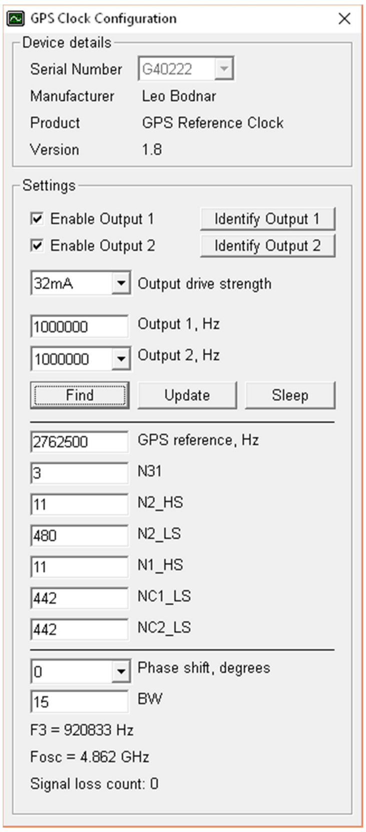
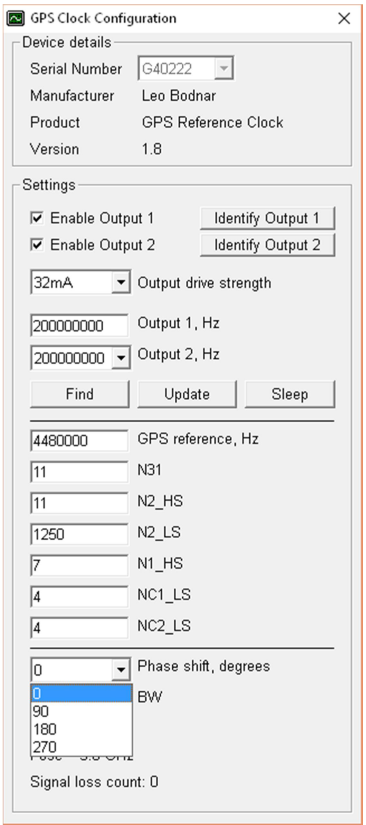
Leo Bodnar electronics	**Investigation of Leobodnar GPSDO now available at SDR-Kits**	SDR-Kits

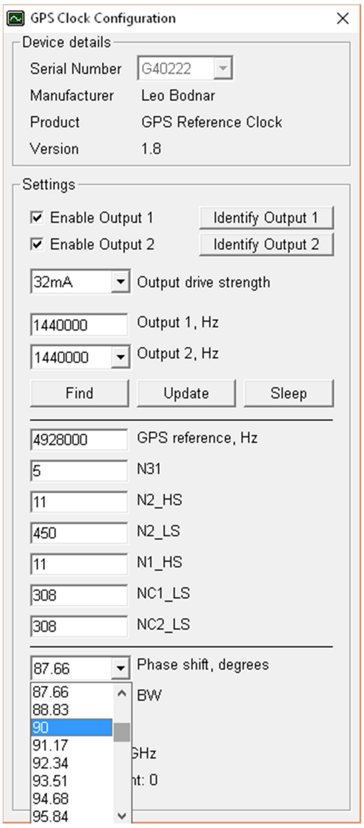
Preface:

The Leobodnar GPSDO is indeed an excellent tool for the RF experimenters and the radio amateurs. It is well designed, mechanical stable so mechanical handling does not impact frequency stability. It is fast locking to GPS and are within spec in 1 minute, which is very fast. It provides two independent outputs from 450Hz til 800MHz and levels up to 13.3 dBm at 10MHz into 50 ohm. Four drive level settings exist to set the output at 10MHz to 13.3dBm (32mA), 12.7dBm (24mA), 11.4dBm (16mA) and 7.7dBm (8mA). The drop of signal level pending frequency from 10 to 800MHz is linear by 3.36dB at 32mA drive setting. For the other drive level settings they are 4.16dB for 24mA, 5.56dB for 16mA and 7.36dB for 8mA. See later about how these measurements were done. So in fact with a bit of careful thinking and use of external attenuator it can be used as an accurate signal generator. It is claimed to approach 1E-12 and under certain circumstances such as outdoor GPS antenna this is correct for an average of some 65000 100ms points measured. Find several measurements in this report documenting the actual performance.
If both outputs are of same frequency then the phase difference can be adjusted in frequency dependent steps of e.g. 0.814degree at 1MHz or at 10MHz in steps of 7.826degree. The highest frequencies for exact 90 degree steps are from 110.3 to 220MHz above 220MHz the steps are 180degree. Below 110.3MHz the steps are 60 degree. Several other useful setting can be found, these are only examples.

A few word about the control software which might be beneficial quickly to figure out how to use it.
At first you enter desired frequency in the “Output 1, Hz” field and click on the “Find” Button. The required frequency is now also automatic update in the” Output 2, Hz” field. The software calculates the values to be programmed into the GPSDO, **but not executed yet**, and the calculated data displayed in the fields “GPS reference, Hz”, “N31”, “N2_HS”, “N2_LS”, “N1_HS”, “N1_LS”, “NC1_LS” and “NC2_LS”.
Now click on the Button “Update” and the GPSDO is programmed with same frequency for Output 1 and 2.
See below the examples for 10MHz, 200 MHz and 144MHz and see also the options for phase differences between output 1 and 2.
If you want a different frequency for Output 2 the enter the required frequency and click on the “Find” button and write down the “GPS reference, Hz”, “N31”, “N2_HS”, “N2_LS”, “N1_HS”, “N1_LS”, “NC1_LS” and “NC2_LS” data and manually enter these data in the fields accordingly, followed by a click on the “Update” button. Only Output 2 frequency changed by this procedure. **In a future software release, a new button called “Update 2 only” would be very nice.**





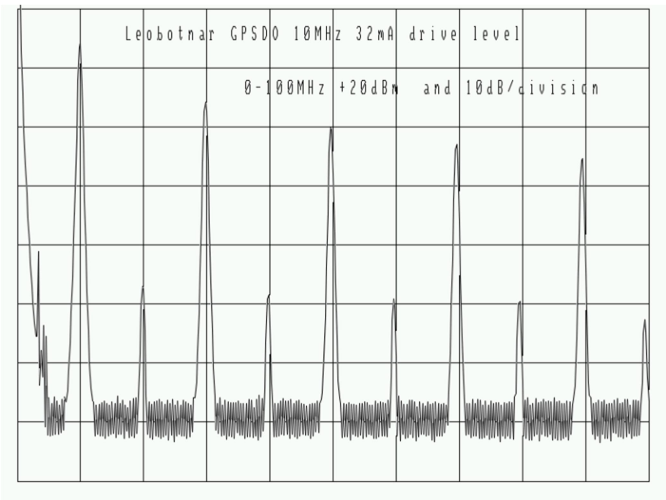


The Leobodnar GPSDO is now of August 2016 available from SDR-Kits and for full technical data visit the Leobodnar GPSDO homepage:
http://www.leobodnar.com/shop/index.php?main_page=product_info&cPath=107&products_id=234

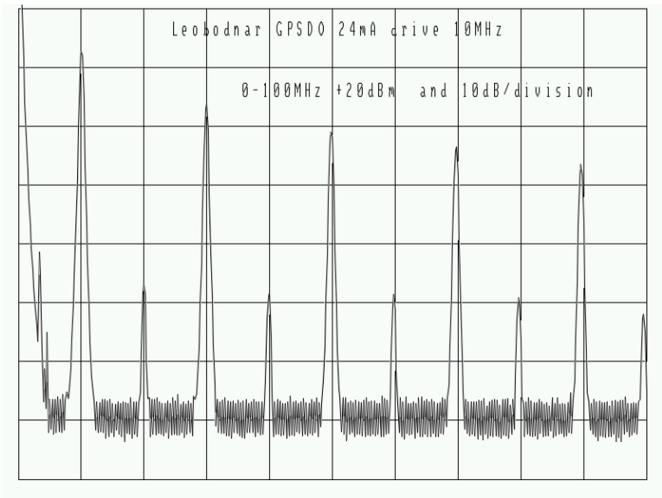
Very nice mechanical design where the USB – B connector and SMA female for GPS antenna are found on the rear panel.

