How to select the very best parts for a SMA calibration kit for the DG8SAQ VNWA

Preface:

Calibrating the VNWA and any other VNA requires the use of Calibration Standards such as a Short, a Open and a 50 ohm Load standard for reflection calibration and a Thru adaptor for Transmission calibration if the test cable(s) connecting the TX and RX port does not mate directly.

This report demonstrates the obstacles you meet, when trying to calibrate a VWNA, and be sure it is calibrated as exactly as possible, within a budget not allowing to buy a commercial calibration kit, which price is several times the cost of a VNWA. Remember the commercial Calibration kits are specified individually and the object for finding the perfect and general VNWA kit, is to find parts, which inherently is with minimum spread in the delay data, and other electrical/mechanical data, from item to item.

And quite frankly, there is no need either for such a commercial calibration kit purchase, as by selection calibration standard parts from specific vendors/manufacturers, you can calibrate the VNWA so it challenges the commercial VNA's accuracy, within the frequency range the VNWA is designed for, being 1KHz to 1300MHz.

In the following will at first be described which parts to select, and which few uncertainties still remaining compared to using a commercial calibration kit/measuring with a professional VNA.

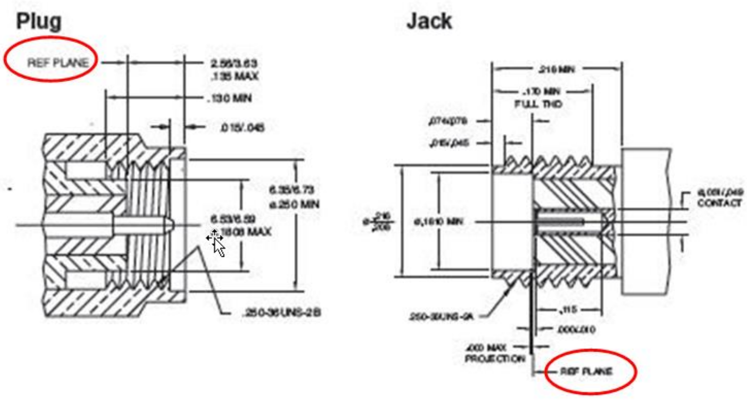
Then secondly will be described what happens if using adaptors in series with the Calibration standards. Such adaptor might be tempting to use, if you e.g. only have a male calibration kit, and you need to calibrate with a female kit. Quite interesting phenomena happens, which will convince you for the need to be the happy owner of a complete set of Male and Female calibration kits, if you aim for perfection.

Of course, using these adaptors, calibrations gives fairly good results, if the given guidelines in this report are followed, but example will be shown where you will obtain "terrible" result without knowing.

MY SMA DREAM KIT…AND WHY IT IS NOT A NIGHTMARE KIT ☺

In the calibration setting for the VNWA you have to enter delays for the Short, Open and Thu calibration adaptor relative the calibration plane you want to use. This preferred reflection and transmission calibration plane is normally the connectors mechanical reference plane, for the connector sitting at the end of the test cable, but might also be the TX Connector (and for that matter the RX connector) sitting on the front of the VNWA.

- Where is the reference plane in the connectors:



For the SMA connectors you clearly see the reference plane as the narrow inside circular contact surface .

The beauty of a calibration is that any test cable or adaptor, sitting in between the TX port and the calibration plane selected, is included in the calibration and need not to be worried about. In addition, the test cable and any adaptors connected to the RX Port are included in the transmission calibration, and not to be worried about.

<u>It all boils down to following fact that the quality of the calibration is only dependant of the quality of the calibration standards fitted to the calibration plane during calibration.</u>

So the ideal calibration standards is a Short with no delay, a Open with no delay, a Load perfectly 50 ohm over the entire frequency band of interest and a Thru adaptor with zero Delay.

How close can we come to this situation ?

Actually pretty close and means are provided to test the quality of the calibration called a T-Check.

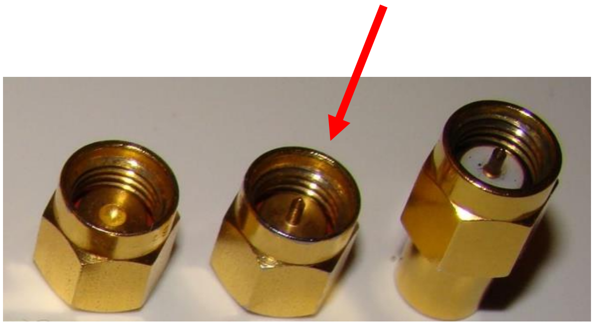
The Dream Male Short:

Long time ago, (in the days where you assembled you VNWA2 from a kit) I bought some parts from Fairview Microwave as seen below. In the Center of the picture is my “Dream Short” shown. The Shorting disk is a machined part and the Center pin is not welded or soldered to the shorting disk so it is absolutely with 0 ps delay. This ensures 100 % reflection meaning 0 ohm and no imaginary part and specified to 18GHz.

(I have bought another “look alike” from the German company WIMO but it is not with machined disk/centerpin but a pressed disk and the centerpin is soldered/welded to the disk adding delay of 1-2 ps).

Fairview Microwave homepage is http://www.fairviewmicrowave.com and search for SC2135 .

This Company is really a “candy store” for VNWA/VNA freaks.



These Adaptors purchased at Fairview Microwave part n/o SC2165, SC2135 and ST1813

I will revert to the left side part, then dust Cap, later on in this Document.

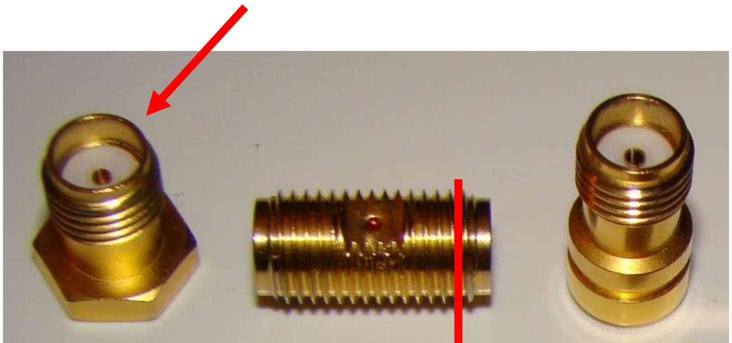
The next best Male Short:

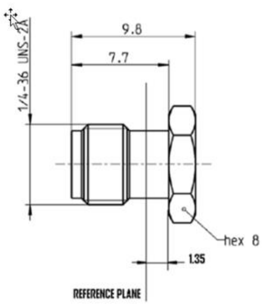
It is the Amphenol Connex Male Short described later in this report

The Dream Female Short:

It is impossible to produce a female Short without delay (although I have produced a homemade with less than 1 ps). The object is to find a commercial Female Short with as little a delay as possible and which is well documented.

I have not found anything better than the Rosenberger Short, now available from SDR Kits. It has proven very stable over time and extreme little spread in delay (measured in total 4 of these, with a commercial and new R&S 4 port VNA), and further one more with the VNWA as well, so it is the perfect VNWA Female Short with a delay of 27.54ps





Male Open reference plane

The Dream Male Open:

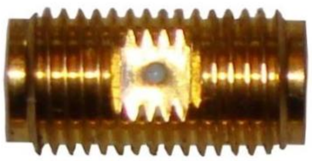
You may think that is a Dust Cap, like the one shown to the left on the picture from Fairview Microwave, is the ideal Male Open. However my Dream Male Open is the female adaptor on its own with nothing connectedto it, just like the TX SMA connector on the front on the VNWA. The reason for this choice is based on three factors.

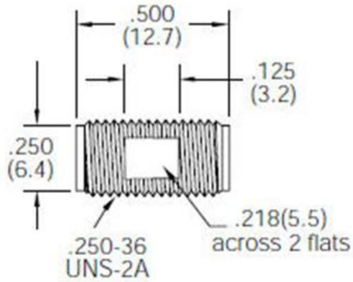
1. It is easy to simulate, with a Field Simulation software, the fringe capacitance and with reliable data.
2. The frequency range of the VNWA up to 1.3GHz does not have any radiation effect justifying using an Dust Cap
3. Use of an Dust Cap is adding additional delays and production tolerances will cause this added delay to spread from item to item.

Using Fields simulation software (se later for the Thru adaptor how this is done) the fringe capacitance is found to be exactly 30fF giving a **delay of 1.5ps** and it is not dependant, by an amount worth considering, of the Epsilon value for the PTFE insert being either 2.0 or 2.05 (see later) pending where you search for this value.

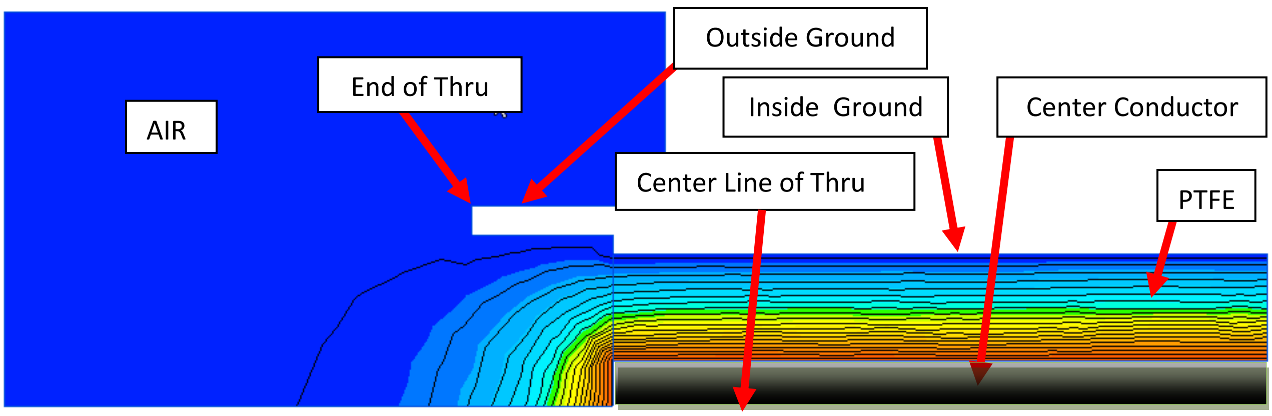
The Dream Female Open:
This is a bit difficult to characterize without using as Field Simulation Software and my choice has been to use the Rosenberger Thru adaptor for two reason.
1. It has been well documented together with the Rosenberger Short and Rosenberger is a trustworthy manufacturer where mechanical data available is for a simulation with a Field Simulation Software.
2. The measurements of 5 Thru adaptors from deliveries in 2009, 2012 and 2013 has been measured with the commercial R&S new 4 port VNA to an average value of 42.35pS within 0.1ps, and is matching the simulation pretty closely. It might be a coincidence, but then a “lucky one” ☺. The data from reason 1 above is based on actual measurement of an elderly commercial VNA and might have a small spread (defined as offset length of 7 mm incl. end capacity) so it I obvious that this information is with a bit of tolerance. Thus the Field Software Simulation is now taken as “the state of the art”.
The Thu adaptor delay as said measured for 5 units, to be average 42.35ps excl. fringe capacitance and with added simulated 1.5pS is gives 43.85ps incl. fringe capacitance.
The simulated delays incl. fringe capacitance calculated to 42.7425ps for epsilon 2.00 and 43.775ps for Epsilon 2.05
Delay without fringe capacitance calculated to 41.245ps for epsilon 2.00 and 42.276ps for epsilon 2.05.
Thus fringe capacitance is 1.4975ps for epsilon 2.00 and 1.499ps for epsilon 2.05 and **<u>1.5ps being the selected value</u>**.
The uncertainty for the Rosenberger Thu - now Available from SDR-Kits -is in the range of far less than 1 ps.

The Dream Thru adaptor:
You guessed correctly…. the Rosenberger Thu adaptor, available from SDR Kits, with delay defined to be 43.85ps based on the measurement on the R&S 4 Channel VNA and supported by the Field Simulation Software.

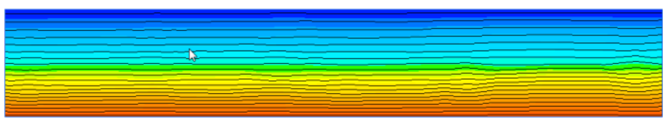




I will below show the field lines from the simulation to demonstrate how the fringe capacitance/endpoint radiation penetrate into the PTFE inside the thru adaptor.



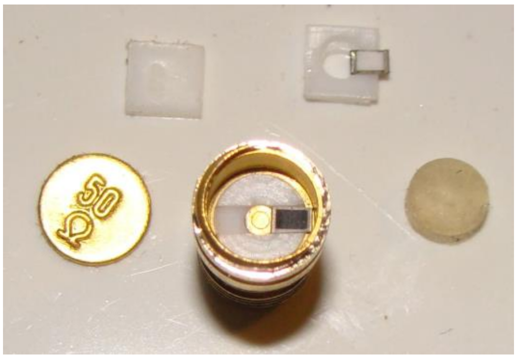
Above shown are the Field lines when open in one end and fringe capacitance in action into open air

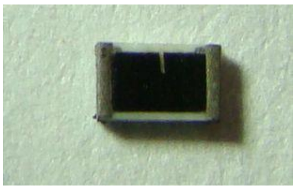


Above shown are the Field lines when in Thru S21 condition and no fringe capacitance in action

The Dream Load:

Such a load does not exist at all. All Loads has some element of parasitic components for commercial Loads.
I have about 10 different types of SMA Male Loads from Huber Suhner, Fairview Microwave WiMo and some others of unknown origin, and on top of that several homemade SMA Female Load.
Then as well, multiple Female and Male Load of brand Amphenol Connex and Rosenberger.
By measurements on the R&S new 4 Channel VNA it has been confirmed that nothing beats the Rosenberger male and Female Loads, due to the internal design. <u>They are available from SDR-Kits now.</u>
Below shownis the interior of a Female Load from the two manufacturers





Rosenberger Female Load with two laser trimmed Thick film resistors . Remark the square silicon pads with holes that minimizes fringe capacitances. Also note no solder used, as the two resistors kept in place by pressure of the soft silicon pads. This explains the good performance with smaller variation from item to item and a controlled performance.

The Amphenol Connex Load uses ordinary 1% SMD resistors and solder. The solder adds fringe capacitance in uncontrolled amount as solder applied by hand

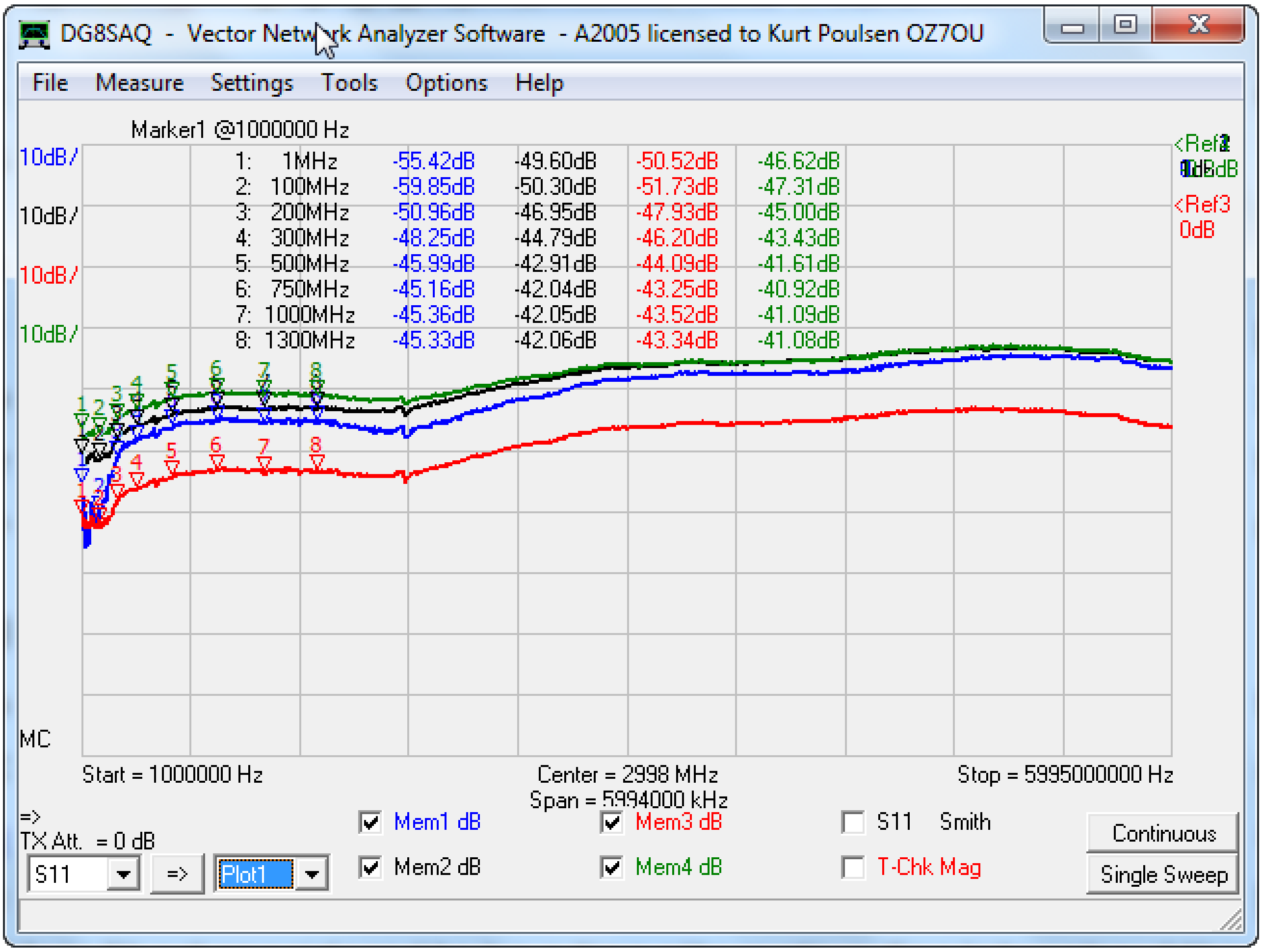
Whatever you do you will never be able to purchase a standard commercial Load which is perfect, as above picture shows, there will be fringe capacitances and as the 2x100 ohm resistors are discrete devices, there will be element of impedance transformation by the 50 ohm Transmission line, from the calibration plane to the resistor position, as the resistors is not exactly 50 ohm. This very short transmission line might also deviate slightly from 50 ohm making things even worse. However this is a discussion about the theoretical interested people and to bring the discussion/comment down to real life the Rosenberger Male and Female Load is specified with a return loss of 32 dB from DC to 2GHz and thus a bit better in the region up to VNWA limit 1.3GHz, as shall be shown below.
Please note it is important to know the exact value for the Load and SDR-Kits provides the service to measure the accurate DC Resistance with a test jig, using a 4 point measurement technique.

So bottom line… You have to rely on the load you purchased you have no other option, except you get it measured against an industrial calibration Kit and get the data derived mathematically. Rosenberger is the one I trust and used as platform for all other comparisons. Future work, I have plannedfor, is to derive data from the measurements made on 4. pc Rosenberger female Load and 3 pc. Rosenberger male Loads by the R&S 4 port VNA and characterize these a bit better if possible. Even then it will be dependant of the accuracy of the used R&S 4 port VNA. ☺.

How to set the calibration Settings for the VNWA:

With respect to how to set the calibration setting for my "Dream Calibration Kit" of the VNWA, reference is made to the just released document "SDR-Kit Calibration Kit of Rosenberger Parts for the DG8SAQ VNWA" at the link http://hamcom.dk/VNWA/Rosenberger Cal standards_rev3.pdf with the exception that for Calibration to Female Reference plane I use <u>0 ps for the Short when using the Fairview Microwave 0 ps Short</u> and <u>- 33.8ps for the Amphenol Connex Male Short</u> considered to be a fine alternative. See later about this and how the use of Rosenberger Male Male adaptor in series with Rosenberger Female Short behaves as a male Short combination.

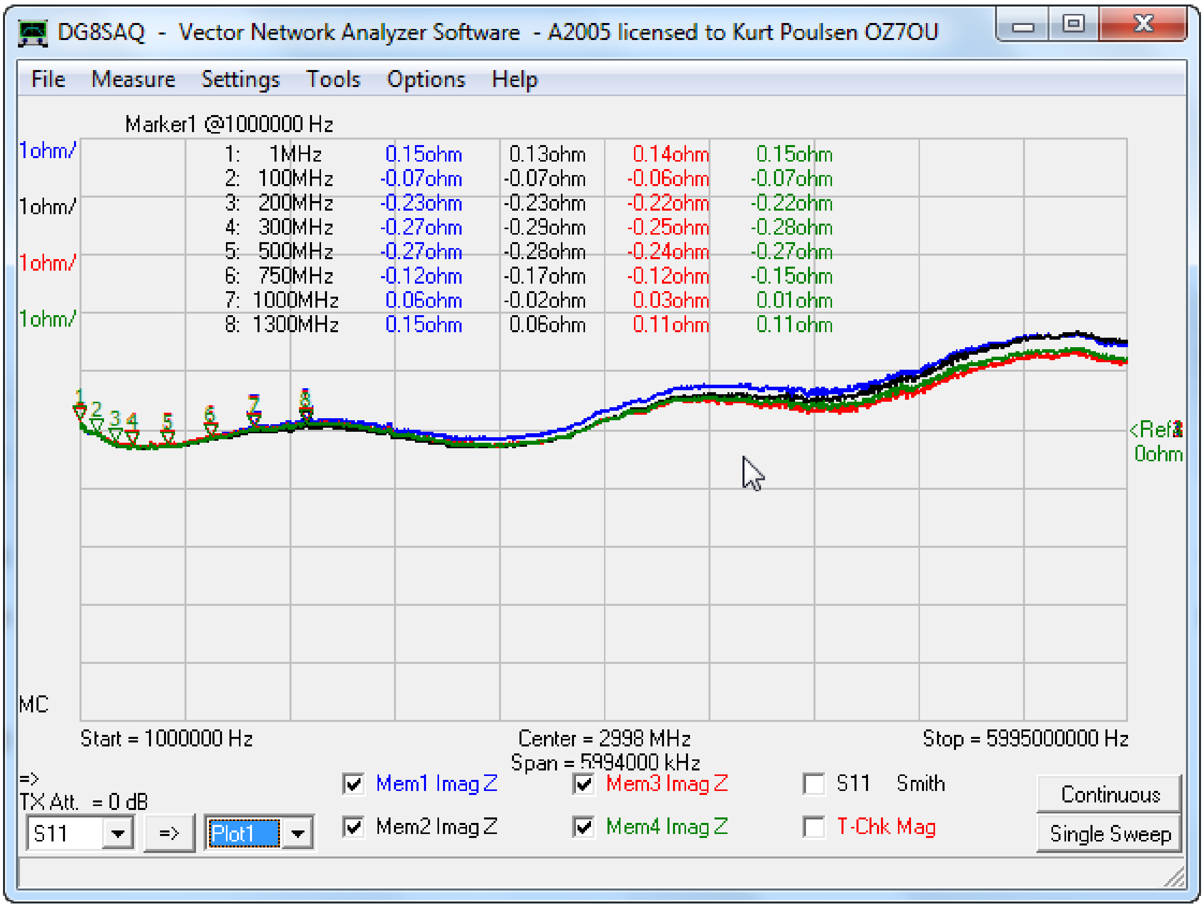
Some real Measurements on the R&S 4 port VNA for the female Rosenberger Load up to 6 GHz:



Reflection Coefficient better than 40dB for all unit. Deviation caused by the different ohmic resistance.
Blue trace 49.92 ohm, Black trace 49.70 ohm, Red Trace 49.74 ohm and Green Trace 49.56 ohm
It you see at 1 MHz the order of Reflection coefficients in the table is correct but above 1MHz small “role changes” happens as blue and red changes role.

