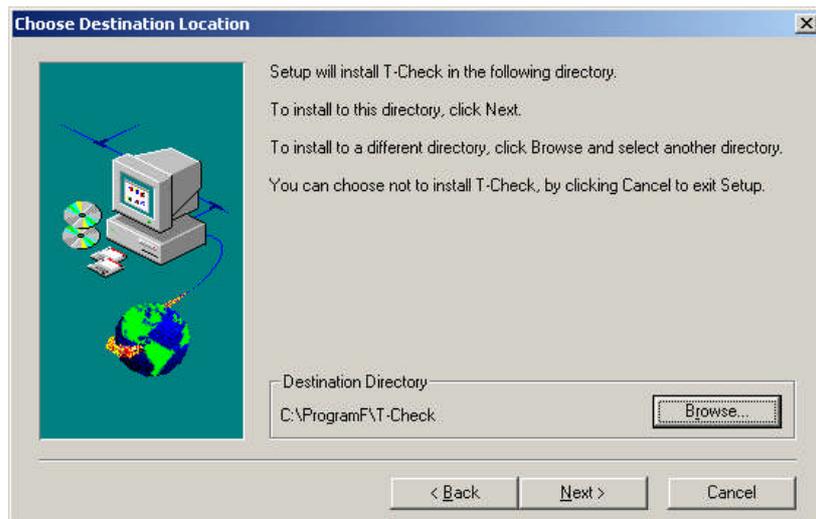
Please note you might change the install folder by clicking om Browse to e.g. C:\T-Check as shown below
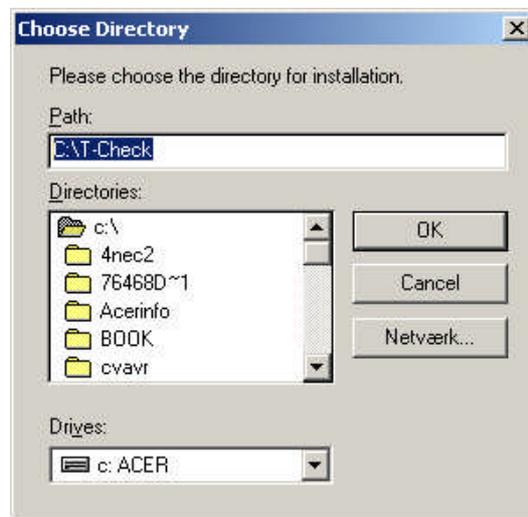
In above folder where the program is installed you can find two files which is able to create two floppy disks for installation of T-Check on a computer using the floppy drive. These files are called TC_Disk1 and TC_Disk2.

By double click on TC_Disk1 following window pops up and change the Folder description to A:\ as shown below and click on Unzip and the first floppy disk will be created.

Just mark the test in the Fiels and write a new Path

Perform same procedure for the TC_Disk2 file, generating the second floppy disk.

How to generate S2P files from VNWA for use by T-Check Software from R&S

To ensure proper scaling of the frequency range the Units for frequency range within VNWA must be defined as Hz. Below example is for the range of 1KHz to 500MHz used for below examples of the calibration/test of VNWA accuracy.
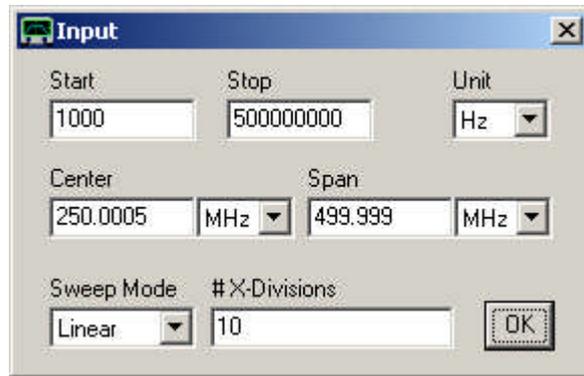
To store a S2P file, which R&S T-Check can read, Select **File/Export Data/S2P/dB-Phase**
Carefully note: use only dB-Phase
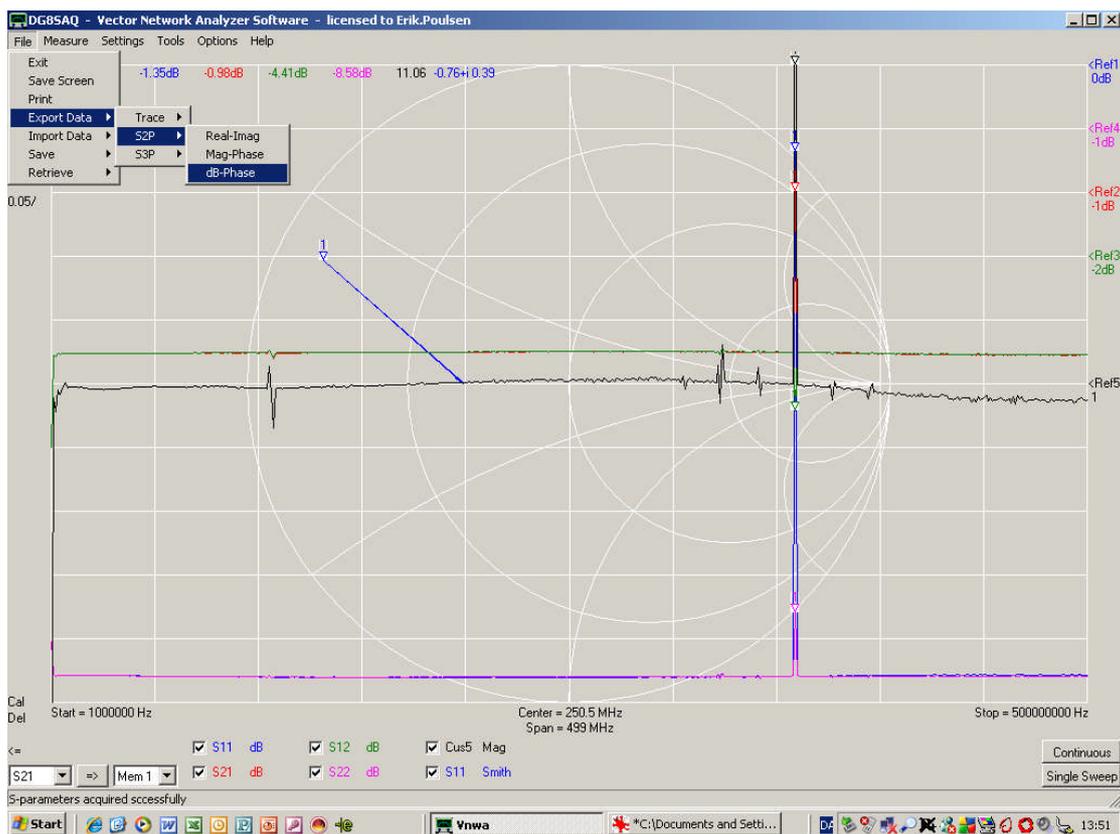
Enter a file name e.g. Final_Test as shown below, in a folder of you choice, for the Exported S2P file and click on Save.
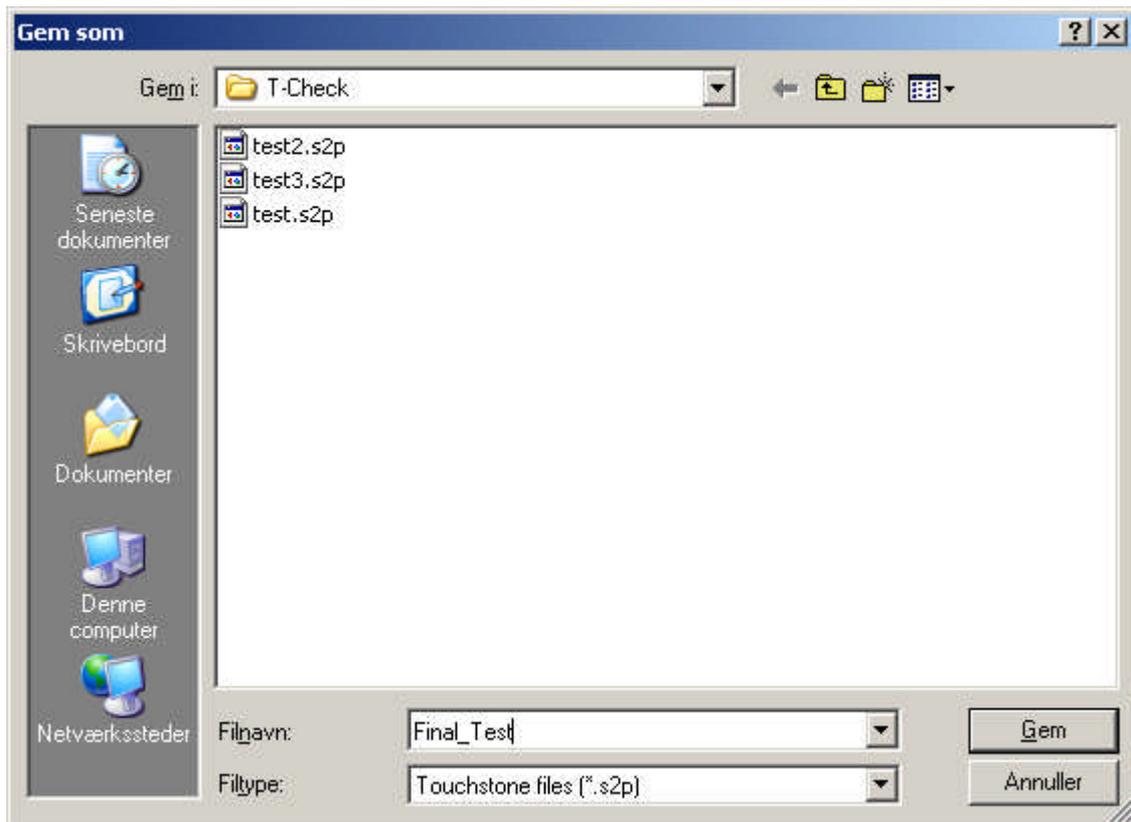
When staring the T-Check Software following warning is shown before program starts.
It clarly point out that a fresh calibration is recommended for the VNWA/VNA in question.