Case Dimensions: WxHxD = 57 x 22 x 88mm
Power either via USB of external 12V DC via 2.1mm plug
Long USB cable supplied with the unit.
Small square GPS with magnet supplied as well.
Everything delivered in a very nice black transport case.
Two front LED's indicate GPS status and output selection for Output 1 and 2
Software downloaded from UK manufacturers website

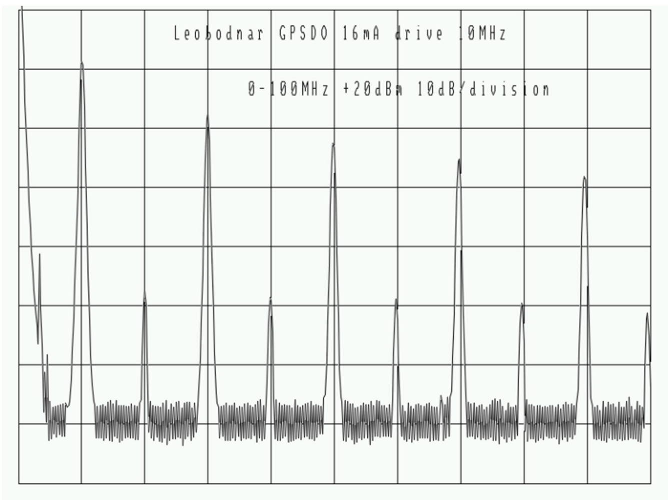
Below the spectrum for a 10MHz signal from 10MHz to 110MHz for the different drive level settings



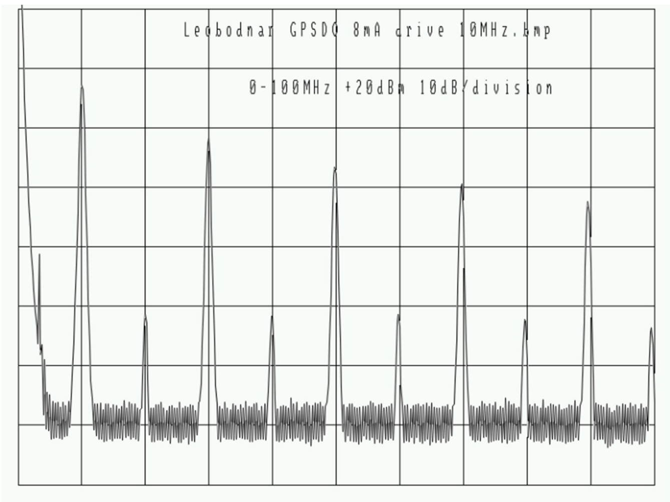
32mA



24mA



16mA



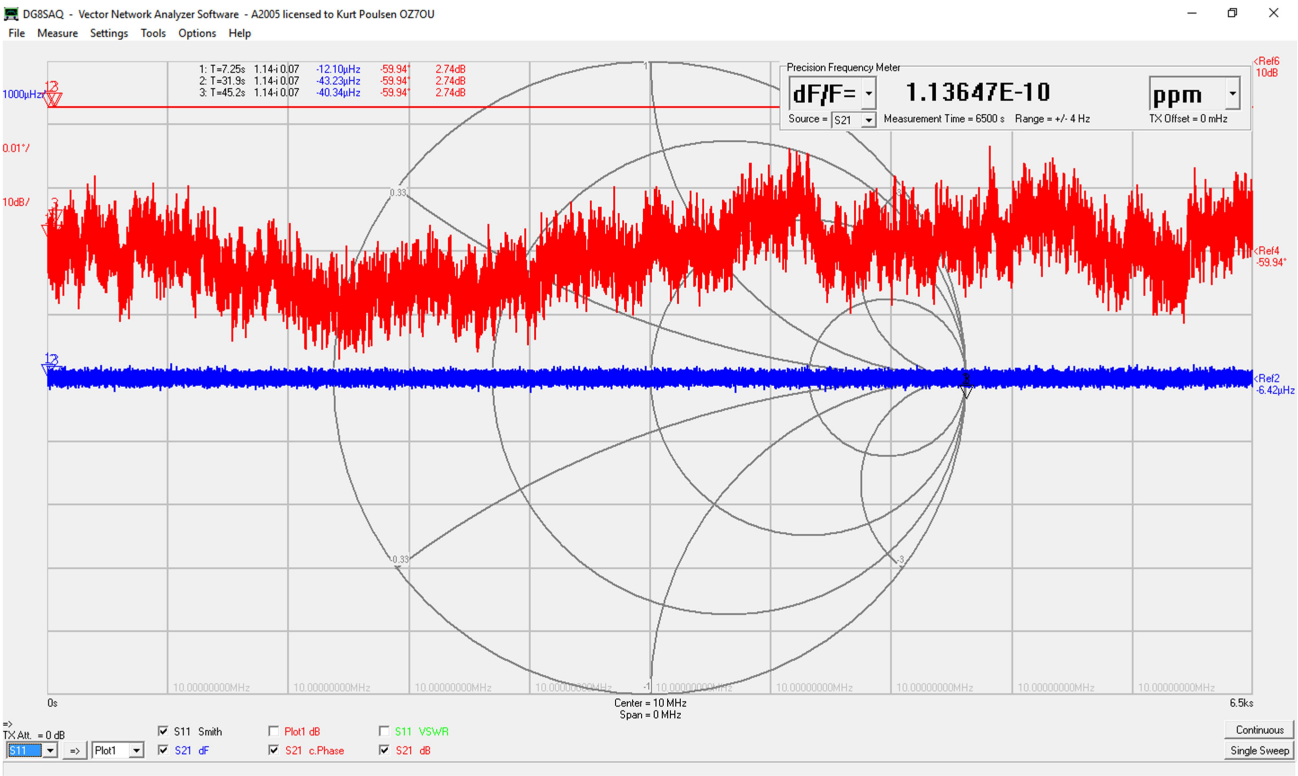
8mA

As seen the output contains Strong odd harmonics which indicates a square wave output