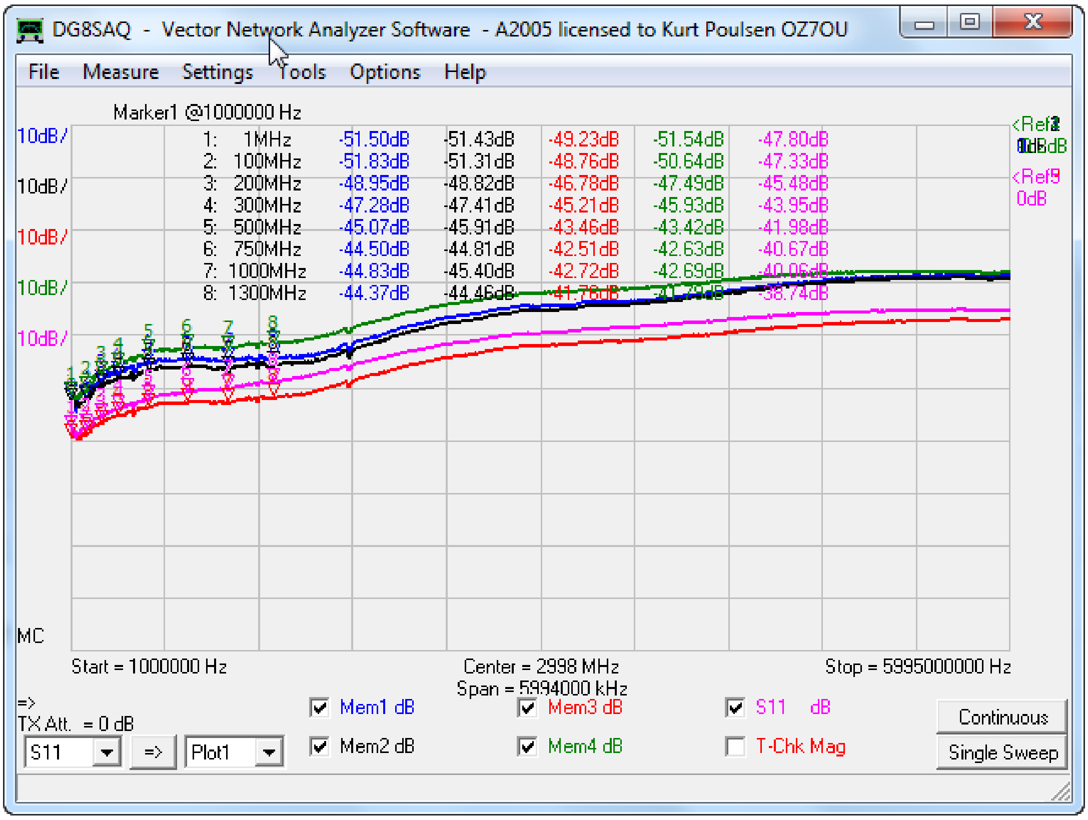
These traces are the RealZ of the same load. Remark the DC value given are measured by the Test Jig SDR-Kits also uses, and made prior to the measurements on the R&S 4 channel VNA. They are spot on the same values at 1 MHz and within less than 10 mohm. Amazing ☺.

Blue trace 49.92 ohm, Black trace 49.70 ohm, Red Trace 49.74 ohm and Green Trace 49.56 ohm



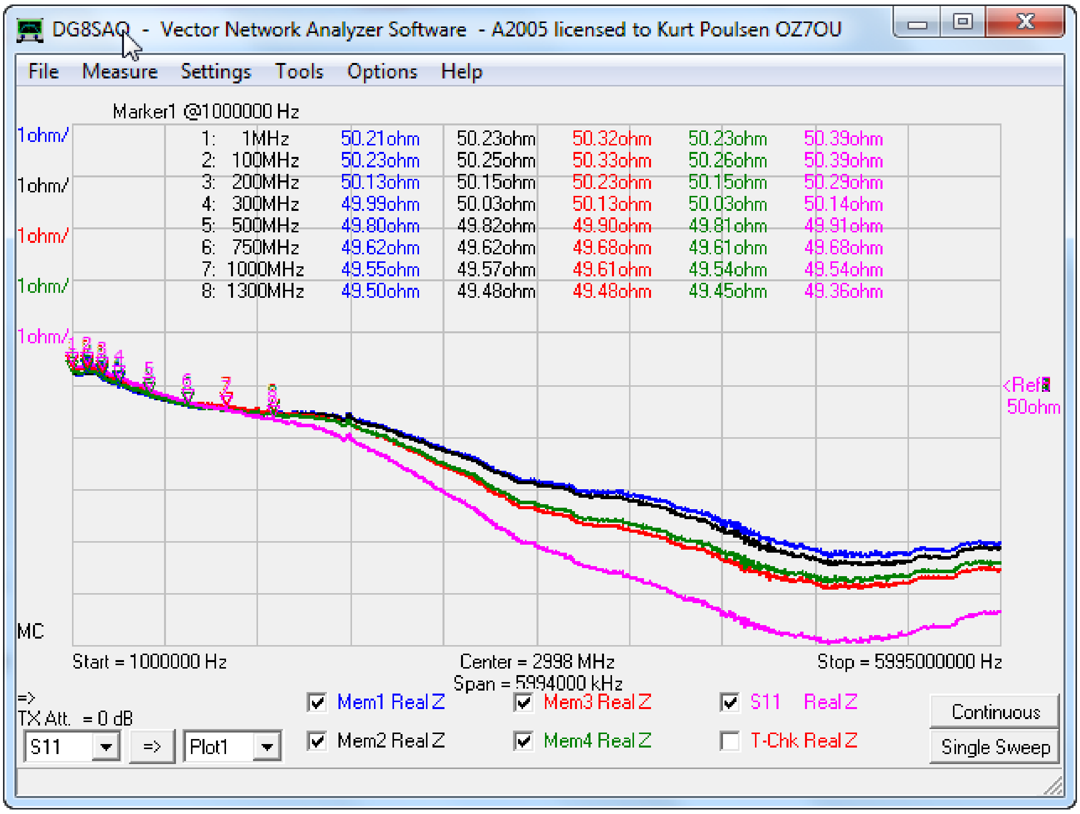
These Traces are the ImagZ and shows a very close match across the frequency span.

These plots representing the Fringe Capacitance shows it is not a single delay figure to enter in calibration settings, as being frequency dependent, and turning towards inductive at 1 GHz, then to capacitive at about 2GHz and back again to inductive above 3 GHz. Still small amount and the match between the 4 units quite nice.



Amphenol Connex Female Load from different deliveries in 2013.

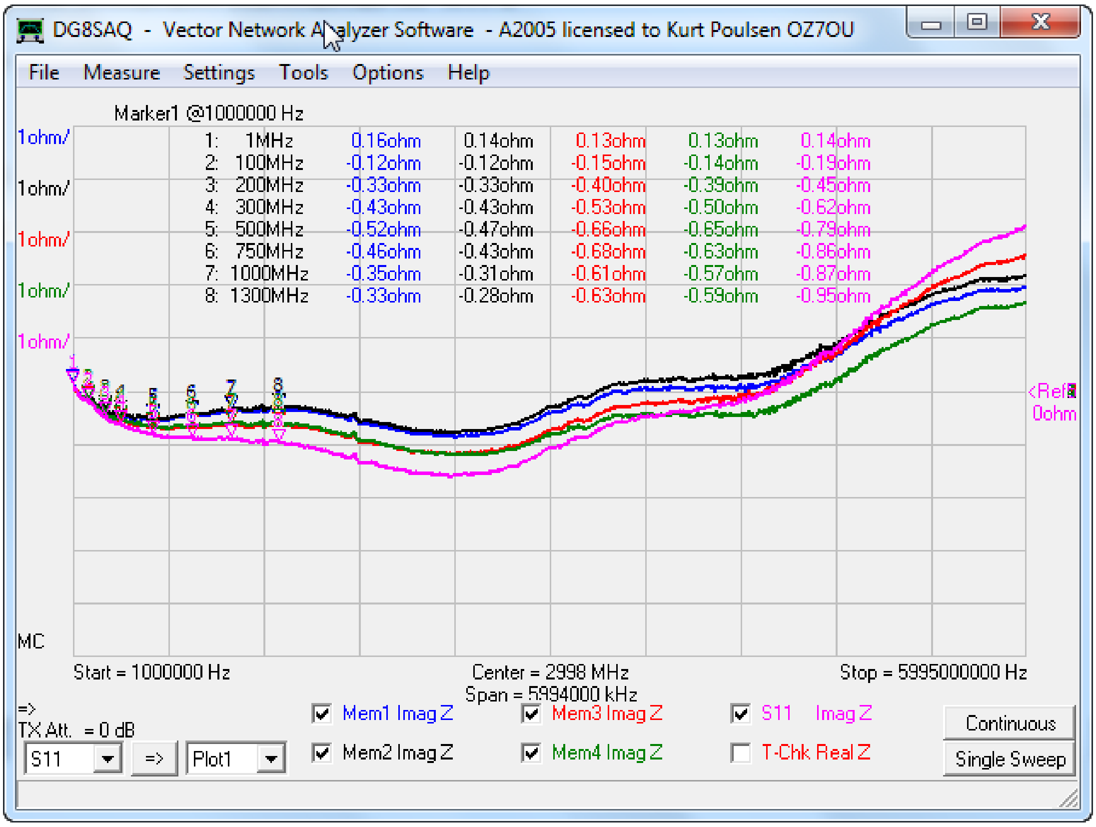
Blue trace 50,21 ohm, Black Trace 50.25 ohm, Red Trace 50.32 ohm, Green Trace 50.23 ohm and Purple Trace 50.39 ohm



Amphenol Connex Female Load as above with Real Z presentation

Blue trace 50,21 ohm, Black Trace 50.25 ohm, Red Trace 50.32 ohm, Green Trace 50.23 ohm and Purple Trace 50.39 ohm.

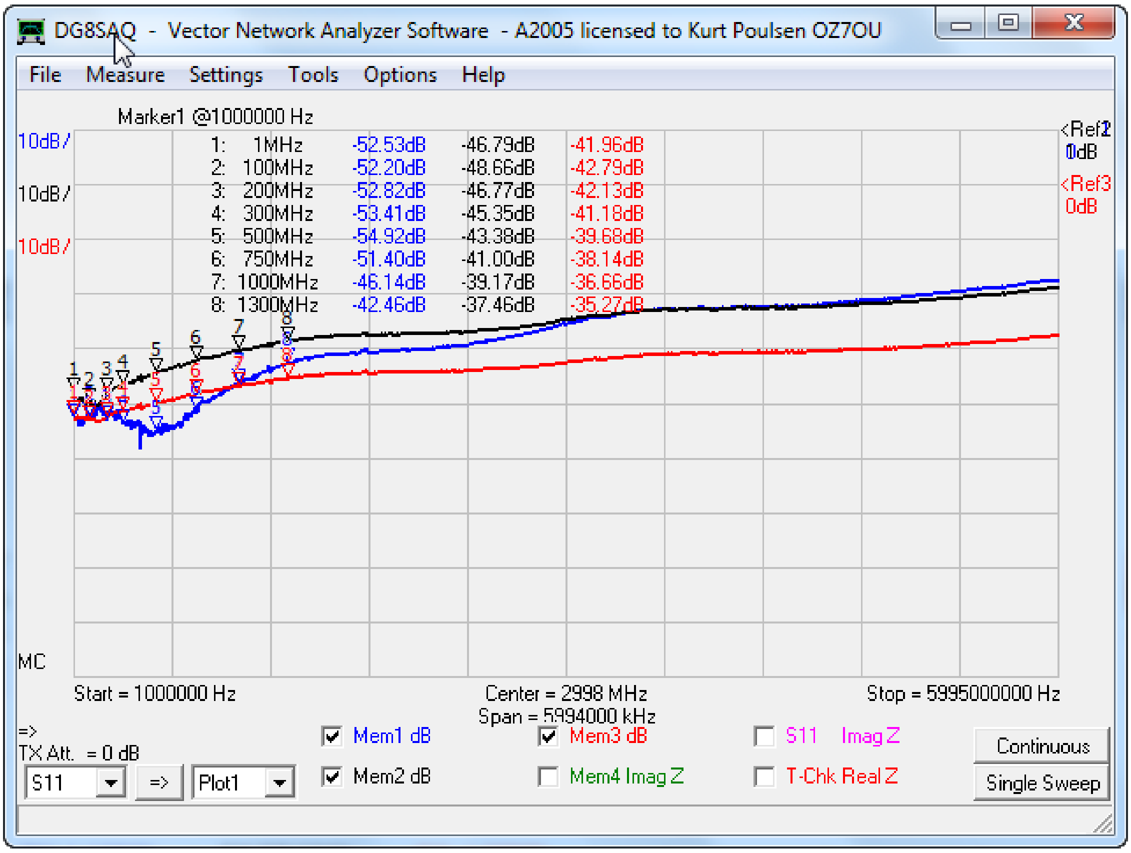
Again exact match between DC value measured prior to measurement on the R&S 4 port VNA except for black trace with 20 mohm difference. The match is quite fine up to 1.3GHz and then they spread considerable.



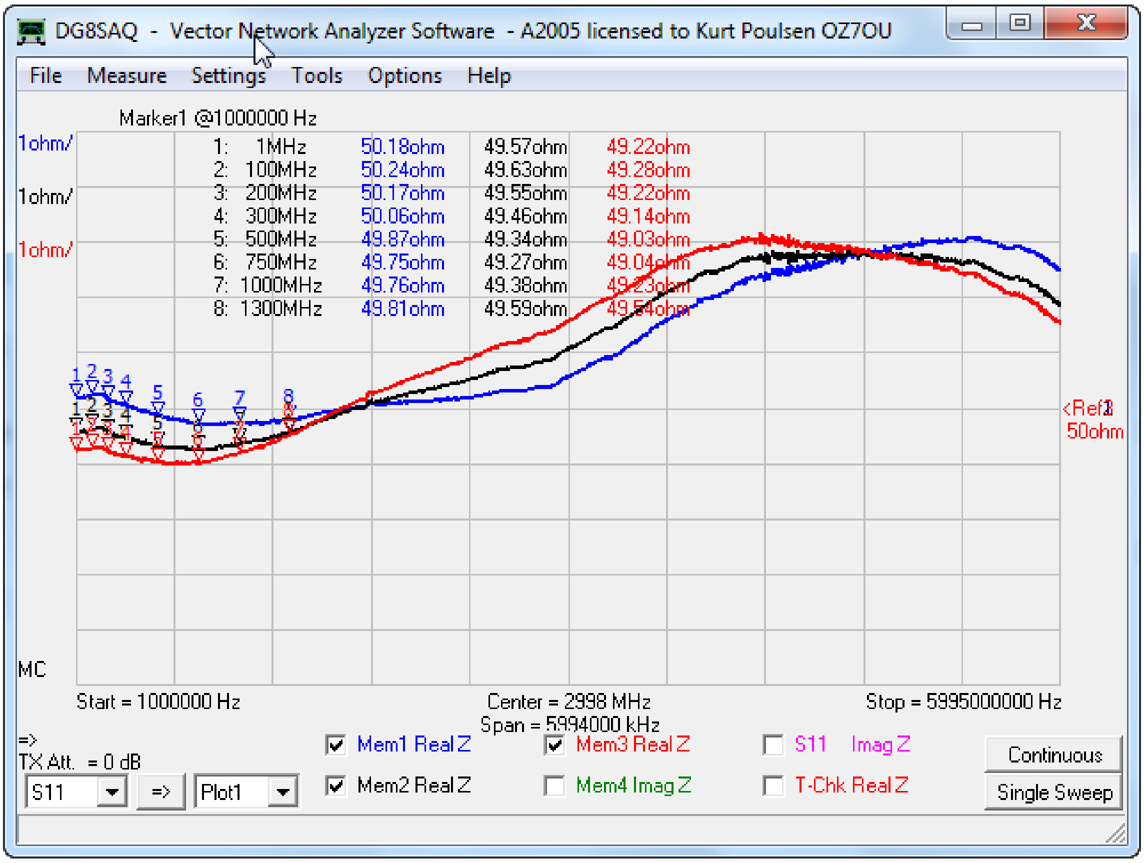
Amphenol Connex Female Load as above with Imag Z presentation
Quite larger spread compared to Rosenberger

Amphenol Connex Female Load as above with Fringe Capacitance representation and same trend as with Rosenberger.

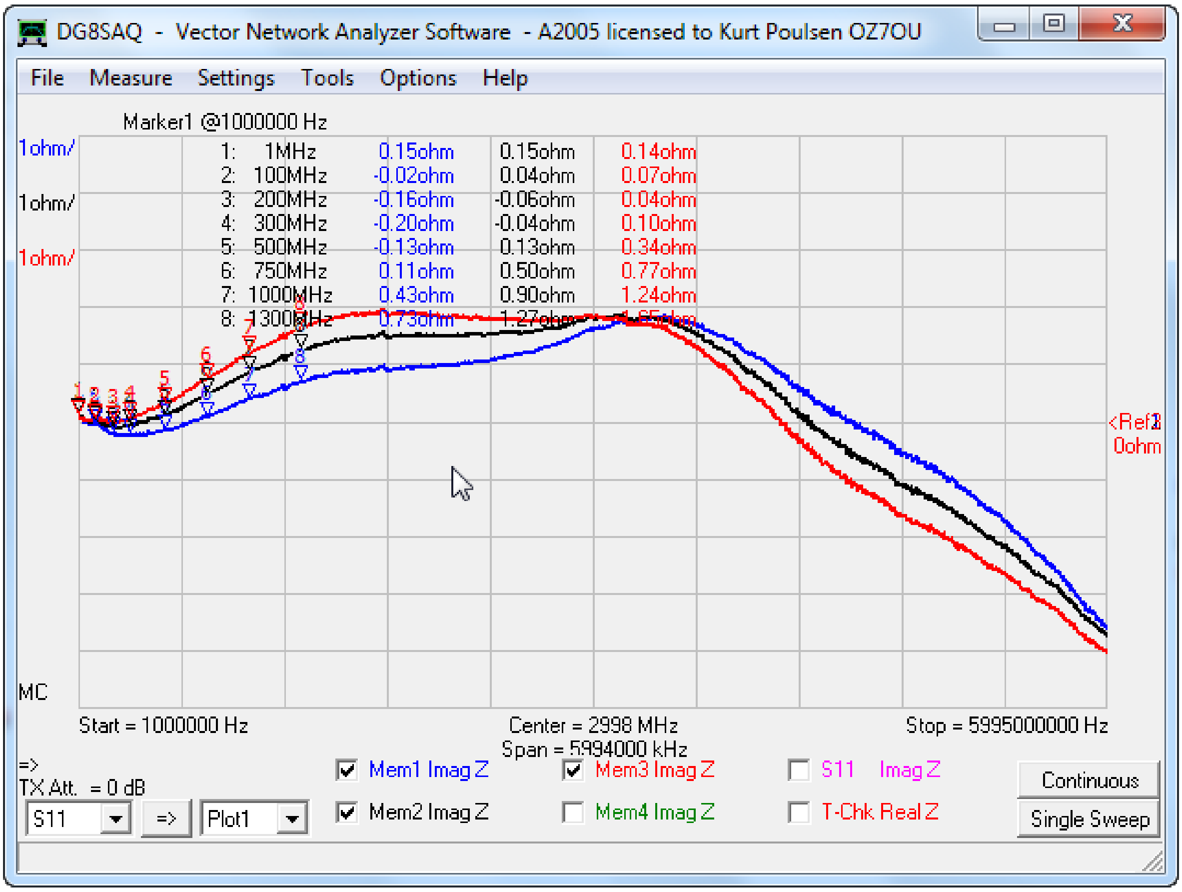
Does the R&S 4 port VNA measure correctly ?? Probably yes, but it requires quite an investigation to figure that out. Or are we dealing with the effect of impedance transformation in the short 50 ohm transmission line from reference plane to physical position of the load resistors.



