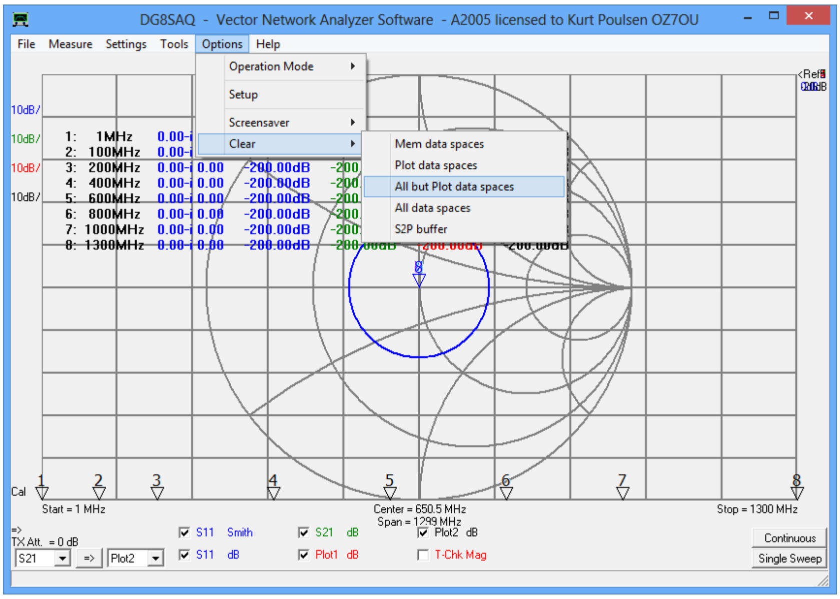
How to measure the isolation in a Transfer Switch

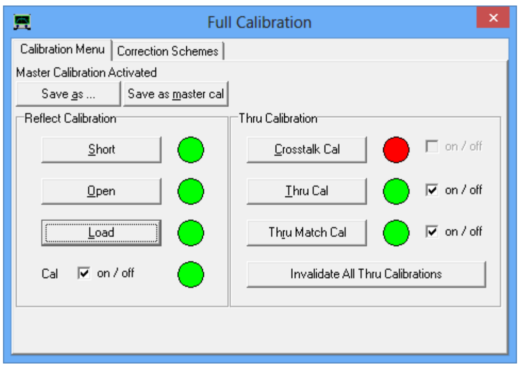
When designing a Test Set for the DG8SAQ VNWA or the N2PK VNA (or any other VNA able to control a Test Set) it is important to figure out what the isolation is for the Transfer Switch you have acquired, one way or the other. When buying from E-Bay such information is seldomly given by the seller. The Isolation is the most important characteristic for a transfer Switch, more important than the insert loss and frequency range, although if going to e.g. 18GHz the isolation at the VNWA frequency range up to 1.3GHz might be high as well but no guarantee.
This document deals with a “simple” hut timeconsuming procedure to investigate whether you will be happy or not with you acquisition ☺

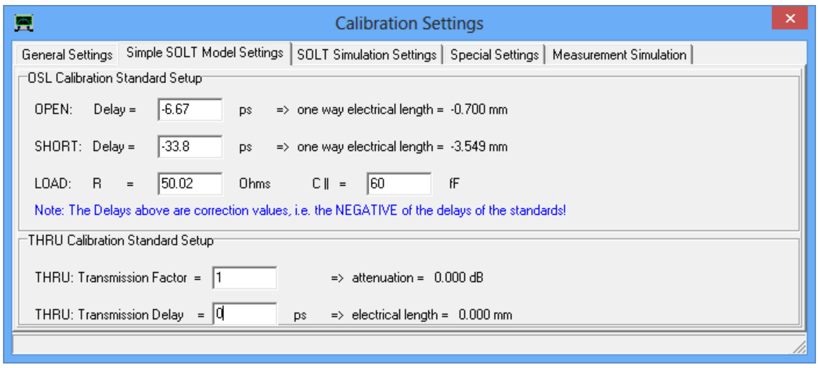
First we have to measure the isolation/performance limits of the VNWA itself, to set a reference for what can be achieved.
Let us get started:
First prepare 5 Traces as shown below with all dB traces having a reference at -20dB at division 10 except the S11 trace have a reference at 0dB at 10 division. The benefit of using Plot traces instead of MEM traces is that they are scaleable when frequency range changed and they can be kept independently. Else, if you fancy MEM traces, use such traces instead of Plot traces. (Trace 6 is not part of this documentation) and later on used as Plot3. (Trace 6 is just a T-Check feature I commonly has active most of the time)

Below screen plot shows you have the various plot data can be cleared.

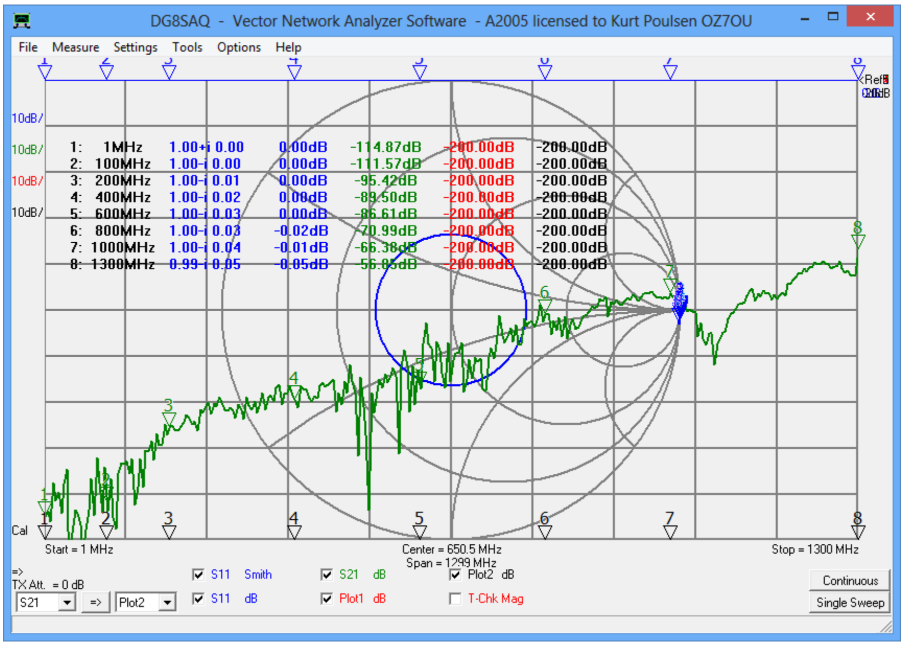


Then perform a SOLT calibration of the native VNWA using e.g. 300 points at 100ms per point and a span from 1-1300MHz.
Place the Short and Load at the TX port (Open is nothing connected) and ***notice that the S21 0 phase calibration plane will be at the VNWA TX port's calibration plane*** as the Test cable now is part of the RX port.
We will later revert to the situation, where the calibration plane will be the RX port's reference plane.
Do not calibrate the Cross Talk !!! Below is shown the calibration settings for the first test setup. Remark the Thru: transmission delay is 0 ps as we are not using any Thru adaptor

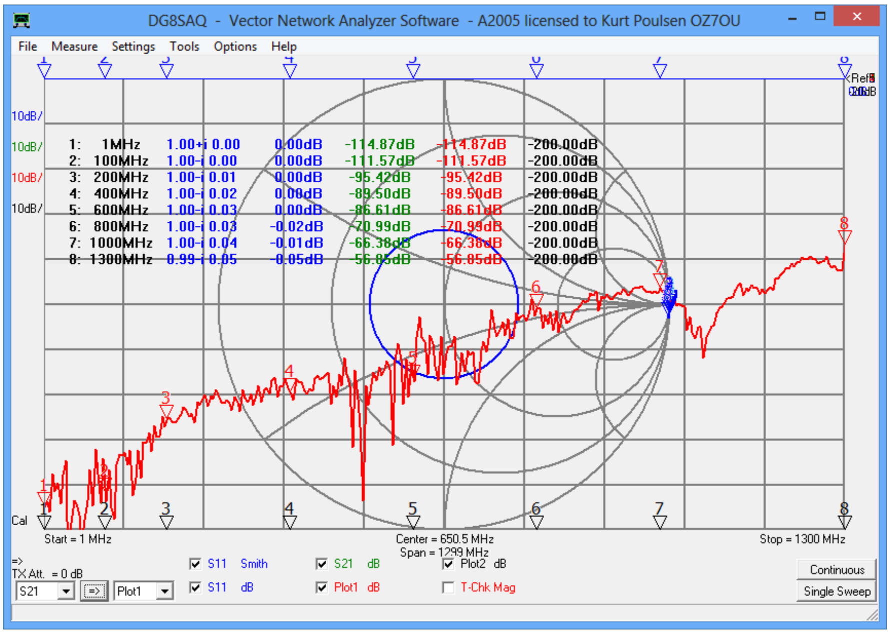




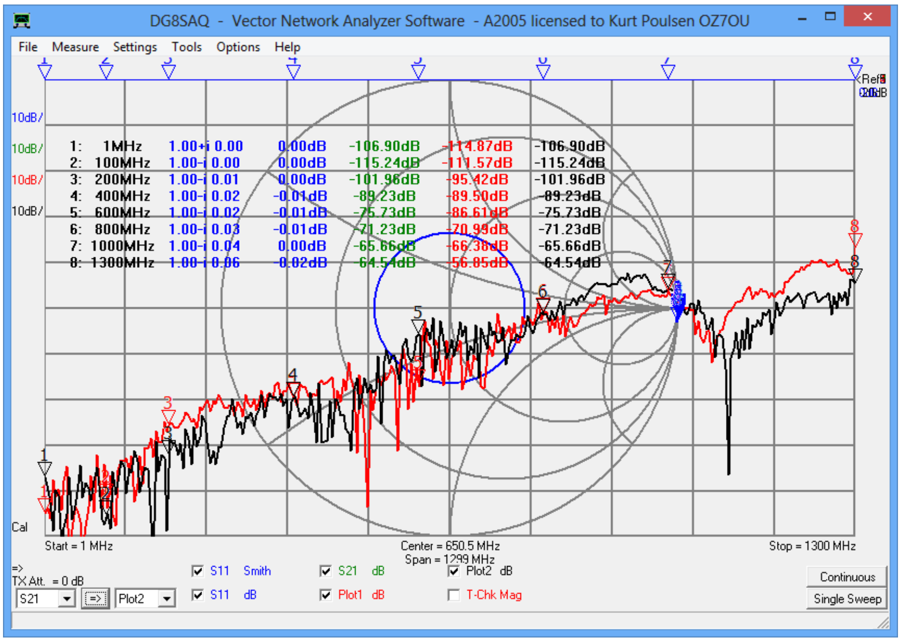
In below picture is seen the Amphenol Connex load and Short (the open is just nothing connected) and a male-male test cable connected, to be used for S21 calibration. After the calibration disconnect the test cable from the TX port and run a single sweep and see a display as seen below.



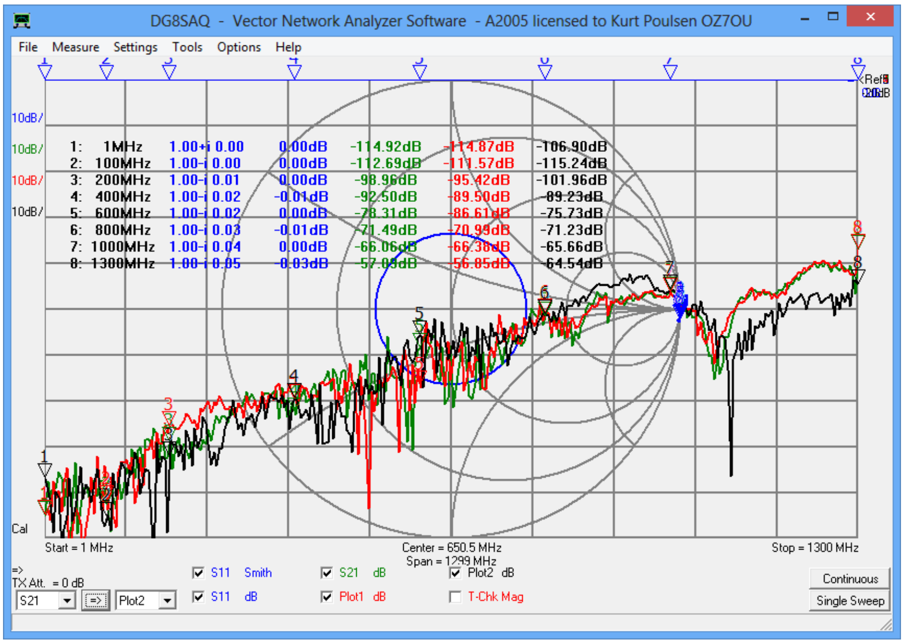
Now save the S21 trace to plot1 by clicking on the lower left transfer facility and you have a (red) copy on top of the red s21 trace as seen below.