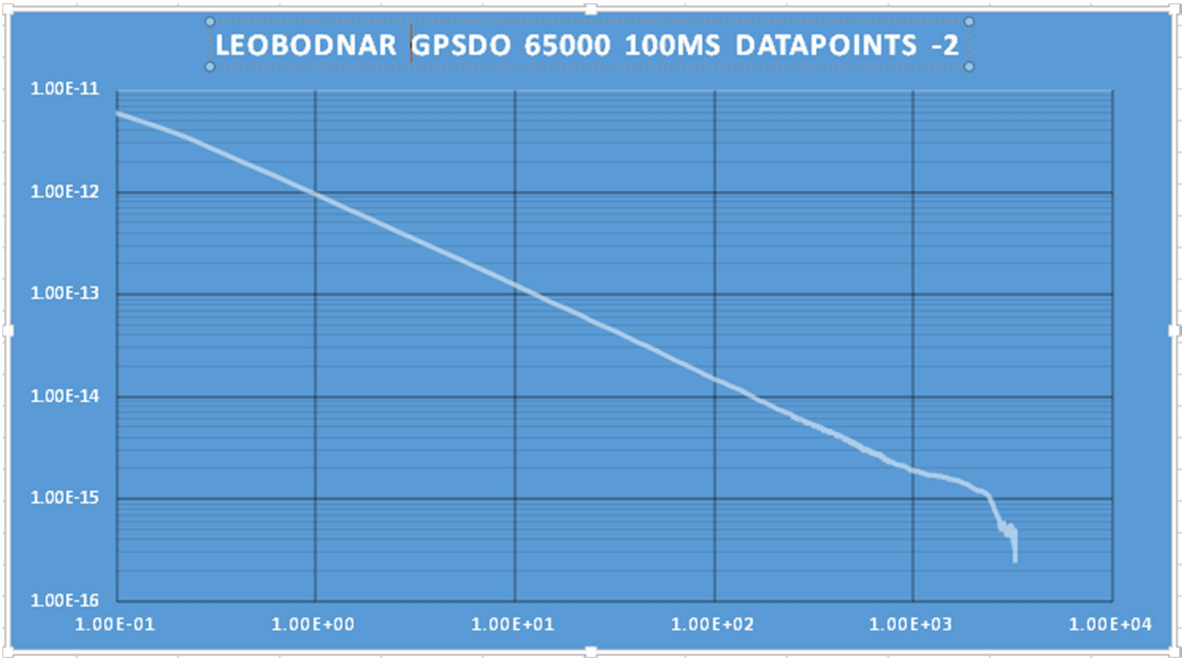
The testing follows

For analyzes of frequency stability is used the DG8SAQ in Frequency meter mode.
At first the Leobodnar GPSDO is connected directly to the external 10MHz reference input (high Z) and as well as the input signal to the RX port via a 30dB SMA inline attenuation so the 13.3dB drive level reduced to -16.7dBm, a safe level for the VNWA RX port and fully linear. Then a sweep is made and subsequent an Allan Deviation calculated to determine the system limits and optimum dynamics for the VNWA.

Some measurements:

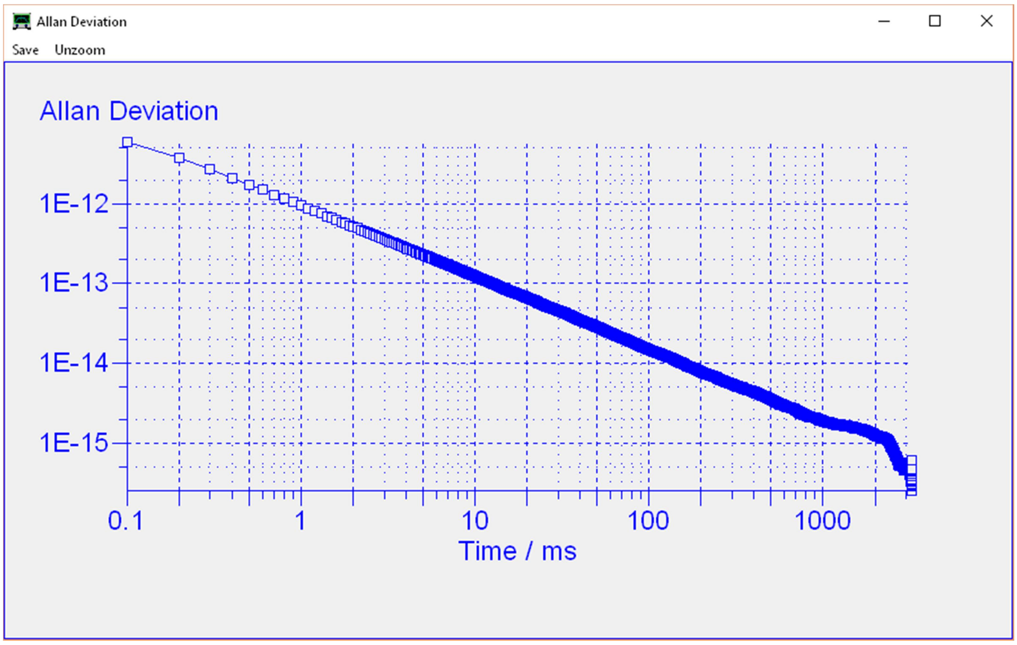


Leobodnar sweep for 65000 100mS points both as external reference at 13.3dBm and signal source to RX port of -16.7dBm. The External reference input is High Z so a SMA T adaptor used for signal distribution



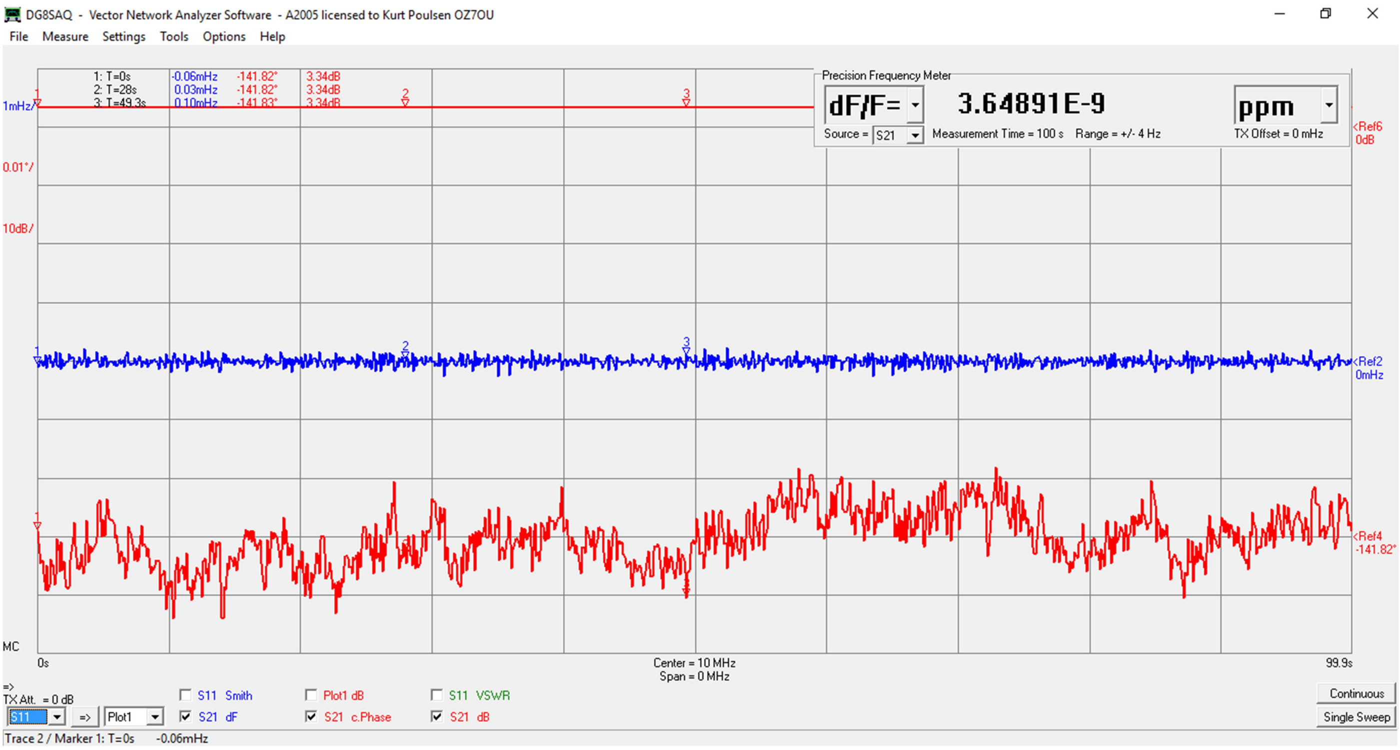
The Allan deviation for above sweep, and it demonstrates excellent risetime for the square wave output, based on experience and many other tests, which will be shown when the HP58503B 10MHz GPS disciplined reference used under same conditions and as the external clock input.

