How to use and verify HP35033C 3.5mm calibration kit

Preface:

For several years I have made calibration sheets for the SDR-Kits calibration kits, composed from SMA male and female standard adaptors, first from Amphenol Connex and later on a female calibration kit from Rosenberger. From the very beginning, after assembling a VNWA2 kit, I purchased a Rosenberger female calibration kit from U.S.A. and received a datasheet of unknown origion, apparently from a university, where enough data was available to trust the kit as a good reference. Later on more Rosenberger male and female SMA adaptors were acquired, with the aim to further qualify the Rosenberger performance and in total 5 sets were acquired. As well, 5 sets of male and female SMA Amphenol Connex adaptors were acquired from SDR-Kits. Measurements on all these adaptors done with a brand new R&S 4 channel VNA last year but not satisfactory for various reasons. In the end, I decided to purchase a HP85033C 3.5mm calibration kit from ebay, with the aim to do it all over again.

For that task I used the DG8SAQ VNWA, in combination with my recently acquired HP85033C 3.5mm calibration kit, which also includes twice of each phase matched, male and female APC-7 to 3.5mm adaptors. That allows for accurate measurements of delays of any type of SMA thru adaptors such as male-male, female-female and male-female, just by exchanging the gender for one of the APC-7 to 3.5mm adaptors, after a full calibration of the VNWA. Off course, the 3.5mm calibrations standards can be applied directly to the VNWA female adaptor, but then direct delay measurements of symmetrical thru adaptors are not possible. Both the 3.5mm male and female short have identical delays of 16.695ps and likewise the 3.5 mm male and female open have an identical delay of 14.491ps and C0=53x10(-15)F C1=150x(-27)F/Hz and C2=0 , C3=0. Male 3.5mm load DC resistance was measured to 49.932 ohm and female load measured to 50.065 ohm with 0.01% accuracy.

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HP85033C 3.5mm calibration kit with 4 pc. APC-7 to 3.5mm SMA adaptors well arrived and in good state

Test equipment for 0.01% precision measurement of load DC resistance

All the soldiers on their feet and ready to battle the adaptors. The 4 point DC measuring device also ready for action.

A closer view of the various adaptor shown below

			
The male and female loads	The male and female opens	The female center conductor extender	The male and female short
			
The male and female loads	The male and female opens	The male center conductor extender	The APC-7 to 3.5mm phase matched adaptors

All adaptors are without PTFE thus airlines. The accuracy totally depending on mechanical dimensions. E.g. the open is just a cylinder and a short center conductor inserted after mounting, in the form of the female center conductor extender.

A frontend was fabricated to utilize the phase matched APC-7 to 3.5mm adaptors

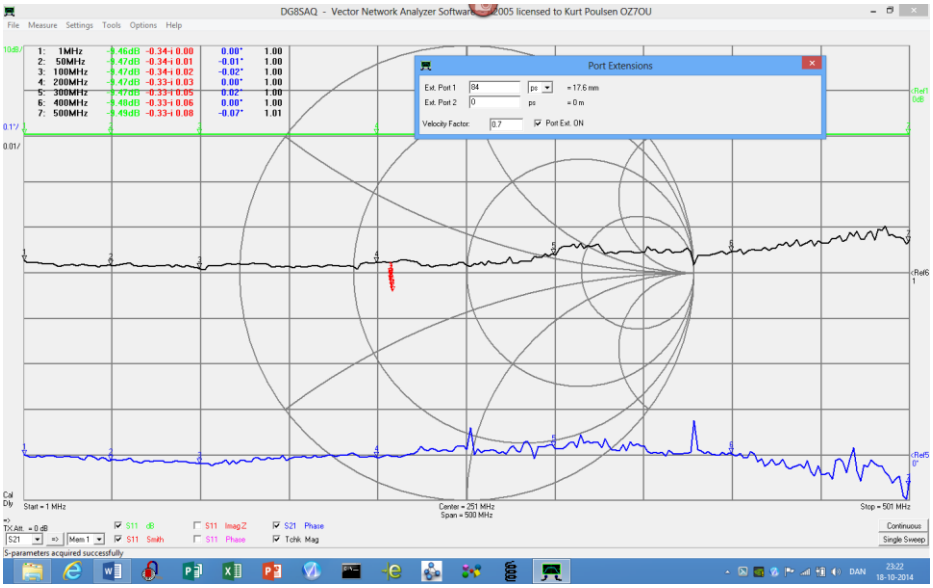
Left image: The APC-7 to 3.5mm female flange fitted to the VNWA with two SMA male-male adaptors.
Right image: The VNWA ready for calibration and measurements of the male female SMA adaptors.