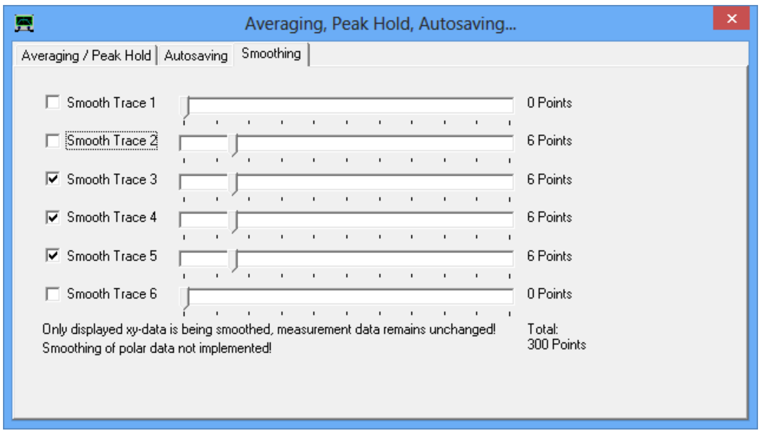
Then remove the test cable completely and run a new Single Sweep and save it in Plot2



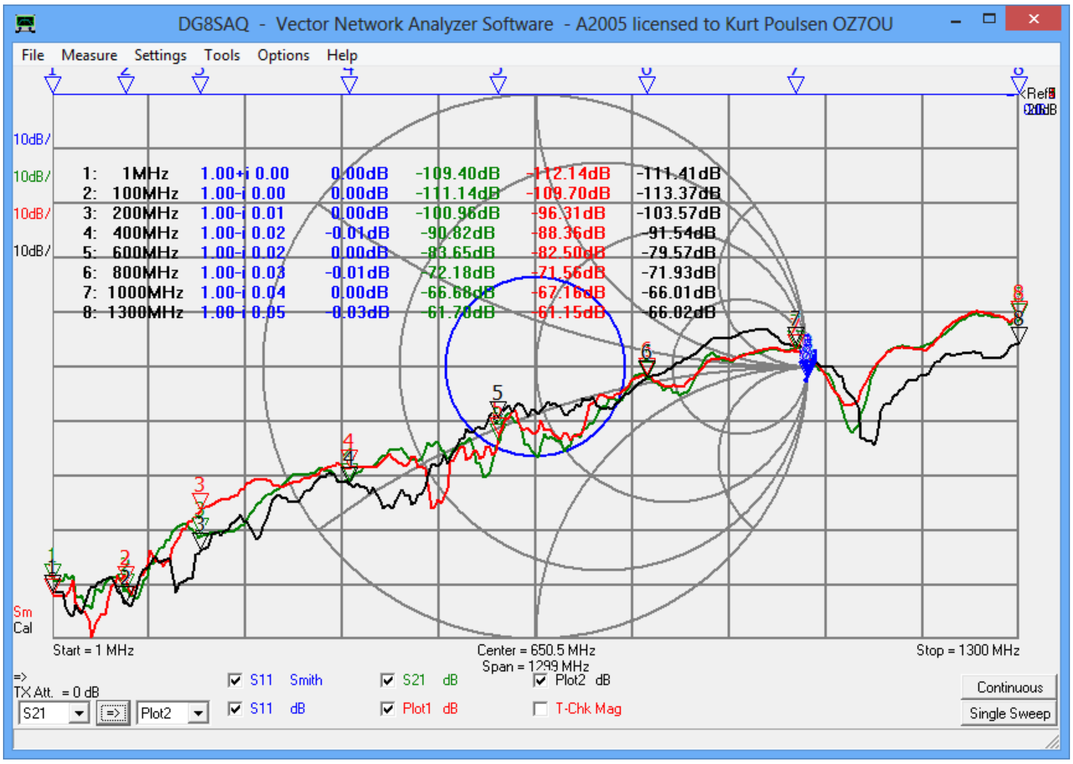
If you now reconnect the test cable to the RX port and run a single sweep you will see that the green trace (live S21 matches the original sweep stored Plot 1, with some small variations as we are dealing with the noise floor, but there is a dependence how the RX port is loaded either as open or with the test cable connected.



It is an advantage to use so mild degree of smoothing when dealing with noisy traces so well will from now on switch averaging on for Trace 3, 4 and 5 which improve the "readability"

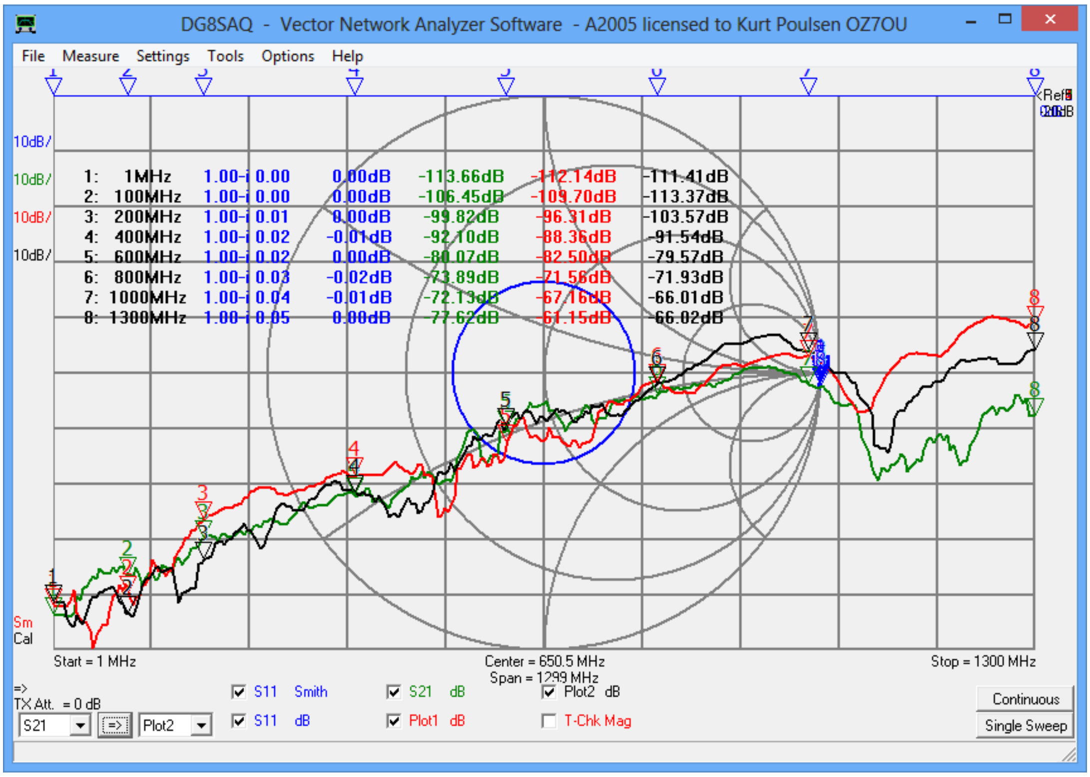


Below picture as above but with averaging applied

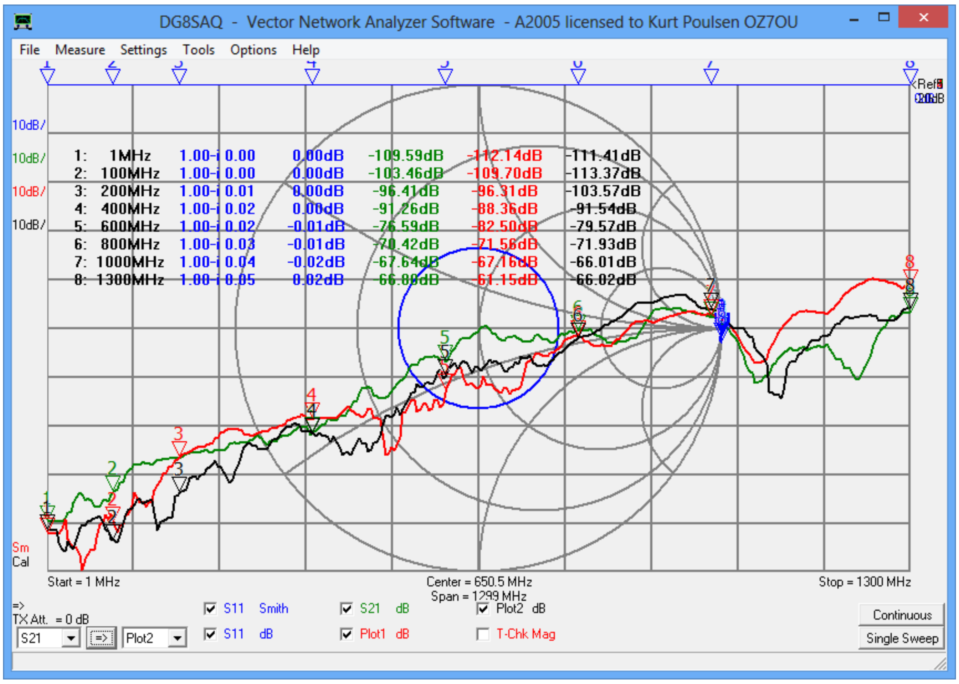


During the S21 calibration the RX port is loaded (through the testcable) with TX port output impedance being 50 ohm at low frequency but some imaginary contribution is present when frequency increases.

Now load the RX port with 50 ohm to simulate the condition during S21 calibration and run a new Single Sweep as seen below. The green “live” shows a new situation especially at high frequencies so what to believe. ?



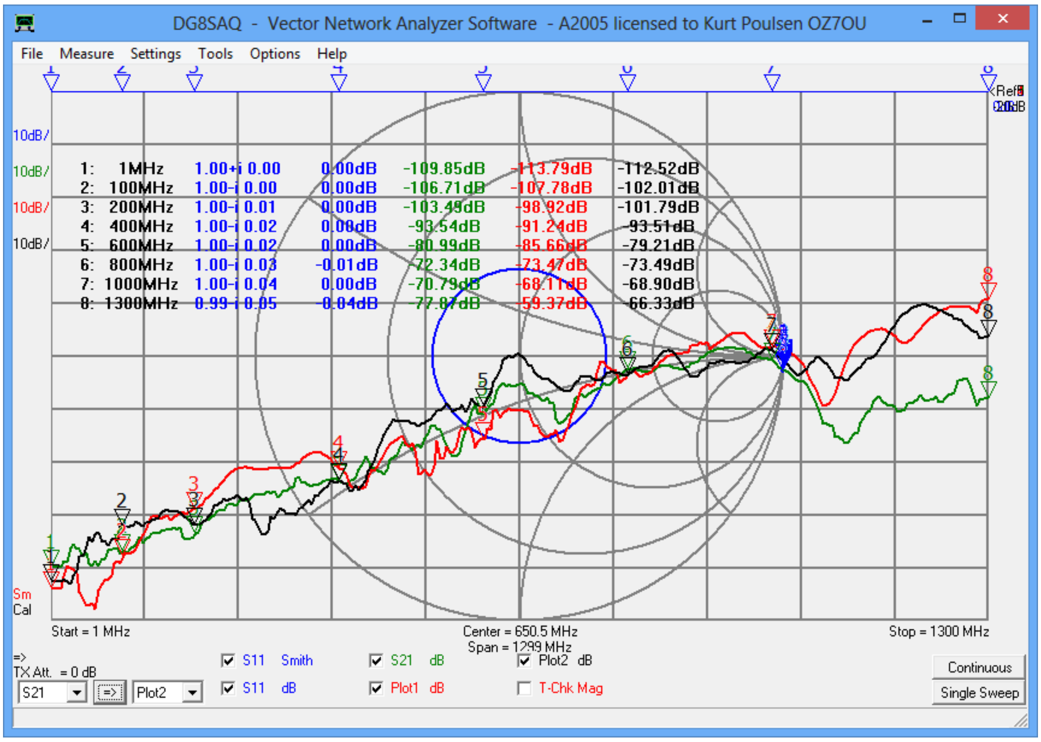
To complete the situation we apply a short to the RX port and Run a single sweep as seen below and it seem to be the worst case at medium frequencies. Remember we are dealing with a calibration where the calibration plane is not at the RX port reference plane and we are thus “making mistakes” so the next step is to see the situation when placing Short, Open and Load at the end of the test cable.



Below picture shows Plot1 with Open at the end of test cable (connected to the RX port9 and Plot2 is Short connected and finally “live” S21 is the green trace with Load connected.

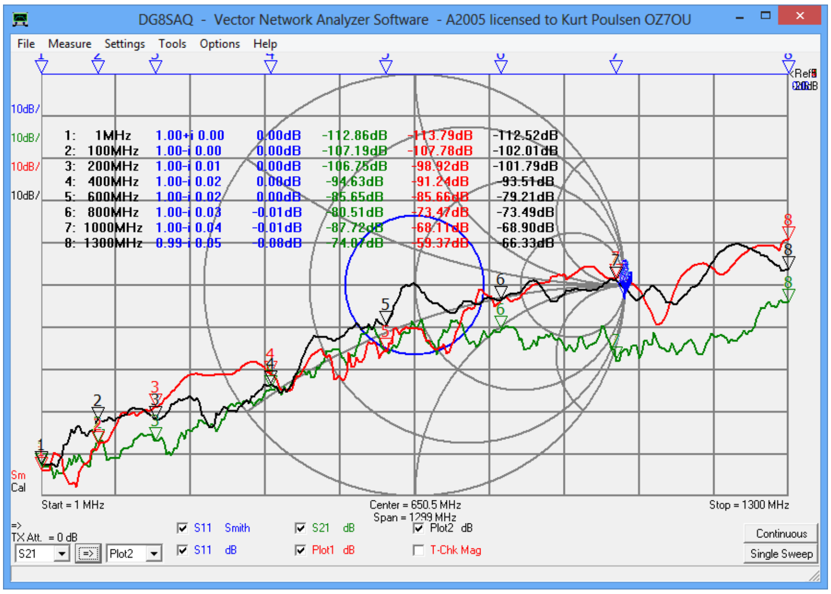
The lesson learned is that there is some varying result pending termination of the RX port.

A speculation could be if there at the same time is a dependence whether the TX is loaded with Short Open and Load but that is not the case at all but not documented in this report.

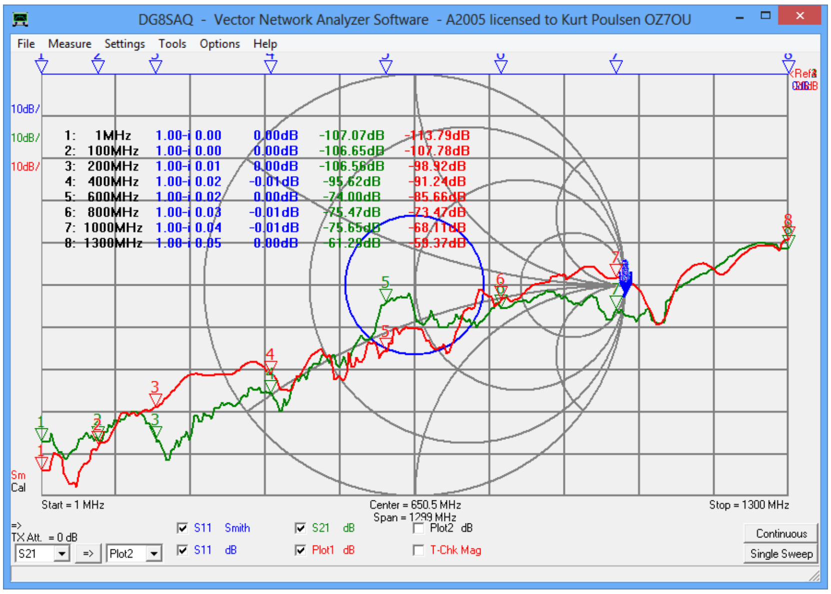


But is the Crosstalk calibration the resque ?? or what then. Below is seen S21 live green trace where the Test cable loaded with 50 ohm and there is an improvement of some 5 dB at some frequencies. We can now examine if the situation with Open and Short is improved as we have those stored in Plot1 for Open and Plot2 for Short