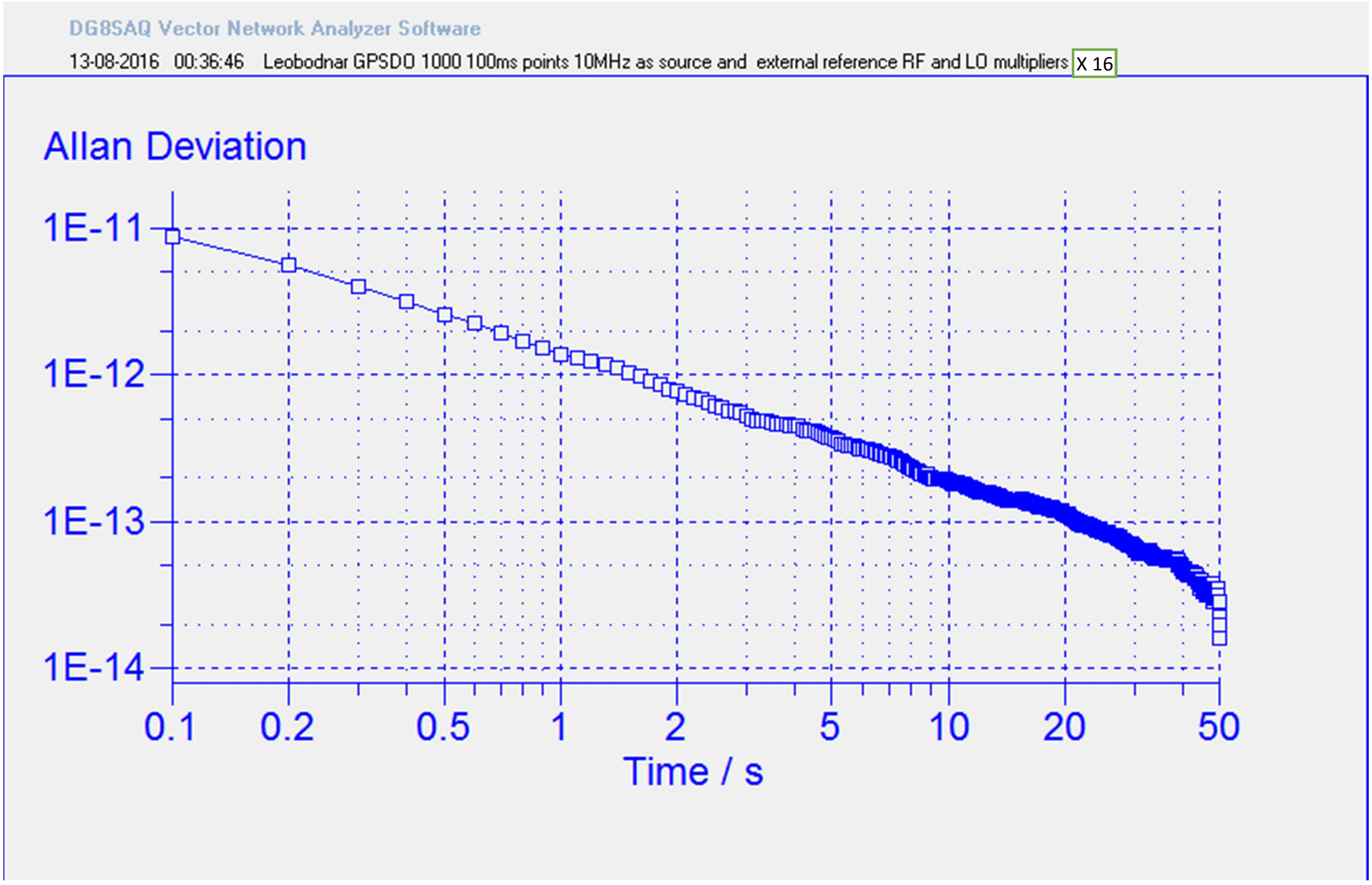
These Allan deviation plots are generated in EXCEL based on saving the Allan Deviation data generated within the VNWA software and saved as *.dat files.
It is quite time consuming to import these *.dat files into EXCEL and format a plot, and the day after the first version of this report was finished, I received from Tom Baier a new test version of the VNWA software 36.6.9.u which directly plots the Allan Deviation graphs.
A SERIOUS WARNING: If You want to save a measurement for later data processing such as saving a dF.dat file or generate Allan deviation based on a saved *.dat file or generate the Allan deviation by the new VNWA feature then save as an Instrument state file.
If the measurement is saved as a S21 s1p Touchstone file and later retrieved, then exactly the same number of point and time per point including DDS multiplier settings, as when the Touchstone file was saved, must be re-established. I did so initially and failed several times, See below Allan deviation plot which luckily is identical to the one generated in EXCEL based on a dF.dat file, because generated while the actual made measurement was still visible "online".



Allan Deviation plot above generated by VNWA for a Leobodnar GPSDO sweep for 65000 100mS points where is it is both signal input and external 10MHz reference. ***Please note the Time indicated as ms a small bug now corrected for version 36.6.9.v or later to download from DG8SAQ VNWA Yahoo forum.***
In all following measurement only the VNWA generated Allan deviation plot will be used.

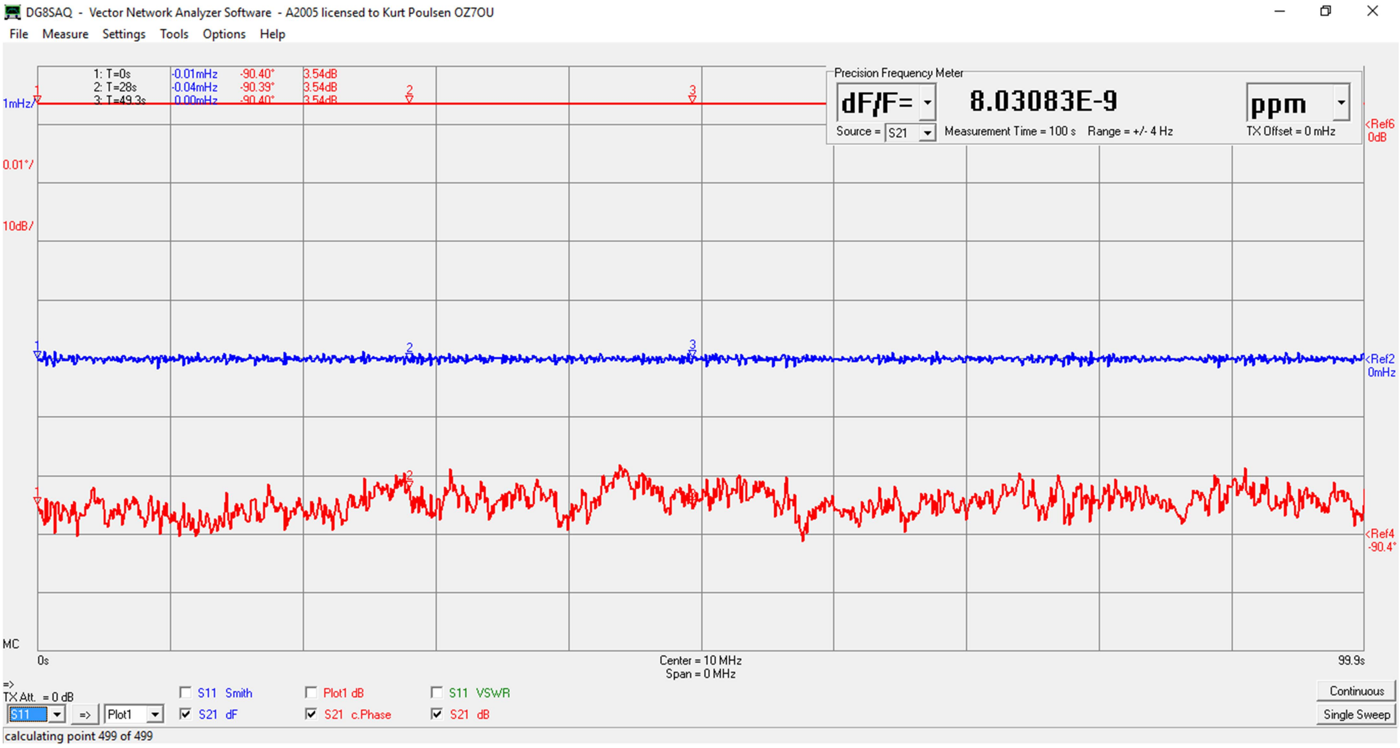
Same test as above repeated just for 1000 100mS points