Above reflection coefficients for 3 pc. Rosenberger Male Load in series with Rosenberger Female Thru adaptor
Blue trace 50.18 ohm, Black Trace 49.57 ohm and Red Trace 49.22 ohm



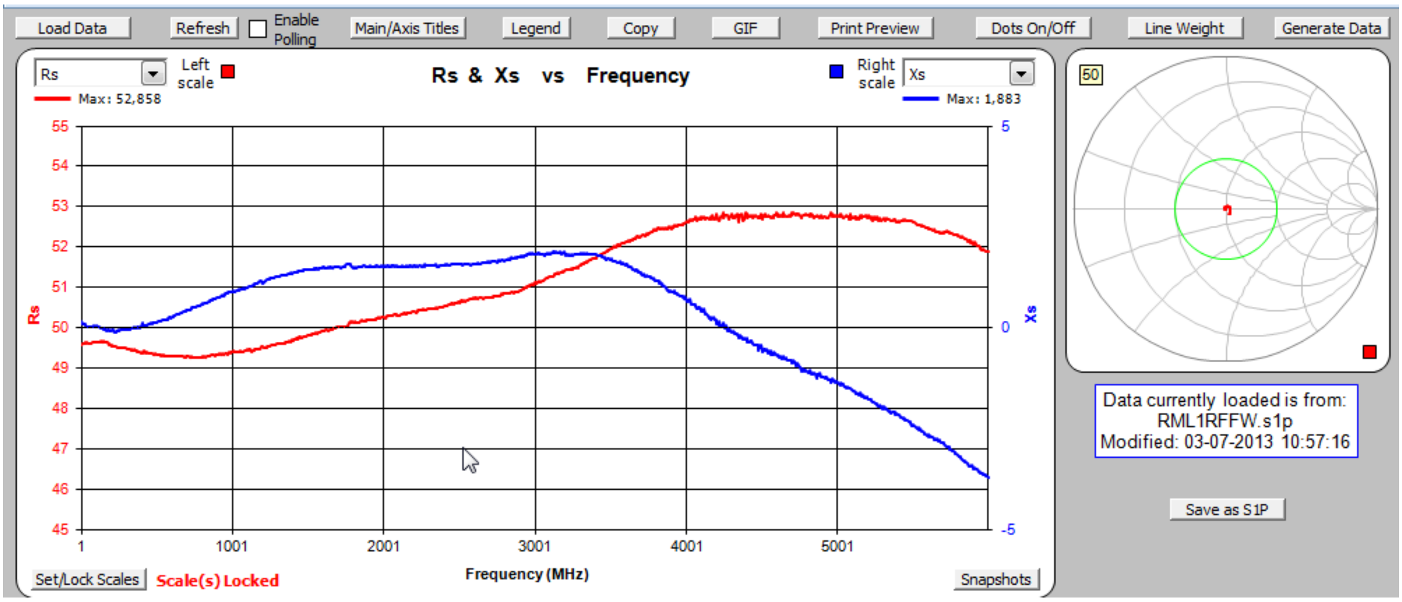
Real Z for 3 pc. Rosenberger Male Load in series with Rosenberger Female Thru adaptor
Blue trace 50.18 ohm, Black Trace 49.57 ohm and Red Trace 49.22 ohm
Exact match at 1 MHz with the DC resistance measurements prior to measuring with the R&S 4 port VNA but above 1 GHz the Plot is apparently quite considerable impacted by the Thru Adaptor.



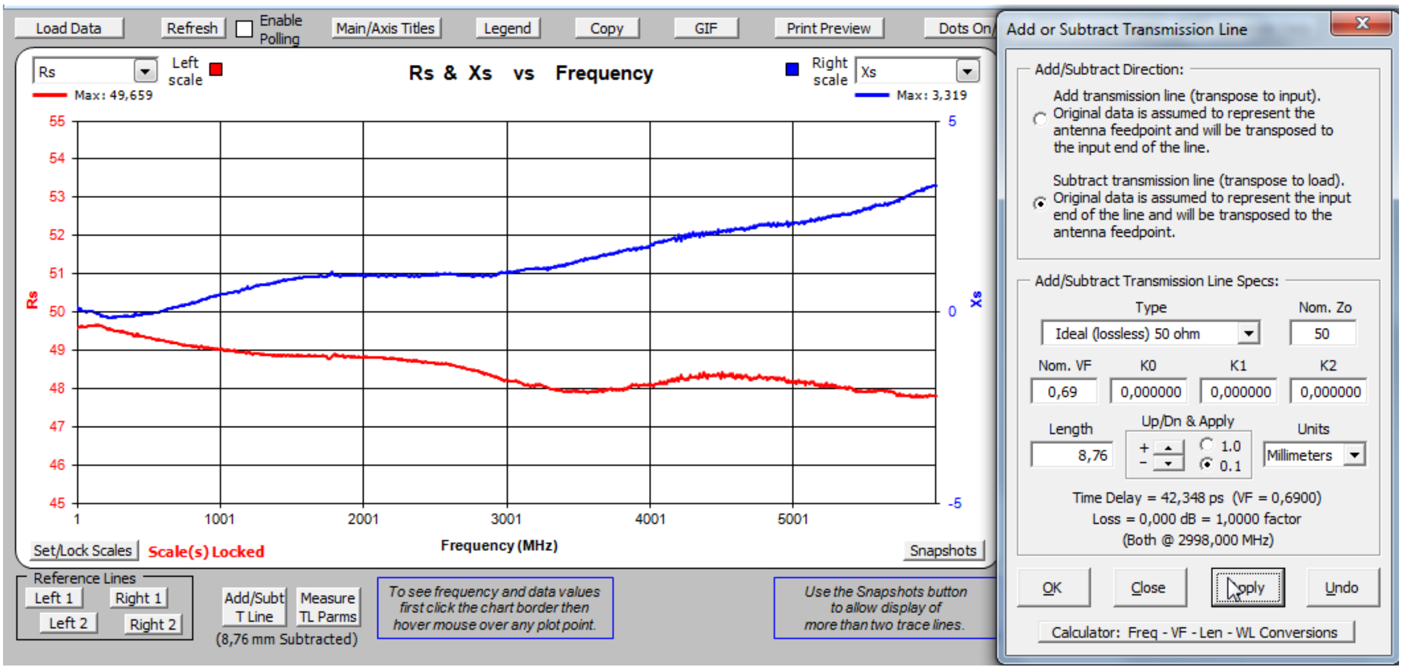
ImagZ for 3 pc. Rosenberger Male Load in series with Rosenberger Female Thru adaptor
Blue trace 50.18 ohm, Black Trace 49.57 ohm and Red Trace 49.22 ohm
Also for the ImagZ the plot are apparently impacted by the Female Thru adaptor. The lower the resistance the higher the deviation from expected values. These traces are not expected to have this characteristic.

We will on next page analyze the effect of the Female Female adaptor using the program ZPlots which the VNWA Software has features for direct interface with.

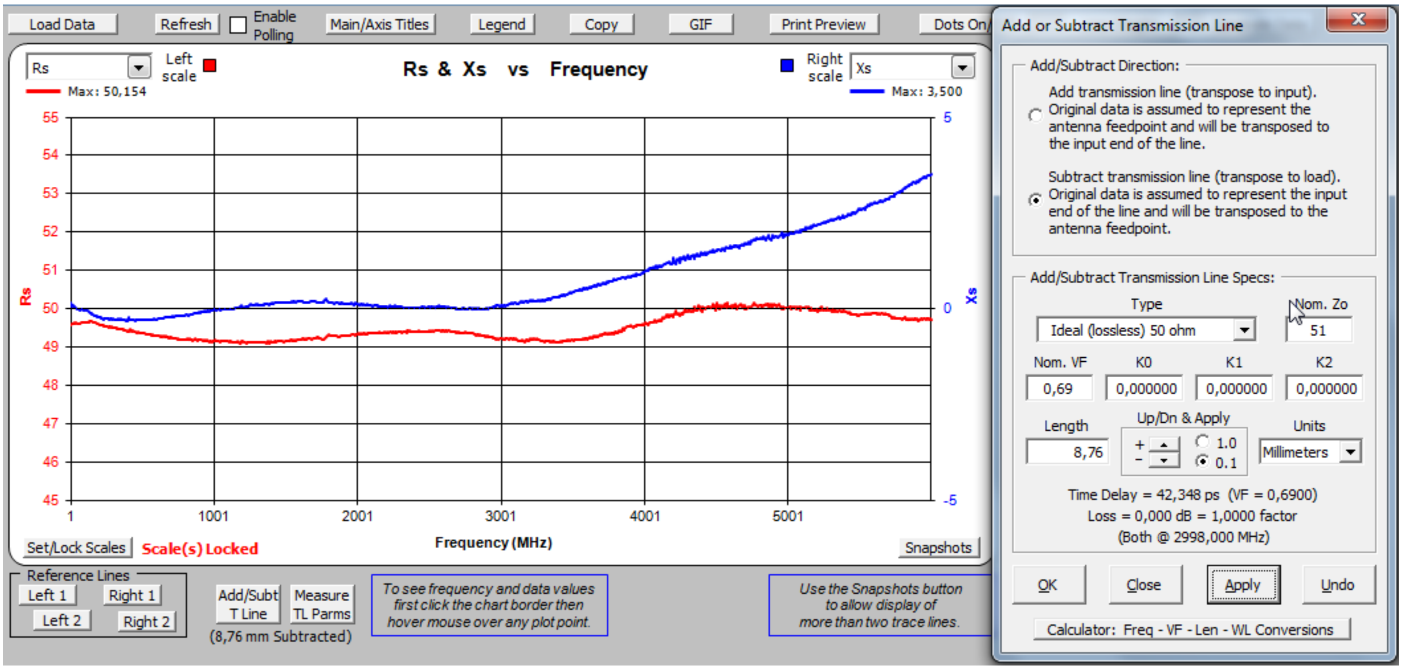
If we chose the black trace Load with DC resistance 49.57ohm, as an average of the three loads, we thencan, with the program ZPlots, analyze if the Female Thru adaptor does generate a considerable transformation.



Data Loaded into Z Plots and identical to previous plots on the VNWA screen. Max resistance 52.858 ohm

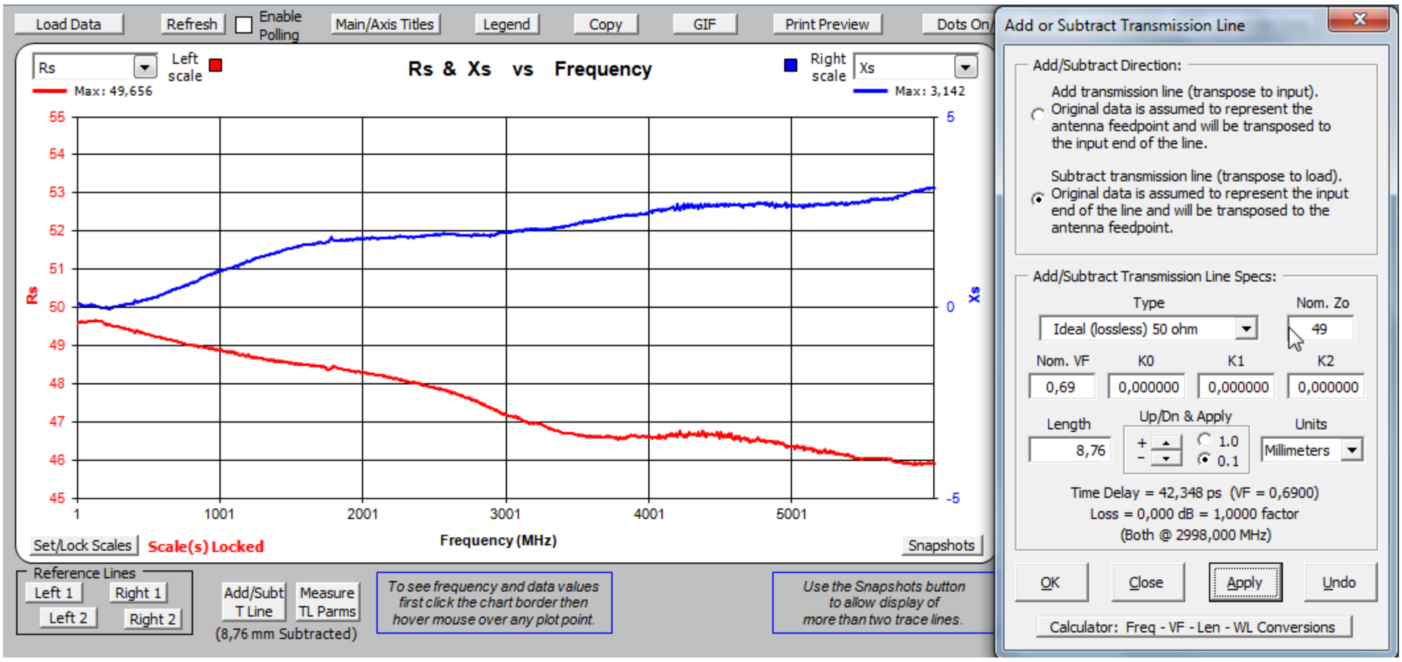


If we then subtract an ideal 50 ohm transmission line of delay 42.348ps (equal to our female Thru of 42.35ps) then the plot is absolutely much more like the Rosenberger Female Short. The Imaginary Z is clearly inductive peaking to 3.3 ohm at 6 GHz.



If we then Change the Ideal Transmission line to 51 ohm then the Real Z is almost flat to 6GHz and the Imag Z almost flat and 0 to 3 GHz.

This is a proof of how sensitive loads are to added adaptors and a Female Thru adaptor supposed to be exactly 50 ohm but might be 51 ohm is most likely. This effect requires only a minor change in the mechanical dimension and based on the tolerances for Rosenberger parts the Z0 may vary from 49,1 to 50.74 ohm alone due to the center conductor tolerances. Below is used Z0 of 49 ohm so what is right ??



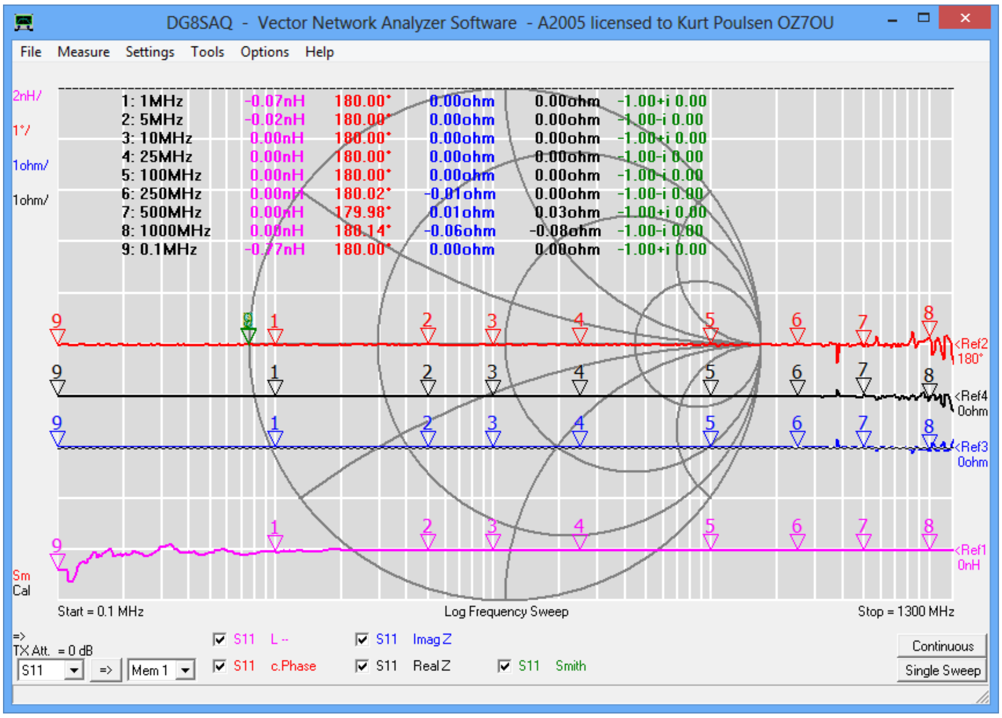
Conclusion of this test DO NOT USE ADAPTORS IN CONNECTION WITH LOADS as you are getting a false calibration. However in the VNWA software you have the option in arbitrary calibration to subtract such a delay and it would be advisable also to additional subtract the delay in the load itself from the reference plane to where the physical load resistors is positioned and that is subject for a special report.

Next Page is dealing with what happens if a short is connected in series with an adaptor.

Influence of a long or short delay in a Short Calibration Standard:

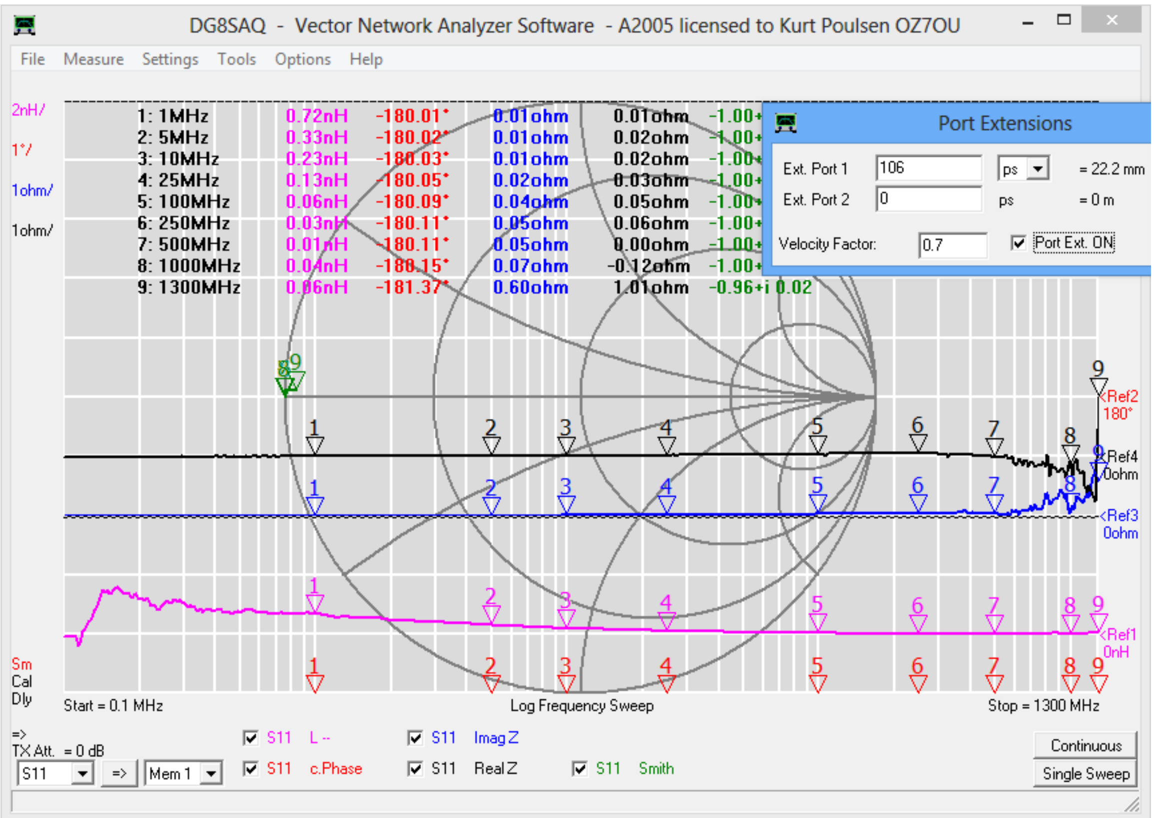
At first we calibrate the VNWA with the “Dream calibration Kit” consisting of Male 0 ps Short, nothing used for Open except the fringe capacitance (delay -1.5ps) and the Rosenberger Male Load 49.90 ohm.

Please note the frequency sweep presentations and calibration is done with logarithmic frequency scale for the specific reason it more clearly shows the explained impact in the following.



Above sweeps shows a complete flat response for RealZ, Imag Z, and Continuous phase, being 180degree as we are dealing with reflections for a Short (open has 0 phase shift for a reflection).

Remark the Trace 1, where the Series inductance is displayed, and observe a deviation up to 200KHz which is an unknown effect for further investigation. A slight smoothing added to trace 1 to remove noise in the region 100 to 200KHz.