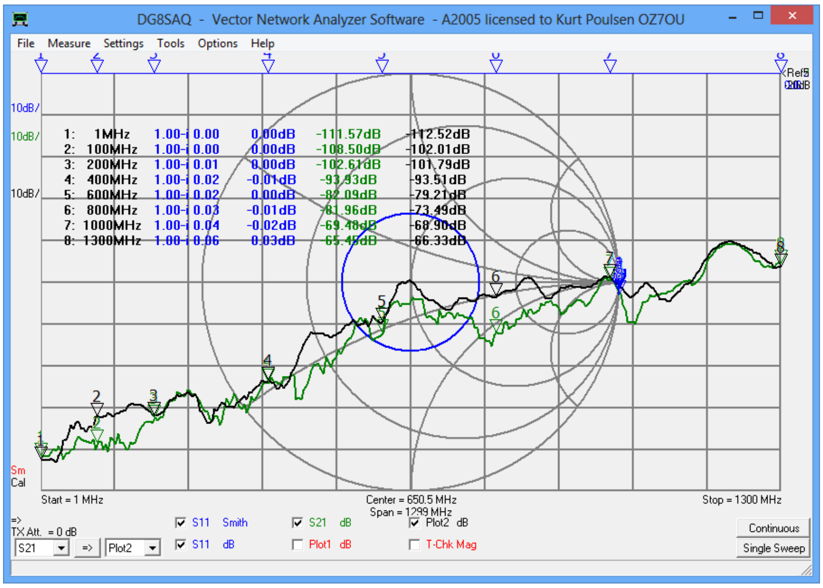
Below is the result for Load connected and there is improvements compared to above picture



Below is the result for Open and it goes both ways so not recommendable to use Crosstalk calibration

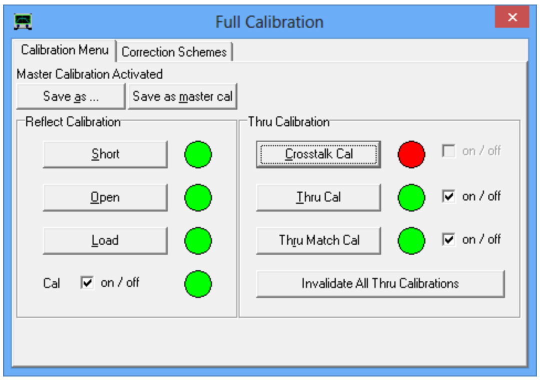


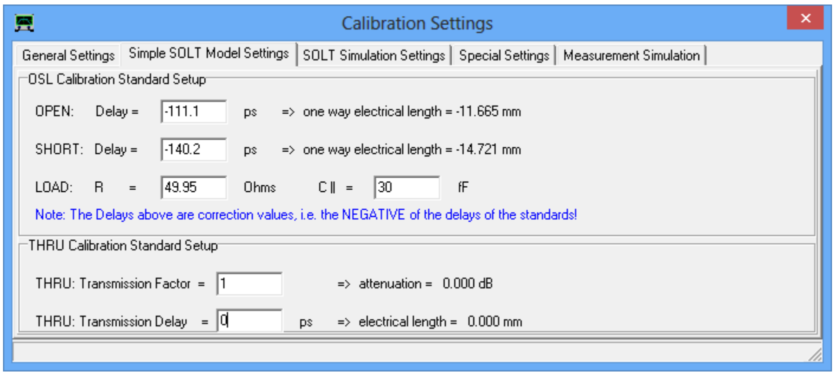
Below is the result for Short and no degradation



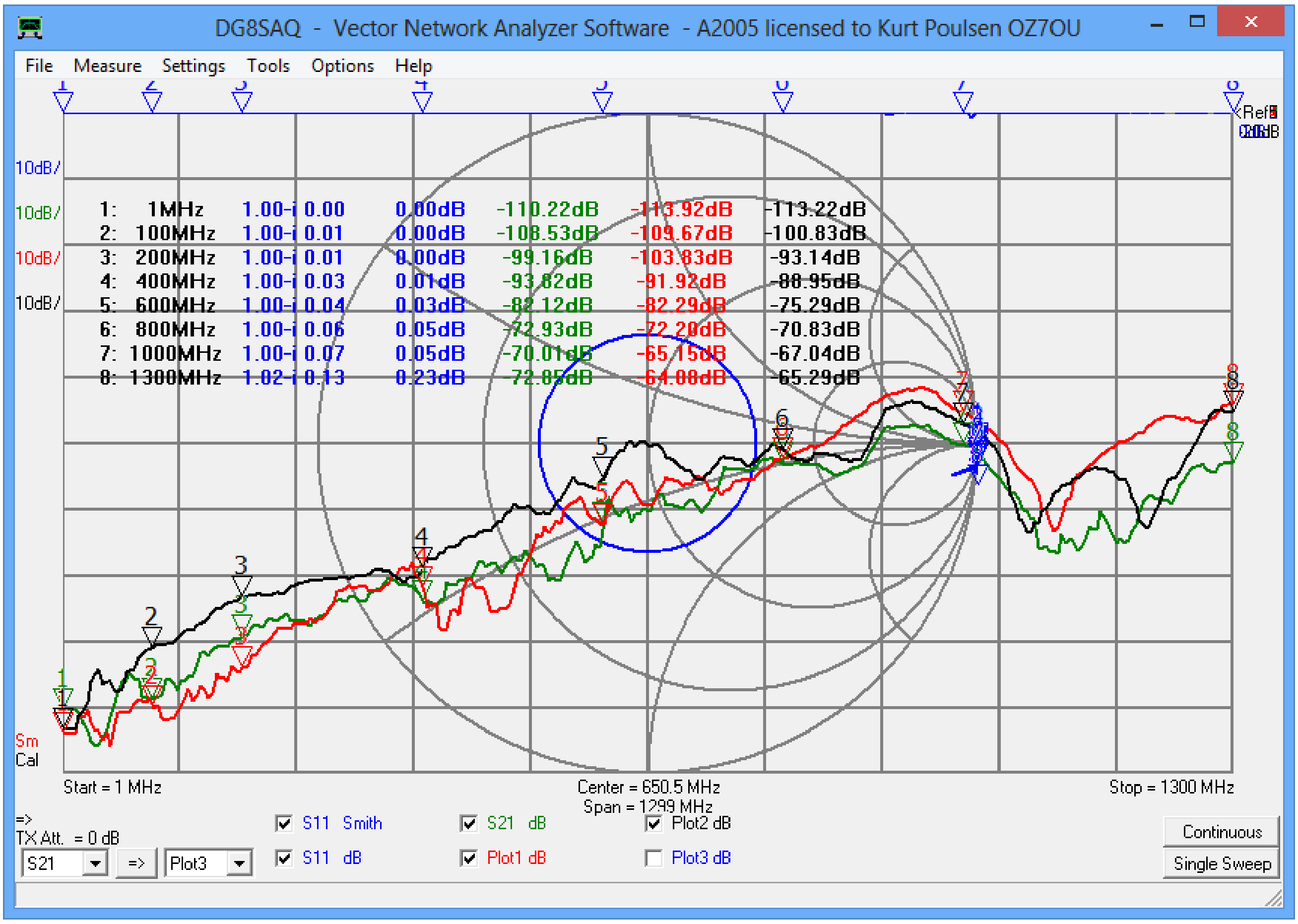
Conclusion so far:
When the calibration plane is at the TX port and the Test Cable is part of the RX port then Crosstalk is not recommendable when DUT's has high impedances on frequencies above 500MHz. Below 500MHz Crosstalk calibration can provide a minor improvement.

What then if we calibrate at the end of the test cable and the S21 reference plane then becomes identical to the RX port's reference plane ? For that purpose, we need a female Amphenol Connex calibration kit, still with 0 ps for THRU: Transmission delay and we do not calibrate Cross Talk yet.



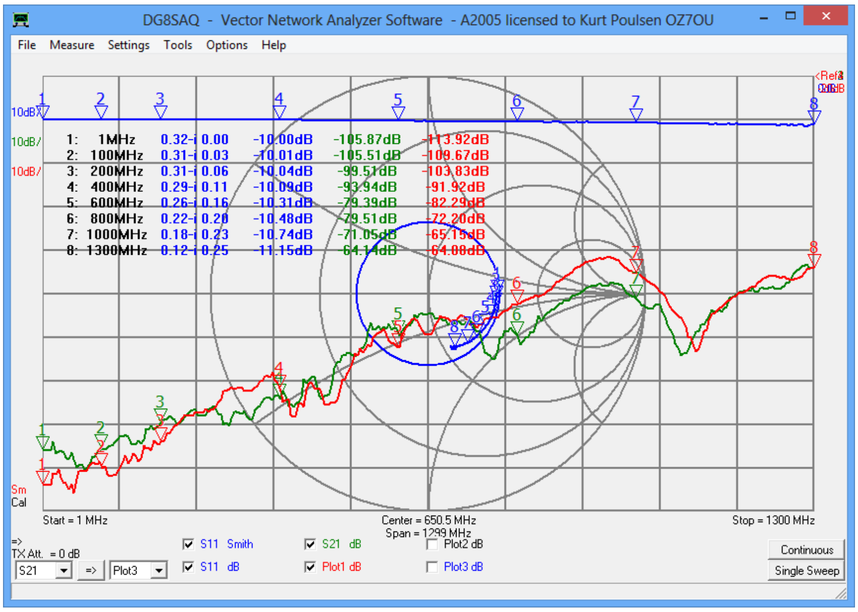


Below result is for the Test Cable disconnected from the RX port and a single sweep performed with RX port as Open stored in Plot1, same for RX port Shorted and stored in Plot2 and finally RX port loaded with 50 and shown as the live S21 green trace.

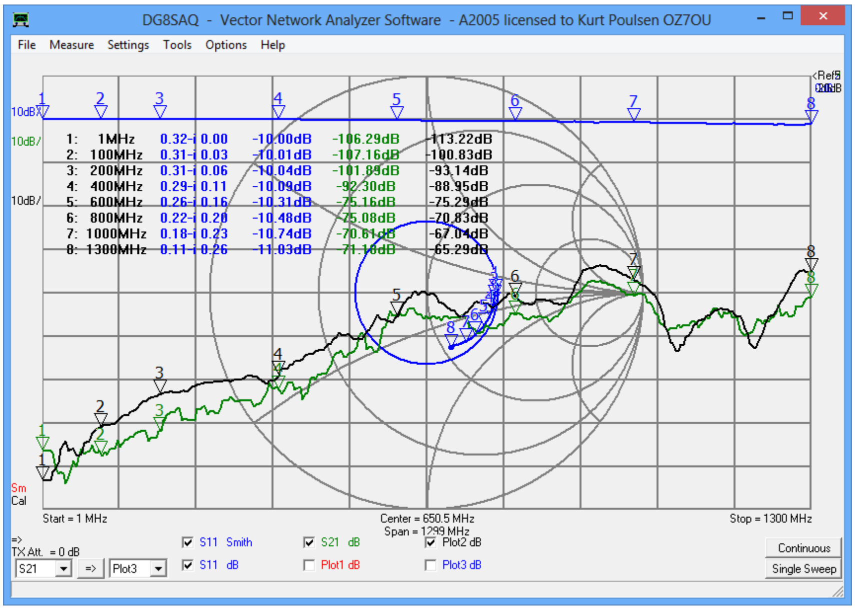


Next step is to see the impact when Crosstalk calibration added and for that purpose trace 6 changed to Plot3 trace for storing the "Load trace" as a blue trace. During Crosstalk Calibration TX and RX terminated with 50 ohm

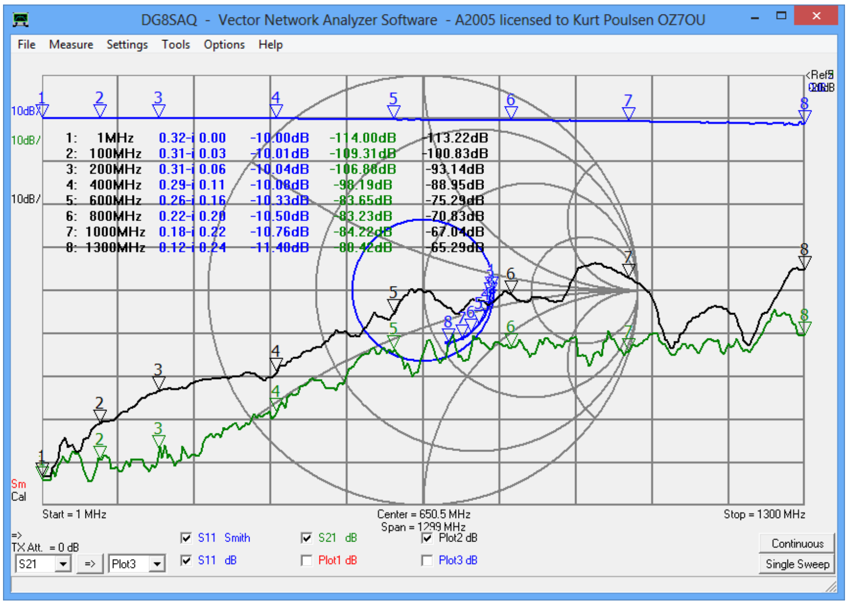
Below is the sweep for RX port as Open with slightly improved/degraded performance



Below is the sweep for RX port terminated with Short and slightly improved performance



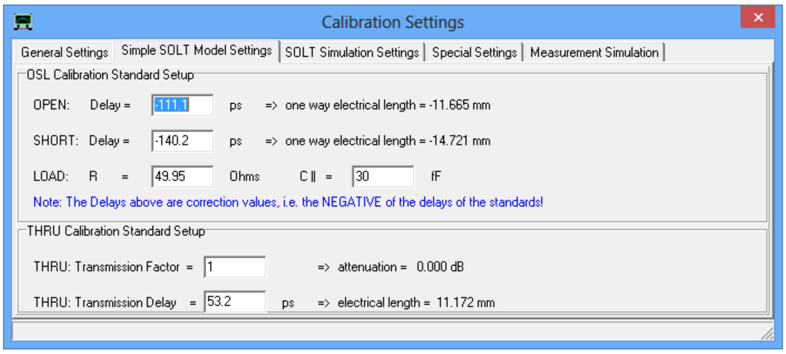
Below is the sweep for RX port terminated with Load and as expected improved only

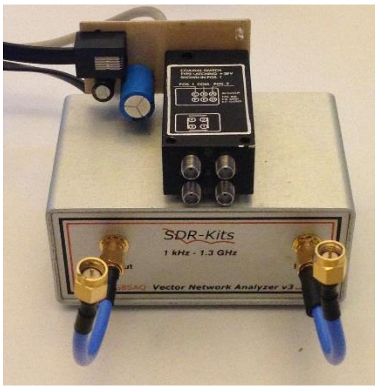


Second conclusion:

As the aim is to bring the VNWA to its extreme condition for measuring the Isolation of the Transfer Switch it is from the latest tests evident that the Crosstalk calibration is to apply, provided the same situation is valid when we in next step add a test cable on both the RX and TX port, as in the real "VNWA measurement world" we never has a situation with calibration plane at the RX or TX port only.