After the T-Check window is shown select file/Open a Touchstone *.S2P file
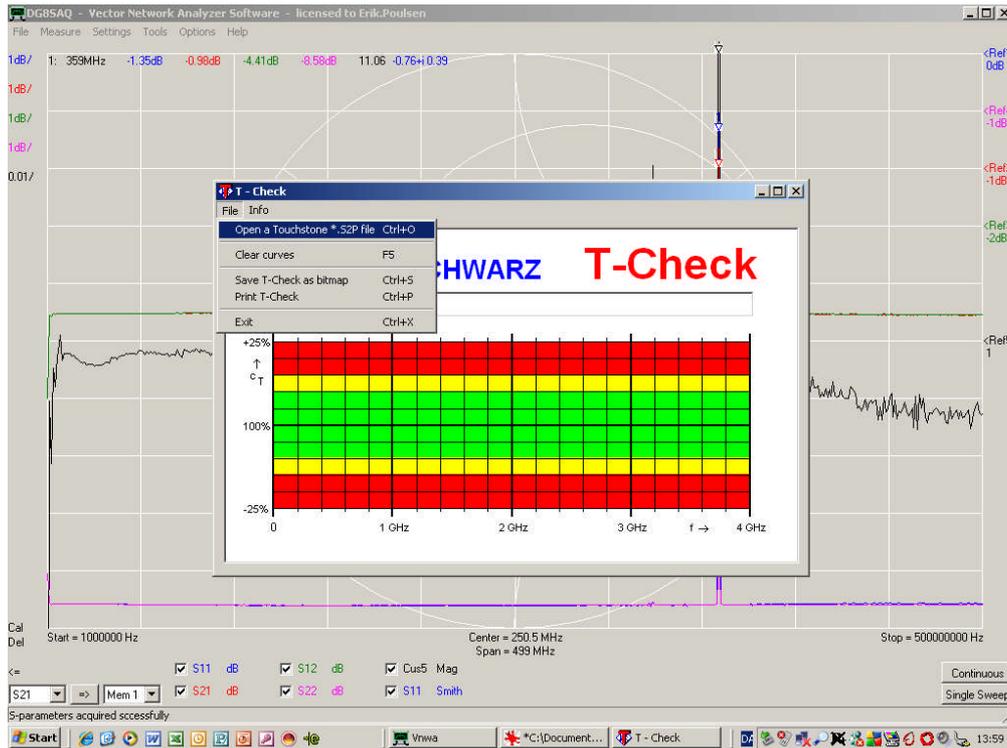
Find the S2P file you have stored and note that these files are limited to 8 characters which is worth remembering when storing the file and create short but descriptive file names within this limitation.
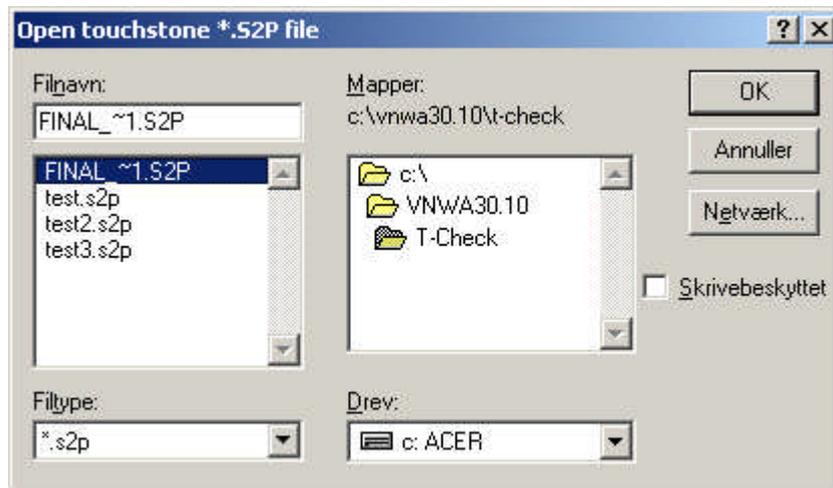
Below is the super fine result obtained by the procedure to follow later. Accuracy below 2% for the VNWA from 1 KHz to 500MHz. It is advicable to start with this frequnecy range to avoid the spikes from 500 to 1300 MHz until your are "an expert" doing the calibrations and test.
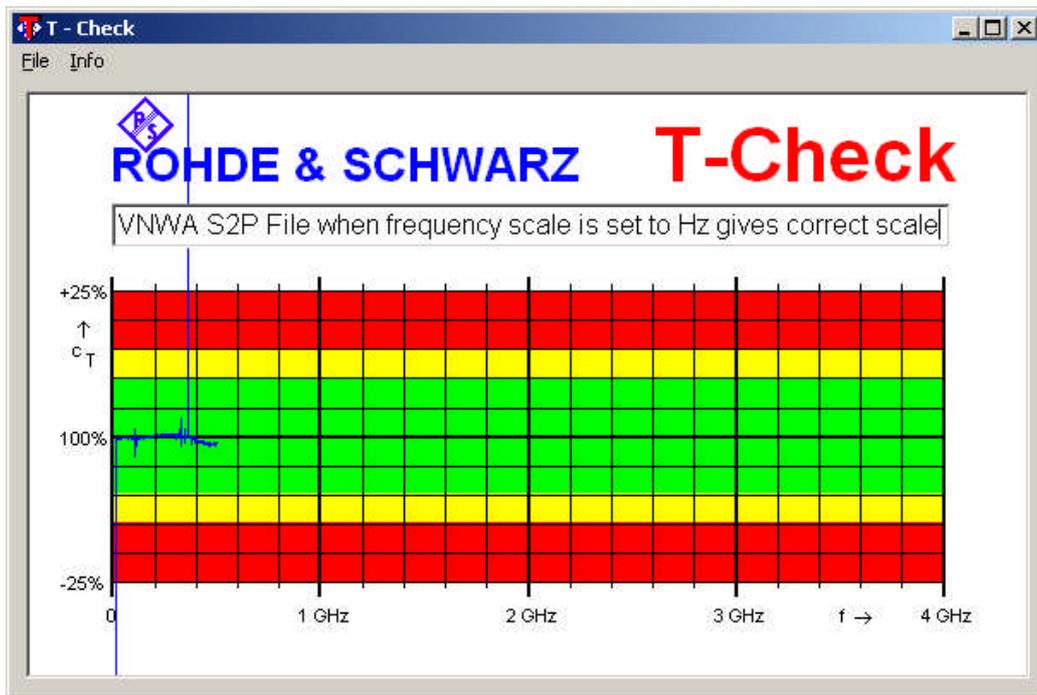
If you had used KHz as unit for the Frequancy range of VNWA below display would had been shown
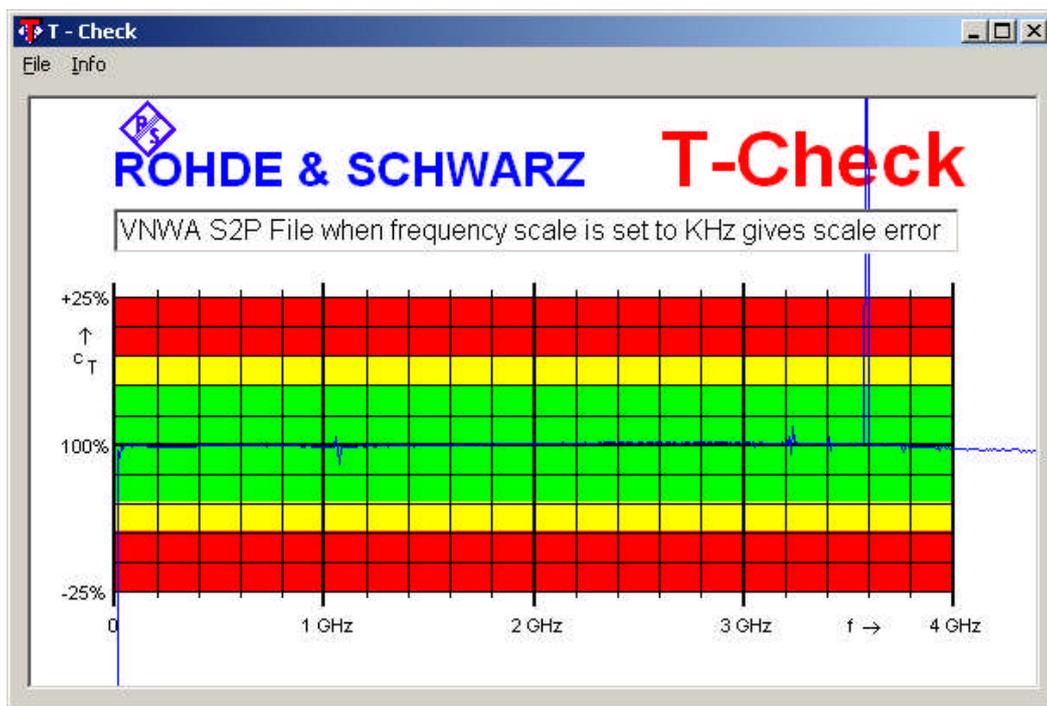
Wrong READOUT

However I will show the Final results obtained from 1KHz til 1300MHz to indicate that that it might be worthwhile to read on how to optimize your skills.
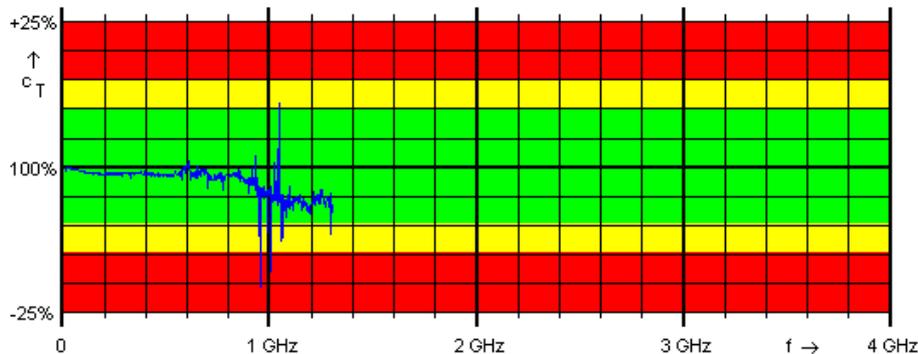
5% accuracy up to 1 GHz and better than 7% from 1 to 1.3GHz is not to bad for the VNWA.

There was many step to this result which involved:

1. Measuring the LOAD resistor with highest possible accuracy

2. Finding the method how to best optimize the SHORT delay in pS and The parrallel capacity of the Load

3. Learning that characteristic impedance an lenght of the Semi Rigid Cable used for point 2 adjustments alsois influencing the parameters quite much

4. Learning that Port extension is quite also important to use to optimize the S parameters measured and to compensate for the shift of Refence plane in the SMA Tee adaptor.

5. Learning that purchase of a fully symmetrical SMA Tee adaptor is highly adviceable

6. Learning that purchaseof a professional SMA LOAD OPEN and SHORT removes a lot of worries

7. Learning the using a 10dB in line SMA attenuator on the RX Port really improves the performance of the VNWA with respect to meauring accuracy. The payoff is 10dB less dynamic range but the Accuray in general for S11 measurement more accurate attennuation measurements, better SWR measurement and so on is obtained. This is mostly because the input inpedance of the RX port is much closer to 50 ohm over the entire frequency range.

8. Use of good quality and short test cables is very important and renew them as soon of the SMA connector are worn out. (I had to change min during these test)
……. Despite my happyness I am convinced there is more to learn and improve. Next step is to have my references measured on a professional VNA.

How to calibrate the VNWA and test the Calibration / Accuracy within VNWA

To top tune the VNWA is is important to have pretty god Open, Short and Load SMA standards to be able to perform good OSL calibration. Is is also recommendable to invest in a good quality SMA Tee and to have short testcables of low loss quality. Below is a picture of the SMA OSL standards and SMA Tee in addition to test cable used for the calibration/Test performed in below description.

The left SMA 12.7 mm Female-Female Adaptor is used for SOL calibration and for connecting the two test cables during Thru calibration. The Right 22.1 mm SMA Female-Female Adaptor is used for finding the delay pr. mm of such an adapter by comparitive measurements with the 12.7mm Adaptor 3.2 pS/mm(se later).

The symmetical 19.2mm SMA Tee Adaptor, used for T-Check together with 50 ohm Load is connecting the testcables instead of the 12,7 mm SMA FF Adaptor. Thus the reference plane for the 50 Load mounted on the angled part of the SMA Tee Adaptor is in the center – not far away from the SOL reference plane, about half lenght of the Tee = 9.6mm. This knowledge is used to adjsut the Thru Delay and bring the phase angle

to zero of the combined 25 ohm load consisting of the the 50 ohm load in the Tee and the 50 ohm input impedance of the RX port.

It is recommended as the first step to measure the resistanse of the load which in my case was done by comparison to two 0.1% 100ohm SMD resistors (gently) soldered together. A 4 wire Thevenin bridge would be the best, but a DMM with good resolution (0.01 ohm) and remembering to subtract the shorted testlead resistance is an accesptable method. Just measure the parralleded 2x 0.1% 100 ohm resistors, subtract the testlead resistance and do a simular measurement of the Load and do a calculation assuming the 0.1% resistors are exact 50 ohm. Alternative connect the reference resistor in series with a SMA connector holding the load and mesure with a DVM the voltage across the reference resistor directly on the terminals and the voltage across the SMA connector, applying a small testcurrent about 10mA and do a calculation of the resistance of the LOAD, as the voltages are proportional to the voltages.