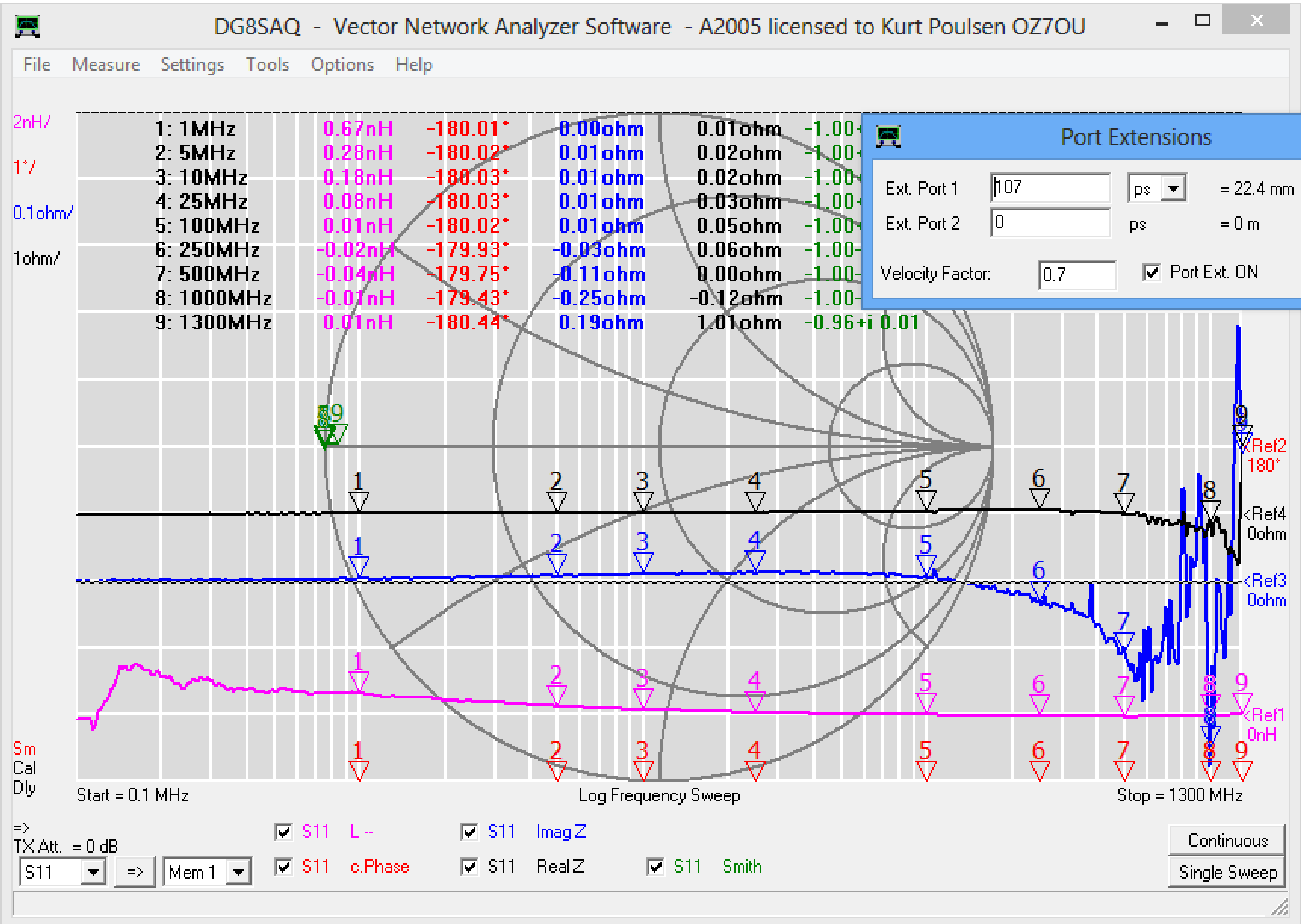


Above is measurements of the Rosenberger Male Male adaptor, of delay 78.46ps, in series with the Rosenberger Female Short of delay 27.54ps - in total 106ps. We have entered in the Ext port delay 106ps, to shift the measurement point to the physical position of the short.

As you can see the ImagZ start to raise it's impedance at 2 MHz and seem to raise more rapidly above 500MHz. Why that ?. It is the nasty beginning quarter wave effect/the complex impedance of a shorted transmission line, which start to show up. As you see in the Port Extension window, the electrical length is 22.2mm corresponding to a ¼ wavelength resonance of 3.38GHz and that is not far away from 1,3GHz. If you calculate the impedance of a shorted transmission line of length 22.2mm at 1.3GHz then you get 0 +j0.69ohm.

The VNWA is measuring 0.60 ohm so an OK match and thus there is no calibration mistake. The deviation can be explained by the natural noise, which exist for the VNWA at 1.3GHz. Just run some more sweep and the measurement fluctuates around the theoretical value. As we know mechanical parts like the Male Male adaptor has mechanical tolerances, then you may question whether the delay 106ps is the exact correct value.

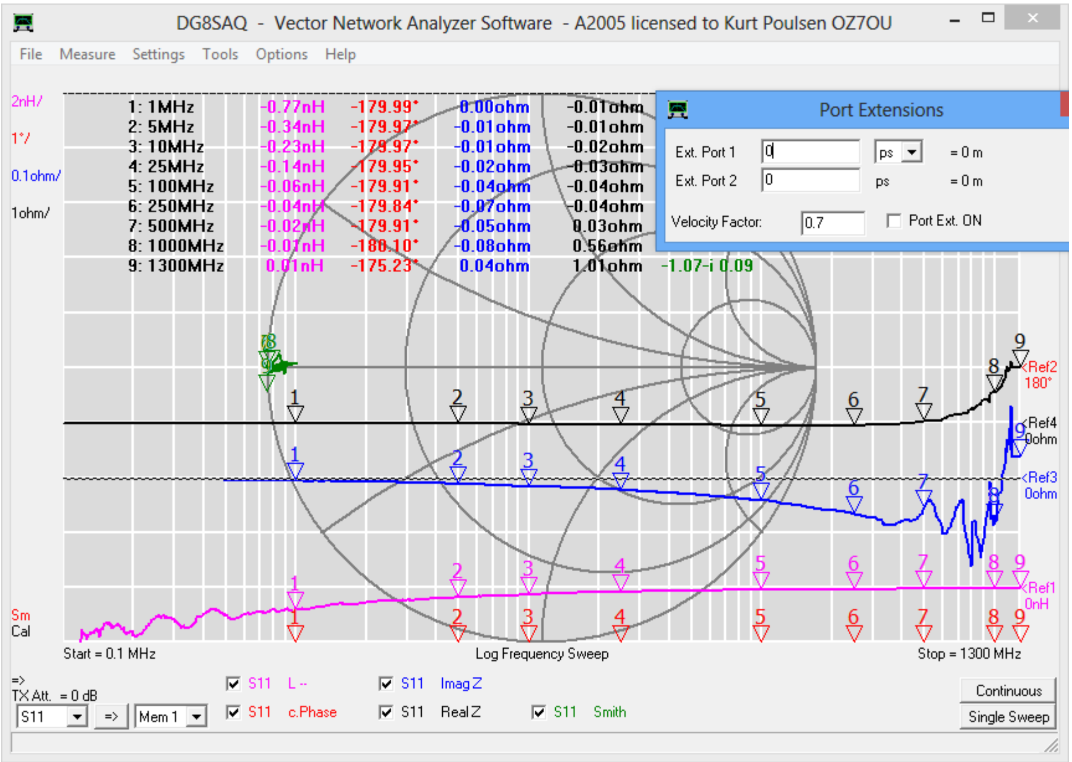
Let us expand the scale for ImagZ from 1 ohm/division to 0.1 ohm/division and tune the Extension Port Delay slightly.



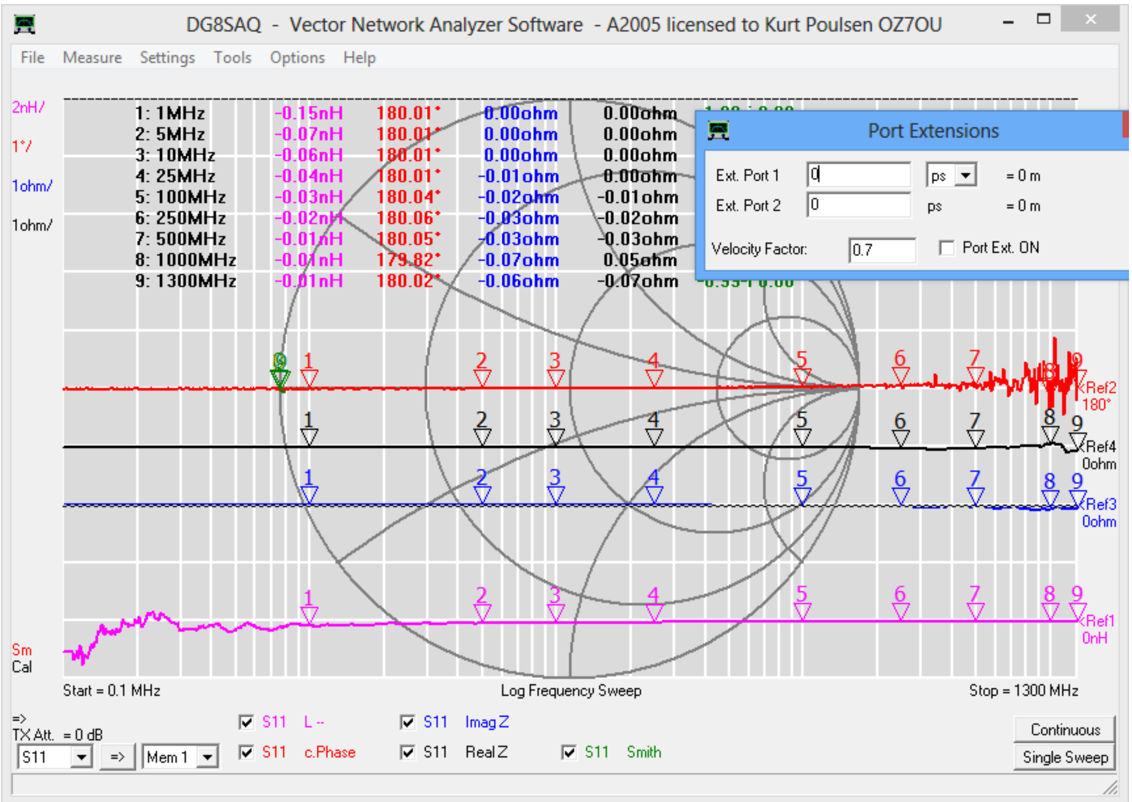
By just 1ps addition you get a slightly better match below 100Mhz but quite worsened above 100MHz.

So the conclusion is that even when adding a very accurate delay for a "long" short, as visualized by displaying a measurement with Ext- port 1 Delay, with the same delay as should be entered in the calibration setting, there is "residuals" embedded in the calibration file.

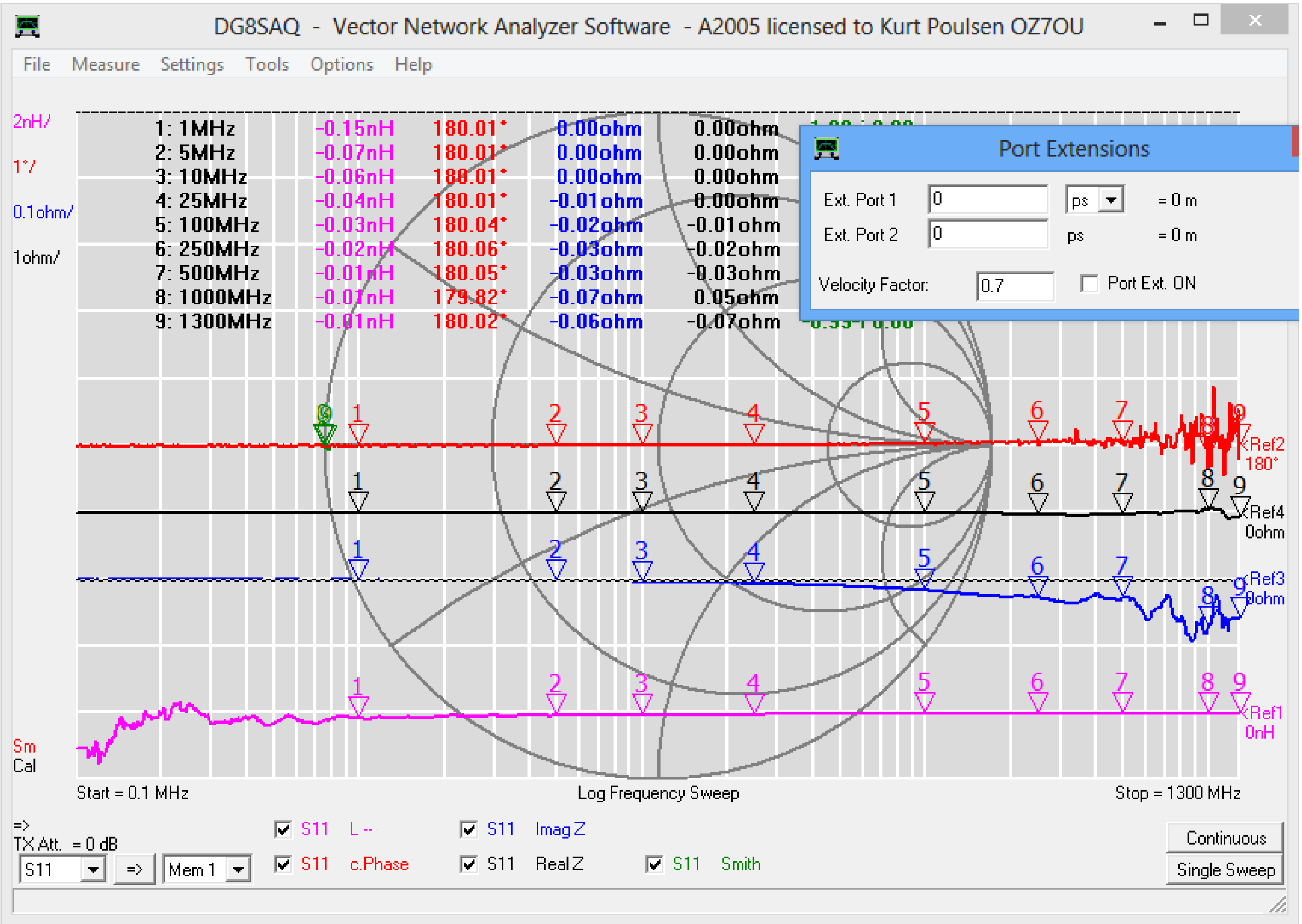
If we then calibrate the VNWA with the Long short and Measure the 0 ps Short we should then get the same error shown.



Above is the result when calibration with the Rosenberger Short in series with the Rosenberger Male Male adaptor. I have increased the number of points from 500 to 1000 and introduced 20 sample smoothing, as the trace was indeed very noisy above 500MHz. As seen errors has been introduced from 1 MHz and upwards.
These errors are however pretty small and up to 0.05 ohm at 500Mhz, but above so large that I definitely fancy using my 0 pS Short.
However the Amphenol Connex Male Short is also a very good short, having very short delay 16.9ps and being an airline with 5.07mm electrical length (no PTFE insert) having a ¼ wave resonance at 14.8GHz and an impedance at 1.3GHz of 0+j0.08186 ohm . Below is a trace of the measurement of the 0 ps Male Short based on a calibration with the Amphenol Connex Male Short.



Above the 0 ps Male Short measured after a calibration with the Amphenol Connex Male Short



Above the ImagZ scale increased to 0.1ohm/division and we see it is a straight inductive impedance introduced in the calibration file of magnitude measured to around 0.07ohm quite close to the theoretical value of 0.082 ohm

Conclusion about the Short Calibration Standard.:

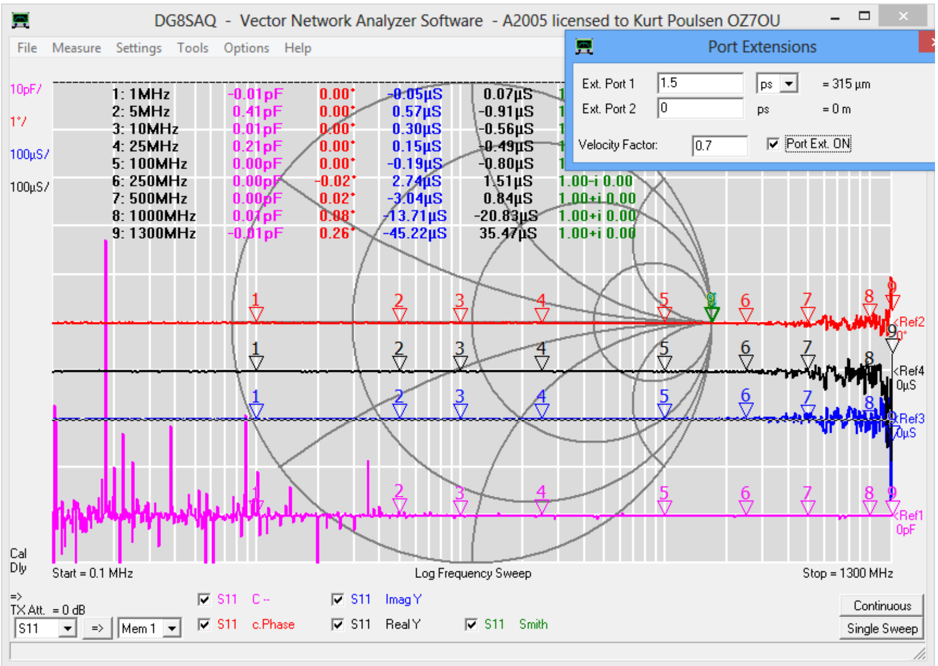
<u>Keep the Delay as short as possible and don not use adaptor if avoidable.</u>

The impedance at 1.3 Ghz for the Rosenberger Male Male adaptor in series with the Rosenberger Short is 0+j0.69 ohm and for Amphenol Connex Male Short it is 0+j0.082 ohm, almost only 1/10 imaginary part so a far better male Short.

Means are provided in the VNWA calibration settings to compensate for this effect, using arbitrary calibration and insert a formula for the impedance of the inductance of the Short and the delay, provided we are dealing with delays in the Shorting Calibration Standards far away from ¼ Wave resonance. Else, a far more complex expression has to be defined.

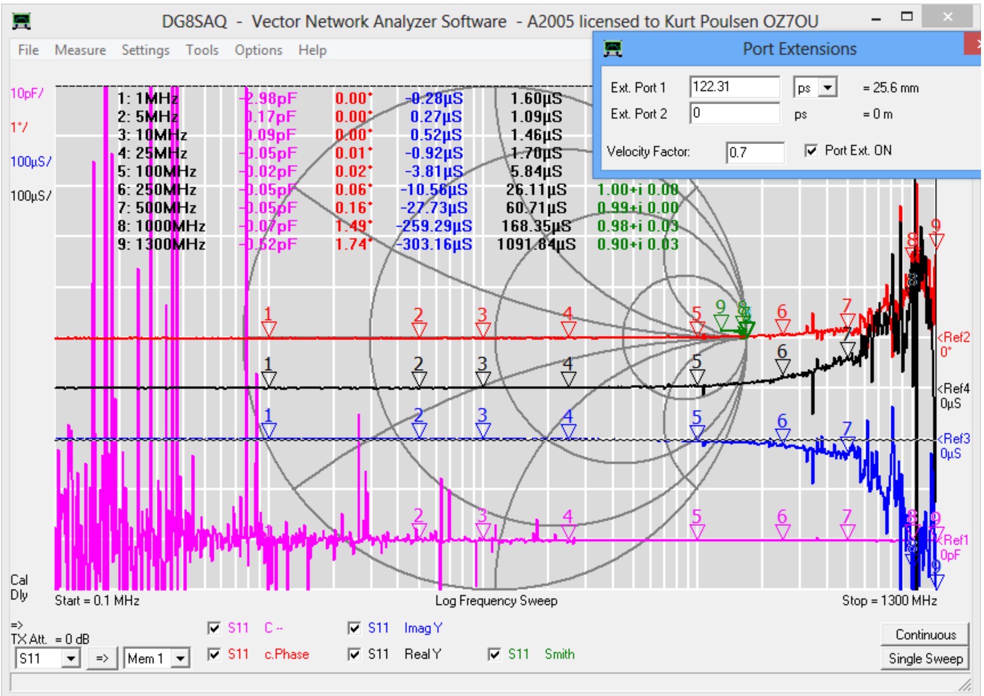
What about the Open Calibration Standard ?

There is no difference, as such. Using a Female Female adaptor in series with a Male Male adaptor to create a Male Open Standard has equally bad behavior. Let us examine what happens.

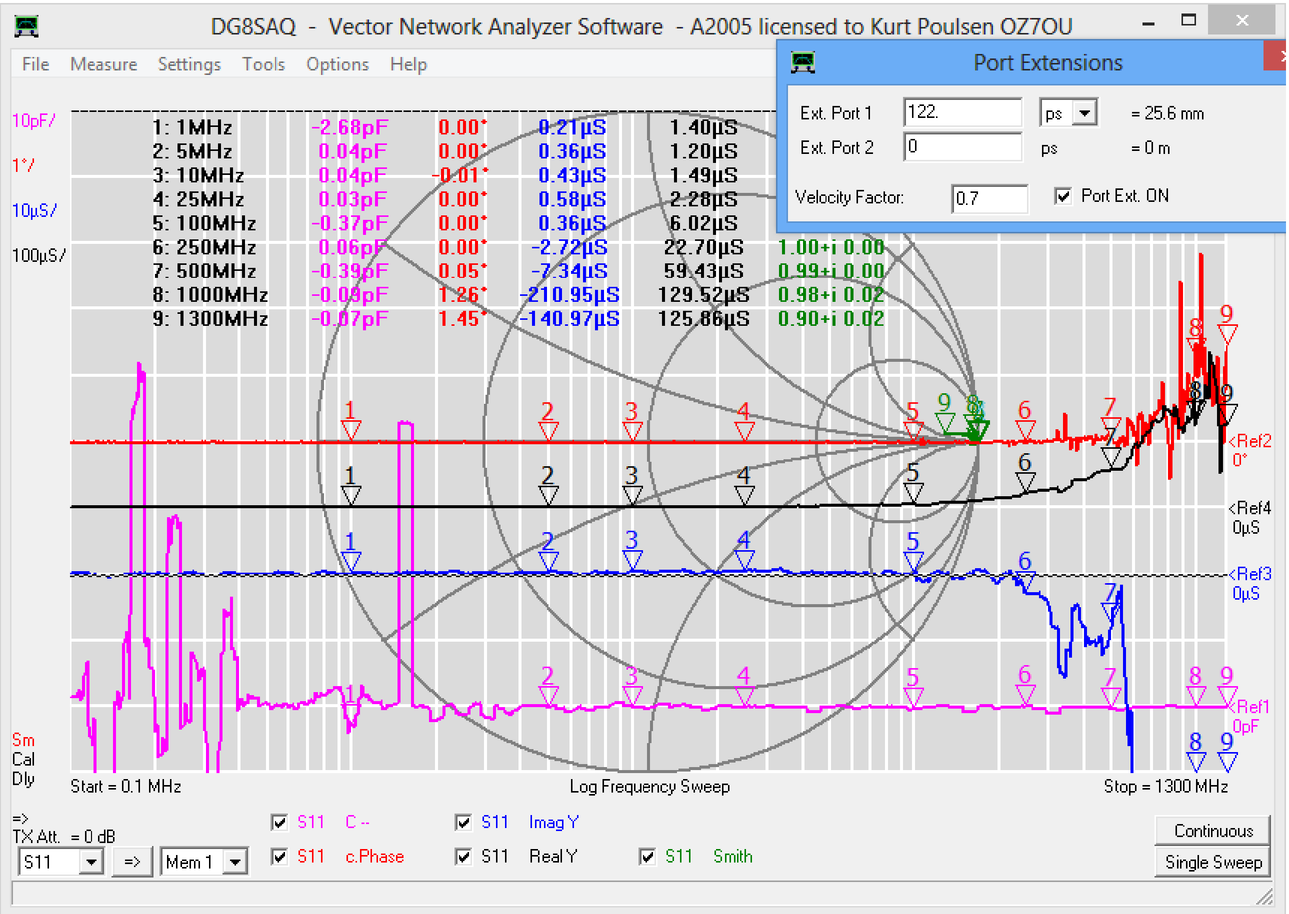


Above sweep is after a calibration with the Male “Dream Calibration Kit” where the Open Standard is nothing apart from the fringe capacitance (1.5ps) of the Female adaptor being calibrated. A nice clean flat plot of Cont.Phase, ImagY and Real.