We will use some high quality short test cables and calibrate again at the end of the test cable using our Female calibration kit (and use the THRU:Transmission Delay) and repeat the investigation for Crosstalk Calibration or not, prior to test the Transfer Switch isolation.

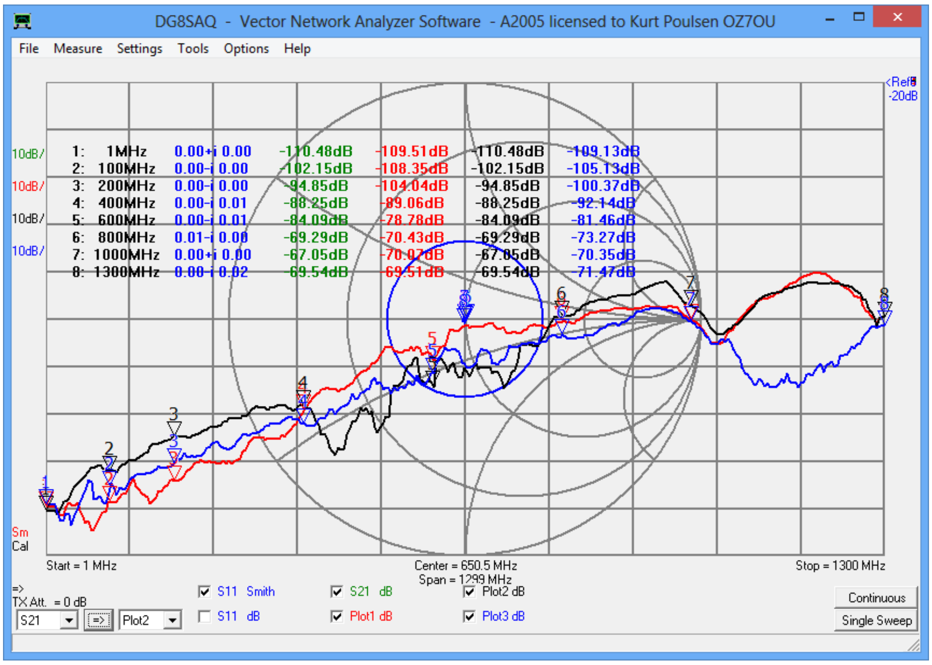




Calibration performed as usual for a one port operation

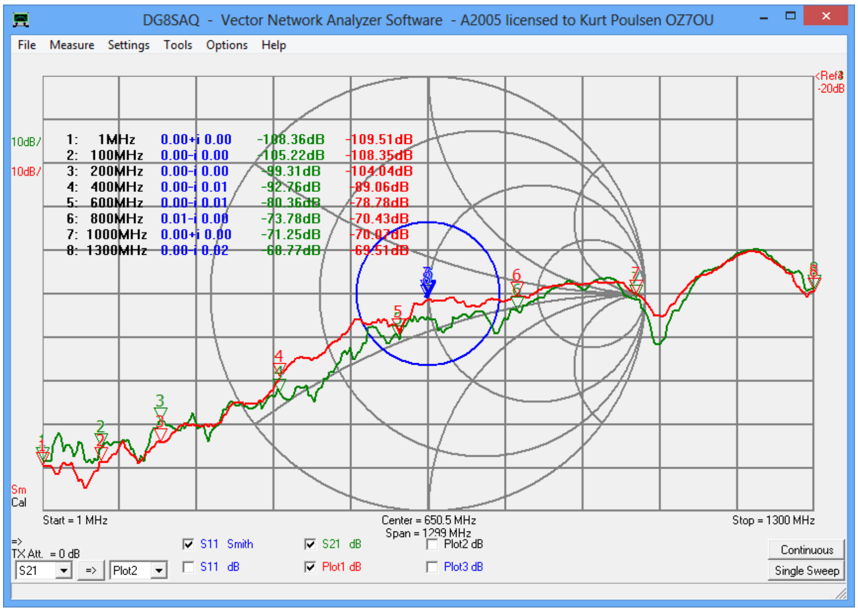
Below the three conditions stored in Plot1, 2 and 3 and whereTX Test cable terminated with 50 Ohm.

Plot1 (red) with RX Test Cable terminated with Open (the barrel), Plot2 with RX Test Cable terminated with Short and Plot3 with Test Cable terminated with Load.

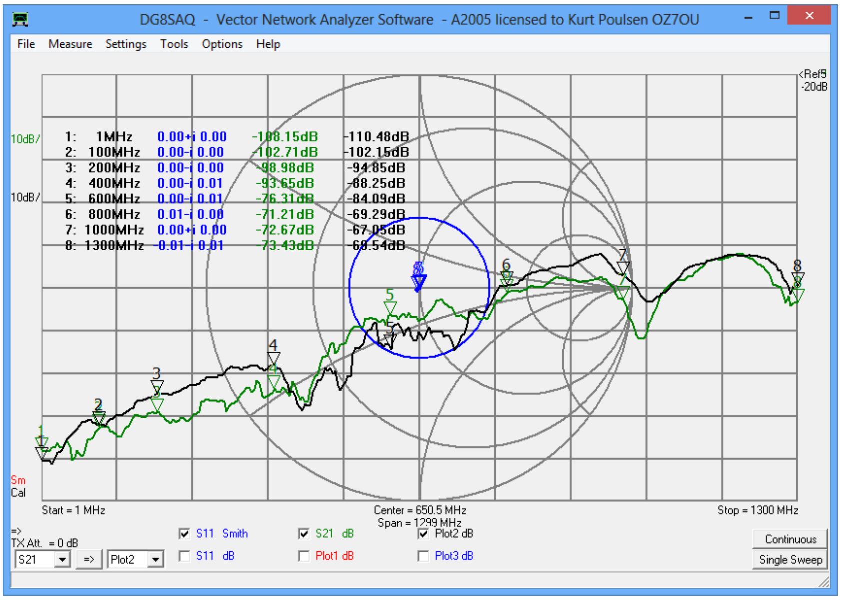


Next step is to perform a Crosstalk calibration and examine for improvement or worsening.

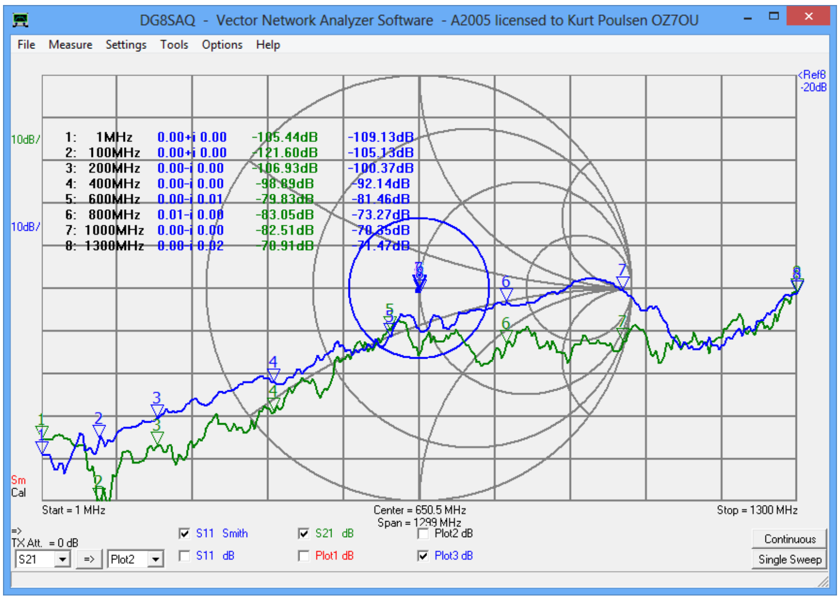
Below is the sweep for RX port terminated with Open. Same as before slight improvement/degradation



Below is the sweep for RX port terminated with both improvement and degradation



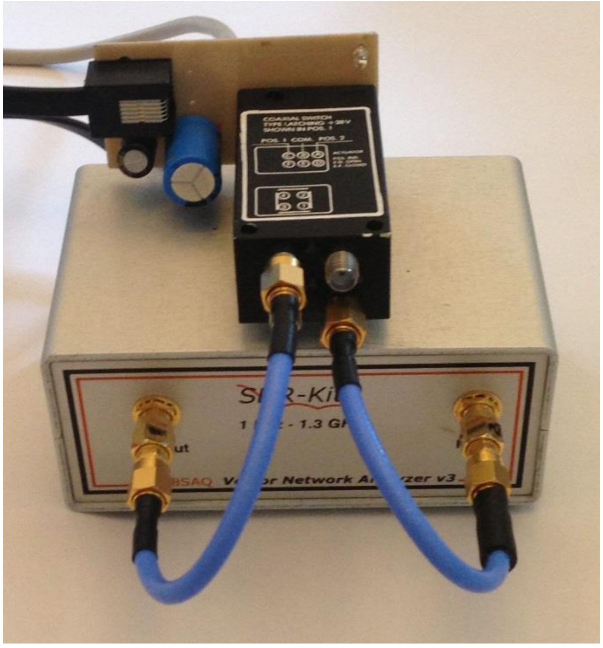
Below is the sweep for RX port terminated with Load and as expected improvement only



Final Conclusion:

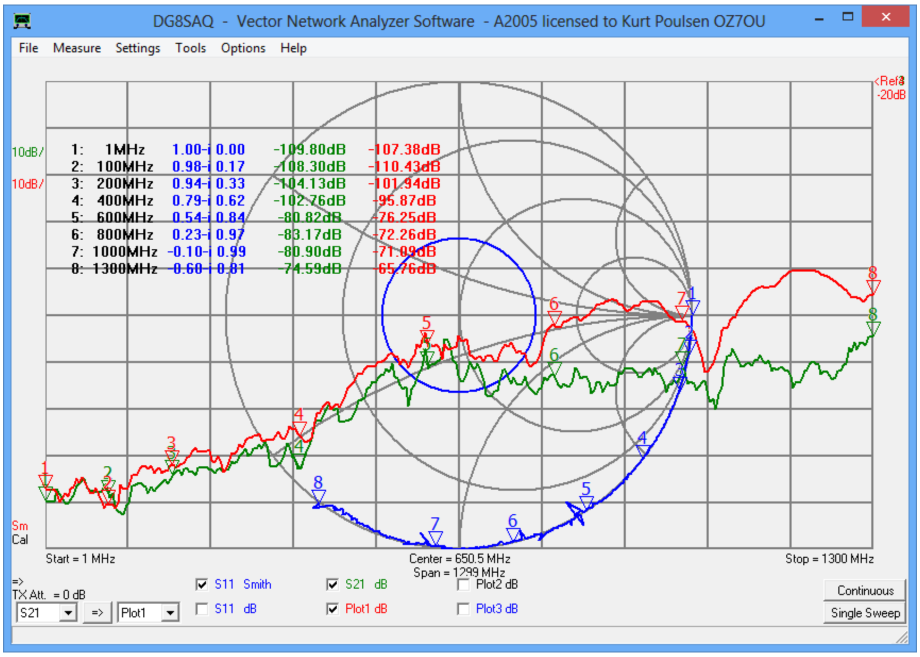
As the improvements is quite good for the Load condition and for Short at low and high frequencies and only worse at rather low frequencies we will use calibration with cross talk for the Transfer Switch isolation investigation and subsequently store new traces for Open, Short and Load in Plot1, 2and 3 with Crosstalk calibration enabled for comparison.

Finally we are ready to connect the Transfer Switch and as the calibration condition now are at the end of the test cables used for connection to the Transfer Switch, we will measure the Transfer Switch with out test cables connected to port 1 and 2.

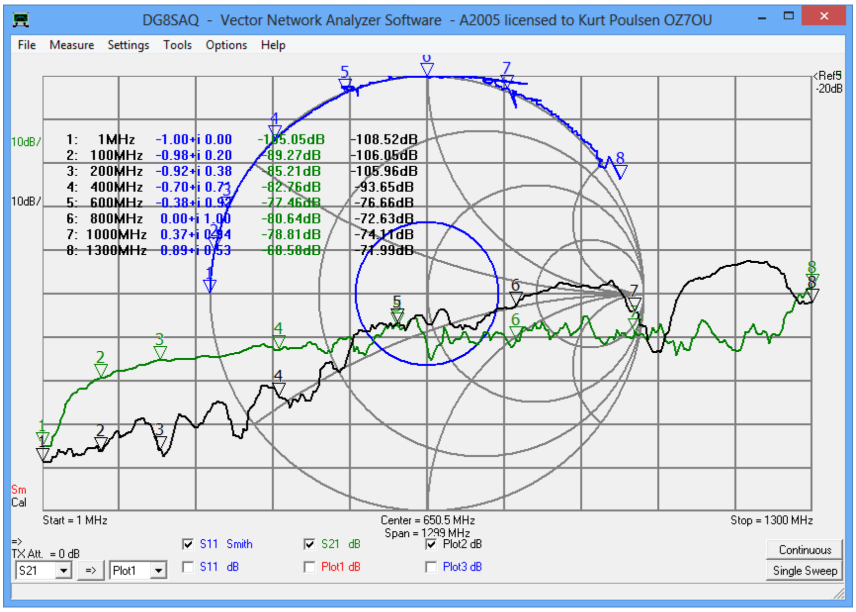


We will have to investigate 9 conditions .
Port 2 terminated with Open, Short and Load and for each of these conditions terminating Port1 with Open, Short and Load.