Before calibration setting are performed set the **Setting/Sweep** values.
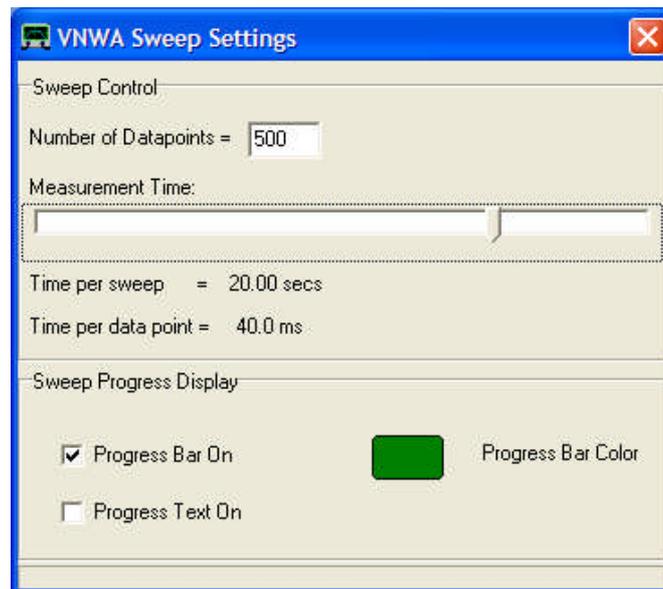
I have used 500 points and Time per datapoint of 40.0m,S giving a sweep of 20 second.
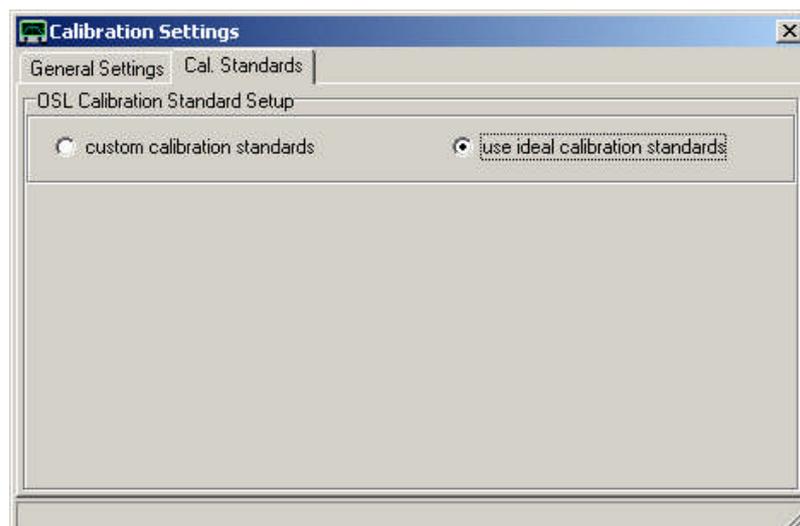
First of all, although not needed, run a calibration with the ideal calibration standard setting as shown above
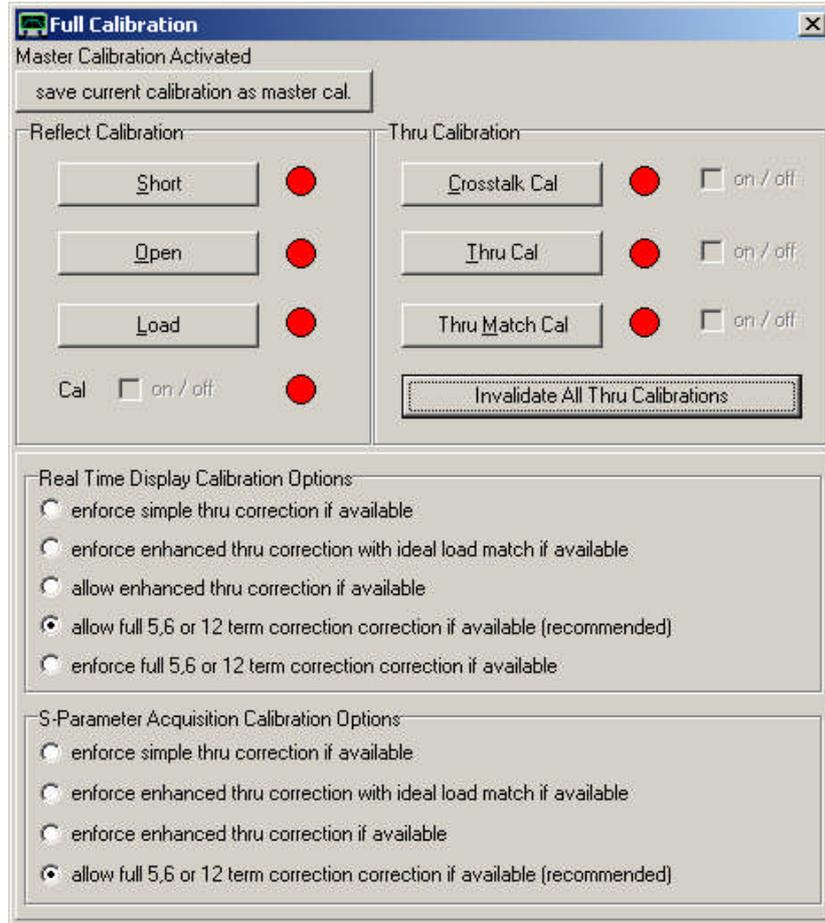
Use only the recommended settings as shown above (advice from Tom DG8SAQ)
and run the complete calibration apart from Crosstalk Cal, which you afterwards might control by a running
4 single sweeps for SOL and Thru, just to make sure everything is working OK.
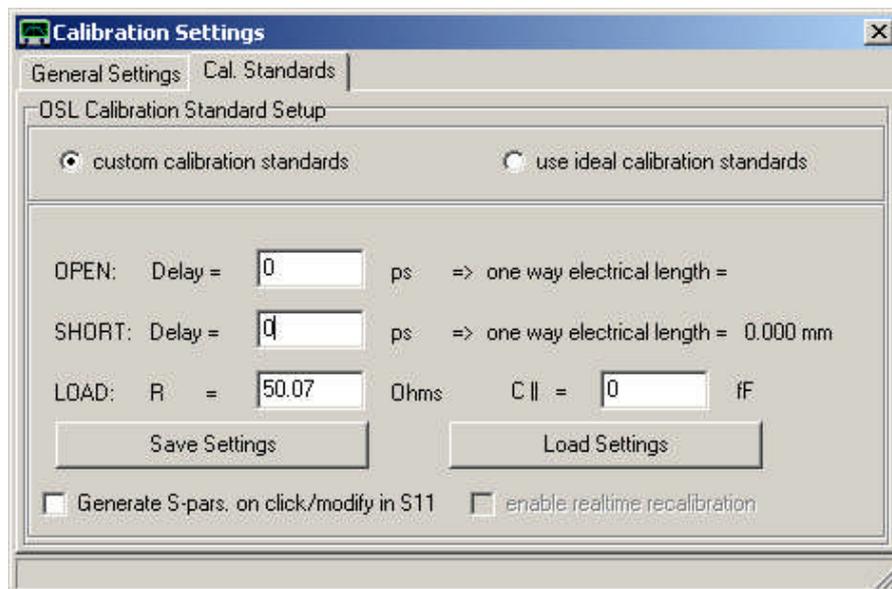
Enter the accurate measured resistance of the LOAD (I was lucky 1 out of 4 was 50 ohm)
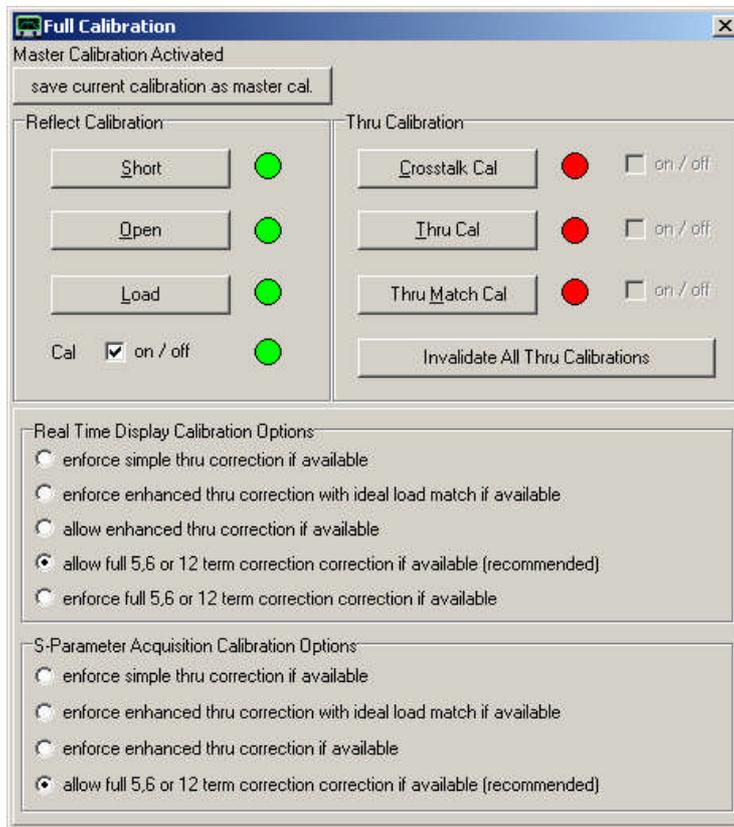
Run a new calibration for SOL
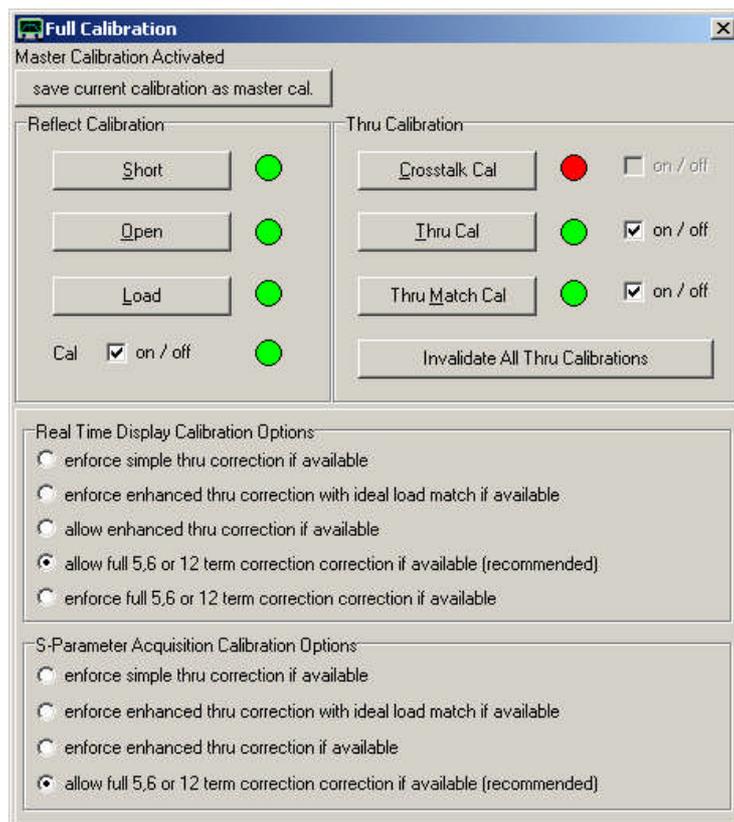
And run also the Thru Cal and Thru Match Cal procedure(not the Crosstalk Cal)
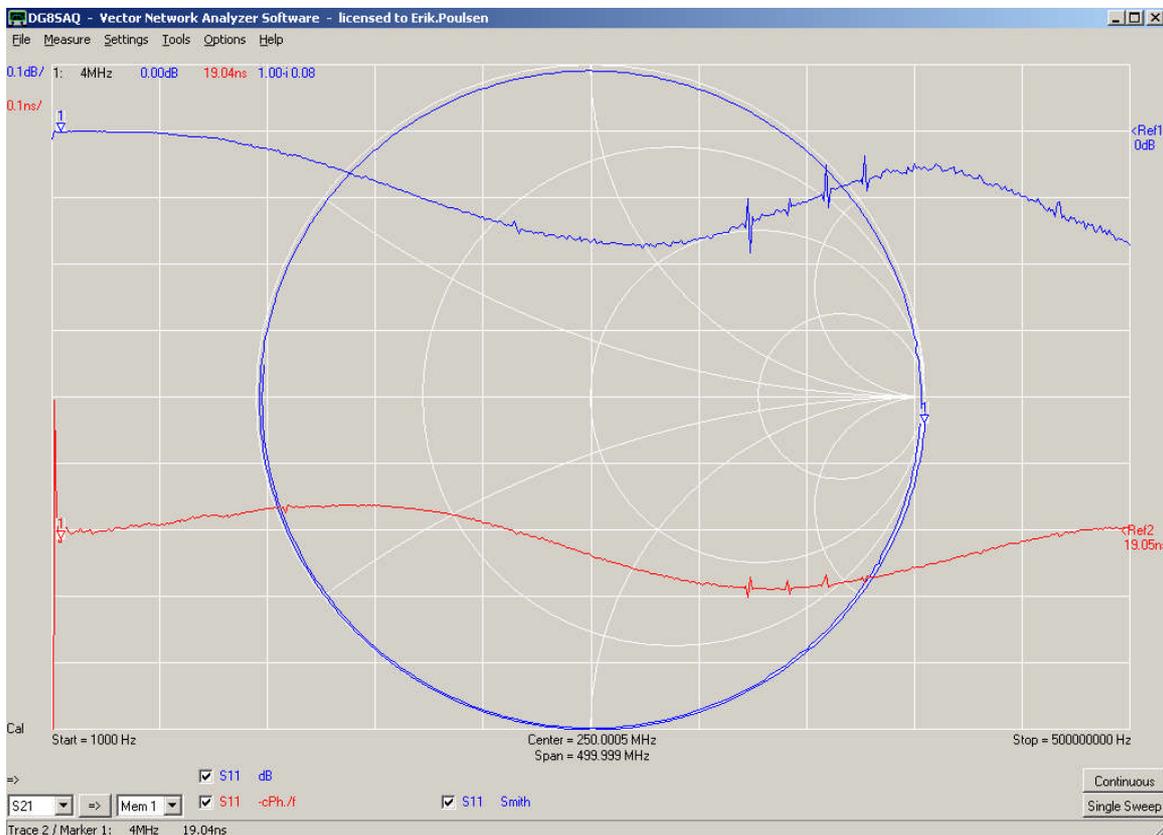
Run a S11 /Smith Card sweep on a 30 cm long open Semi Rigid Cable.
Scale Trace 1 as S11 and dB with 0.1dB/division- Reference Level 0dB and Reference Position 9.
. Scale Trace 2 as S11 and –cont.Phase/f with 0.1nS/division- Reference Level set to the level measured
with a frequenncy marker close to 1KHz (see picture) and set Reference Position to 3.
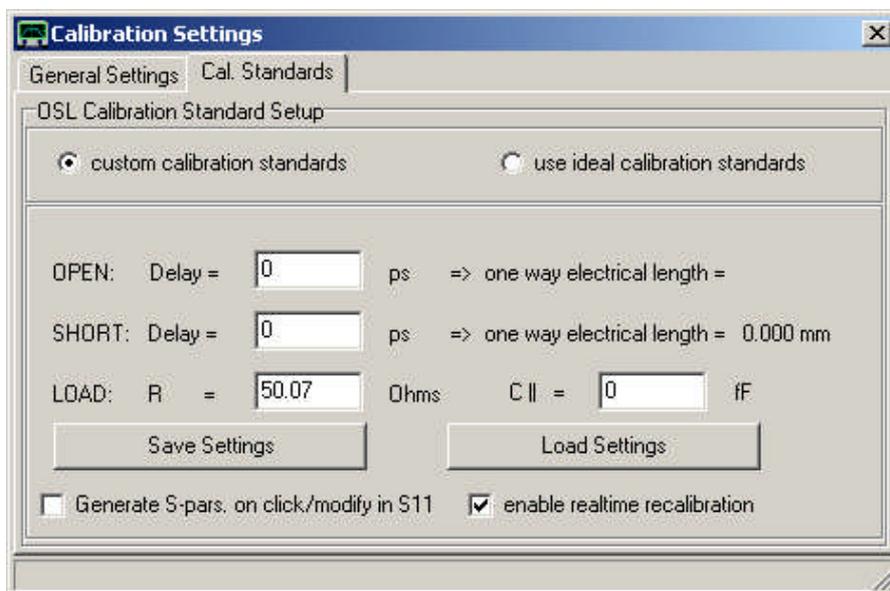
Now select Settings/Calibrations Kit and tune Short delay by marking the field and scroll up and down the
values with your mouse scroll wheel or enter values with the keyboard.
Remember to set the tickmark for "enable realtime recalibration".
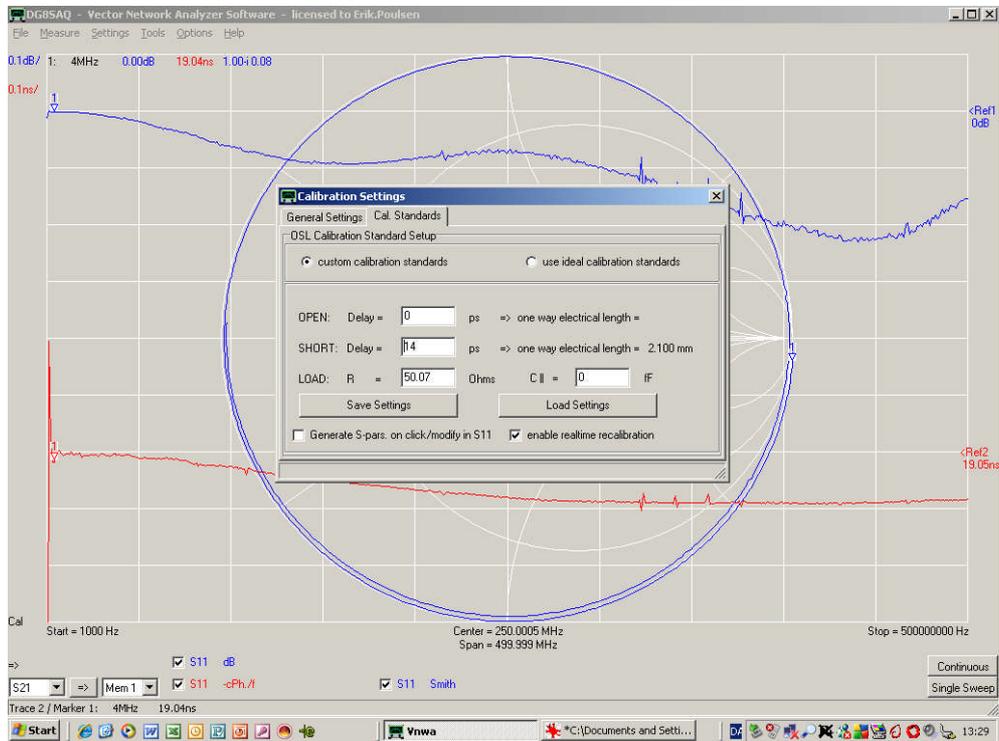
Now adjust observe the –cPh/f only (red curve) and select the SHORT Delay value which gives the smoothest trace/minimum Riple (forget about the S11 dB)
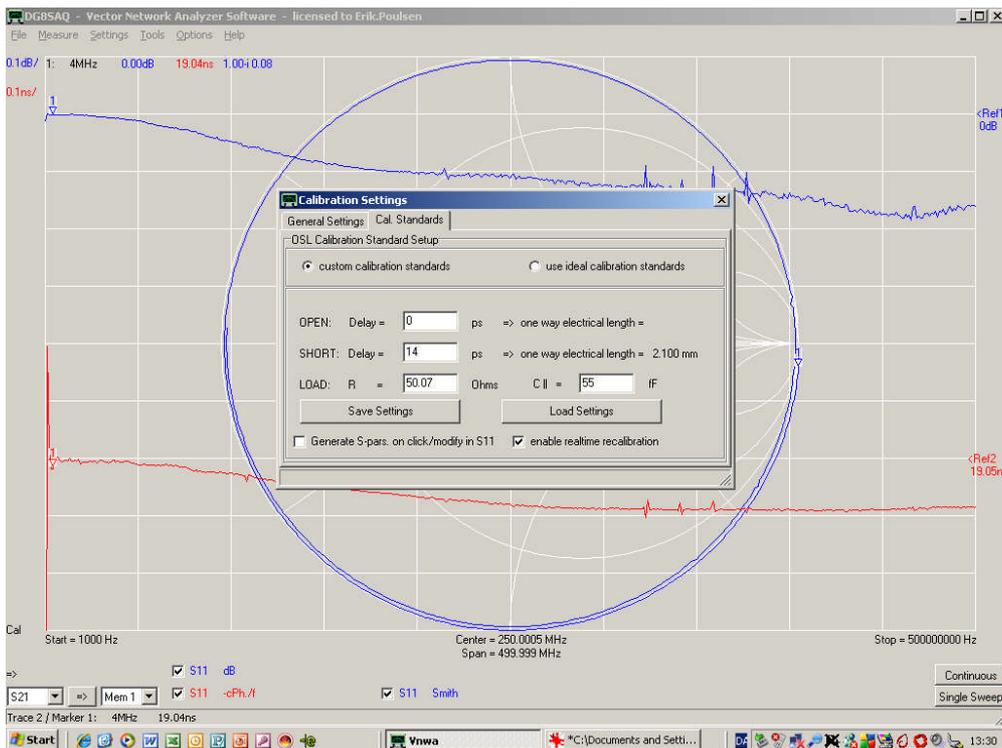
Now adjust the C|| for the LOAD until smoothest trace/minimum Riple for S11 dB (the blue trace)
Now remove the Tickmark for "enable realtime recalibration" and close the window.