Next is measured the Male Open Calibration Standard consisting of the Rosenberger Male-Male and Female Female adaptor in Series. The total delay of this combination is 42.35 plus 78.46ps = 120.81ps to which shall be added 1.5ps fringe capacitance = 122.31ps



As seen above 100Mhz the frequency dependency starts to add. The electrical length is 25.6mm and the ¼ wave resonance where the open turns into a short is 2.93GHz and the imaginary impedance at 1.3GHz of an open transmission line of said electrical length (0.111 wavelength) has a similar effect on the calibration if used as Open calibration Standard.



Above is same plot but smoothing added for the three traces and the scale for the Imag Y increased by a factor of 10. The Ext. Port 1 delay changed to 122.00ps and a better match obtained below 100MHz but worsened above.

The change of 0.31ps correspond to a distance change of the measuring point of 0.093mm in open air, which can be caused by a mechanical difference alone, from one adaptor to the other. Such differences measured to be in the range of 1 ps amongst a number (5 or more pieces) of Aphenol Connex adaptors produced over a period of 2 -3 year corresponding to 0.2mm.

Why the Logarithmic frequency scale. ?

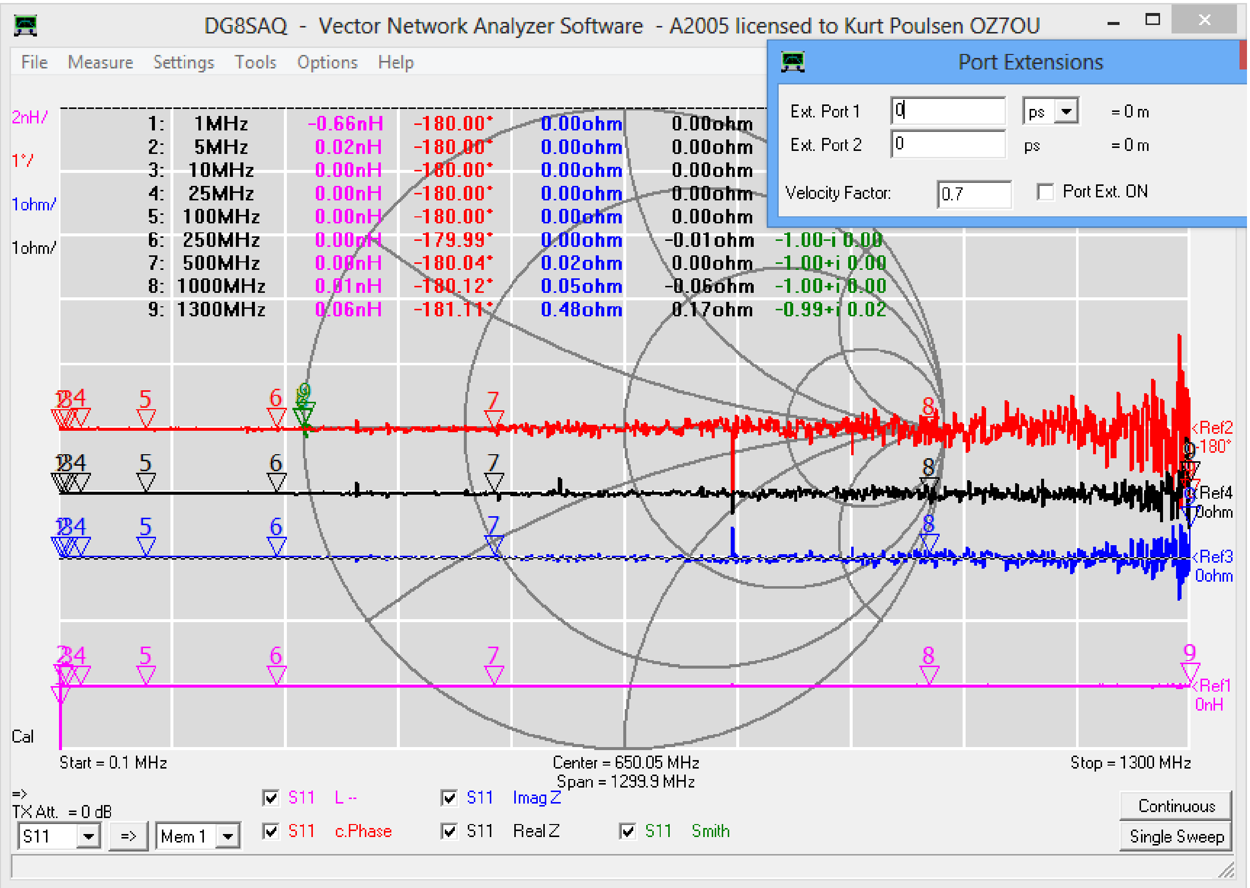
As you probably has noted it magnifies the lower frequency range as opposed to the linear frequency scale. I also reduces the effect, not likely to happen for these types of measurements, where the time it takes for the reflected wave to return is in the ballpark of 200ps.

Despite quite outside the scope of this report, the logarithmic frequency scale can be used if measuring reflections or transmission on very long cables, by old school VNA's with analog sweept oscillator and by using narrow IF bandwidth and fast sweep, as the reflection might arrive outside the pass band of the IF filter, or detection distorted, due to the IF filters group delay and creates measurement errors.

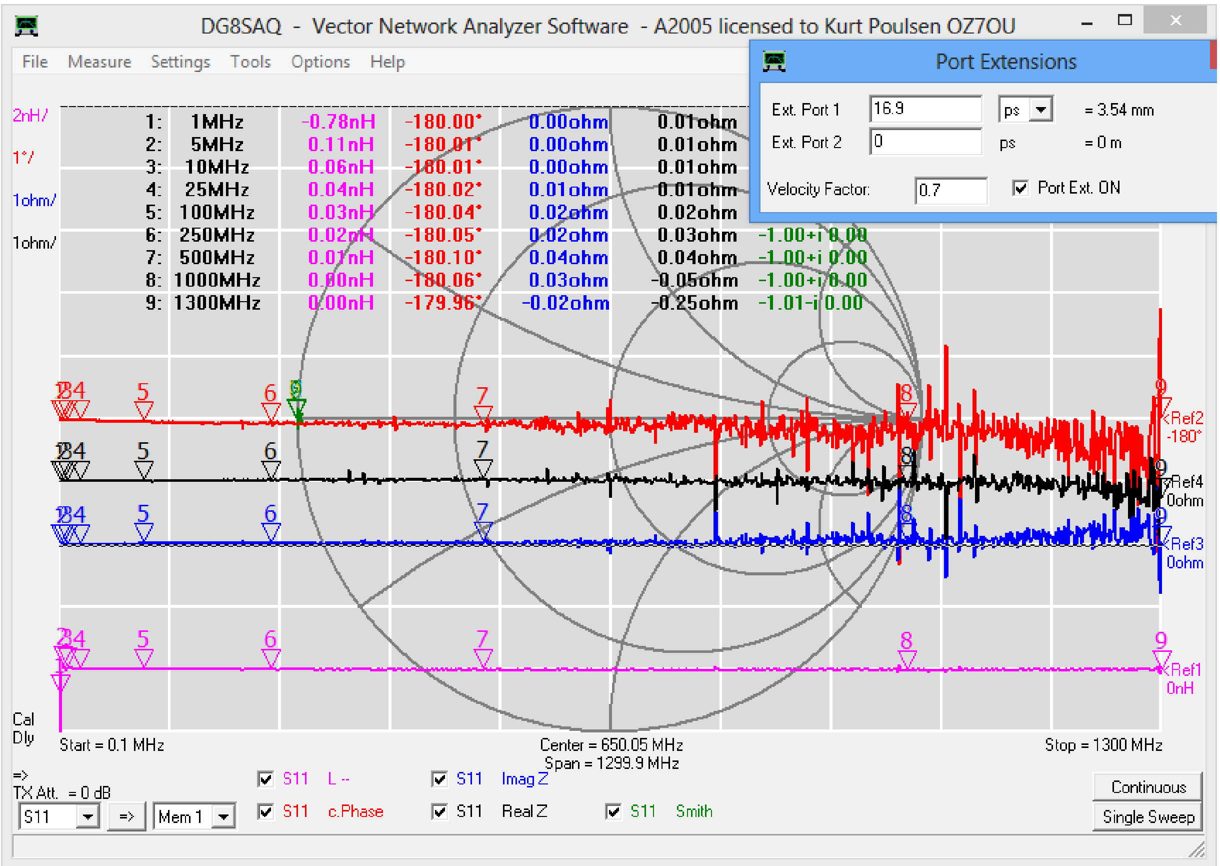
I read recently and article where this effect is described for S21 attenuations measurements of cables. However, the VNWA is not sweeping in the analog fashion, but measures on a fixed frequency a number of times and then step to the next fixed frequency. It is the number of point and the time per point, which is to consider. Using linear frequency scale the frequency change per time unit (time per point) from one frequency point to the next (called **df/dt**) is much larger at 0.1MHz than e.g. 1GHz whereas by logarithmic scale it is compensated considerable. With 1000 datapoints and 10mS per point leading to a sweep time of 10 second, there is 1.3Mhz between data points so in the analog world is means frequency changes 13KHz. The relative frequency change at 0.1MHz 13/100=0.013 and by 1.3GHz = 0.00001. As said, the VNWA does slide slowly across the frequency span but stays at the fixed frequency for a while. Time per point of 10mS is corresponding to a length of the cable/coaxial structure of 3000 km so not likely to happen ☺ but for old school analog VNA it causes problem if not taken care of and logarithmic frequency scale would help on this effect.

New topic:

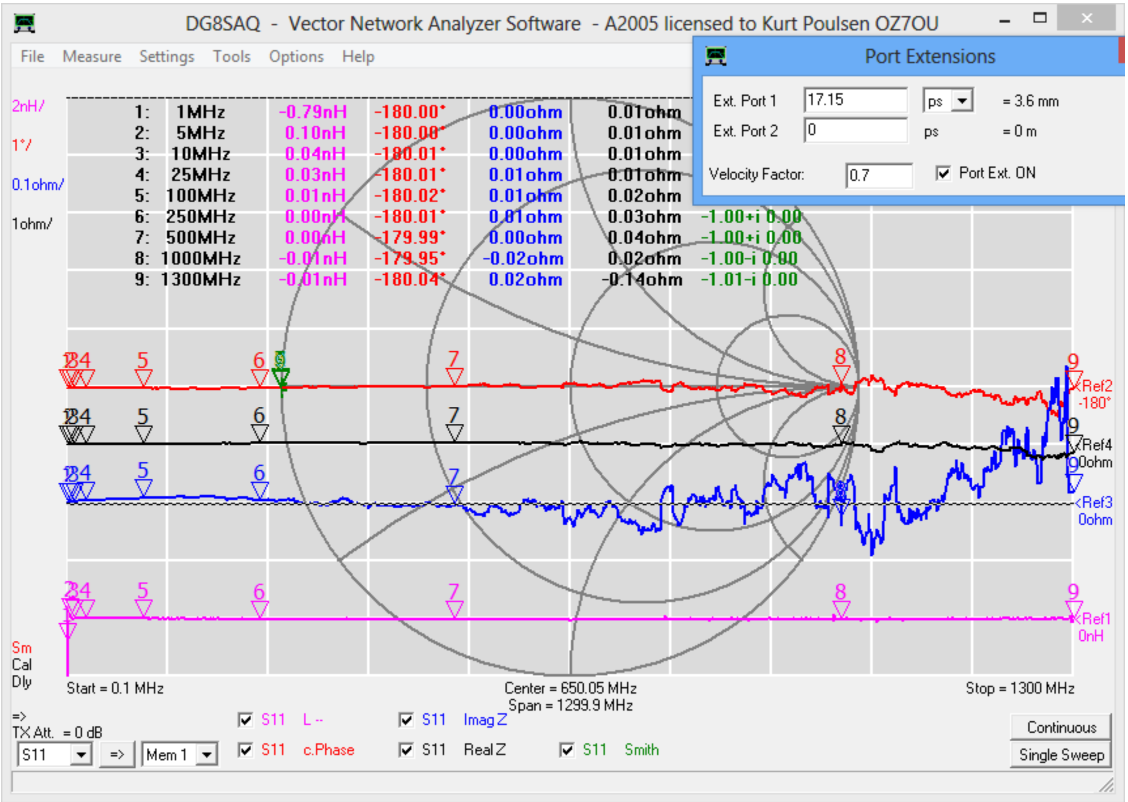
Let us instead look on what we can derive of information using linear frequency scale regarding Short calibration standards.



After calibration with the dream Male Calibration Kit and use of 0ps Short

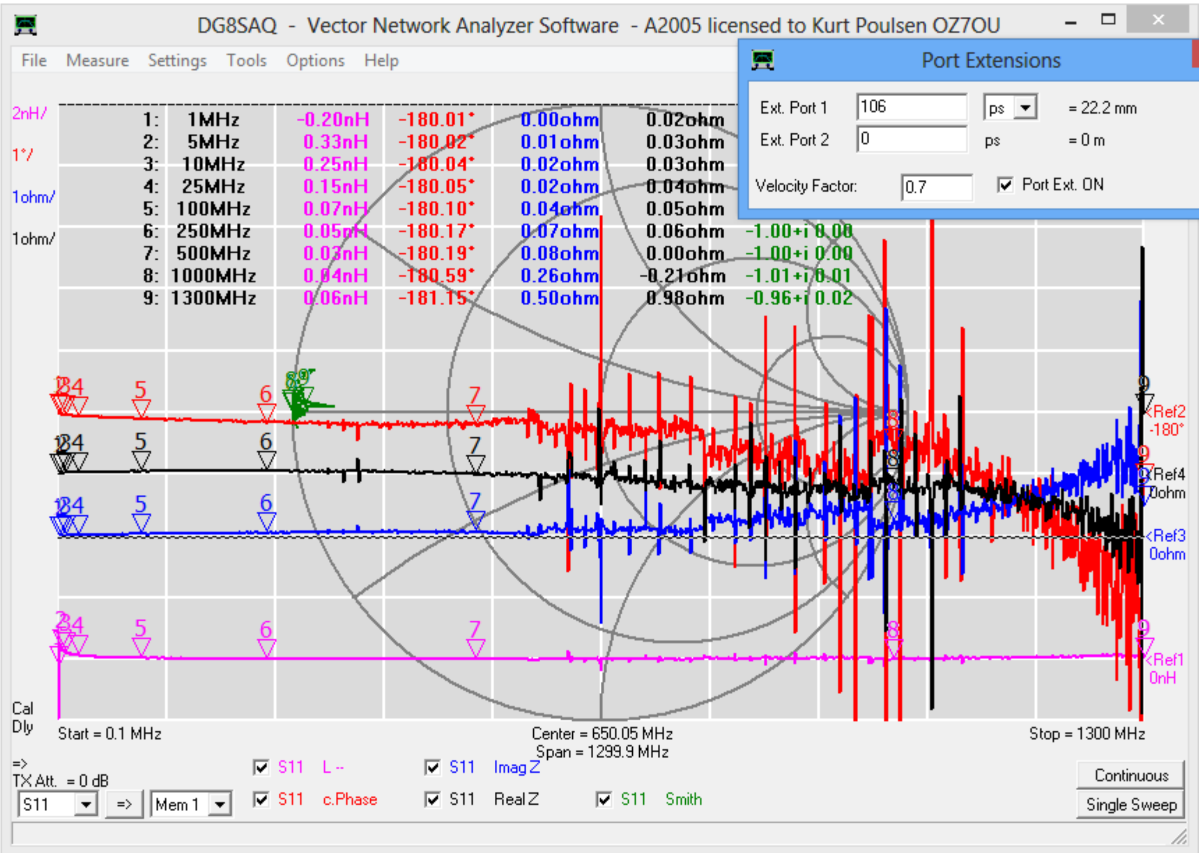


Measurement of the Amphenol Connex Male Short with the defined delay 16.9ps entered in the Ext. Port1 delay

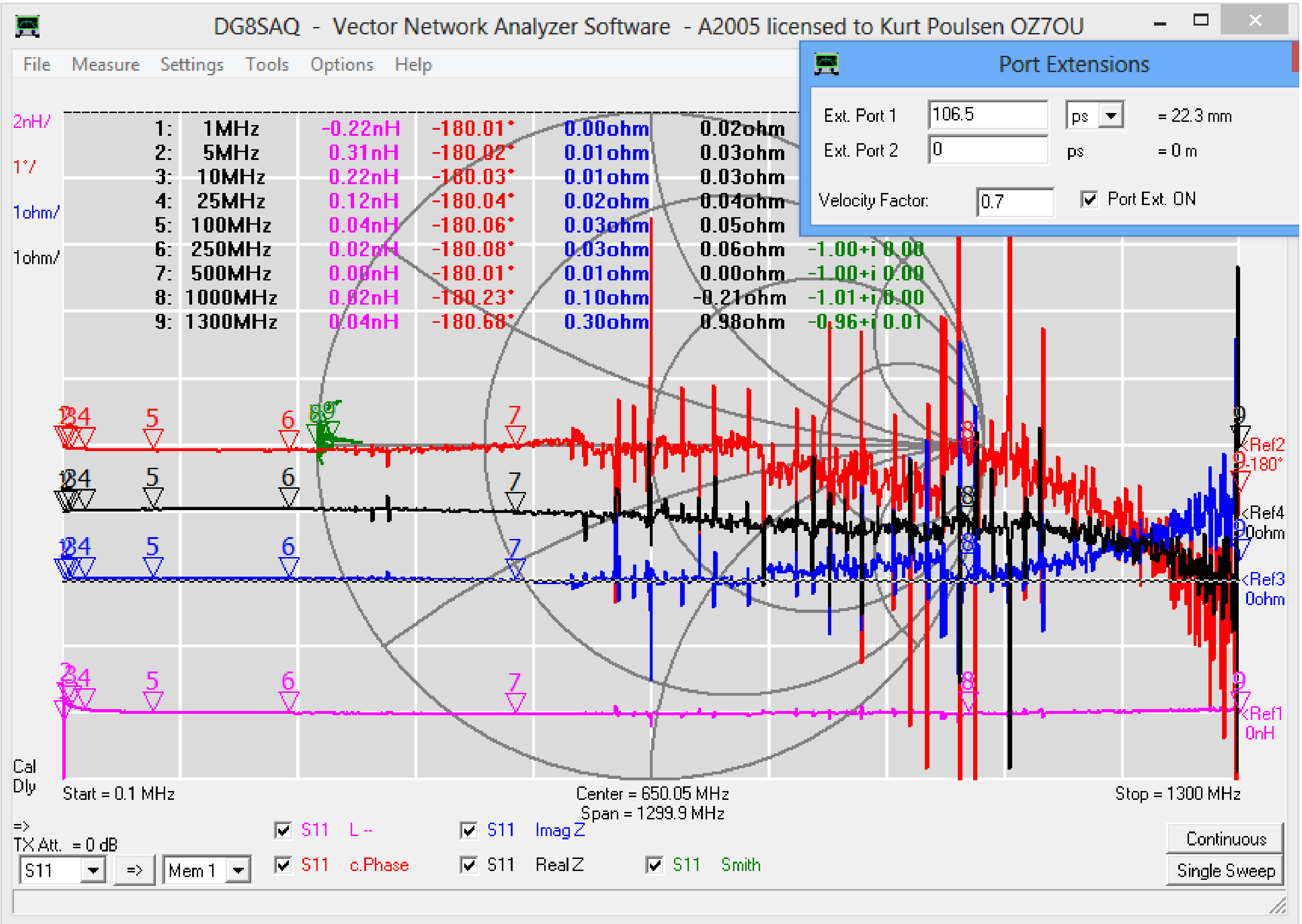


Measurement of the Amphenol Connex Male Short with increased resolution from 1 to 0.1 ohm per division and smoothing applied to trace 2,3 and 4 . The trimmed delay 17.15 ps entered in the Ext. Port1 delay gives better fit up to 1GHz then a very small deviation is introduced. At least we can conclude it is straight inductive to 1 GHz and highly useable to 1.3GHz

Next we will measure the Rosenberger Male-Male adaptor and Male Short in series.



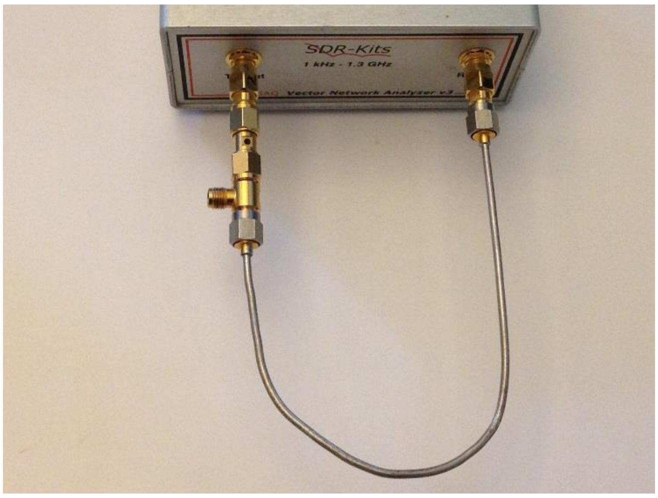
With the defined delays from the Published Calibration Sheet of 15/12/2013 entered in the Ext. Port1 delay we see an additional inductive element and we then will trim the delay to get the imagZ and Cont. Phase to be horizontal.