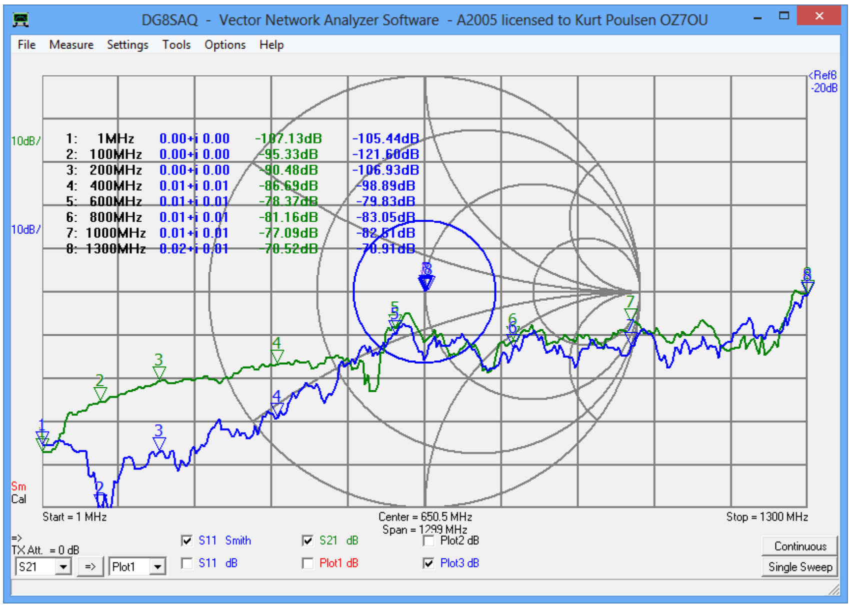
Port 1 as Open with Port 2 terminated with Load OK condition



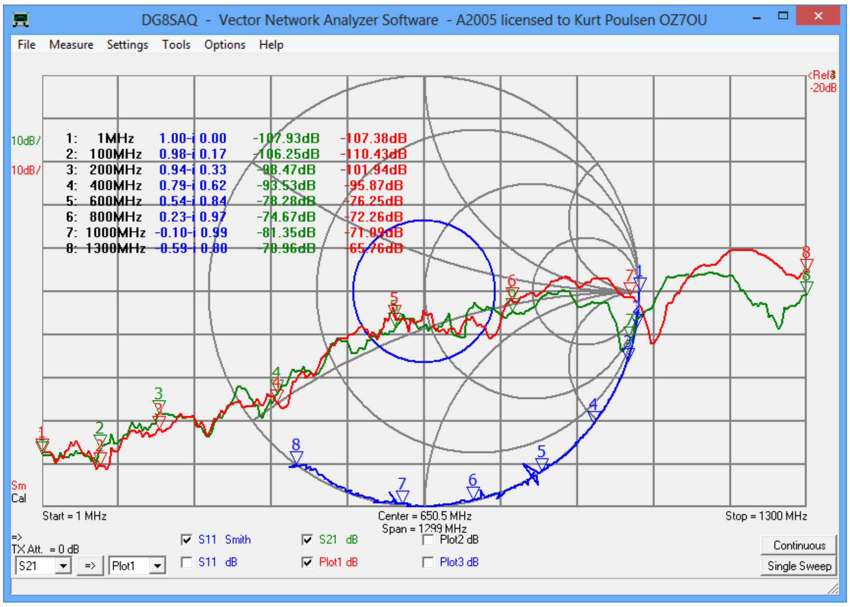
Port 1 as Short with Port2 terminated with Load condition degraded below 600MHz and improved above 600MHz



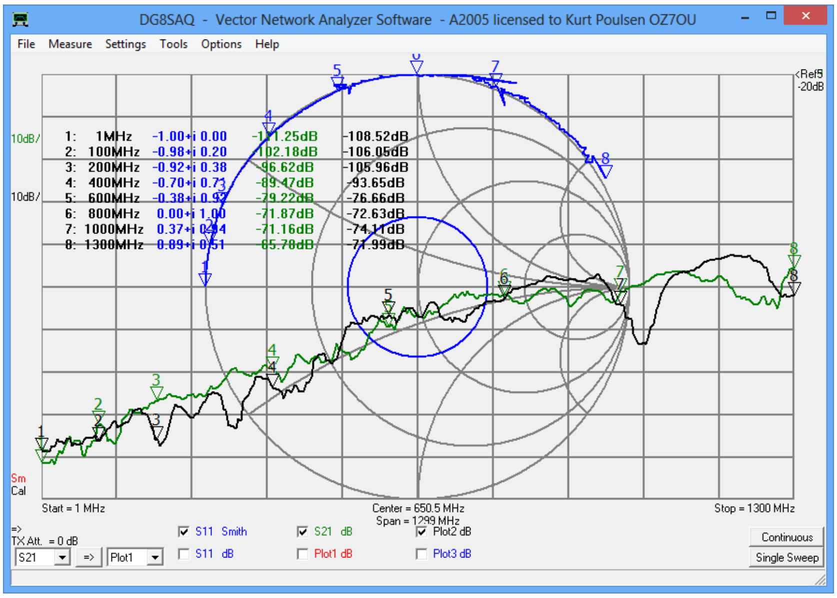
Port 1 as Load with Port 2 terminated with Load and degraded below 600MHz



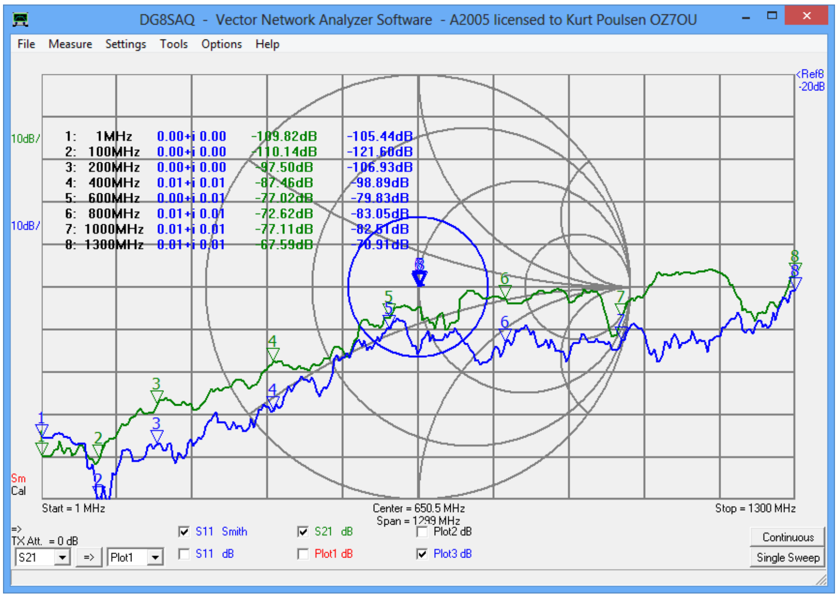
Open on port 1 with Port 2 terminated with Open



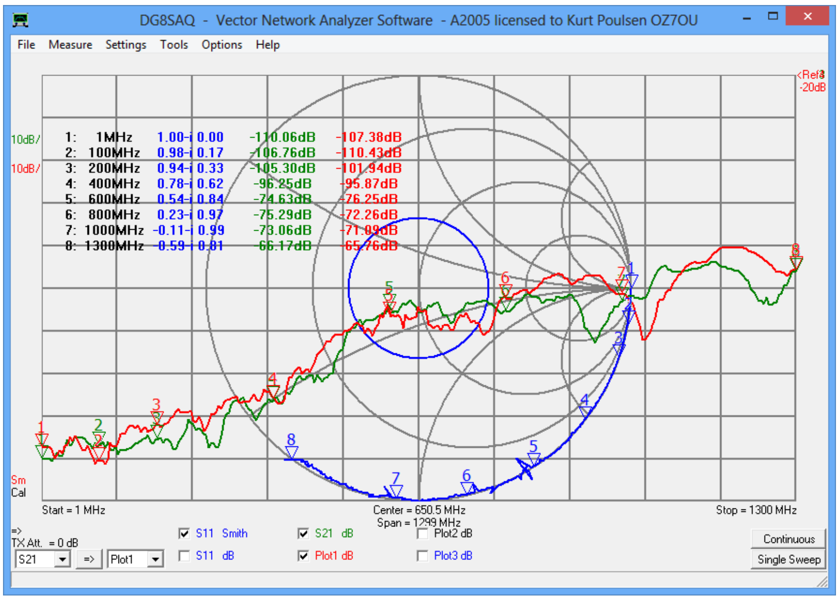
Short on port 1 with Port 2 terminated with Open and partial improved or degraded



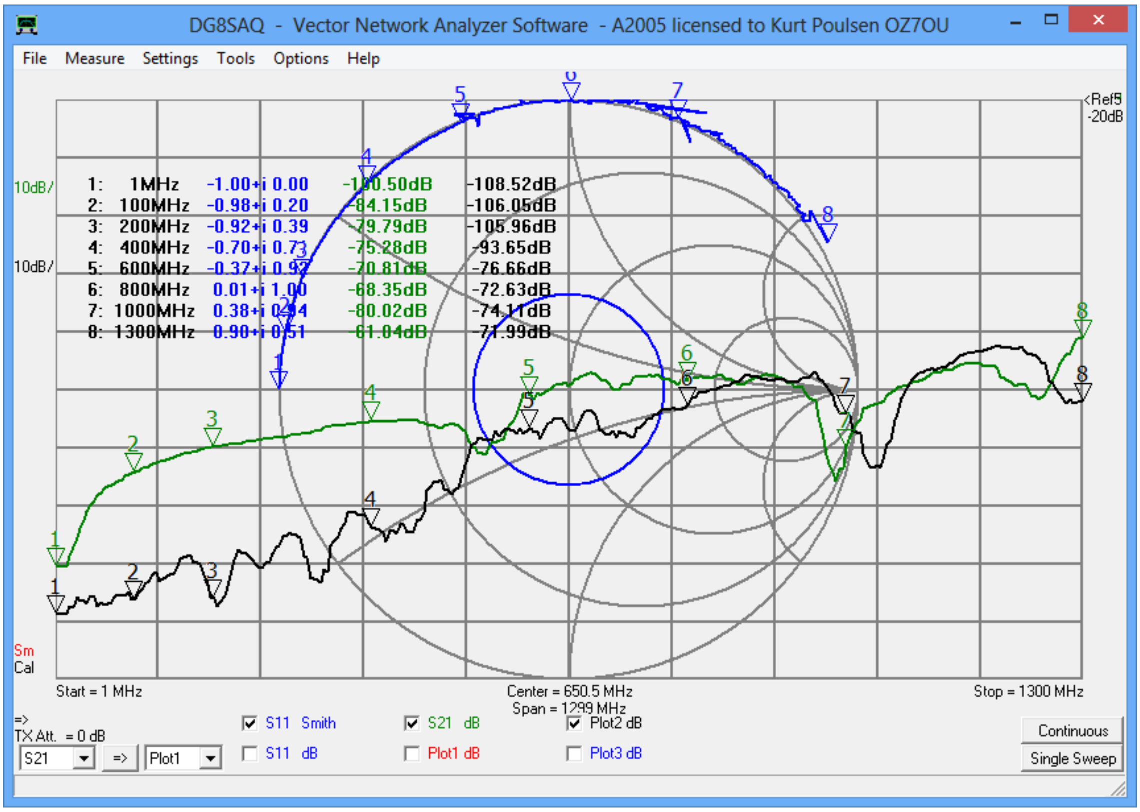
Load on port 1 with Port 2 terminated with Open and improved performance



Open on port 1 with Port 2 terminated with Short



Short on port 1 with Port 2 terminated with Short

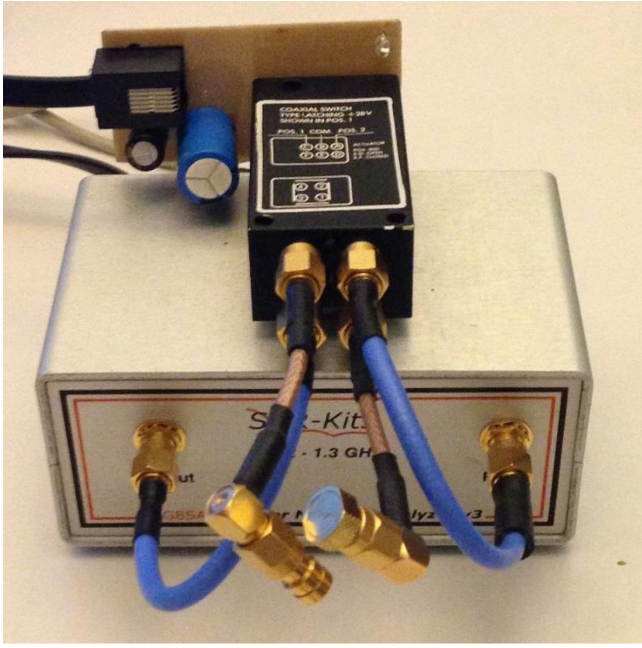


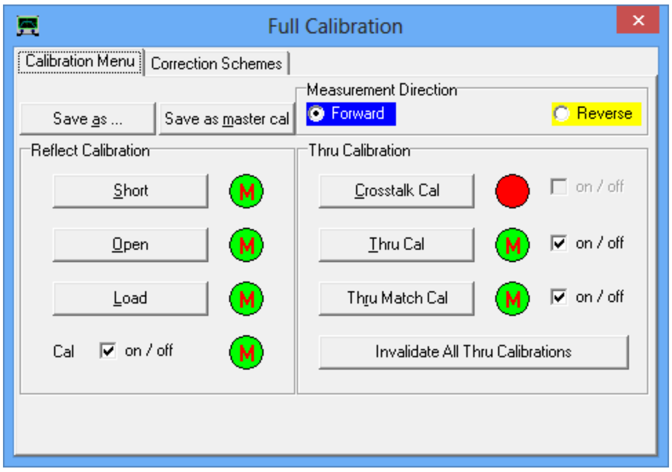
Load on port 1 with Port 2 terminated with Short

Summary:

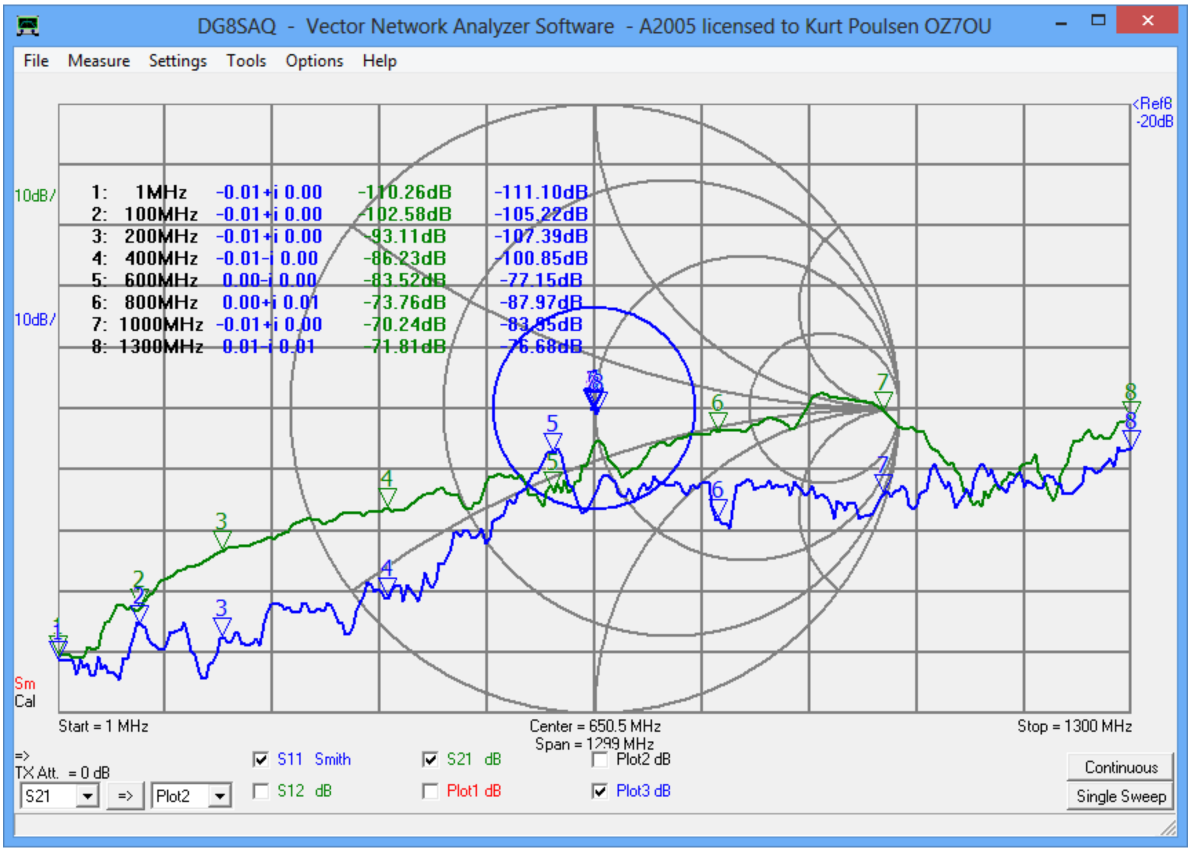
So far we have seen the isolation in the Sievert Lab Transfer Switch is inferior to the VNWA performance and Crosstalk calibration cannot improve on that situation except for load conditions quite close to 50 ohm as the crosstalk calibration done with 50 ohm termination (the system impedance) for both TX and RX.