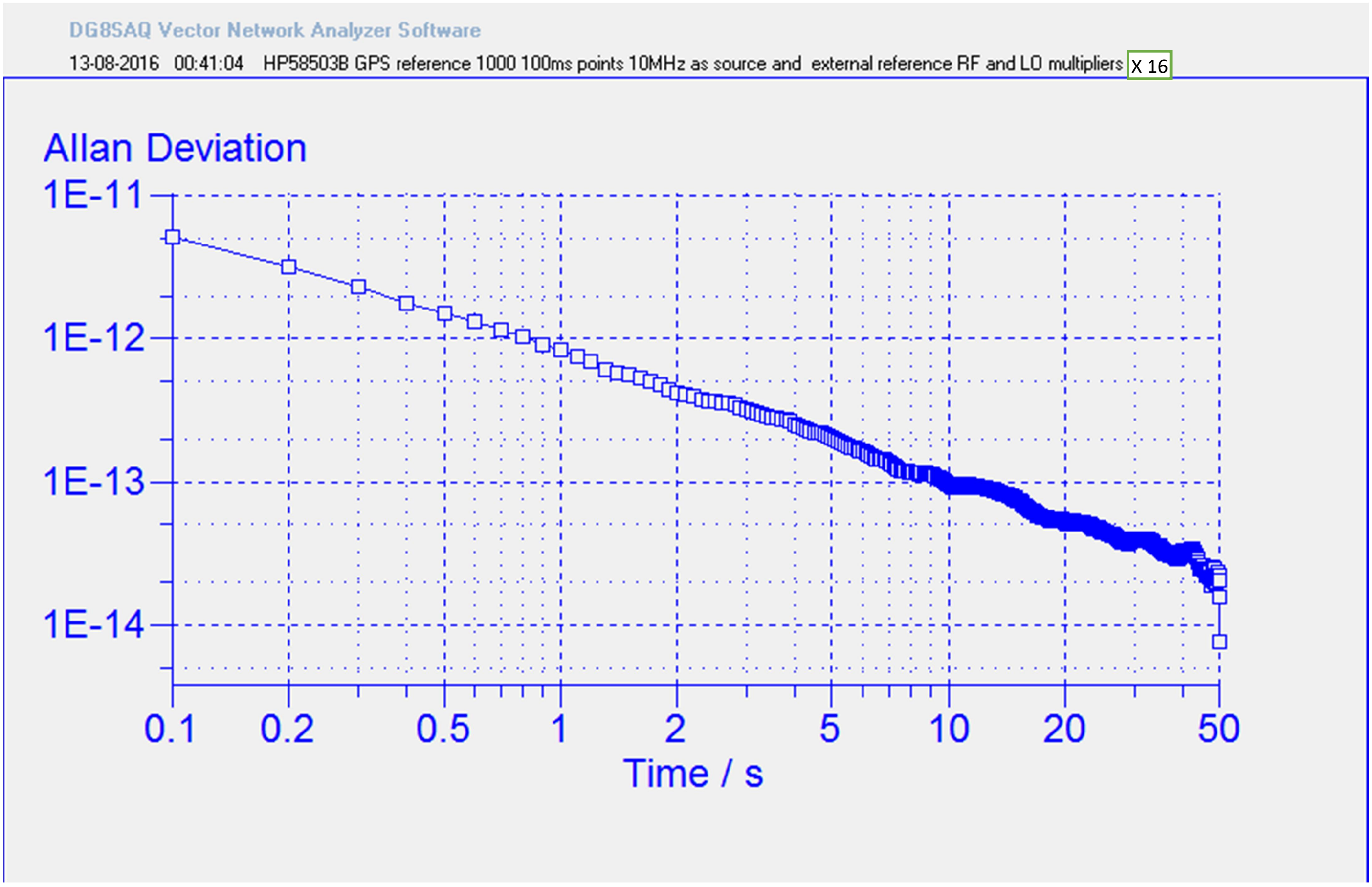




The Allan deviation is almost identical to the sweep with 65000 100mS points so for systems limitation test no need for such many points. The same plot generated quickly by the VNWA software so to speak on the fly.

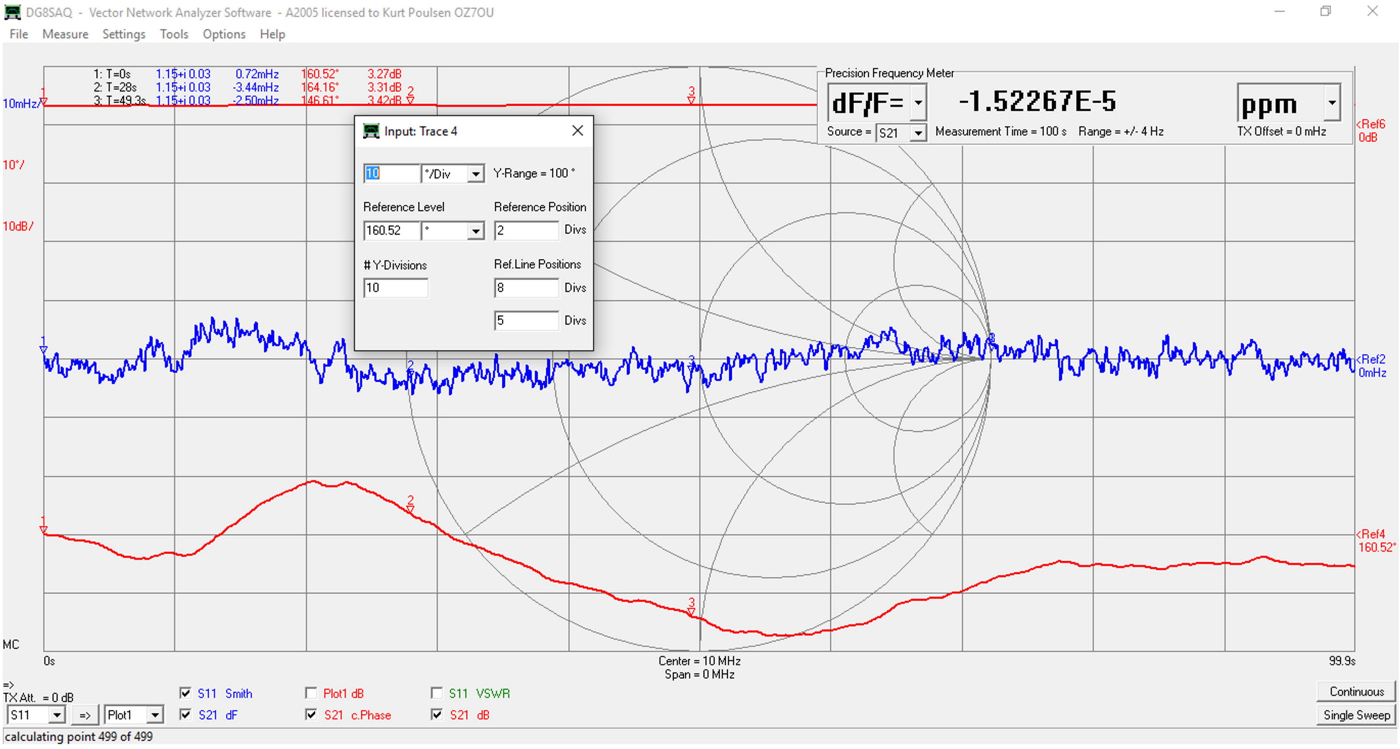
Below sweep is showing the result when a HP 58503B 10MHz GPS disciplined reference is used for 10MHz External Reference and as signal to the VNWA RX port via an 30dB SMA inline attenuator. As the HP delivers a sinus signal a homemade square wave shaper used delivering a +12dBm level.