NB! **RUN A NEW COMPLETE CALIBRATION ROUTINE AND SAVE THE CALIBRATION SETTINGS**

Now prepare the system for Running a T-Check using the VNWA facility

Find your SMA Tee Adaptor and pepare the Display Settings as shown on next page and perform the Trace Setting/Scaling as follows:

Trace 1   S11   1dB/Div   Reference level 0dB   Reference Position 10

Trace 2   S21   1dB/Div   Reference level -1dB   Reference Position 8

Trace 3   S12   1dB/Div   Reference level -2dB   Reference Position 7

Trace 4   S22   1dB/Div   Reference level -1dB   Reference Position 9

Trace 5   Cus5 Mag   0.05/Div   Reference level 1   Reference postion 5

Connect the Test Cables with the SMA Tee adaptor with the LOAD connected to the 90 degree part.
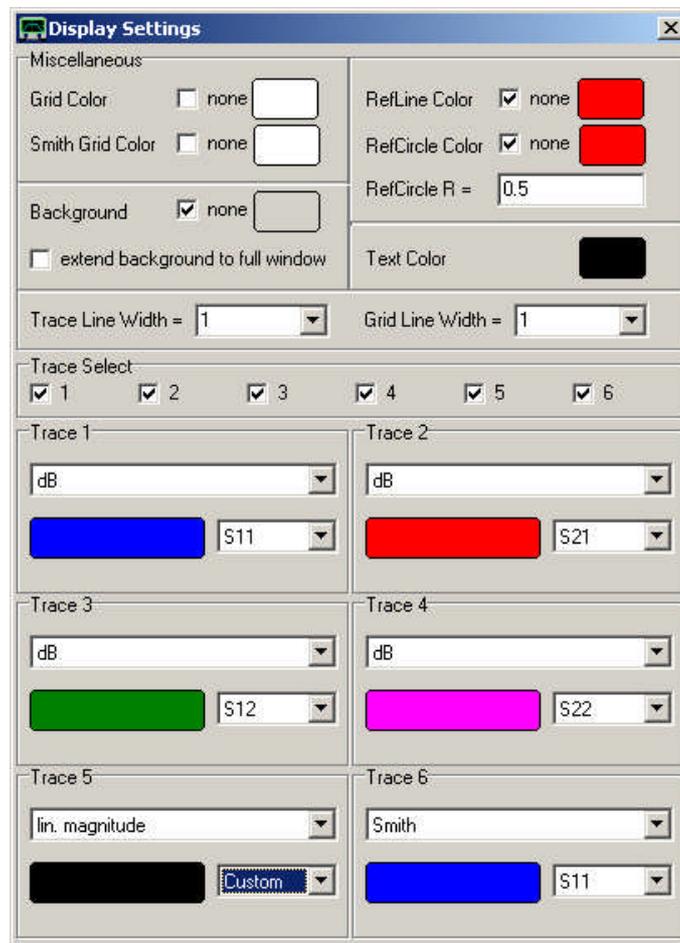
Change the Display setting as follows and **remark the Trace 5 Setting** and close the windows