Now we want to calibrate the port 1 and port2 on the Test Set/Transfer Switch. That requires to set the Test set for manual direction control and it causes the one port calibration to be erased by the software (from version 36.3.1.7) and a new full two port calibration needed (no Crosstalk). Two short test cables fitted to Port 1 and 2 (with 50 ohm termination)

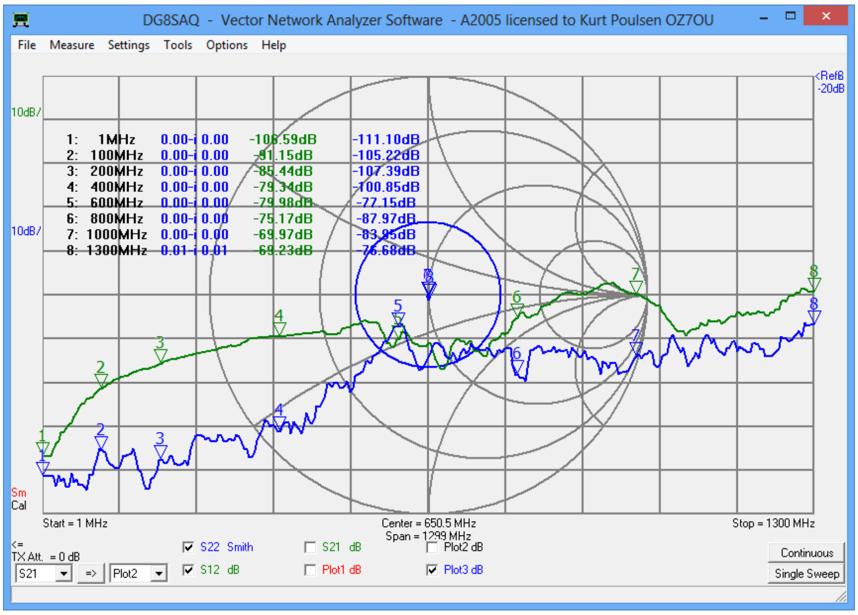




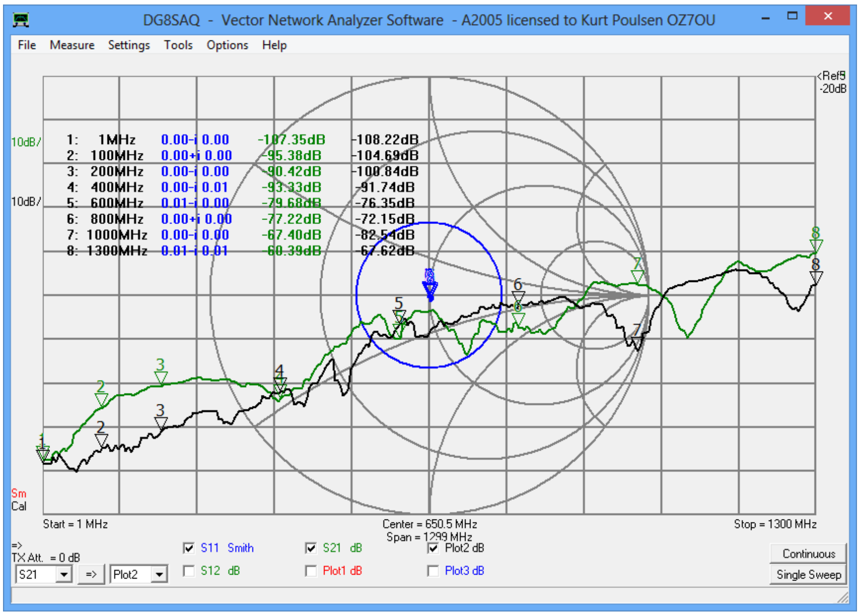
Forward Direction terminated with Load on Port 1 and Load on port 2



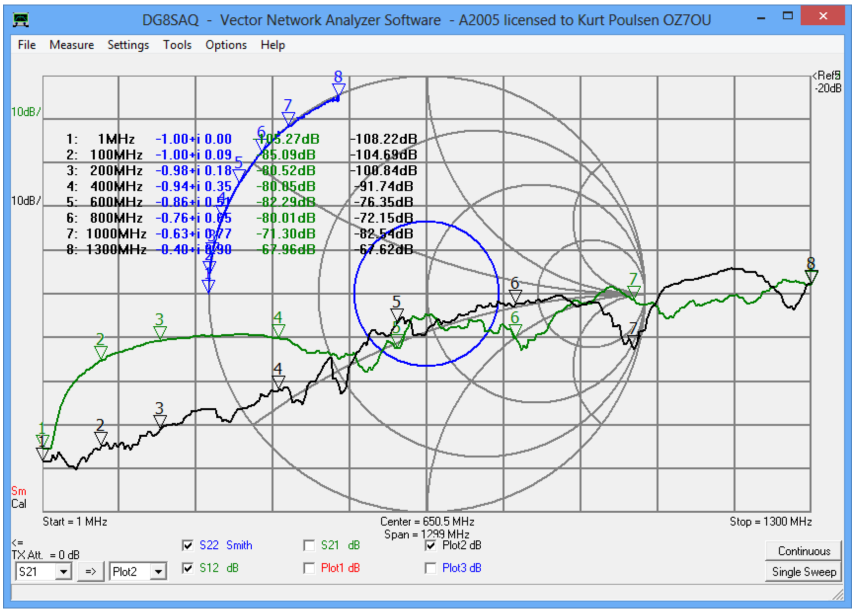
Reverse Direction terminated with Load on Port 1 and Load on port 2



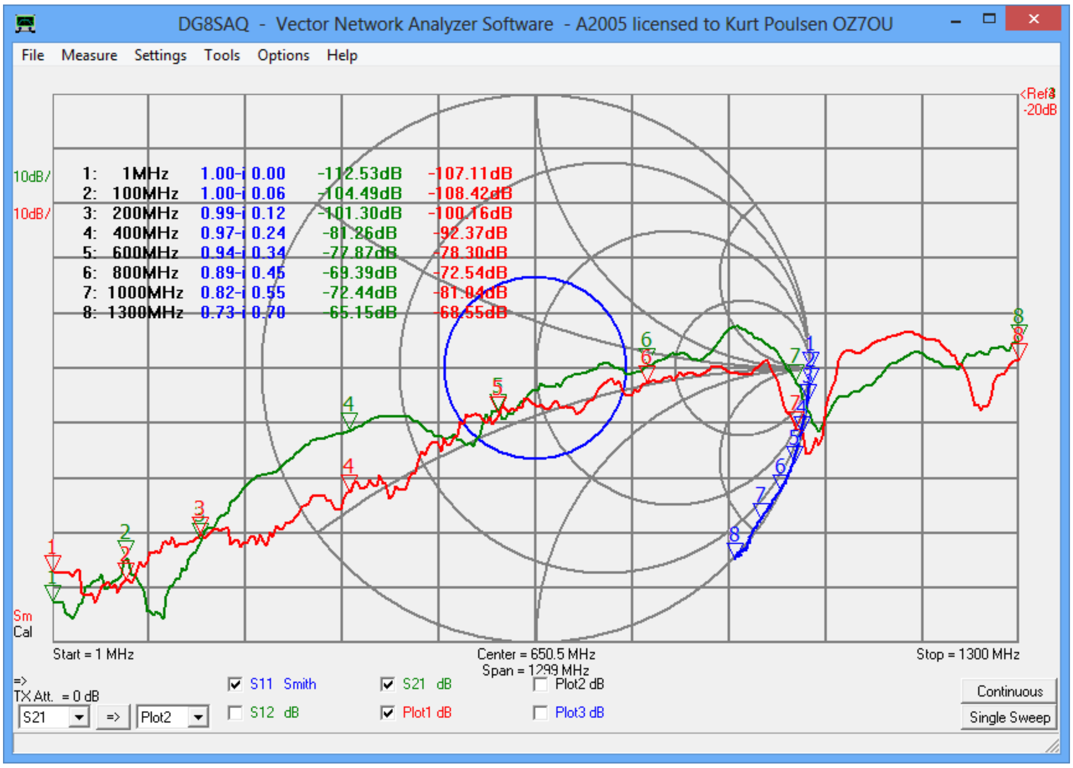
Forward Direction terminated with Short on Port 1 and Short on port 2



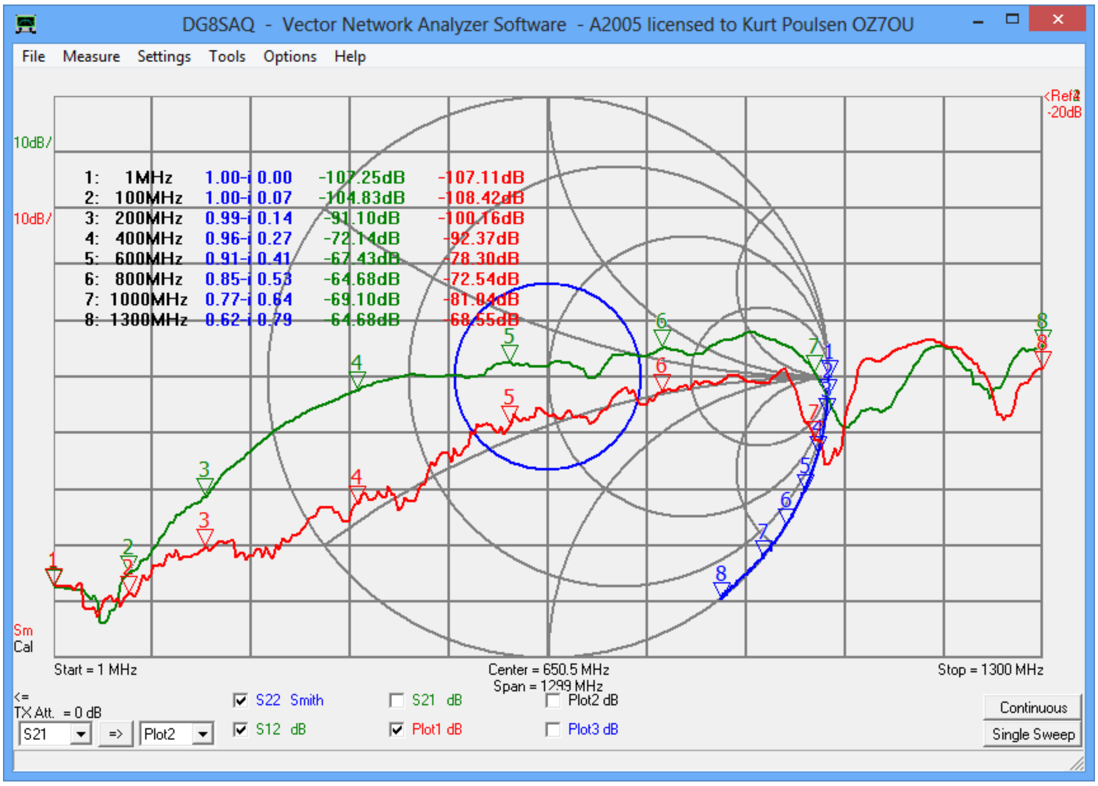
Reverse Direction terminated with Short on Port 1 and Short on port 2



Forward Direction terminated with Open on Port 1 and Open on port 2



Reverse Direction terminated with Open on Port 1 and Open on port 2

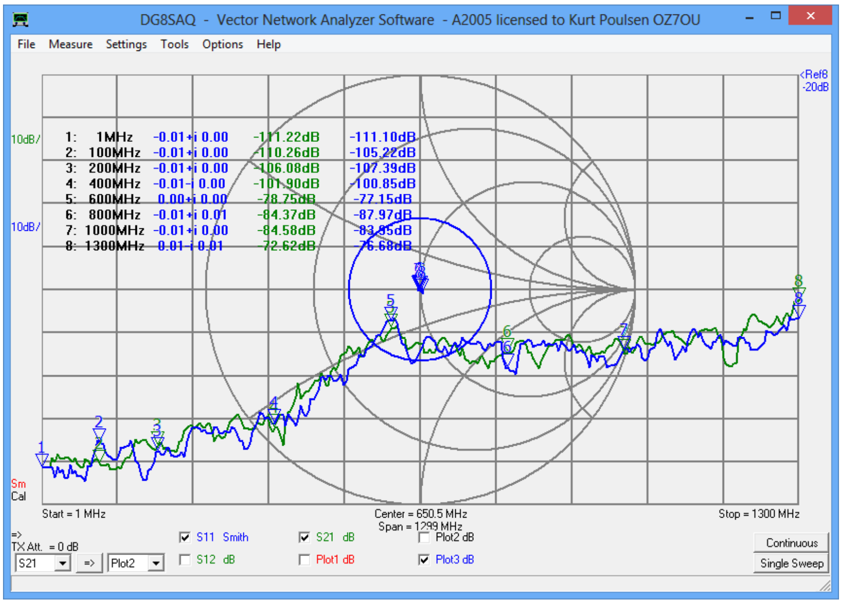


Comment to the measurements so far

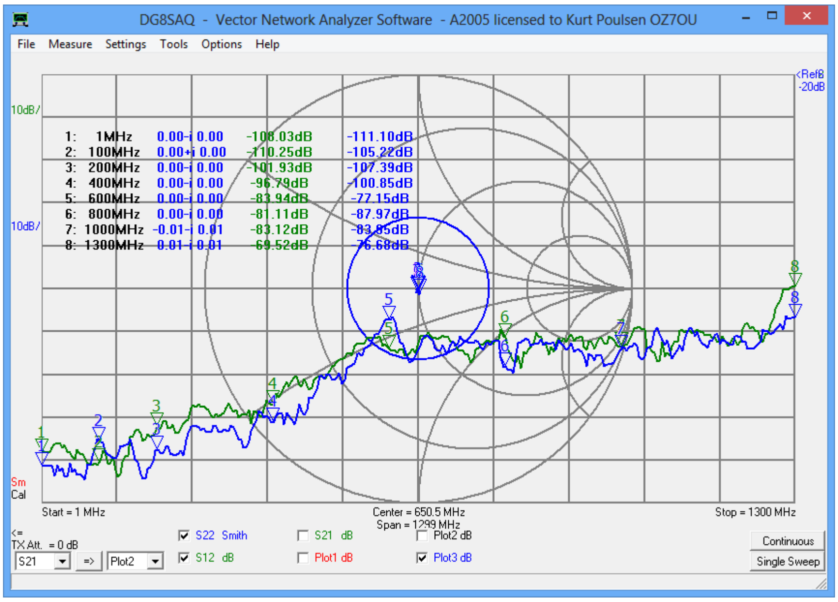
I was quite a surprise that the reverse direction was quite different from the forward direction

Let us see if and how the Crosstalk calibration can improve the situation.