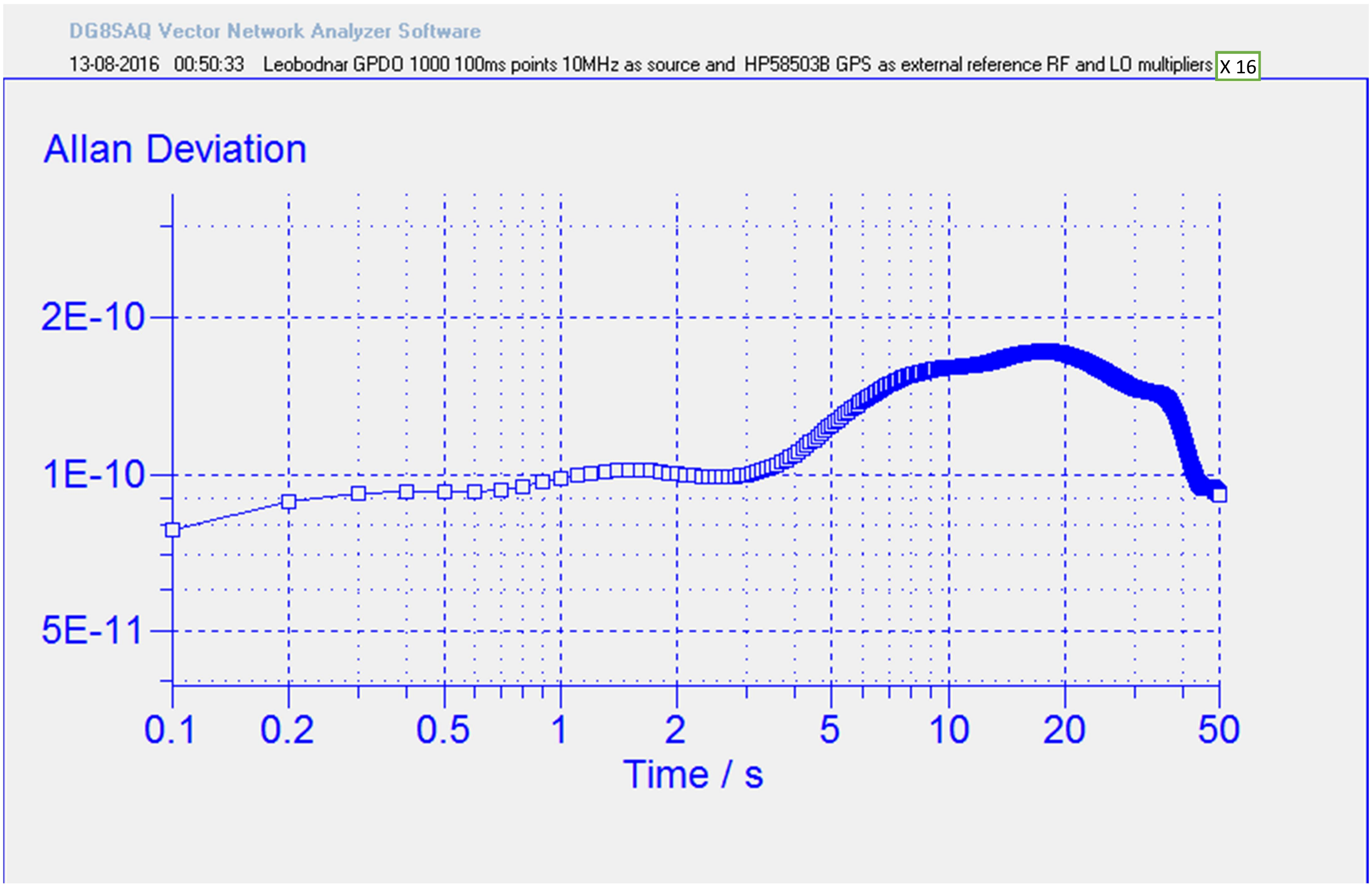


The Allan deviation demonstrates a slightly better system performance with the HP58053B, e.g. 9*1.00E-13 against 1*1.00E-12 at 1 sec measuring time for the Leobodnar GPSDO. This is mainly due to the rise time for the external reference square wave is faster for the HP58503B setup as a homemade shaping device used.

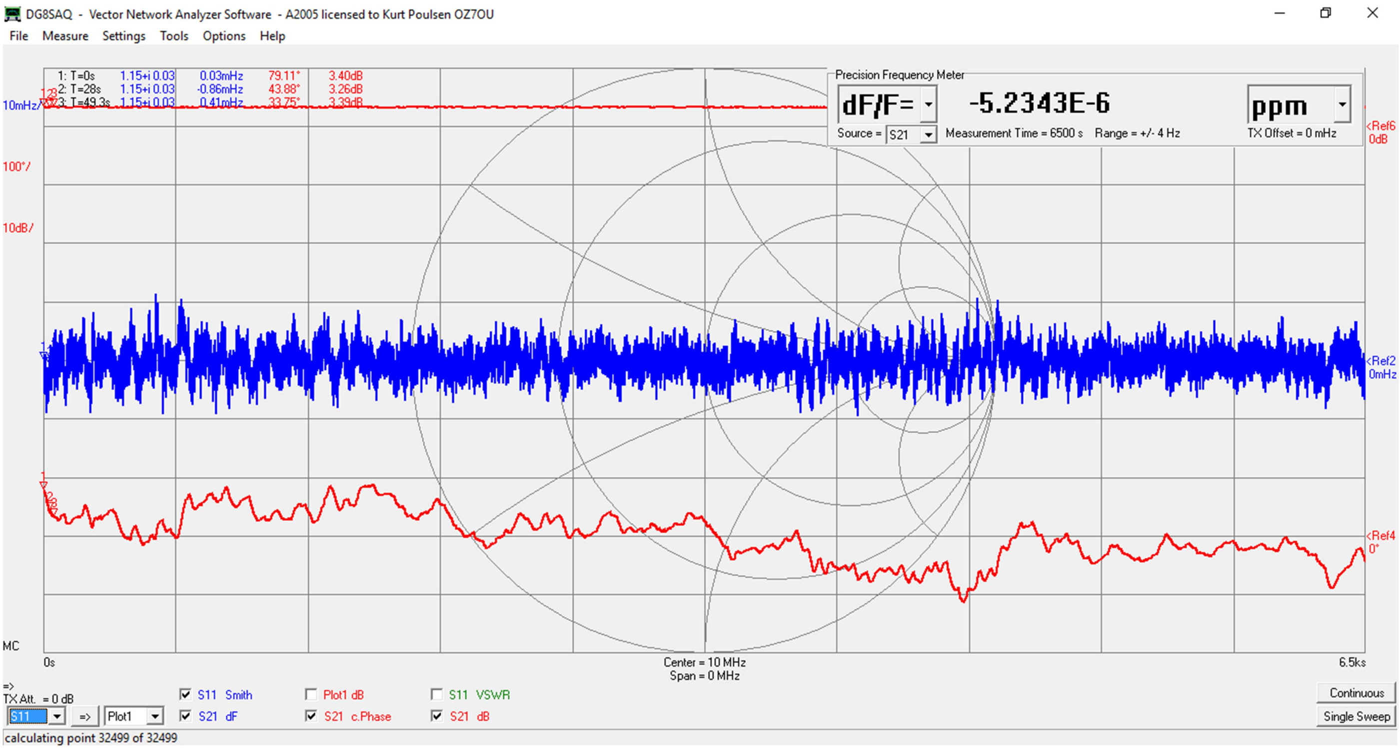
Next measurement is for the Leobodnar GPSDO against the HP58503B as external reference