Dubleclick in the windows on Trace Cus5 Mag to open below window
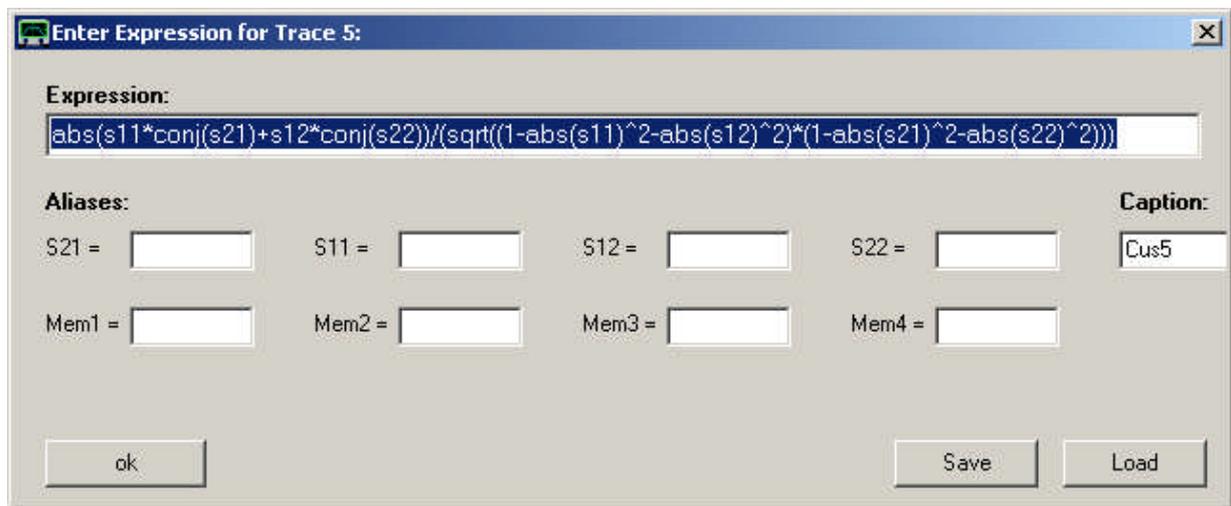
Enter the following T-Check Expression in the fiels as shown. You may mark and copy/paste from below

abs(s11*conj(s21)+s12*conj(s22))/(sqrt((1-abs(s11)^2-abs(s12)^2)*(1-abs(s21)^2-abs(s22)^2)))

Formula provided by Tom DG8SAQ
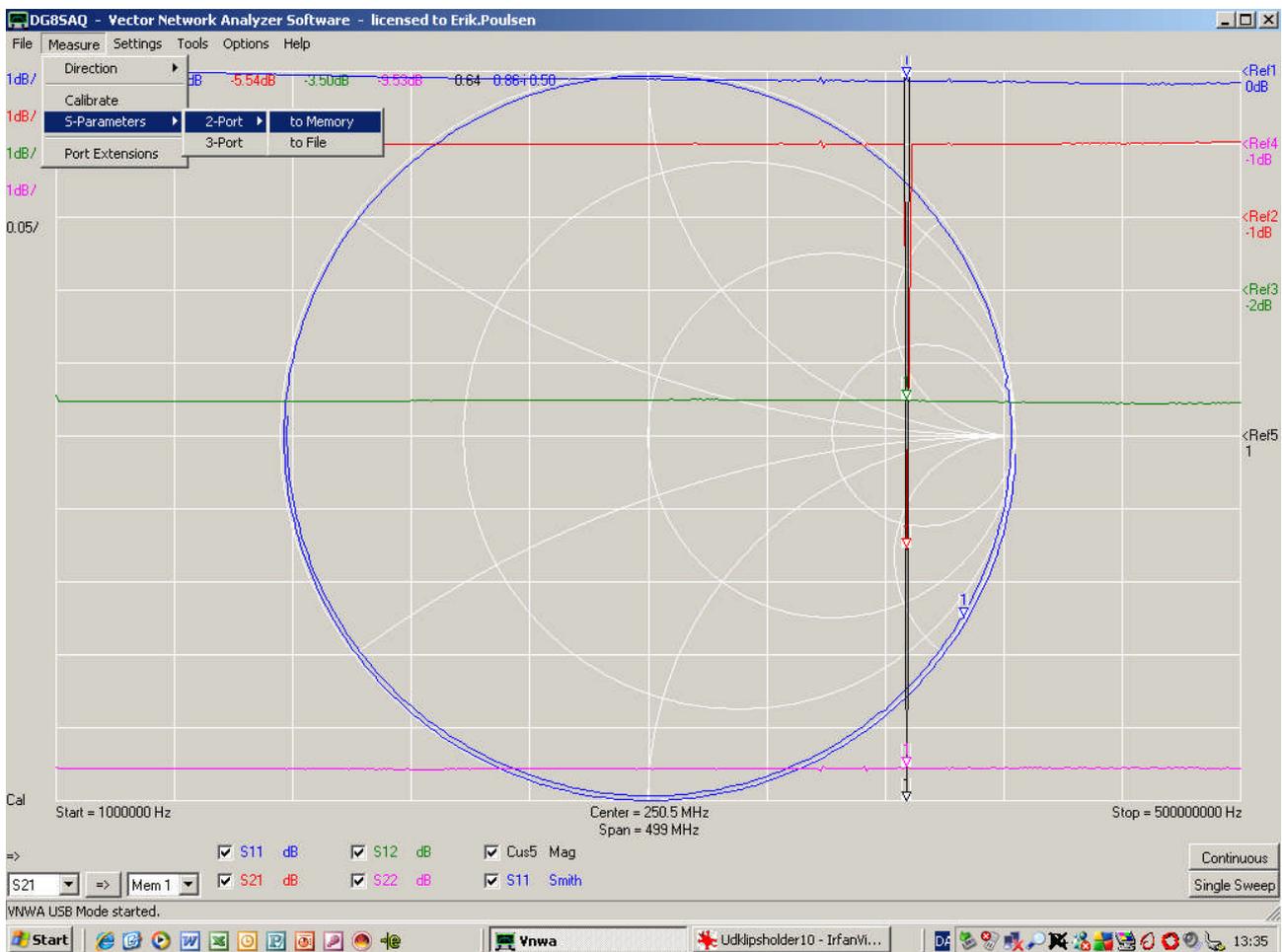
Now run a full bidirectional Sweep by selecting Meaure/S-Parameters/2-Port/to Memory and follow the instructions.
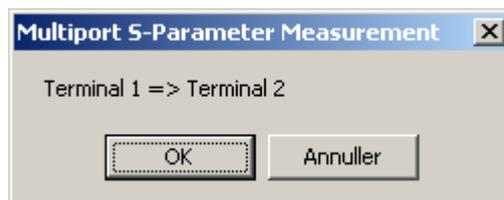
First run the forward S11 – S21 test
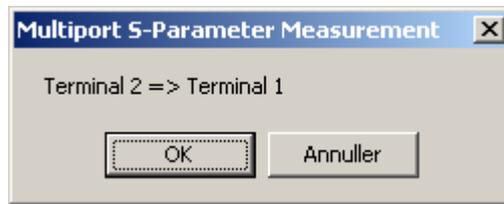
When this prompt is shown reverse the SMA Tee adaptor between the Testcables for the Reverse run meaning measurement of S21 and S22. However you might have a SMA Tee adaptor which is totally symmetrical, then there will be no difference whether you revert the Tee Adaptor or not. Do you own test!!
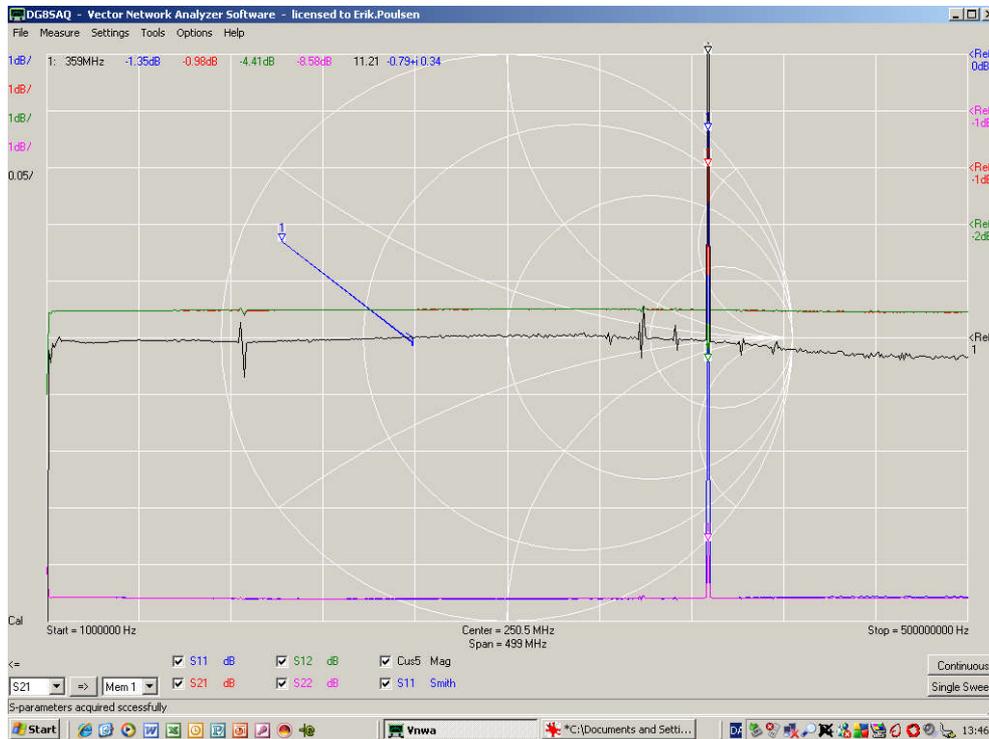
The T-Check trace 5, with 0.05 setting (5% / div) shows fine result but on the Smith Chart the 25 ohm point is not exactly on the horizontal line (zero Phase). Open the Measure/Port Extensions and set the tick mark Ext. On as shown below
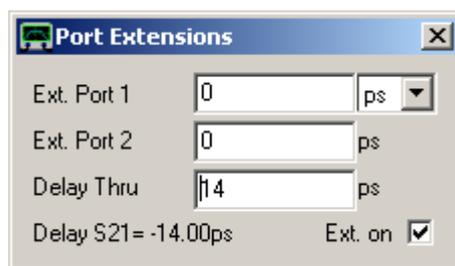
Now trim the Delay Thru (here to 14 ps) until the 25 ohm plot on the Smith Chart is on the horizontal line **which moves the Referens plane for the T Center to the SOL Reference Plane.**
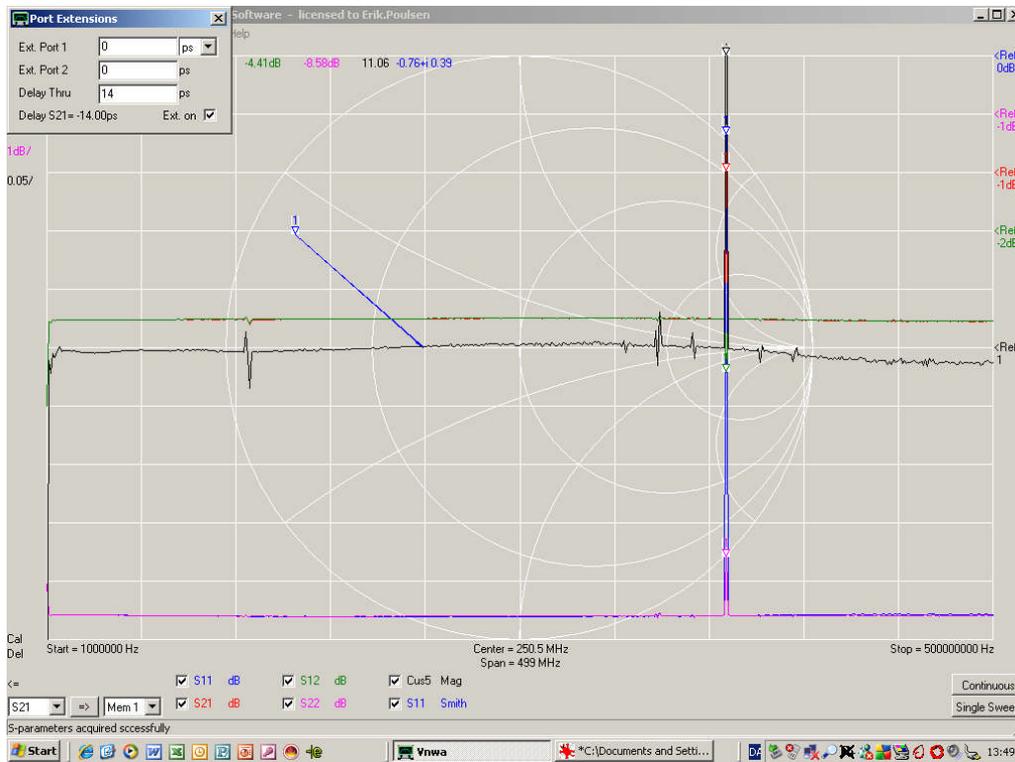
While the Port Extension is still active (Tick mark Set to on for Ext. On) save the S2P file for the S11,S21,S12,S22 by selecting File/Export Data/S2P/dB-Phase anf provide a file name desribing the T-Check.
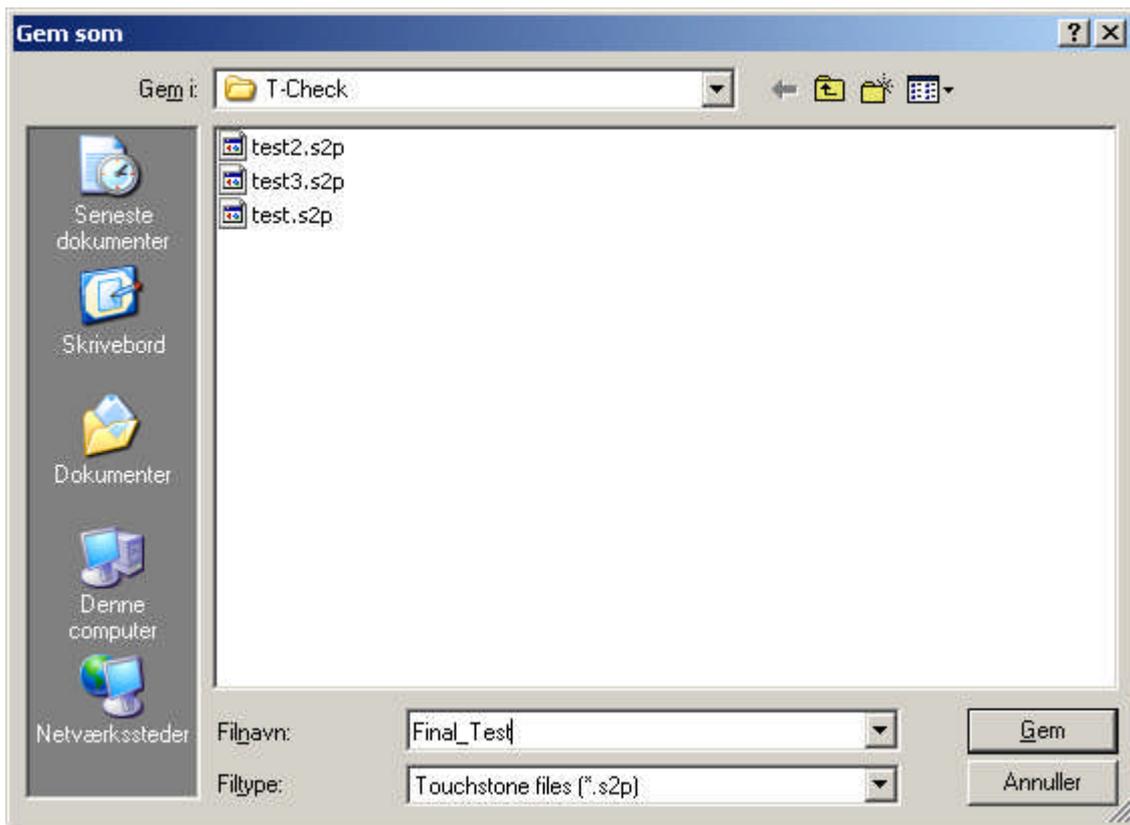
This file can be read out by R&S T.Check Software provided you **remember to set the Unit for frequency range to Hz.**