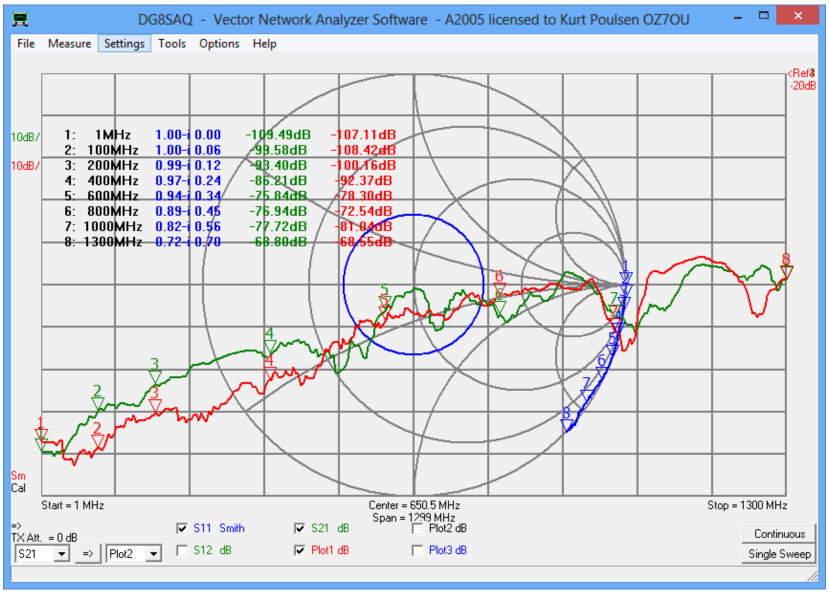
Forward with Crosstalk Calibration and Load on Port 1 and Load on port 2 and completely corrected



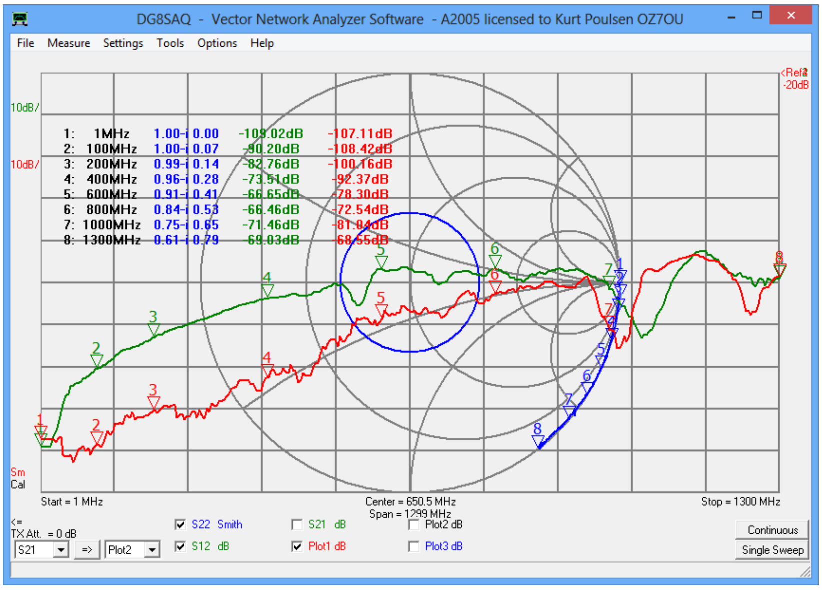
Reverse with Crosstalk Calibration and Load on Port 1 and Load on port 2 also completely corrected



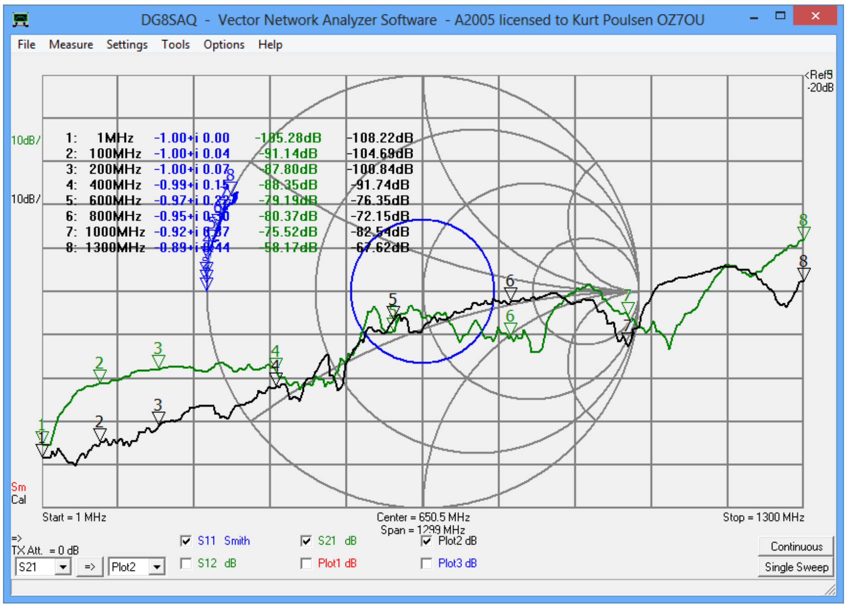
Forward with Crosstalk Calibration and Open on Port 1 and Open on port 2



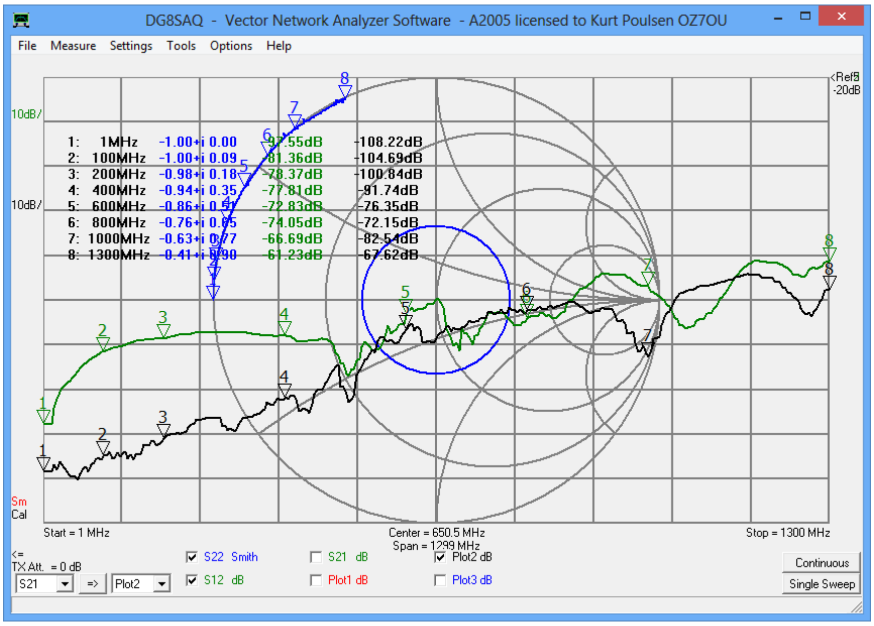
Reverse with Crosstalk Calibration and Open on Port 1 and Open on port 2



Forward with Crosstalk Calibration and Short on Port 1 and Short on port 2

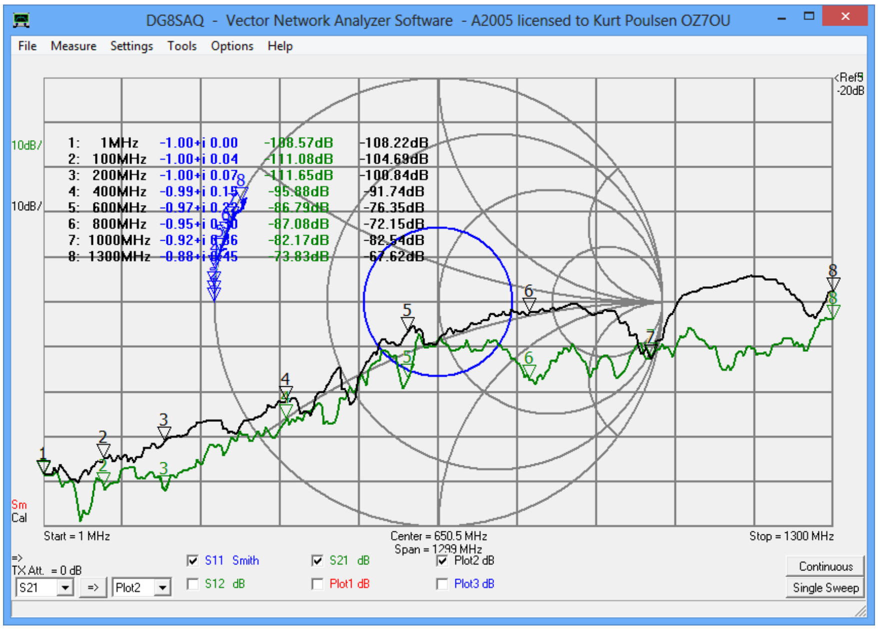


Reverse with Crosstalk Calibration and Short on Port 1 and Short on port 2

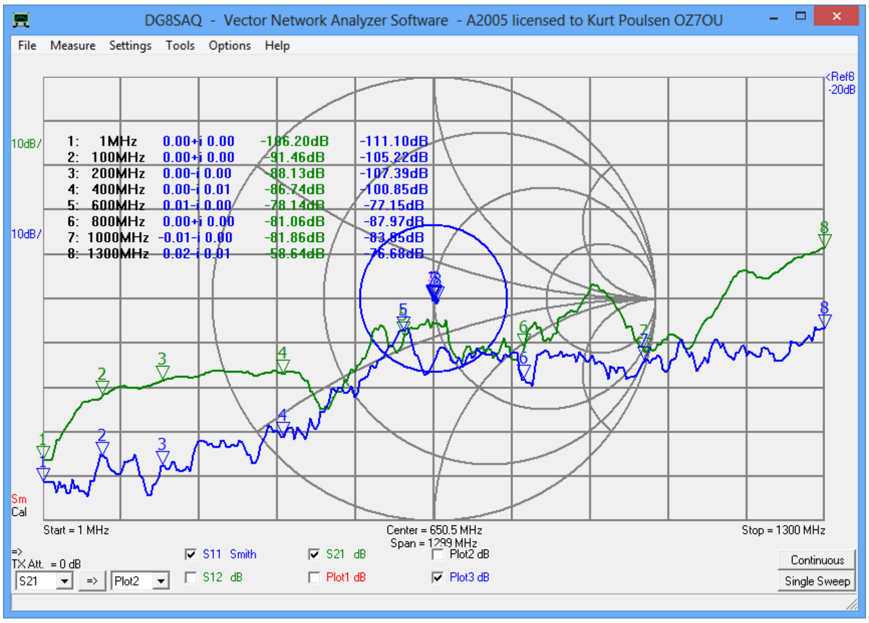


Before we summarize the complete set of experiences, a test is done for Crosstalk calibration with short termination and then see how it influences the condition with Load termination.

Example where the Crosstalk Calibration performed for Short on Port1 and improvements as expected



And then with Load on port 1 the isolation is destroyed



Final conclusion:

Crosstalk calibration is a "dangerous calibration" and can only be used for specific condition where you have exact knowledge of Device under test (DUT). If you want to measure symmetrical filters out of band attenuation and you can measure it is very high impedance then you might gain some dynamic range by crosstalk calibrate with the port 1 and 2 left open. In the pass band where the filter is close to 50 ohm the crosstalk is not important. On the other hand if the out of band is low impedance on the input side only then forward Crosstalk Calibration with Short on port 1 may improve the dynamic range.