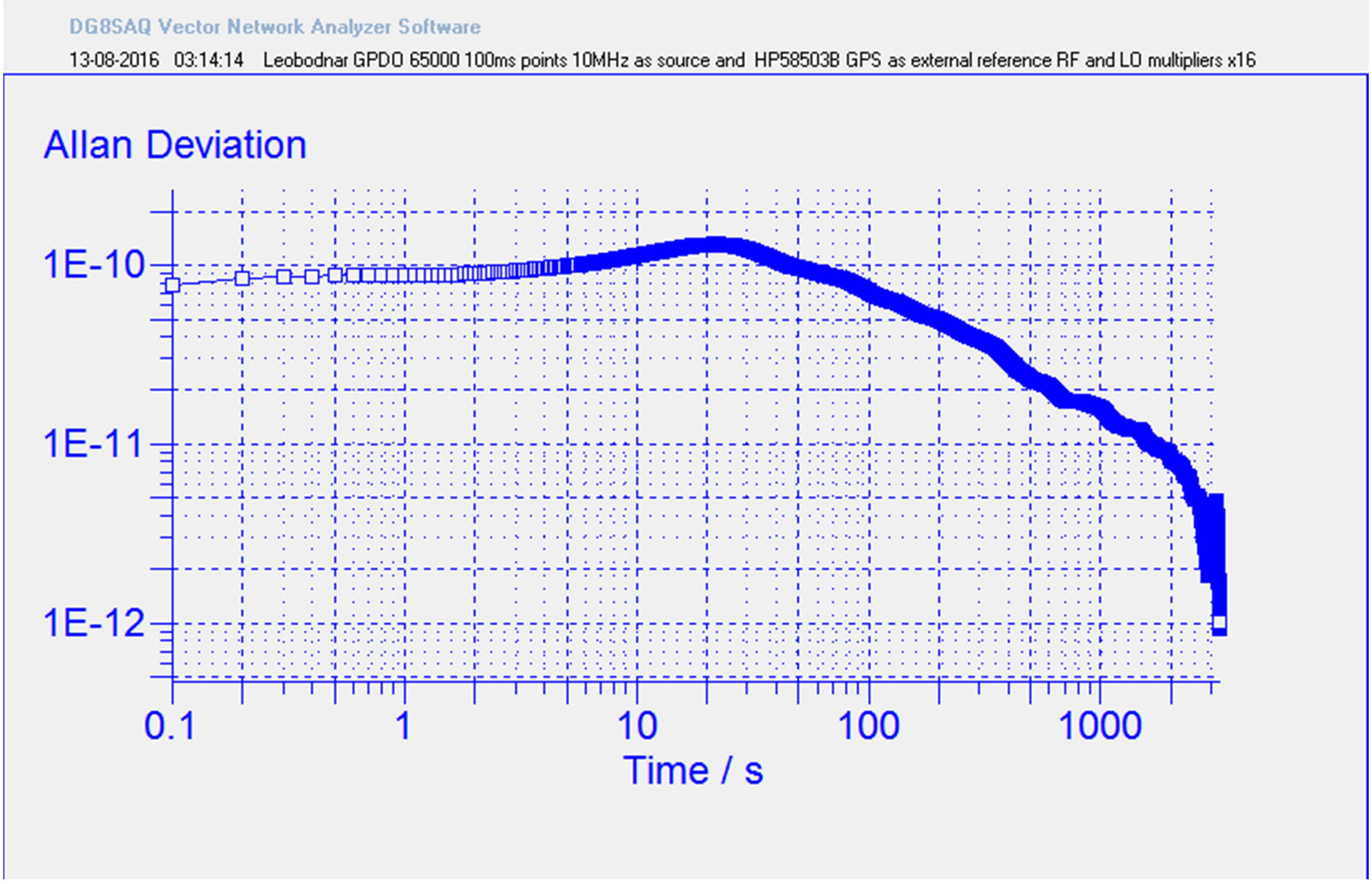
Leobodnar GPSDO against HP58503B GPSDO 1000 100ms points



The Allan Deviation does not follow the usual trend for an oscillator due to the design principles of the circuitry. It has however an excellent short term stability maintained over time. It will be seen later on that the Leobodnar GPSDO is very fast to reach this stability, thus a perfect tool for field usage as spot on very quickly. See However next measurements with 65000 points



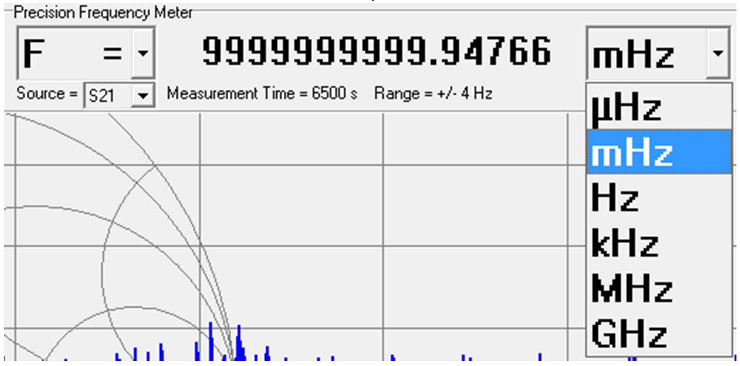
Leobodnar GPSDO against HP58503B GPSDO 65000 100ms points.
The average dF/F for the entire sweep -5.2343E-12 so quite impressive equal 52.2343 uHz