Setting the Cus5 Mag display setting to 0.01/Div (1 % / division) proofs that an accuracy of 1% is obtained.
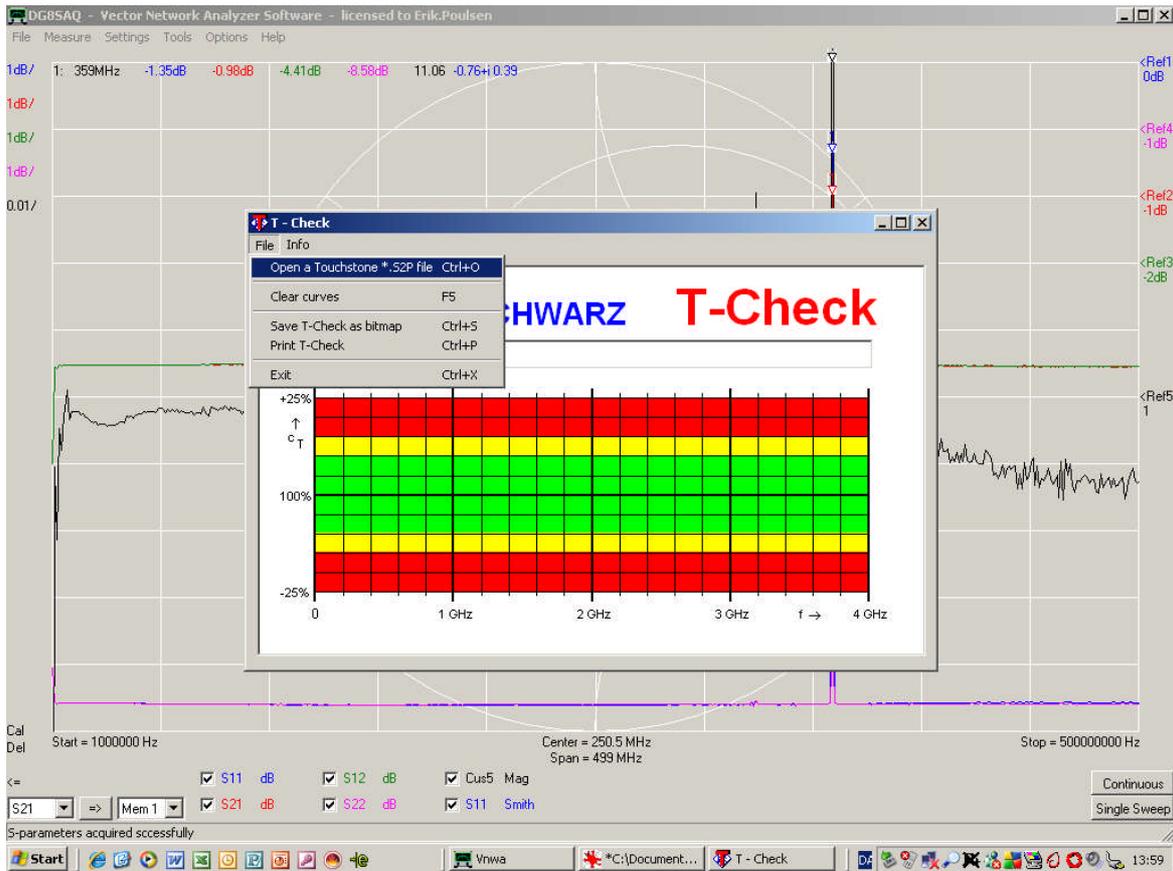
Start R&S T-Check and open the jsut stored S2P file
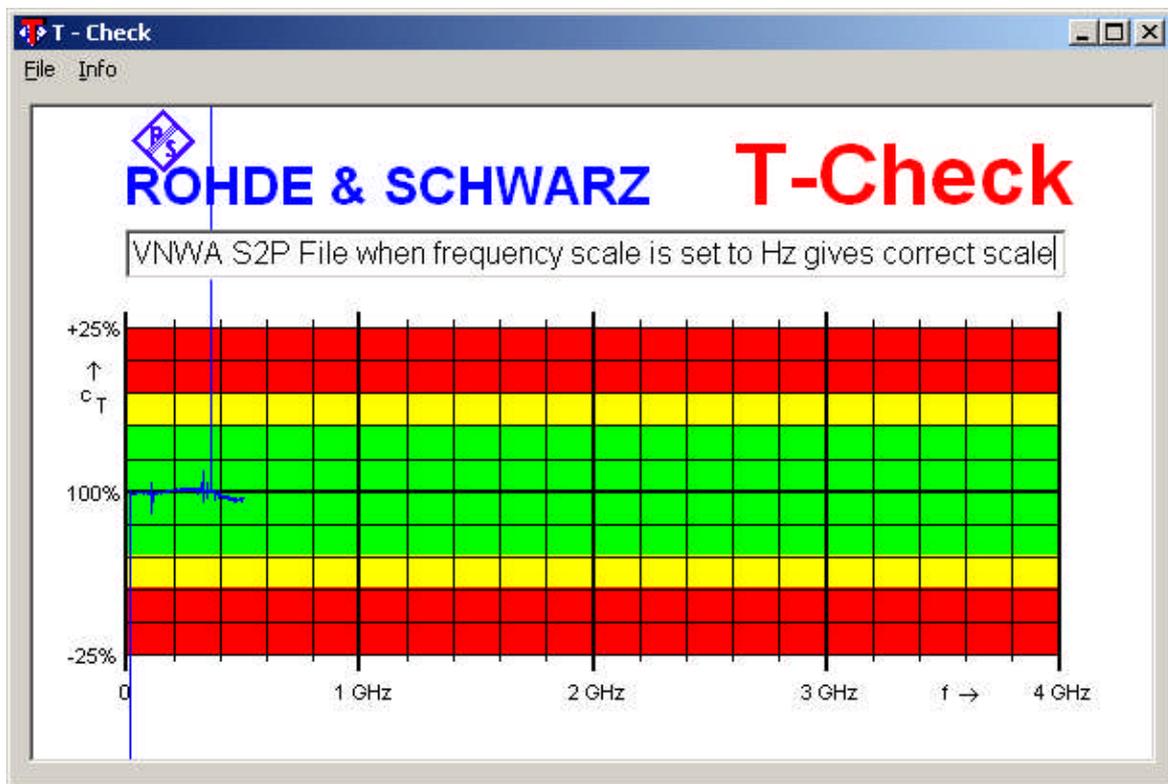
A super accurate VNWA up to 500MHz is proven !!!
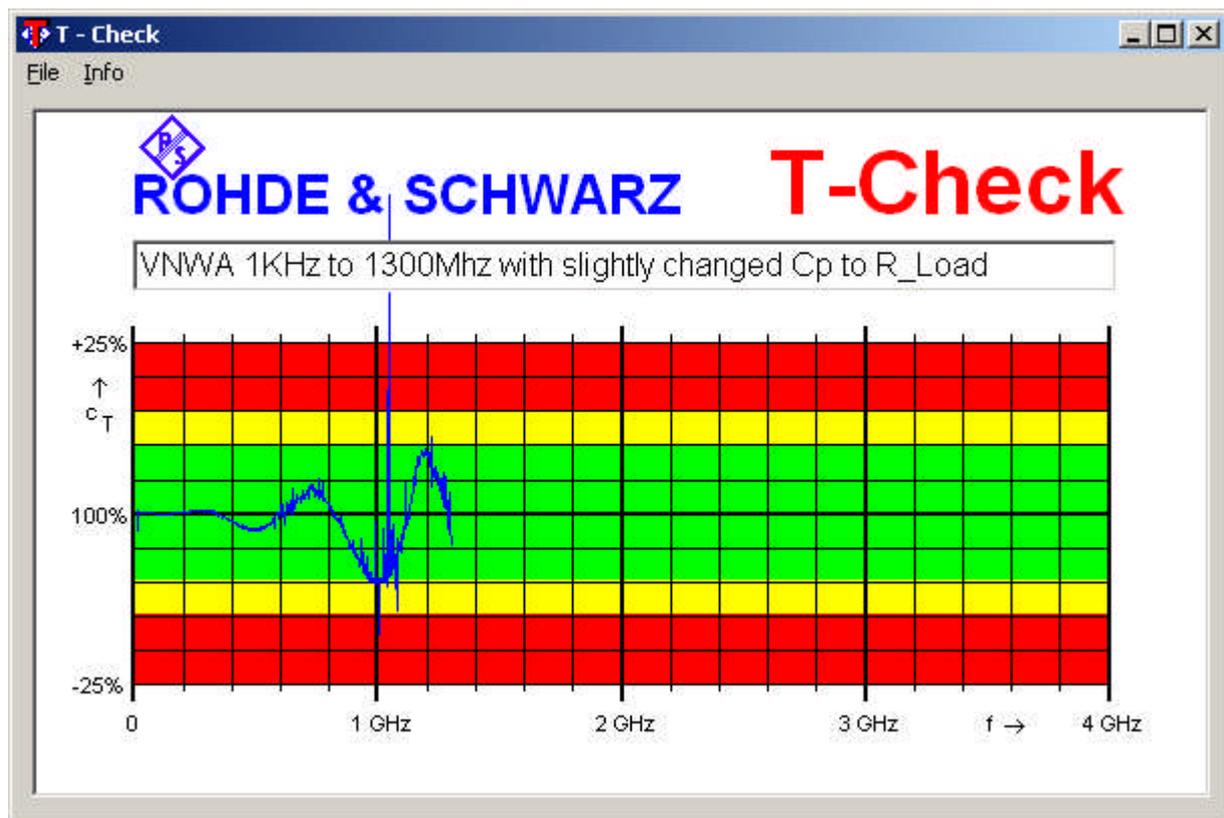
A quick change of the frequncy scale from 1kHz to 1300MHZ and 1300MHz and a new full calibration shown that the VNWA is still with in +- 10% (the green band) but let us chase some improvements. !!!