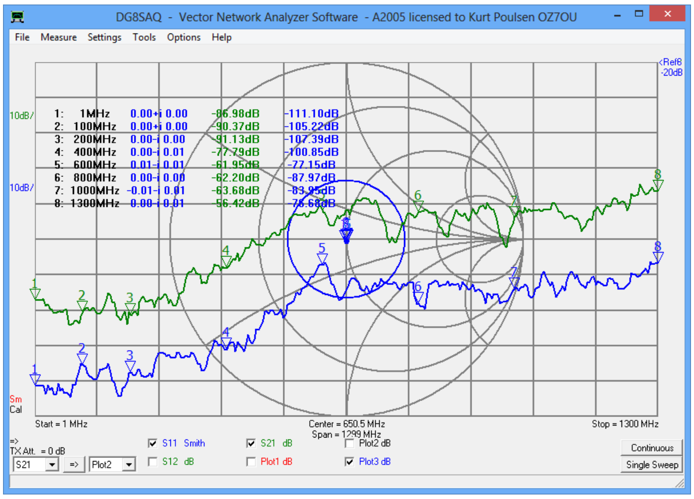
But in general if the Transfer Switch is not having enough isolation, as in this case, just note the results without Crosstalk calibration for the 3 condition of Port 2 in forward direction, and Port 1 in reverse direction, and be happy or build a better Test Set using 4 microwave relays in a H configuration, as I have described in the Yahoo Group in a OZ7OU folder. ☺ **Or is there despite all a sort of rescue solution ? YES … See the addendum.**

1 of August 2013 Kurt Poulsen

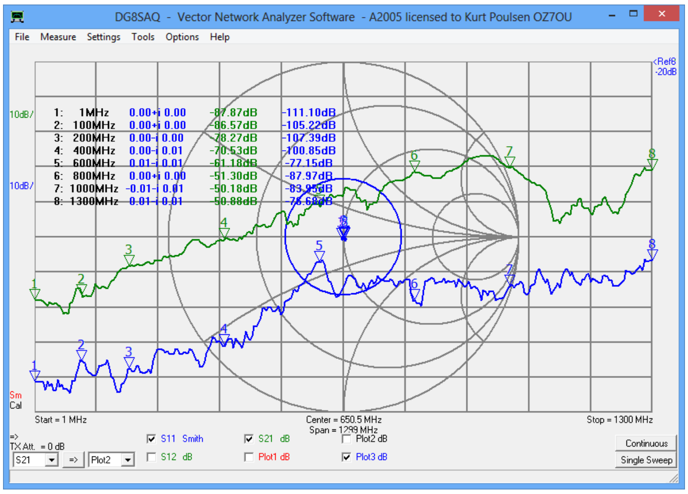
Addendum:

The experience so far has been that the critical issue is the RX port sensitivity with respect to Crosstalk and Crosstalk Calibration pending the impedance the RX port is seeing toward the DUT via the Test Cable. One way to improve this negative influence is to insert an inline Attenuator in front of the RX port. To see the effect of such a solution, which of course will reduce the dynamic range but the unwanted crosstalk in the Transfer Switch does not allow utilization of the full dynamic range of the VNWA so may this is the way to optimize the concept. If the attenuator can remove the sensitivity, because the RX port then will see an impedance close to 50 ohm for load from the DUT ranging from Short via 50 ohm to Open, then the Crosstalk calibration also be effective for this DUT load span. **See the summary**

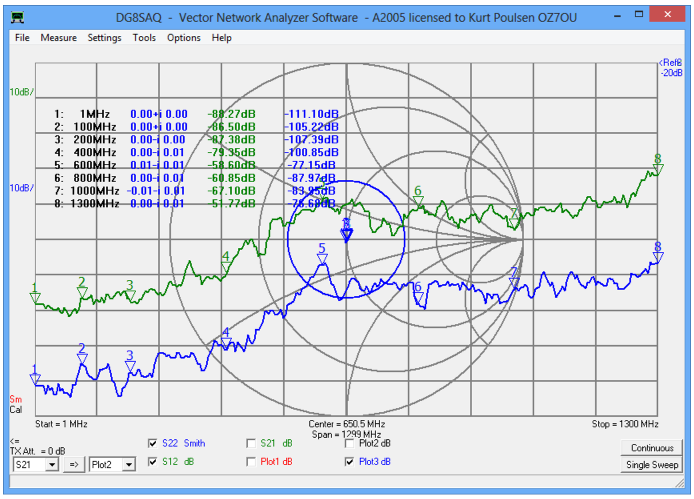
Forward Load with Crosstalk Calibration



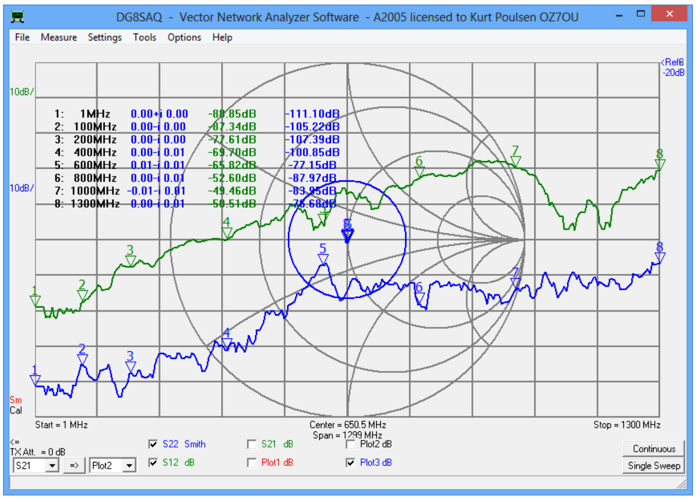
Forward Load without Crosstalk Calibration



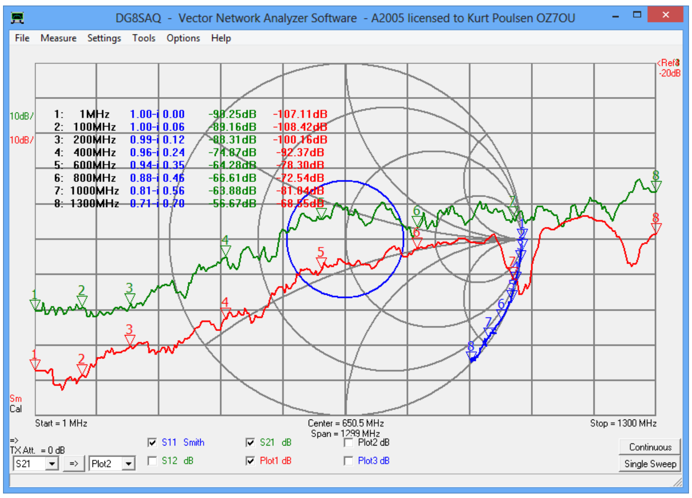
Reverse Load with Crosstalk Calibration



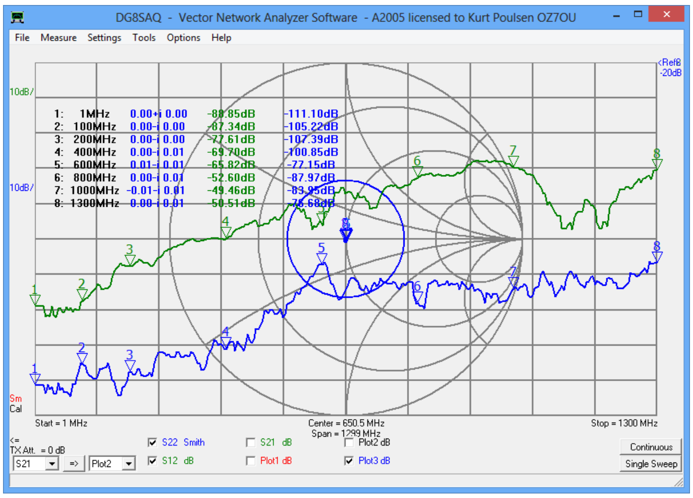
Reverse Load without Crosstalk Calibration



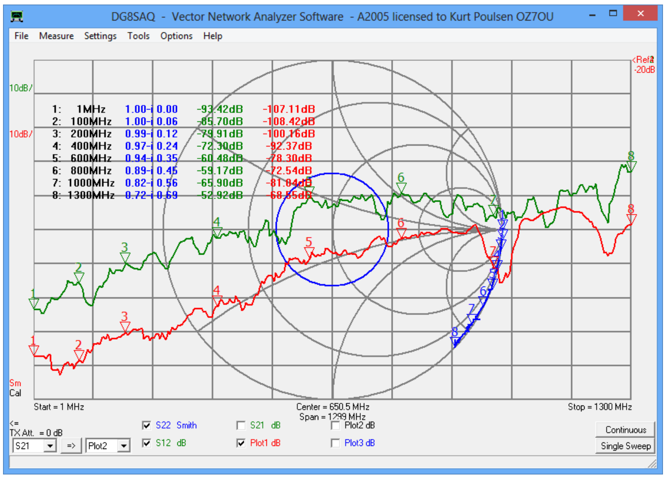
Forward Open with Crosstalk Calibration



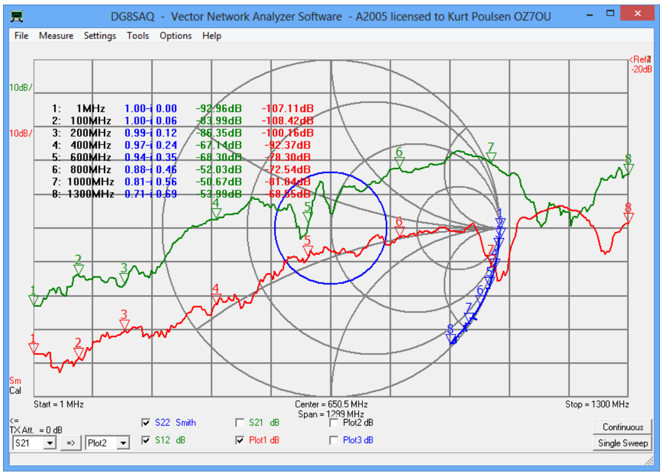
Forward Open without Crosstalk Calibration



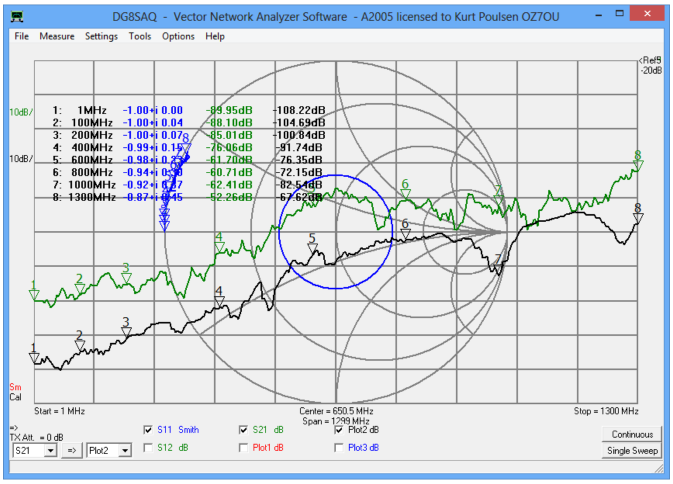
Reverse Open with Crosstalk Calibration



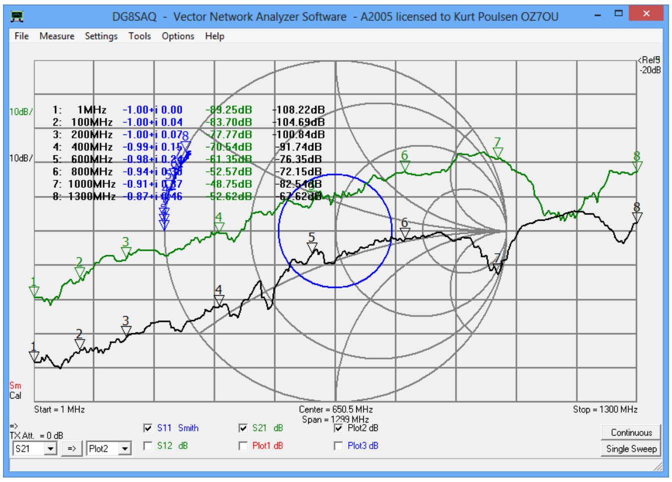
Reverse Open without Crosstalk Calibration



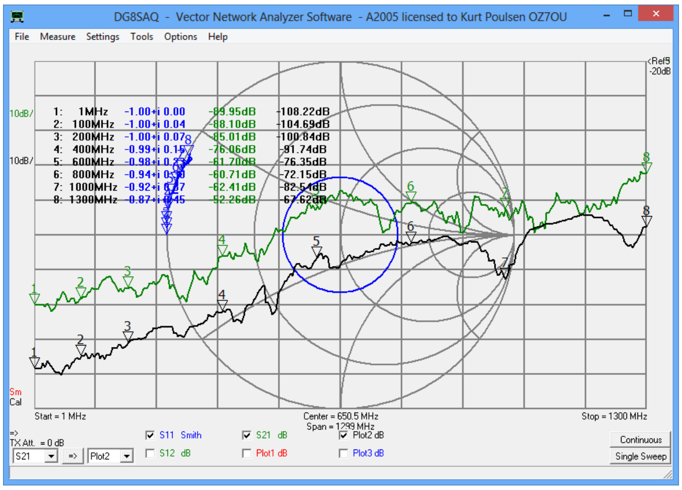
Forward Short with Crosstalk Calibration



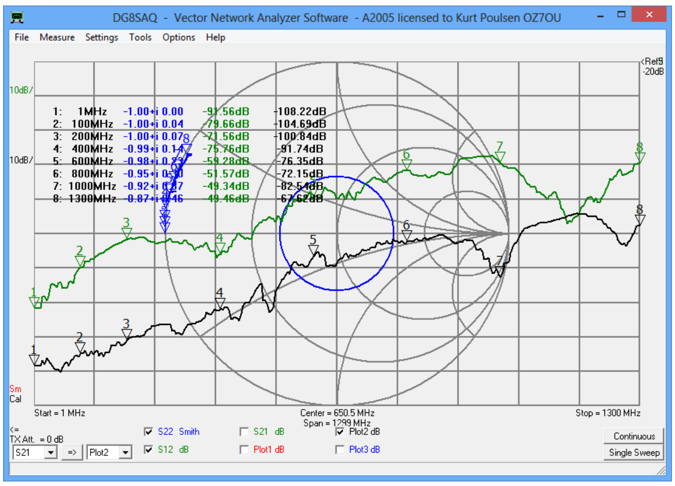
Forward Short without Crosstalk Calibration



Reverse Short with Crosstalk Calibration



Reverse Short without Crosstalk Calibration



With above screen shoots this theory is proven for an inline attenuator **of 20dB**. With the Crosstalk calibration in force all three conditions – Load , Open and Short - are identical. The images at the right side is same conditions with Crosstalk Calibration disabled and the result are also identical for all three conditions – Load Open and Short - but poorer than with Crosstalk Calibration. The dynamic range 90dB at 1 MHz reduced to 60dB at 650MHz and constant 60dB to 1.3 GHz (The sharp increase at 1.3GHz is due to the mild averaging where point beyond 1.3GHz is missing)

Final comment:
Summa summarum not so bad a solution, where the measurement result are to trust totally independent of the impedances the DUT has on its two ports and which is presented to the Test Set/Transfer Switch . Many Transfer Switches has 80dB isolation specification, in the VNWA frequency range, and this is specification is always measured at 50 Ohm condition. Not commonly know is the effect of other impedances presented to the Port 1 and Port 2 of the Test Set and thus the isolation specification degraded.
You may obtain adequate result with a 10 of 15dB attenuator for you specific Transfer Switch so try it out. But is not really the Transfer Switch these fine result depend upon it is mainly the linearization effect the inline attenuator has on the RX port and allowing full utilization of the Cross Talk Calibration.

Good Luck

August 2 2013 Kurt Poulsen