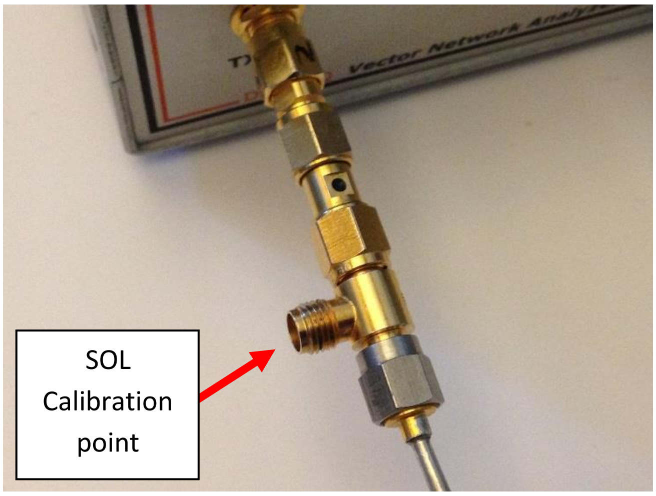


Above is seen that a reduction by 0.5 ps bring a better fit to 1 GHz but that is only a trick to optimize up to 1GHz as the right way is to use arbitrary calibration because the delay only is not an adequate method. The trimming counts for a delay adjustment corresponding to 0.1mm in electrical length.

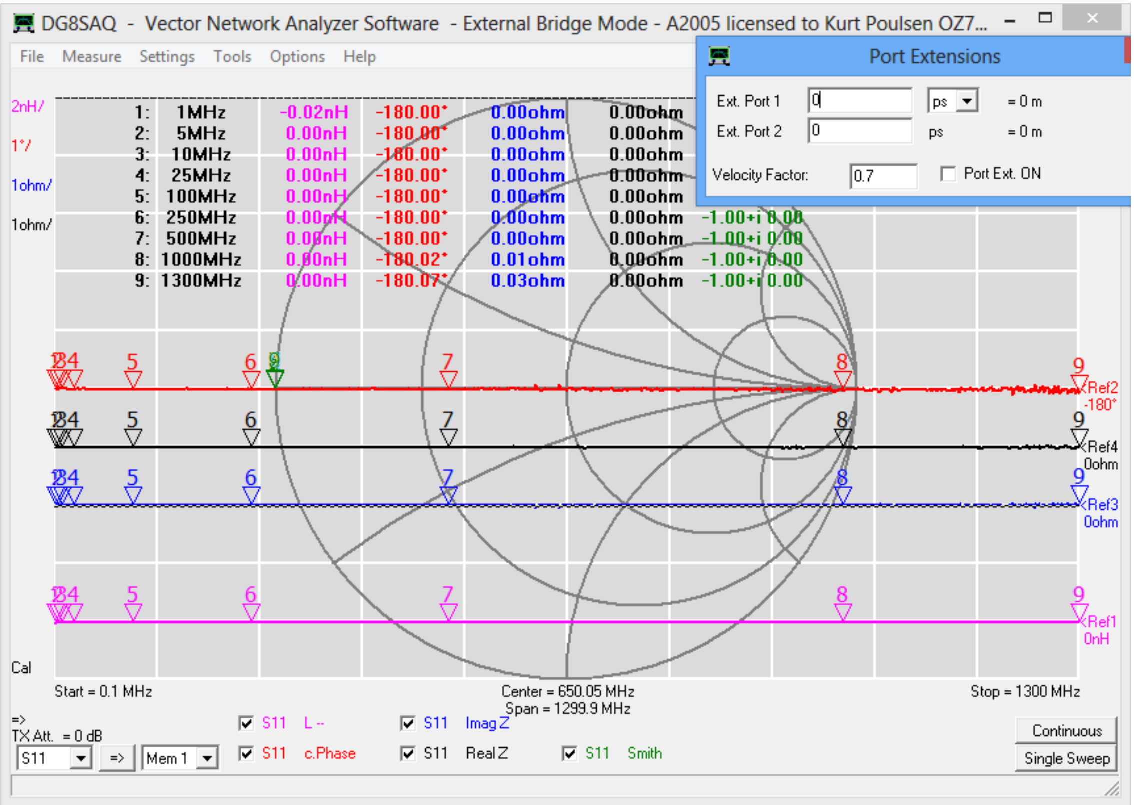
A different approach to measure Short standards:

All above measurements has been with the VNWA in Operation mode VNWA which the standard way where the best accuracy is focused around impedances close to 50 ohm. However the Instrument mode “External Bridge” is a better method to measure low impedances, such as the Short Calibration Standards, using a T Adaptor as the Bridge as shown below. It is the same External Hook Up used when doing T-Check to be mentioned/shown/discussed a bit later.



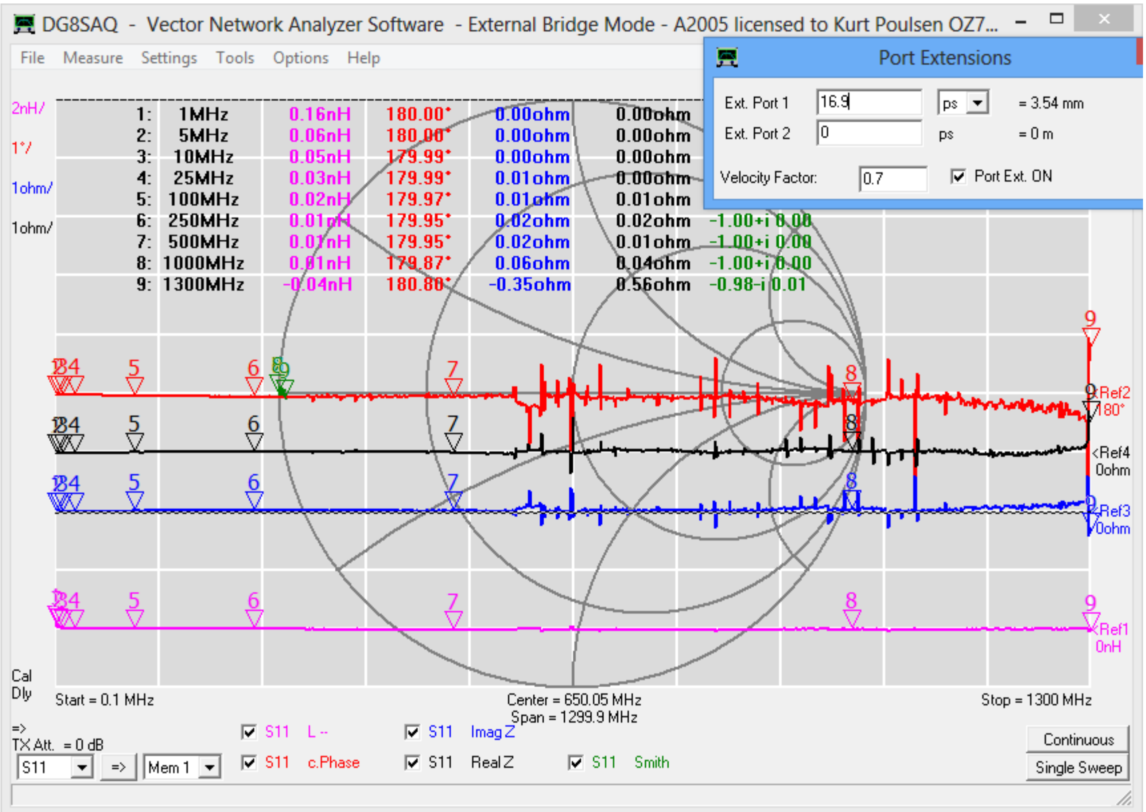


After a calibration with the "Male Dream Calibration Kit" a measurement is done right away of the 0 ps Male Short



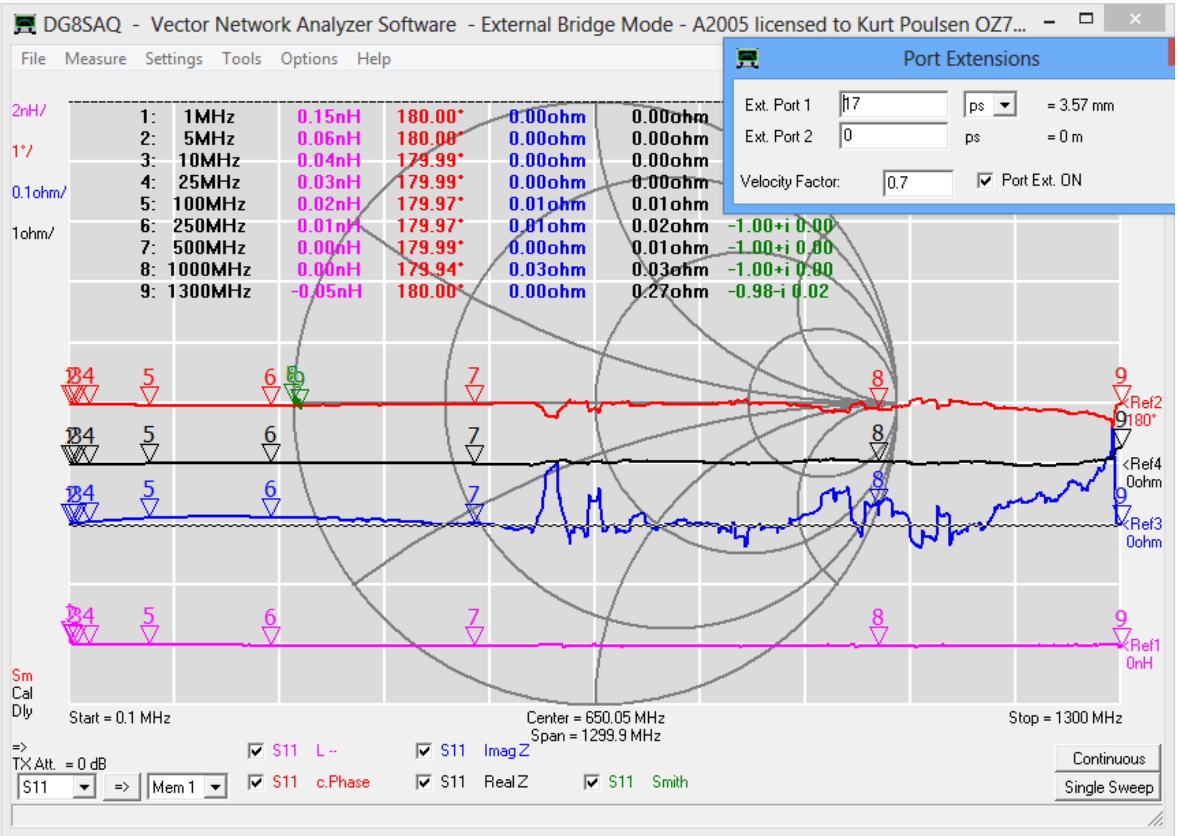
Very Clean Traces....wonderful improvement

Then we measure the Amphenol Connex Male Short with 16.9pS delay



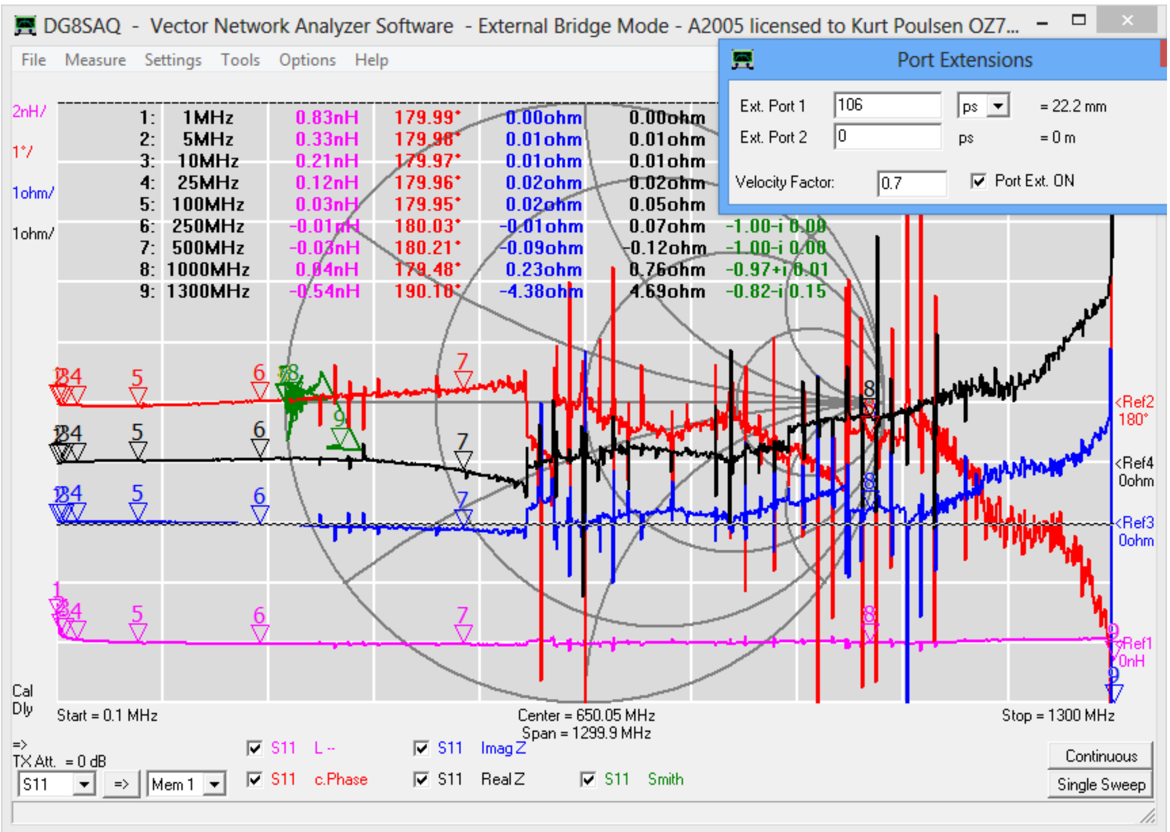
Said delay for the Amphenol Connex Male Short entered in Ext.Port1 delay and the traces very smooth and almost perfectly horizontal. The "lift" at 1300MHz of ImagZ even about the same as when Operation Mode was VNWA but with less noise.

Next the Ext. Port1 delay trimmed



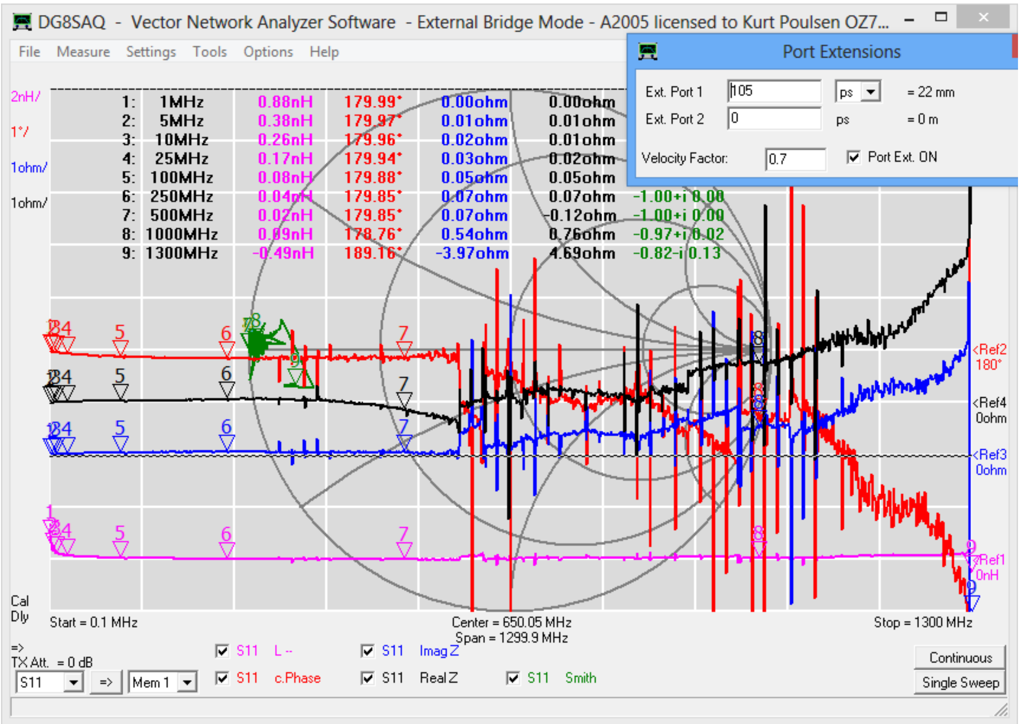
By trimming the delay to 17ps - a correction of 0.1ps - brought the response to more than 1 GHz to a better fit. Smoothing applied to the traces.

Now the Rosenberger Male Male adaptor and Male Short in series measured



As before much larger deviations seen with the Ext.Port1 delay set to the delays from the calibration sheet dated 15/12 2013.

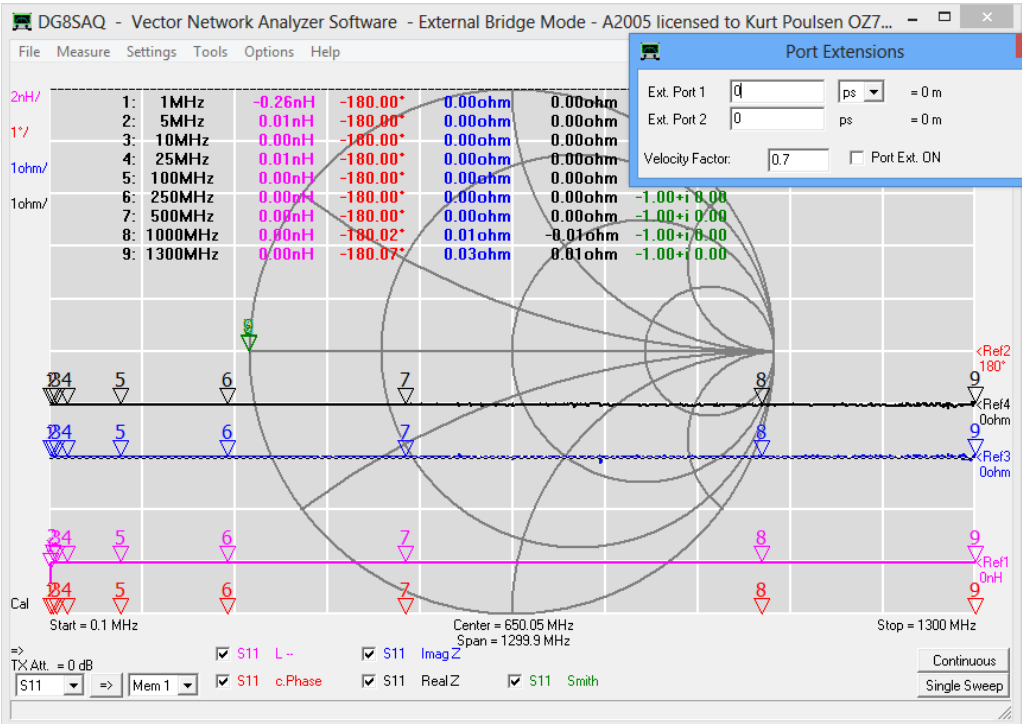
Next trimming of the Ext. Port 1 delay applied



Up to 500MHz a better fit for an adjustment by 1 ps to 105ps obtained by all the Jumps in the traces are making such judgment doubtful what is the better.

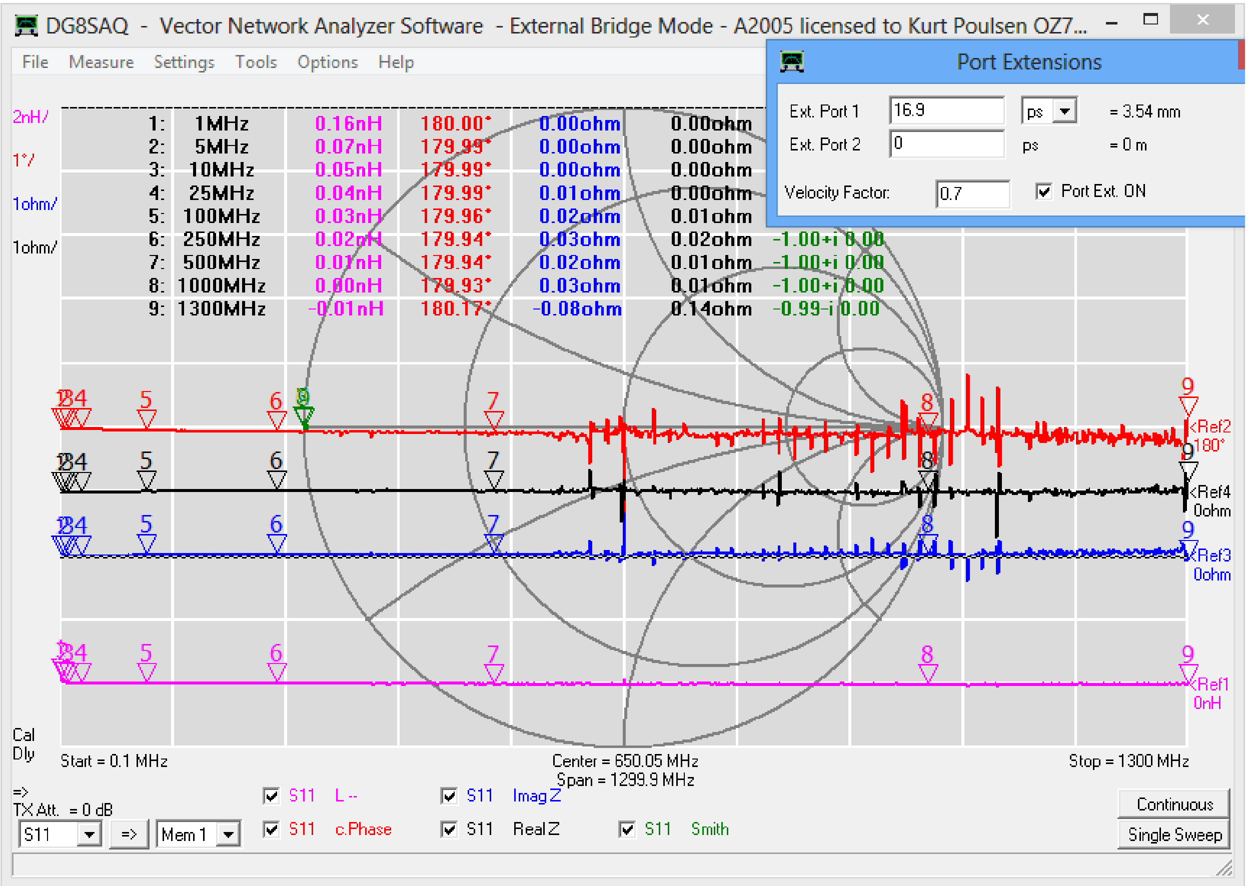
Past experiences has shown that adding a 10dB attenuation helps a lot to reduce these jumps and improve the general accuracy of the VNWA. The reason is, as mentioned before, the imperfection of the VNWA RX Ports input impedances as it before more and more imaginary as frequency increases, especially above 500MHz. The 10 dB inline SMA attenuator linearize it to be almost perfect pure resistive 50 ohm.