Initial test was made with fully S11 and S21 calibration of the VNWA, and then by a swap, the TX port APC-7 to 3.5mm female adaptor swapped with APC-7 to 3.5mm male adaptor followed by measurement of the HP85033C 3.5mm female short, open and load calibration standards. As both male and female short have identical calibration definitions, as a delay of 16.695ps, and likewise the male and female open have identical definitions as a delay of 14.491ps and C0=53x10(-15)F C1=150x(-27)F/Hz and C2=0 , C3=0, there should be no difference in these measured delays. However before swapping, the open delay must be measured, as the C0 and C1 contributions adds to the delay. The total delay is 17.15ps for the open, when center conductor extender is fitted. When the center conductor extender is removed, the delay is 5.55ps and when the 3.5mm open standard is fully removed, the delay is 4.50ps, which represents the fringe capacitance of the center conductor of the male 3.5mm adaptor. Fitting a standard empty SMA female thru adaptor, where center conductor and PTFE was removed, the delay is 5.00ps, as the internal diameter is larger than for the 3.5mm open female standard.
For the 3.5mm male open calibration standard when removed the delay is 1.35ps. FEMM simulation shows 1.32ps. So just using the VNWA female adaptor/a female test cable with nothing connected, equals a delay of 1.35ps.

Repeating the S11 test using the second APC7 to 3.5mm adaptor of same gender showed “exactly” same result, ranging from 0 to 0.1ps for the APC-7 to 3.5mm female adaptors, and for one of the male adaptors likewise, but for the second APC-7 to 3.5mm male adaptors showed a larger difference for S11 measurements (for short and open around 0.5ps) as the internal Z0 for that adaptor was slightly different from 50 ohm. It was evaluated with ZPlots by AC6LA to be 50.5 ohm, which explains the difference observed.
The same swapping of adaptors, of same gender, was performed for S21 as well, and the S21 phase difference was measured and expressed as a delay difference, which was from 0 to 0.1ps, depending how accurate the alignment in axial direction and the spanning torque applied was for the APC-7 side. For the entire range of 3.5mm and SMA adaptors, a calibrated Huber Suhner torque wrench from SDR-Kits, was used all times.
As such mechanical instabilities exist, it is the nature of a mechanical calibration kit, and not to be avoided. However using such a mechanical calibration kit one learns, over time, to align and span the APC-7 always the same way.
For these test a frequency range of 1 to 501MHz with a 2MHz step size and 100ms per data point was used.

Test of the accuracy of the calibration:
Rohde & Schwarz has developed a so called T-Check method, which by a formula in a custom trace for the VNWA software, can measure the quality of the calibrations. A T-adaptor is inserted in the transmission path, and a 50 ohm load mounted on the “third leg” of the T-adaptor. Then after a forward/reverse calibration a full measurement of S11, S21, S12 and S22 was performed by **pressing the F4 key** of the VNWA and a fullblown 10/12 term error correction was applied. Traces for both forward and reverse must be selected and enabled. The formula to enter is : (just copy and paste below line)
abs(s11*conj(s21)+s12*conj(s22))/(sqrt((1-abs(s11)^2-abs(s12)^2)*(1-abs(s21)^2-abs(s22)^2)))
Trace representation is lin.magnitude and scale settings are Reference Level 1 and Y scale is 0.1/Division for a 10% T-Check per division and as in below images 0.01/Division was chosen, representing a 1% T-Check per division.