A new S11 run of the 30cm Semi Rigid Cable and subsequent adjustment indicated a different C|| for the LOAD from 25 to 95fF. The T-Check just still within the 10% and porer below 500MHz
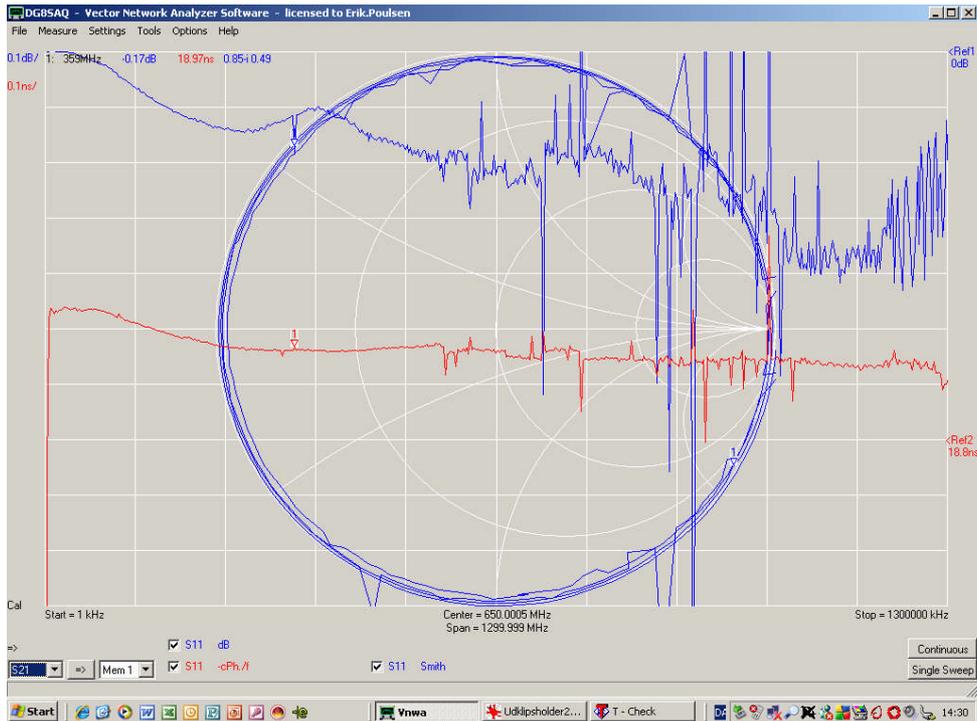
Using a shorter(15 cm) Semi Rigid Cable from another Manufacturer the number of "revolutions" in the Smith Chart is fever and SHORT Delay is now 9pS and the C|| for the LOAD is only 15fP and we see aa much flatter curve for the –cPH/f trace.

After these adjustment of C|| a new calibration is run and the adjustment checked
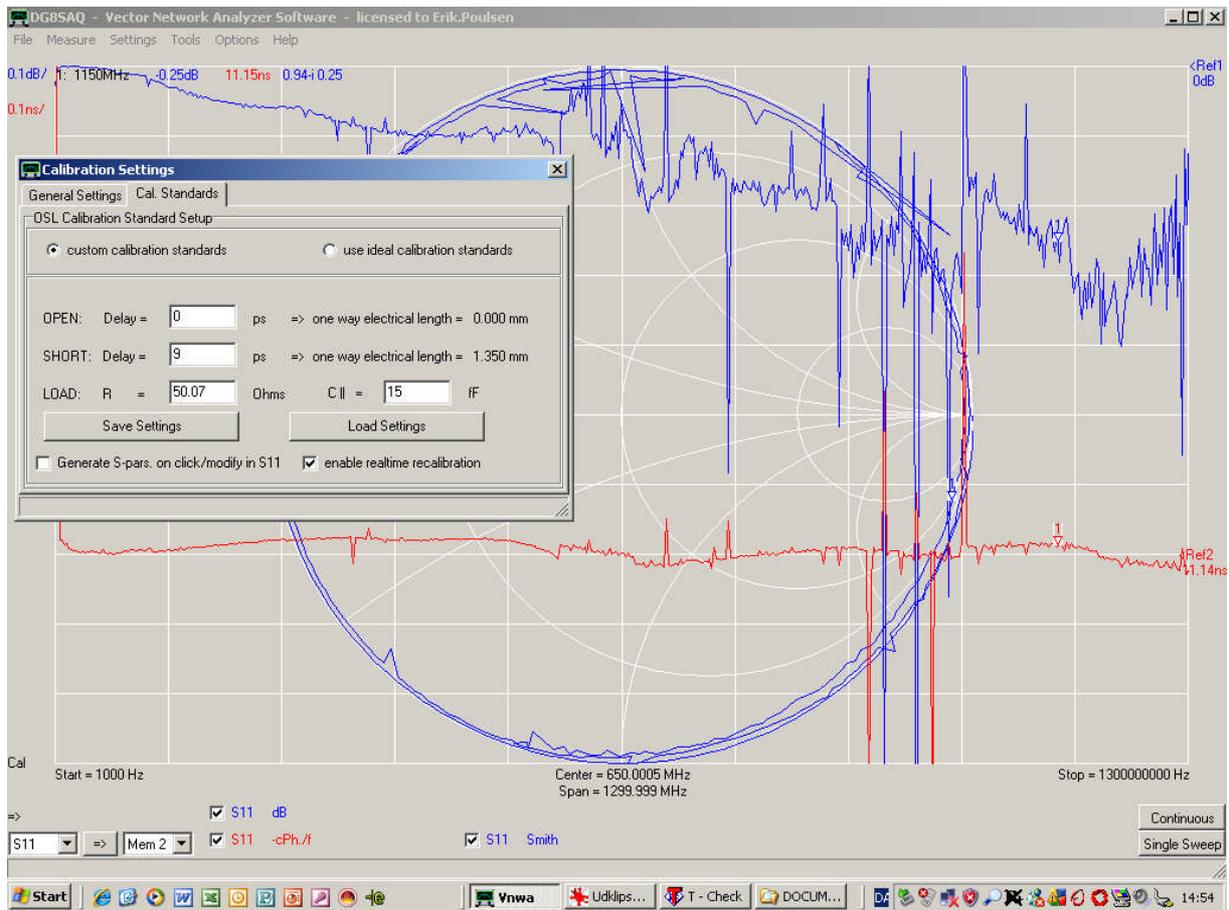
By introducing a 10 dB SMA inline attennuator directly connected to the RX Port (se previous picture af the setup) a condiderable improvement is obtained.