A renewed calibration done and a measurement of the 0 ps Male Short done .

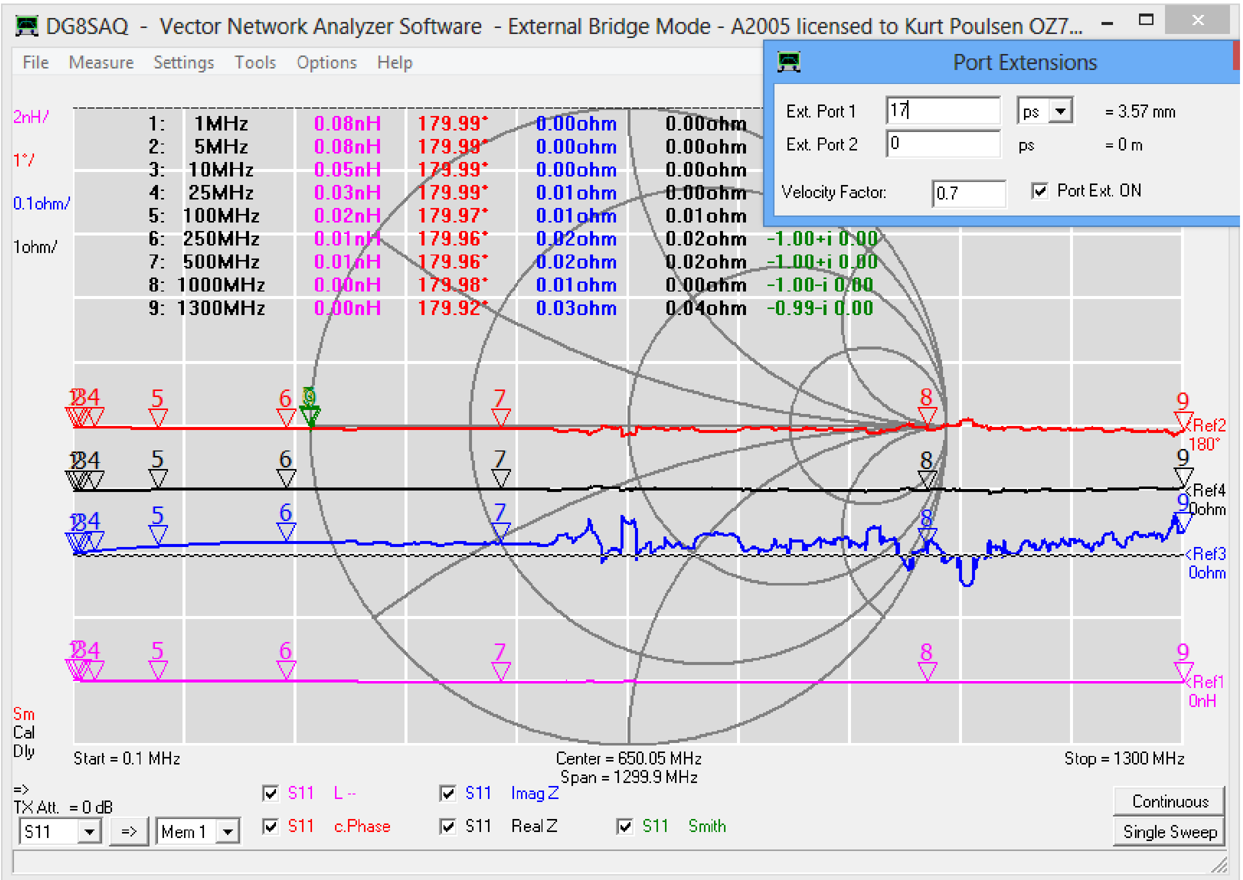


The measurement with the 10dB attenuator of the 0ps Male Short does not make the trace more noisy to any great extend.

Next the Rosenberger Male Short measured

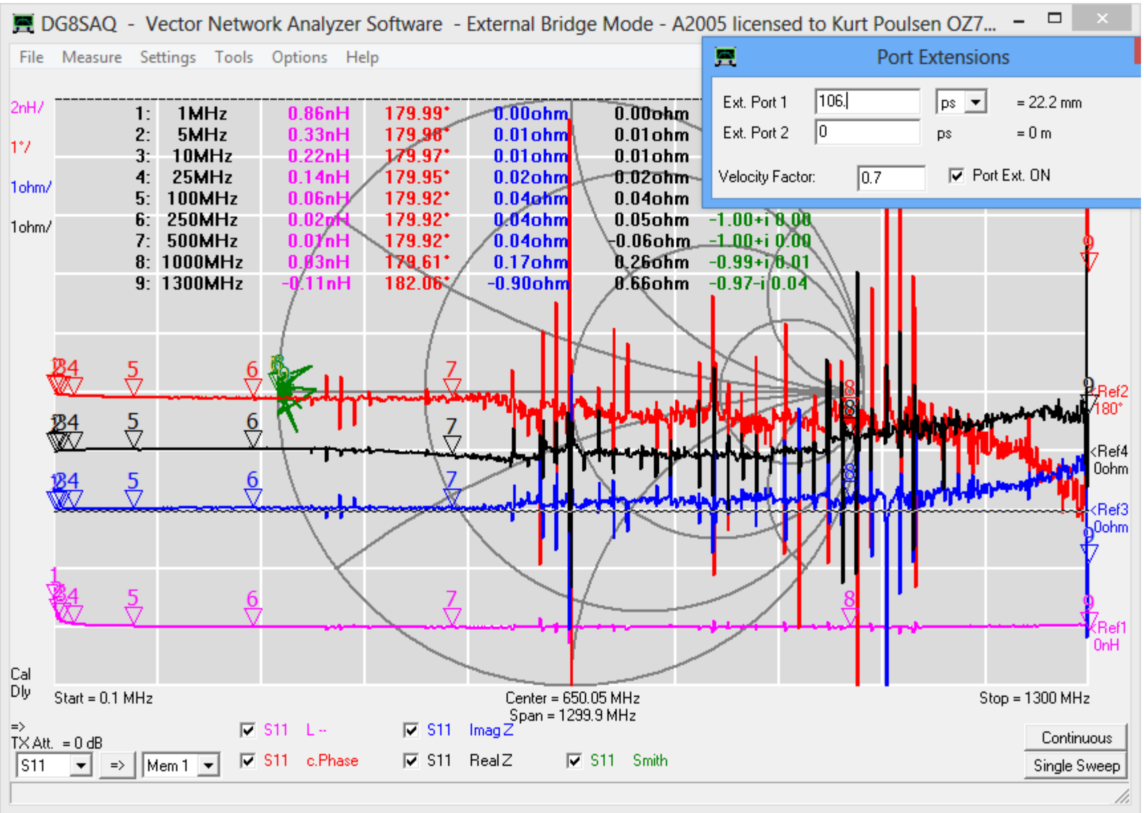


And great results seen as the response without severe jumps and the ImagZ "lift" at 1.3GHz almost gone. The theoretical ImagZ was 0.08 ohm and on the next screen shoot it is observed to 0.05 ohm



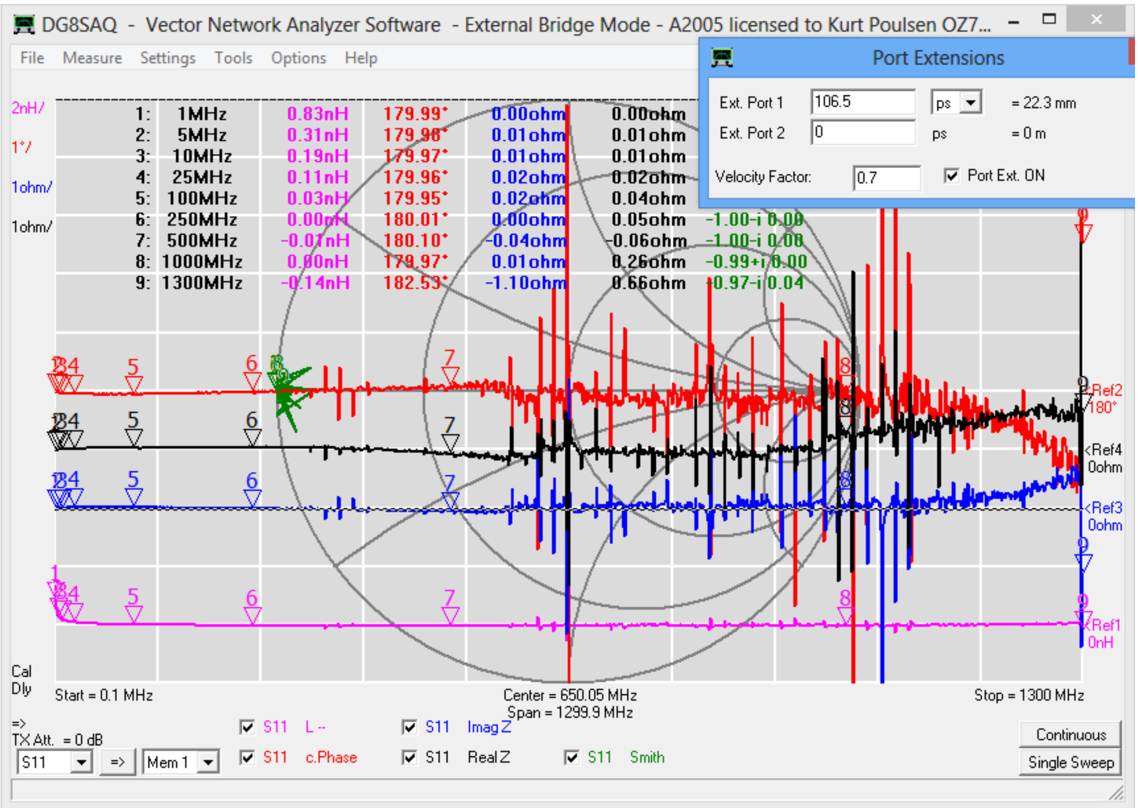
Same as above but smoothing applied and Ext. port1 delay trimmed to 17ps, an increase of 0.1ps

Next the measurement of the Rosenberger Male Male adaptor and Male Short in series.



With the Ext. Port 1 delay corresponding to the published delays of 15/12/2013 a much cleaner trace obtained with the added 10dB attenuator.

Next a slight trimming of the delay done.

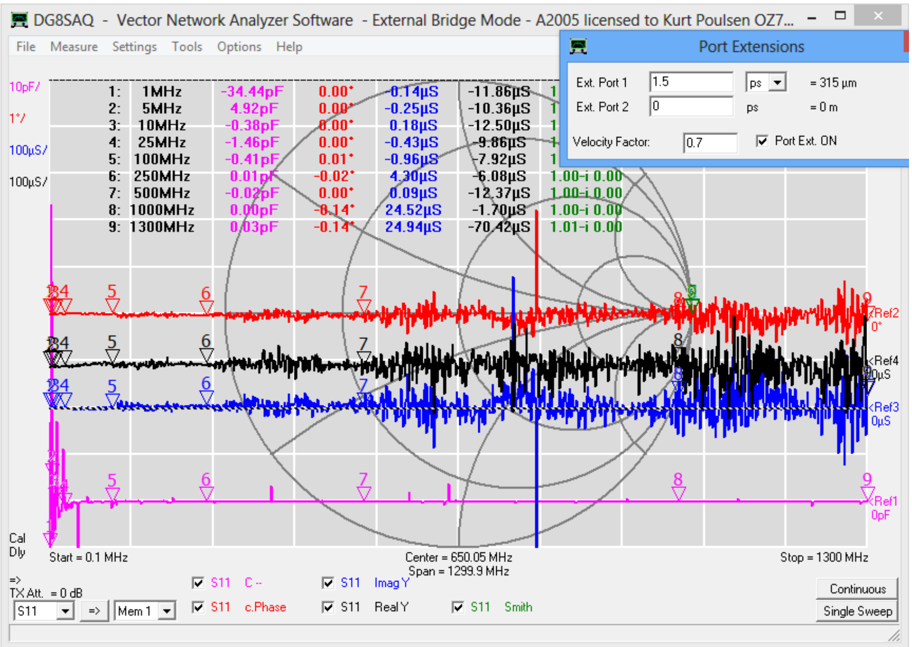


A reduction by 0.5ps to 106.6ps brings the fit to more than 1 GHz . The ImagZ approaching 0.6 to 0.7 ohm at 1.3GHz where the theoretical value was 0.69ohm

Conclusion about the External Bridge mode.

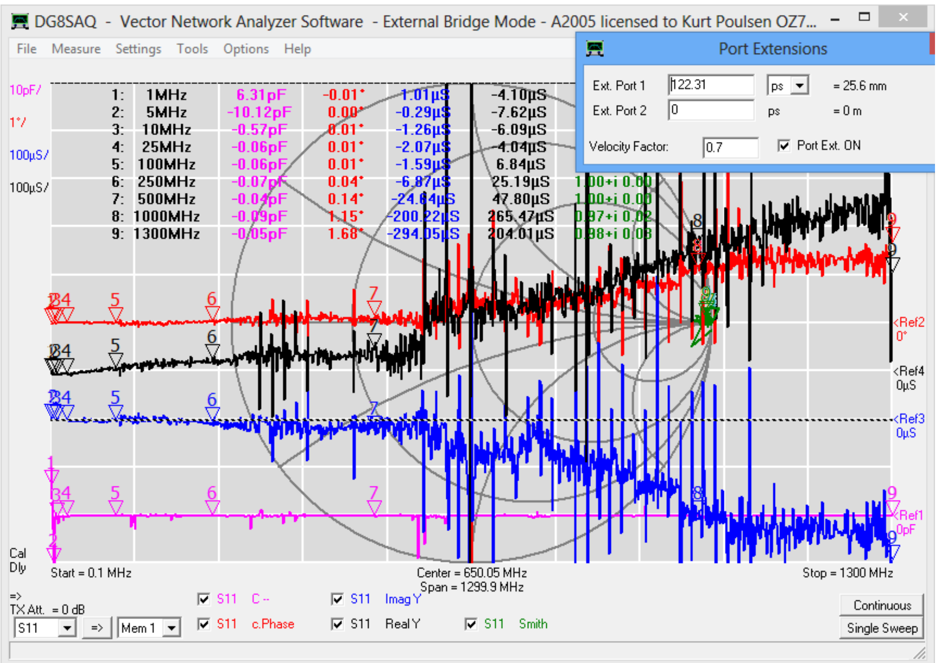
This method is far better for low impedance measurement and especially when the SMA inline 10dB attenuator added. Very accurate, less noise and proves the quality of the VNWA performance is superb. Please note that there had been no attempt to select any particular Male Male adaptors or Male Shorts, it is a random pick amongst the numerous devices I have.
Although not documented here in great details, the External Bridge mode is also to prefer when measuring Open Calibration Standards as lesser noisy and more accurate.

After calibration with the "Dream Male Calibration Kit" the Open Standard measured (nothing applied except fringe capacitance)



Perfect trace of the Open standard with Ext. Port 1 set to 1.5ps

Measurement done of the Rosenberger Male Male adaptor in series with the Female Female adaptor as a male Open standard.



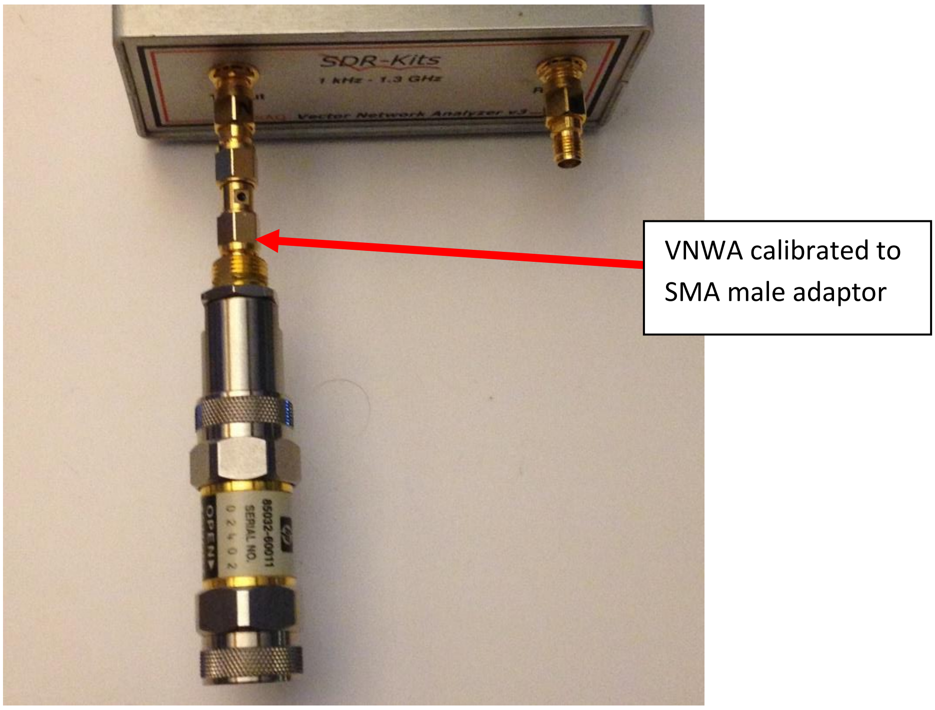
Here seen the real "ugly face" of adaptors connected in series. Phase error above 1 degree at 1.3GHz

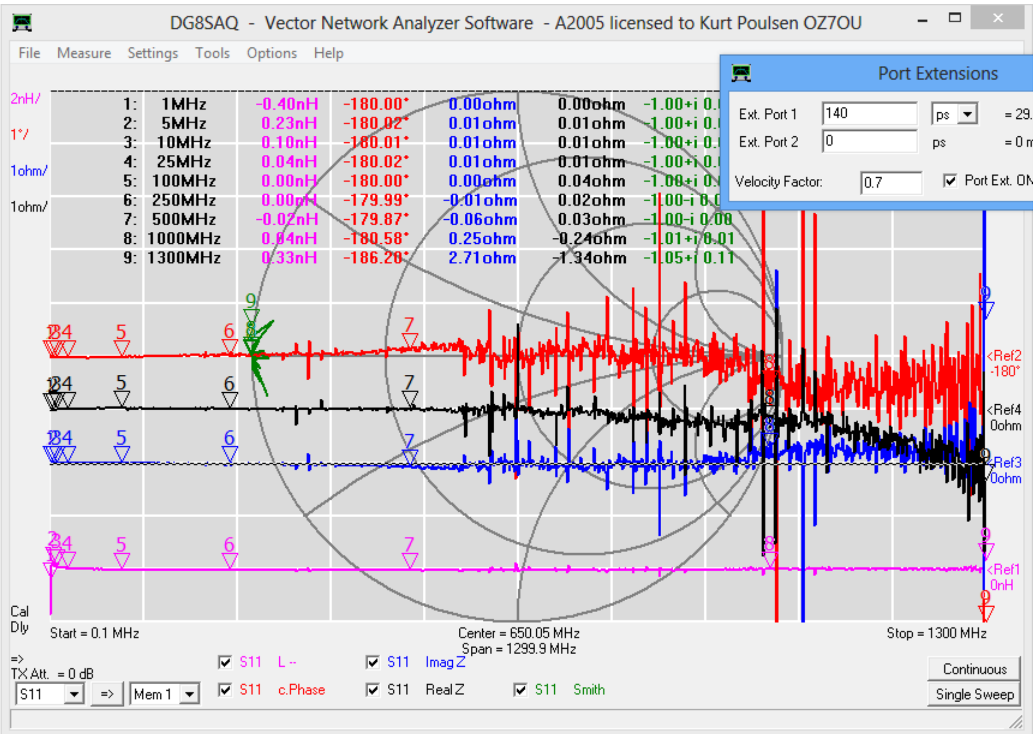
Now shown a real ugly case….

This example demonstrates when a VNWA owner tries to measure thru a Gender changer adaptor, because he only own a SMA calibration Kit. In fact, it is possible to do so it the adaptor is of good quality and by use of Ext Port delay and its delay is known. It is seldom the case so some intelligent guesswork is a need, based on the physical length between the two reference planes and use of the formula 4.83ps per mm. However many adaptor does not have PTFE all the way through the adaptor, but section with air with velocity factor of 1 giving 3.33ps per mm.

Below is demonstrated what happens if good quality adaptors used and at last how ugly and adaptor can be.