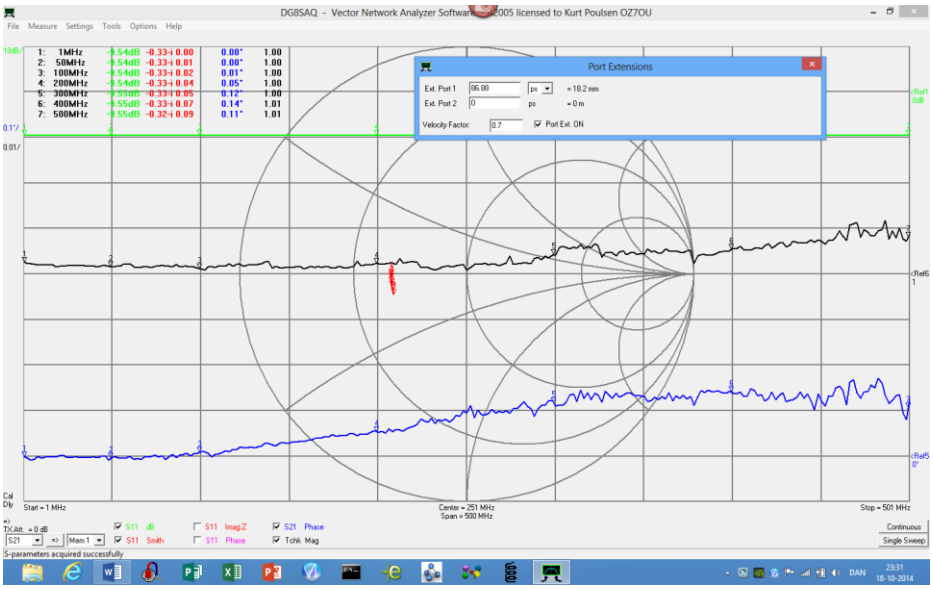
After a full S11 and S21 calibration using the HP85033C 3.5mm calibration kits a T-Check was performed.



T-Check using female Rosenberger load and T adaptor. The extension Port1 delay enabling has no impact on the result and selected just to monitor the S21 phase characteristics. As seen the calibration is just superb well below 1% which is more than perfect ☺

I have manufactured a homemade SMA T-Check adaptor of same length as an identical thru adaptor, thus same delay applying during S21 calibration as during T-Check. The T was made by milling a 2mm slot in the center of the thru adaptor until the center conductor was exposed and 2 pc. 100 ohm 0.1% SMD 0805 was soldered to the center

conductor pin and the outer conductor. Below the T-Check result indicates it is identical up to 250MHz and then a slight deviation occurs.



T-Check using homemade inline T-Check adaptor. Extension port 1 delay adjusted until S21 phase is flat up to 100MHz.

Summary:

A large number of measurements were made for the male and female adaptors from Rosenberger and Amphenol Connex, and two items from Fairview Microwave, being an endcap, acting as male open standard, and a male short measured for comparison to the Rosenberger male short of identical design. For most of the adaptors a quantity of 5 measured units were made and an average calculated, which is used in the revised calibration sheets published by SDR-Kits and on my homepage http://www.hamcom.dk/VNWA . Comprehensive documents are written, for both Rosenberger and Amphenol Connex, documenting all the measurements and with a link to this document. The documents are not “easy reading” and made only for my own sake, but will be published so e.g. the spread from the average value can be studied, which is summarized in the report for each type of adaptor.

The experience made from this “exercise” is that choosing (the past), the Rosenberger female calibration kit, was a very good choice. However, provided my new HP85033C 3.5mm calibration kit as the new master is trust worthy, which I believe, then the specification for Rosenberger female calibration kit of unknown origin was pretty good, but now the data is far better and more accurate. (see new Rosenberger CAL sheet)

One finding is worth mentioning that the delays for adaptors in S11 mode are frequency dependent so a S21 delay added to the fringe capacitance delay is not the correct value for an open calibration standard. This is due to factors like the velocity factor is frequency dependent, being lower at low frequency and the actual Z0 of the adaptor is changing the S11 delay.

As you probably are a happy owner of the VNWA, or any other VNA, you do not have adaptors measured and verified, based on the comparison with my HP85033C kit, there will be some deviations, due to natural production spread of the delays in mass production, but these are pretty small, which you will be able to study in the mentioned reports, if interested.

Else just run a T-Check and you will see that you as well are in good shape, using my calibration sheets of revision 4 oct 2014 or just dated oct. 2014.

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