7 % accuracy before trimming the Thru delay is obtained
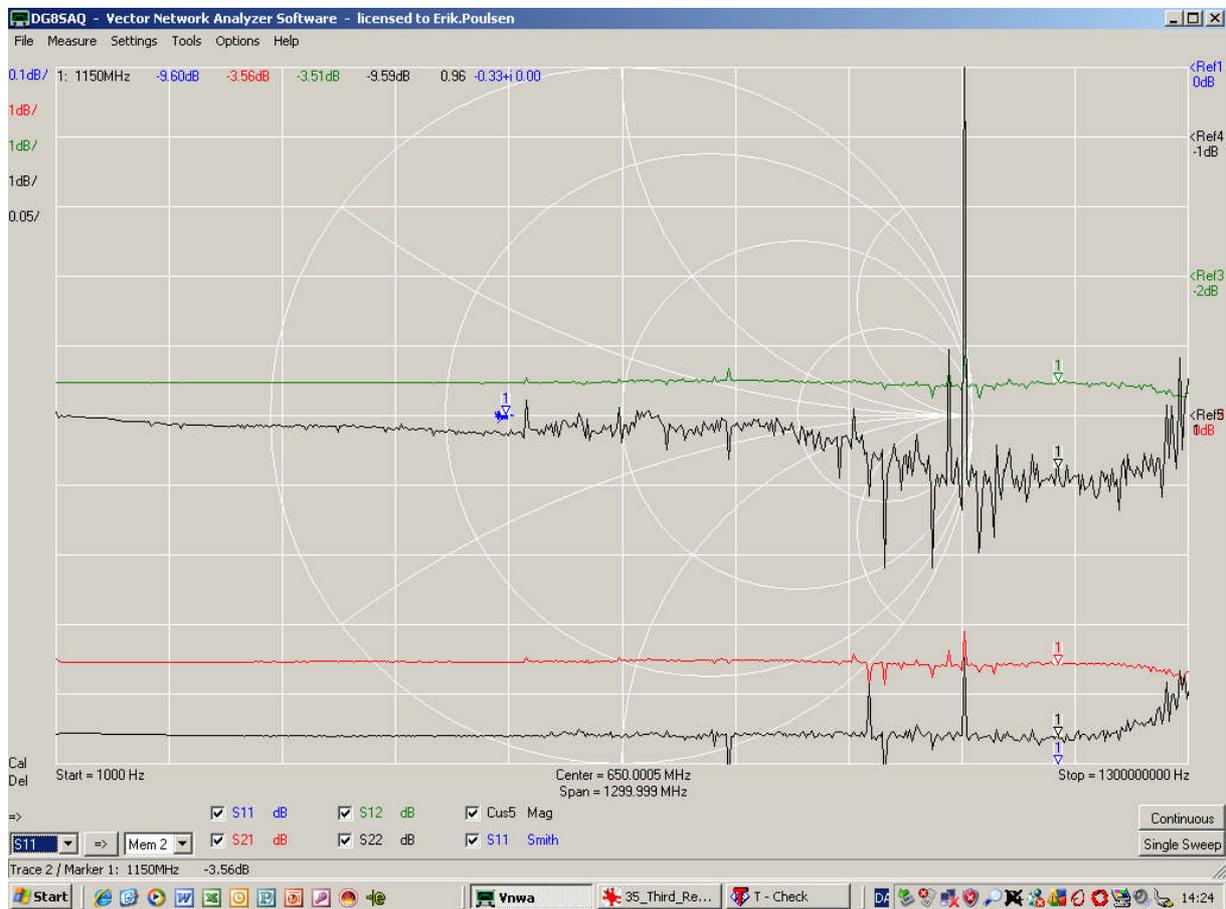
By trimming the Thru delay to 14pS so the 25 ohm phase is adjusted to zero we see a 5% accuracy obtained maintaning 1% below 500MHz. The different manufacturer of Semi Ridig Cable made the difference together with the 10dB inline attenuator.
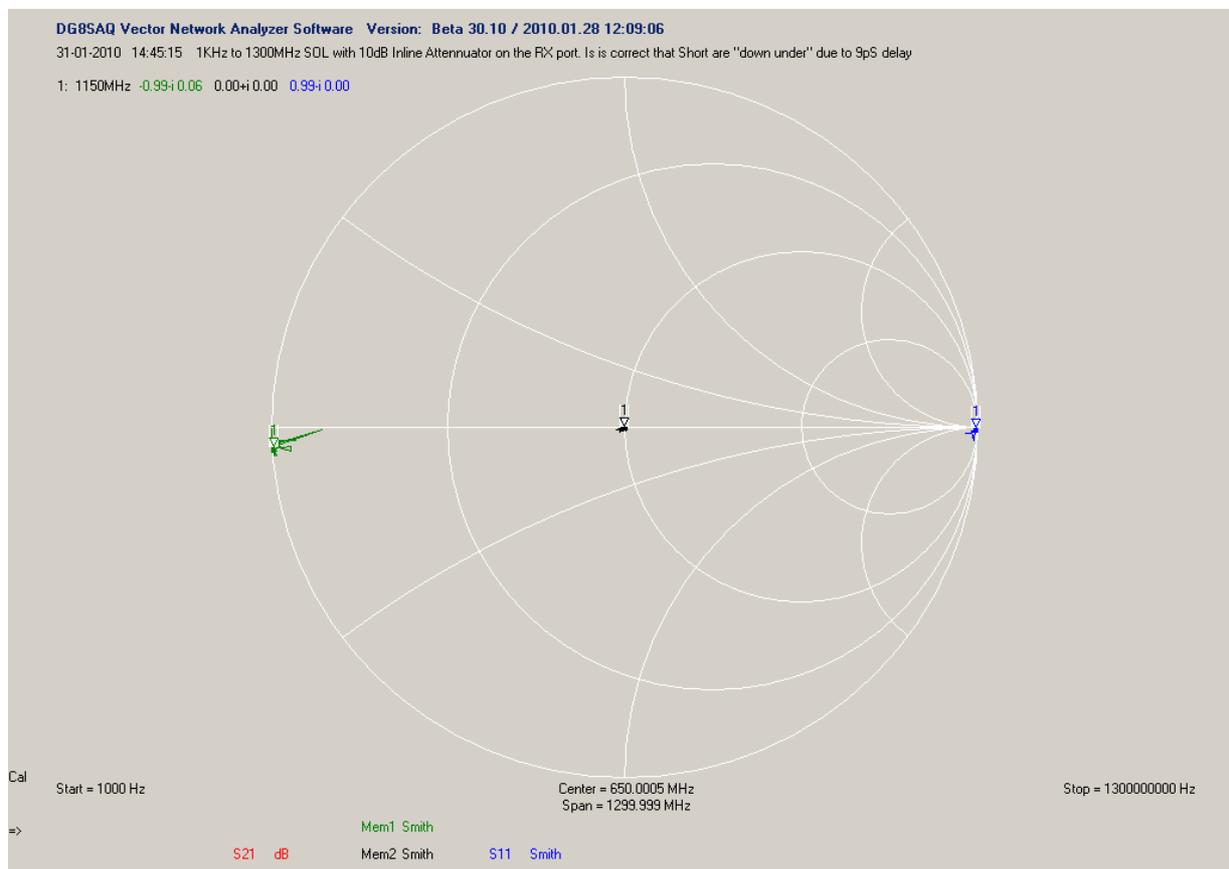
Plot off Smith Chart of the Short Open Load Standards with 10dB atteenuator inserted on the RX port shows fine result. The short must show a trace below the Zero line due to the 14pS corrections.

Measuring the delay/mm in a SMA Female-Female Adaptor
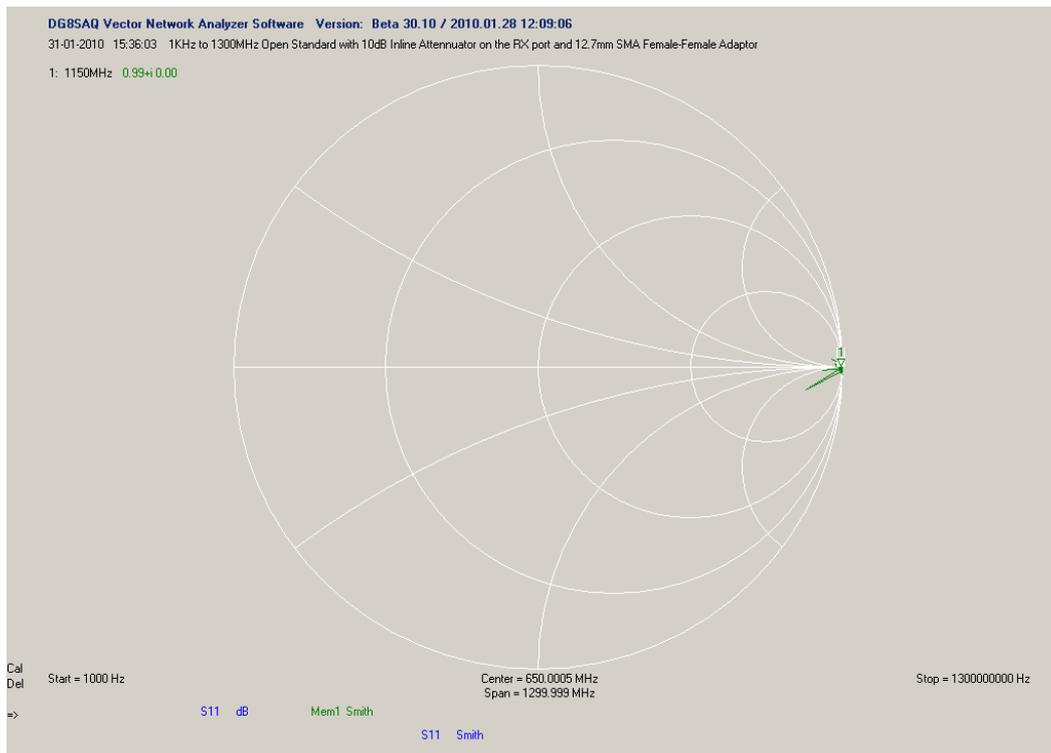
The plot of The open standard with using the 12.7 mm SMA FF adaptor
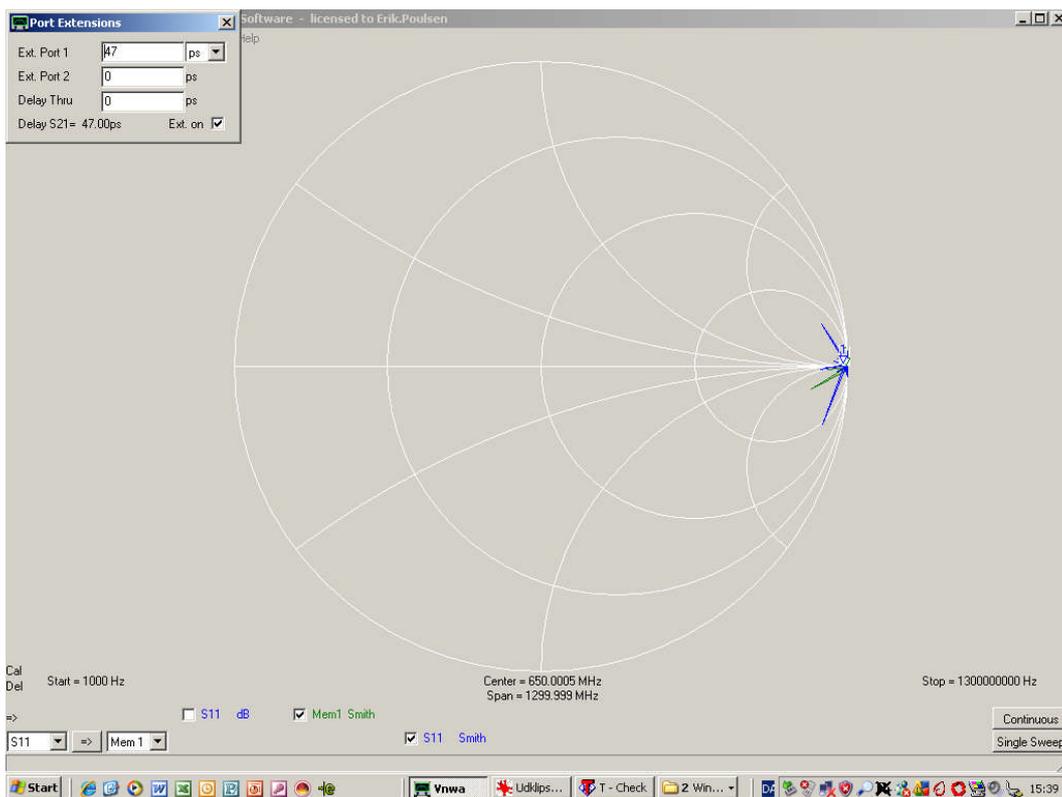
Plot of the OPEN standard using the longer SMA FF adaptor of 22.2 mm (9.5mm longer) moved back to zero phase position for the 12.7mm plot stored in MEM1 by enabling Port Extension Port 1 by 47 pS. Thus the dual travel is 2x9.5mm and gives 47pS divided by 19mm equals to 2.5pS/mm . The SMA Tee adaptor has its surface to contact 2.2 mm from the end = 7.3mm from center correcponding to 18 ps and the calibration standard has their reference plane slightly behind said surface. The Thru delay was 14ps so the remaning 4 mm correspond to a distance of 1.6mm and not way off from the "real thing" .

Report written on 31/01/2010 by Kurt Poulsen de OZ7OU