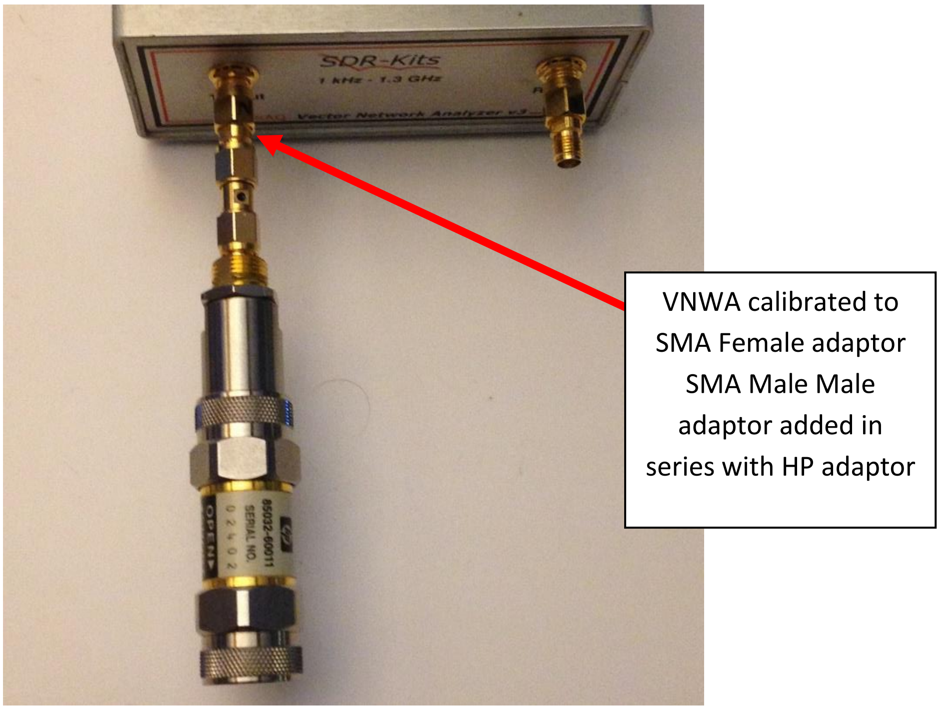
As test item is used an N Male Short from a HP Calibration Kit 85032E with a delay of 35.6ps. The first example is using a HP/Agilent well known SMA Male to N Female adaptor hooked up as seen below. Calibration performed using the Female Rosenberger calibration kit.

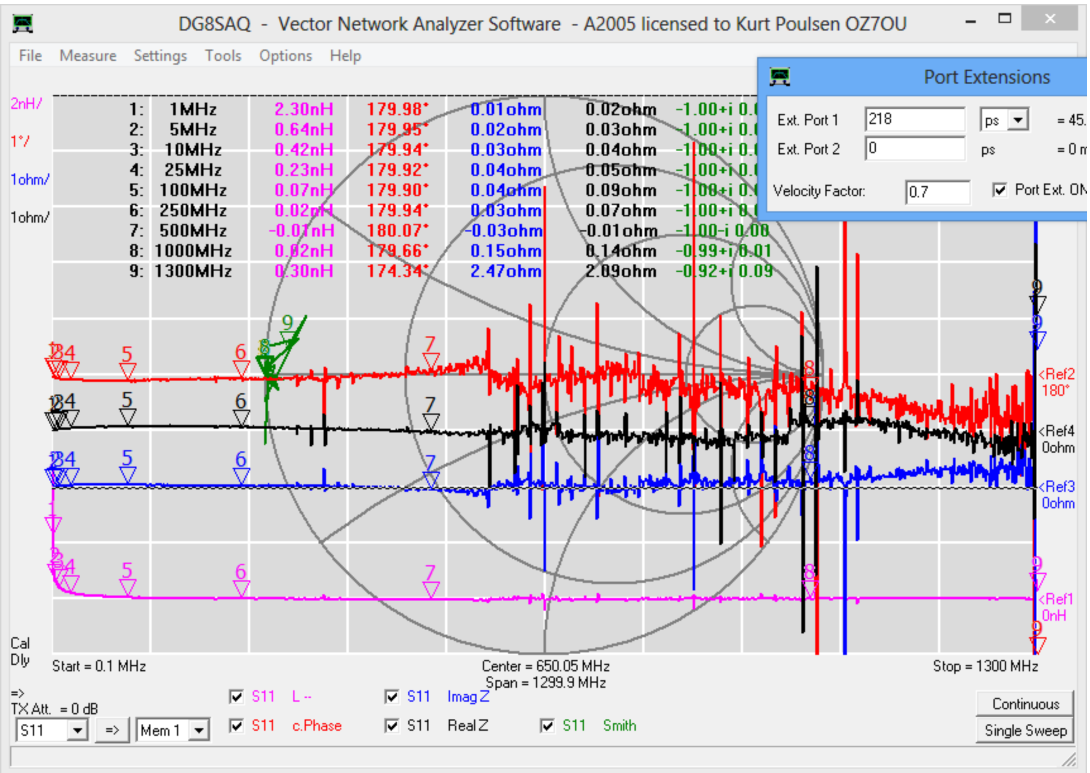




HP SMA Female to N Female measured above with the entire delay found to be 140 ps and results accept table. As the HP N Male Short has a delay of 35.6ps then the adaptor delay is 104.4ps. Quite useable to 1 GHz.

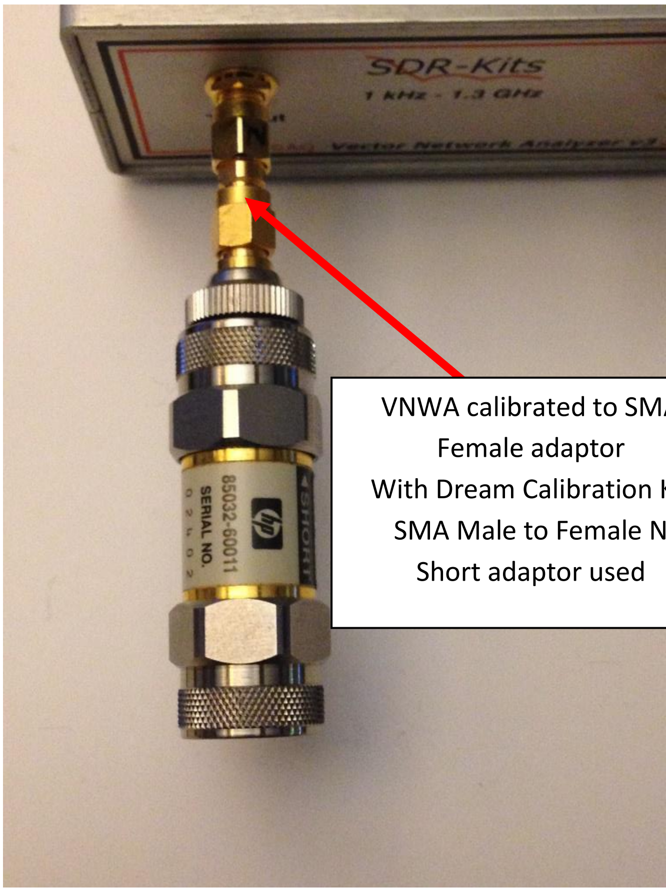
In below example the VNWA is calibrated to the Female adaptor with my Male Dream calibration Kit and the Amphenol Connex Male Male adaptor added and compared to above.



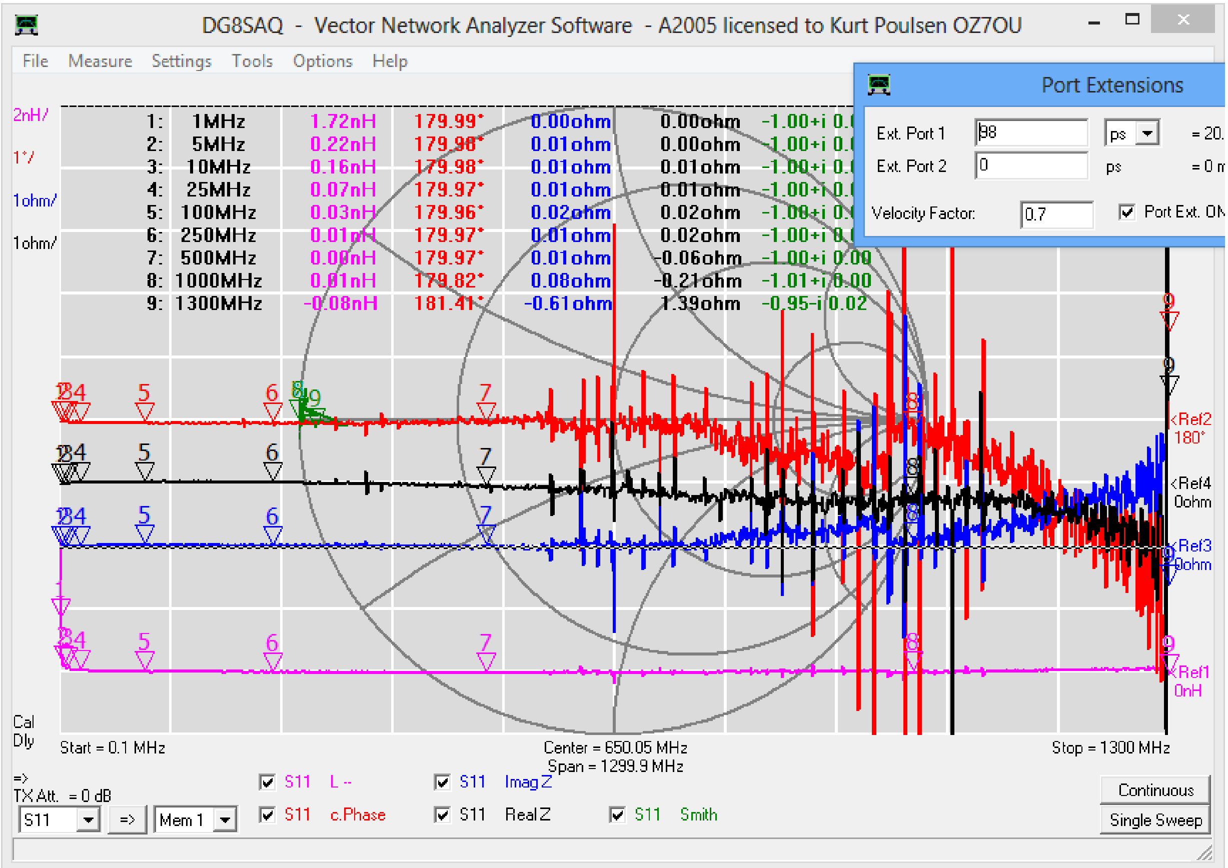


Measurement of N Male Short from a HP Calibration Kit 85032E with a delay of 35.6ps in series with a HP SMA Female to N Female and further in series with Amphenol Connex Male Male adaptor. Result acceptable t 1 GHz. Total delay 218ps which constitutes of Amphenol Connex 76.8ps HP Male standard 36.6ps so the HP SMA Female to Female N adaptor should be (218-76.8-35.6)ps = 105.6ps. In above example found to be 104.4ps, a difference of 1.2ps. It is a quite common problem when the VNWA is in Operation mode VNWA. In the External bridge mode as described earlier these differences are much smaller.

A pretty short SMA Male to N Female adaptor, bought on the Hamradio 2013 Flee Market is used.



VNWA calibrated to SMA Female adaptor
With Dream Calibration Kit
SMA Male to Female N Short adaptor used



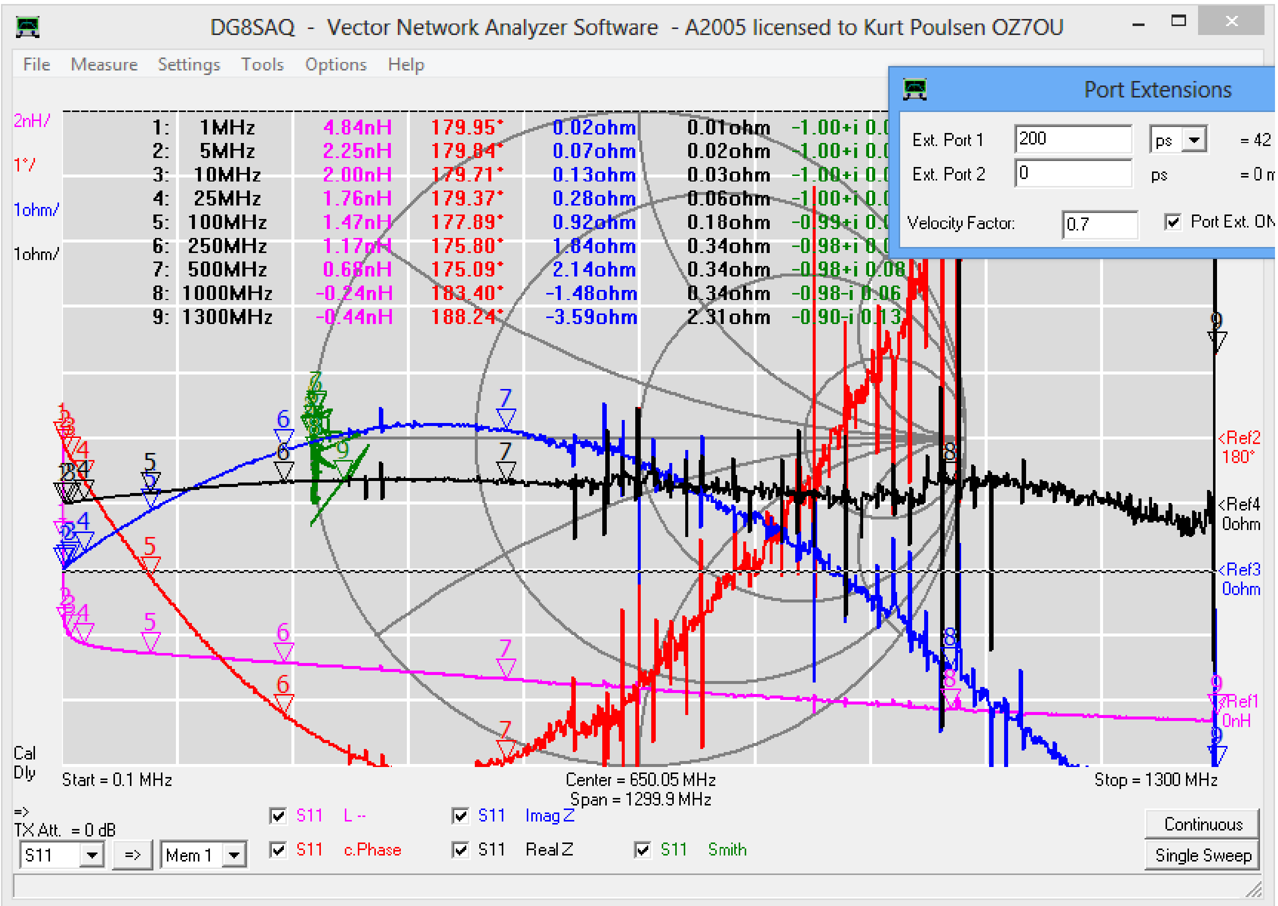
The Short SMA Male to N Female. Despite it's short length it is not so well designed as the other used adaptors.

Its delay is 98ps-36.6ps= 61.4ps

And now to the very ugly example.

Long time ago I bought this universal gender changer kit converting between all sorts of connectors and genders. PL259, mini UHF, N , BNC , TNC and SMA. Shown is the parts for a SMA male to N female and used for measuring the HP N Male Short from a HP Calibration Kit 85032E with a delay of 35.6ps.

The terrible result is shown below



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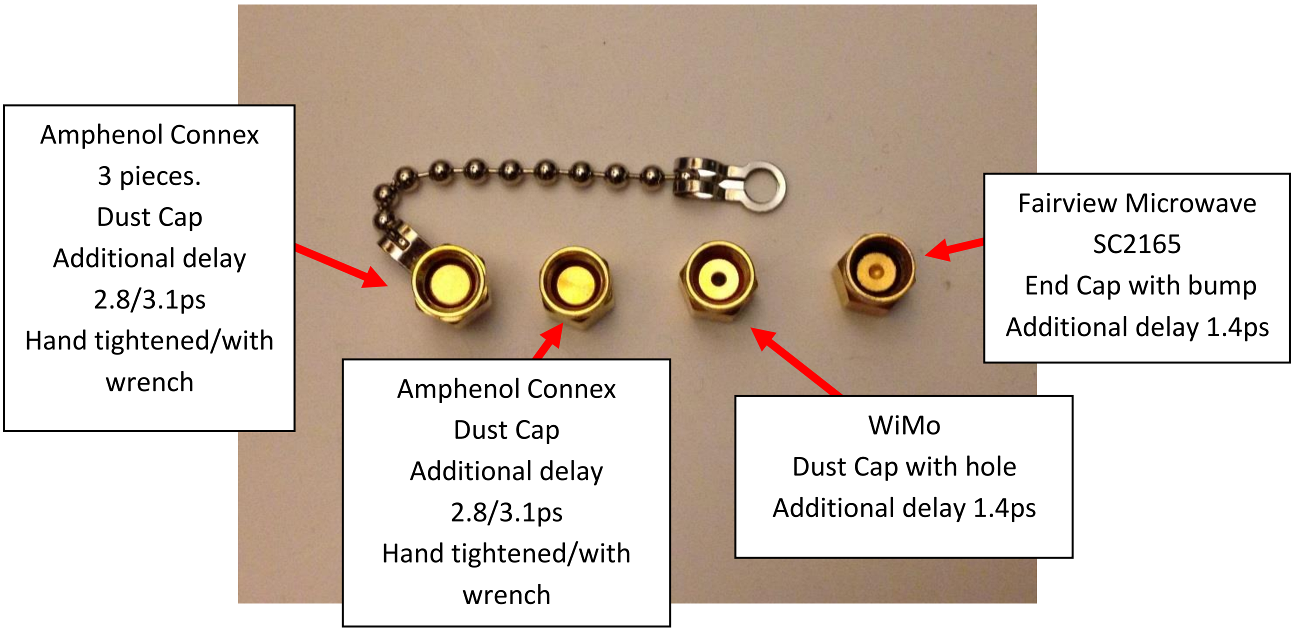
It is totally hopeless to find a delay for this adaptor. Shear junk costing 250 Euro ☺

The "funny" Open standard or using the dust cap as Open standard

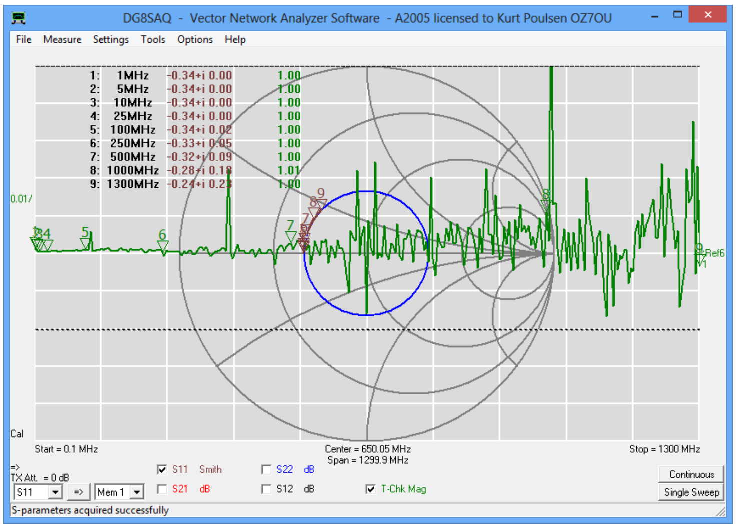
In my opinion there is no justification for using the Dust Cap for anything else than keeping dust away. When a Dust Cap is fitted to a Female adaptor, it does nothing but adding additional fringe capacitance and as being a mechanical device, the capacitance it adds depends on mechanical tolerances and then variation from item to item adding uncertainties to the calibration data. Examples of such Dust Caps are shown below and the added delay they provide.



A common additional uncertainty is the position of the center conductor which can vary by 0.4mm relative the disk inside the End Cap. That's most essential for the Amphenol Connex Dust Cap as not having a bump or hole in the center. The WiMo and Fairview Microwave types was not sensitive to the strength of tightening like the Amphenol Connex was.   The total delay is 1.5ps plus the additional delay. This total delay must as usual be multiplied by 2 in the calibration settings.

What about T-Check

A T-Check can verify the quality of the calibration. It requires only the use of a T-Adaptor and setting up the VNWA with a Custom Trace. A T-Check can oly be performed for the VNWA in standards mode. It is not possible to do it in Operation mode "External Bridge". How a T-check, regarding single port calibration is performed, is described in details in the document. http://www.hamcom.dk/VNWA/How to perform a T-Check for a VNWA Calibration.pdf and since the this T-Check report was written the Calibration Sheet for the used Rosenberger Female kit has been revised to revision 3 dated 15/12/2013. This updata facilitates improvements and below is the present T check result with 1% per division and the result is superb.



Further work on T-Check in progress:
Above excellent result with less than 1% to 1 GHz and less than 0.2% to 500Mhz was obtained using the 10dB attenuator in the RX path. It also required the addition of 50fF to the Load, a subject under investigation for some time and not finalized yet. So a slight update will be made shortly accordingly.

Summary:
Whatever you chose for calibration of you VNWA the quality of you calibration is directly dependent the quality of you calibration kit. As a general rule, and said in the preface, try to keep the delays as short as possible meaning close to 0ps for the Open and Short Standards. Regarding the Load standards purchase a good quality standard and my conclusion is that a Rosenberger Load is good quality for the money paid.
Use this report to be more qualified to understand what happen when adaptors and calibration items is connected in series. Also to be qualified to judge companies offering calibration kit, which combines Male Male and Female Female adaptors together with calibration standard for Loads, Shorts and Opens (e.g. in the form of end dust caps), to create Male and Female calibration standards. Such suppliers are "breaking the rules" for optimum solutions and by cosmetic wrapping the technical data into delays, with three decimal points, is not helping you out of the dilemma. Such calibration standards is not optimal and causes inferior calibrations of the VNWA.
I welcome definitely other points of view and especially comment if you find direct error in this report

December 21 2013 Kurt Poulsen