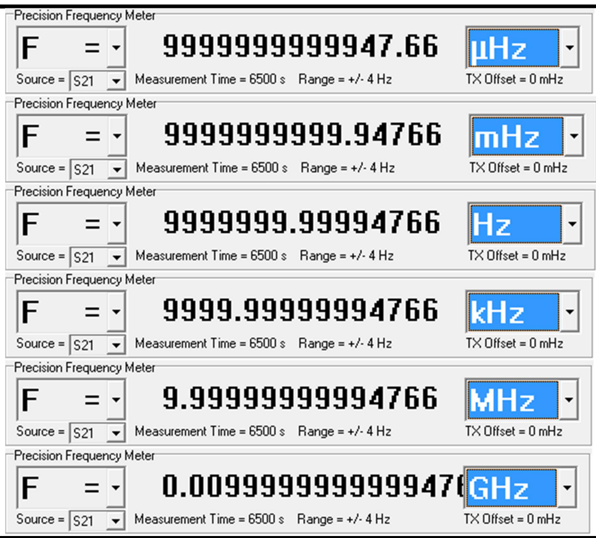


Allan deviation for 65000 100 ms points shows the tradition path above 20seconds

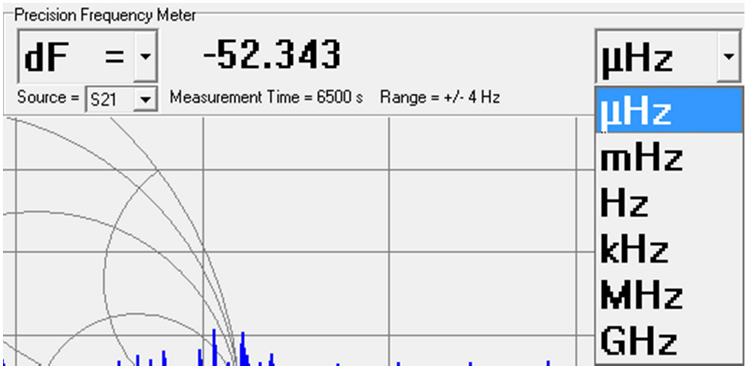
The various presentations for the frequency meter is shown below

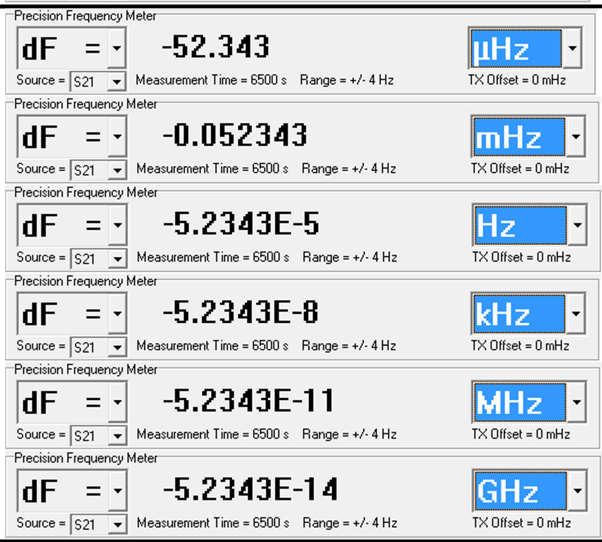
The result of the sweep average frequency
in selectable presentations



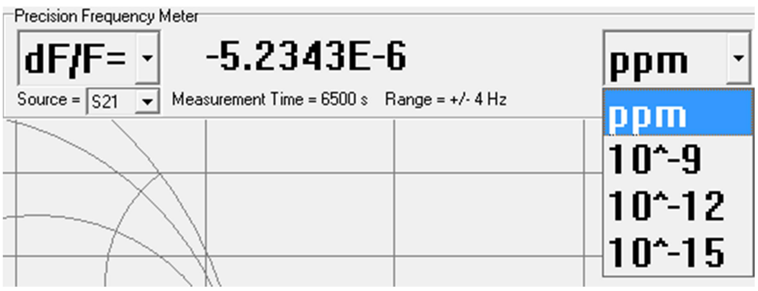


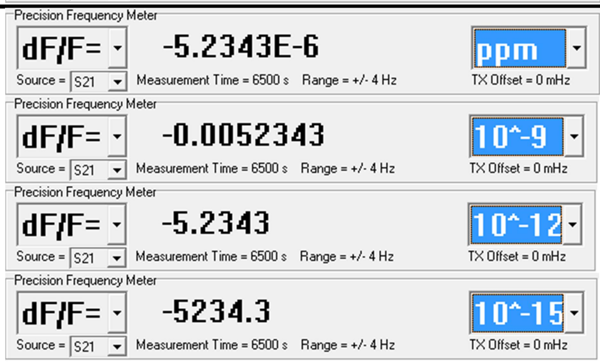
Average frequency deviation relative carrier
in selectable presentations



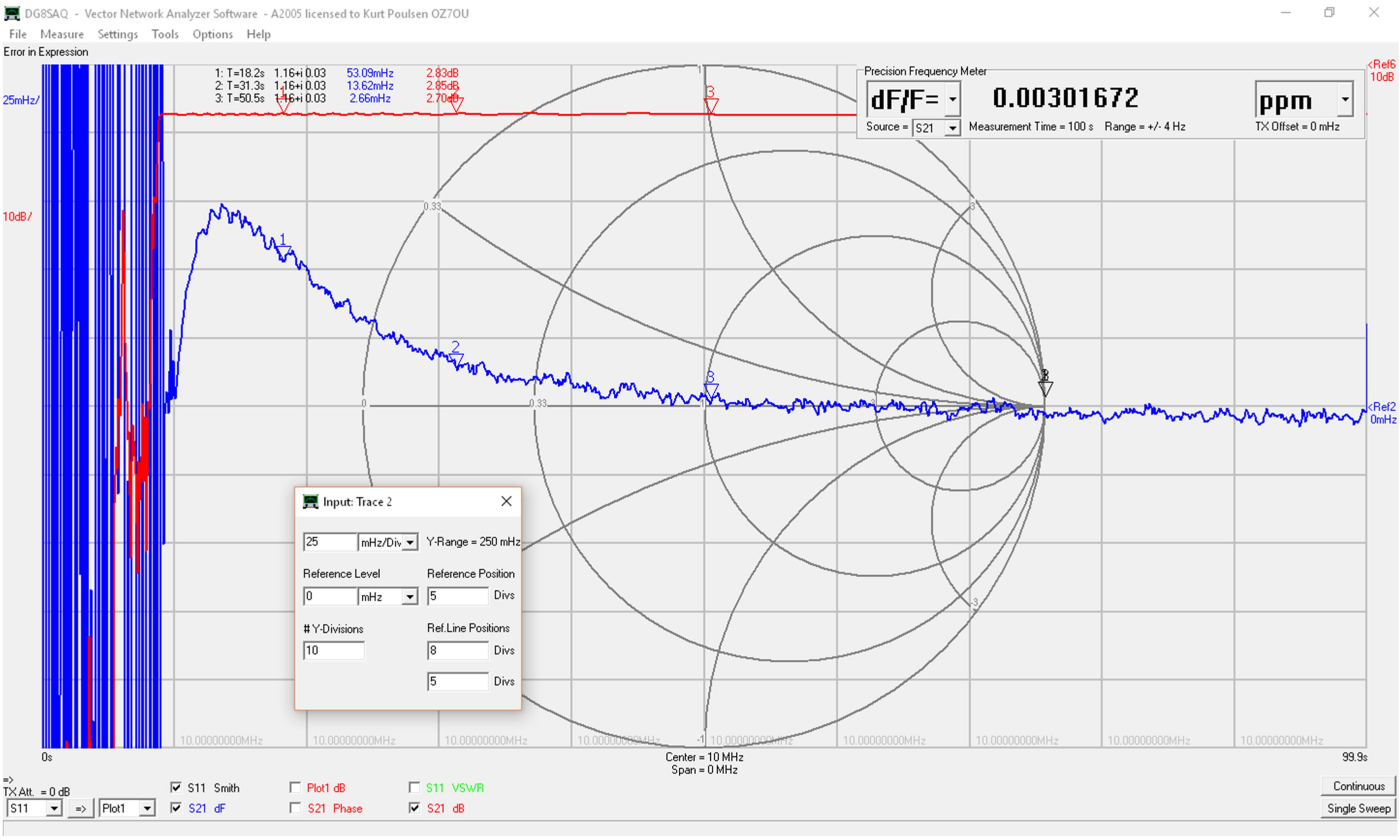


Average frequency deviation relative carrier frequency
in selectable fresentations

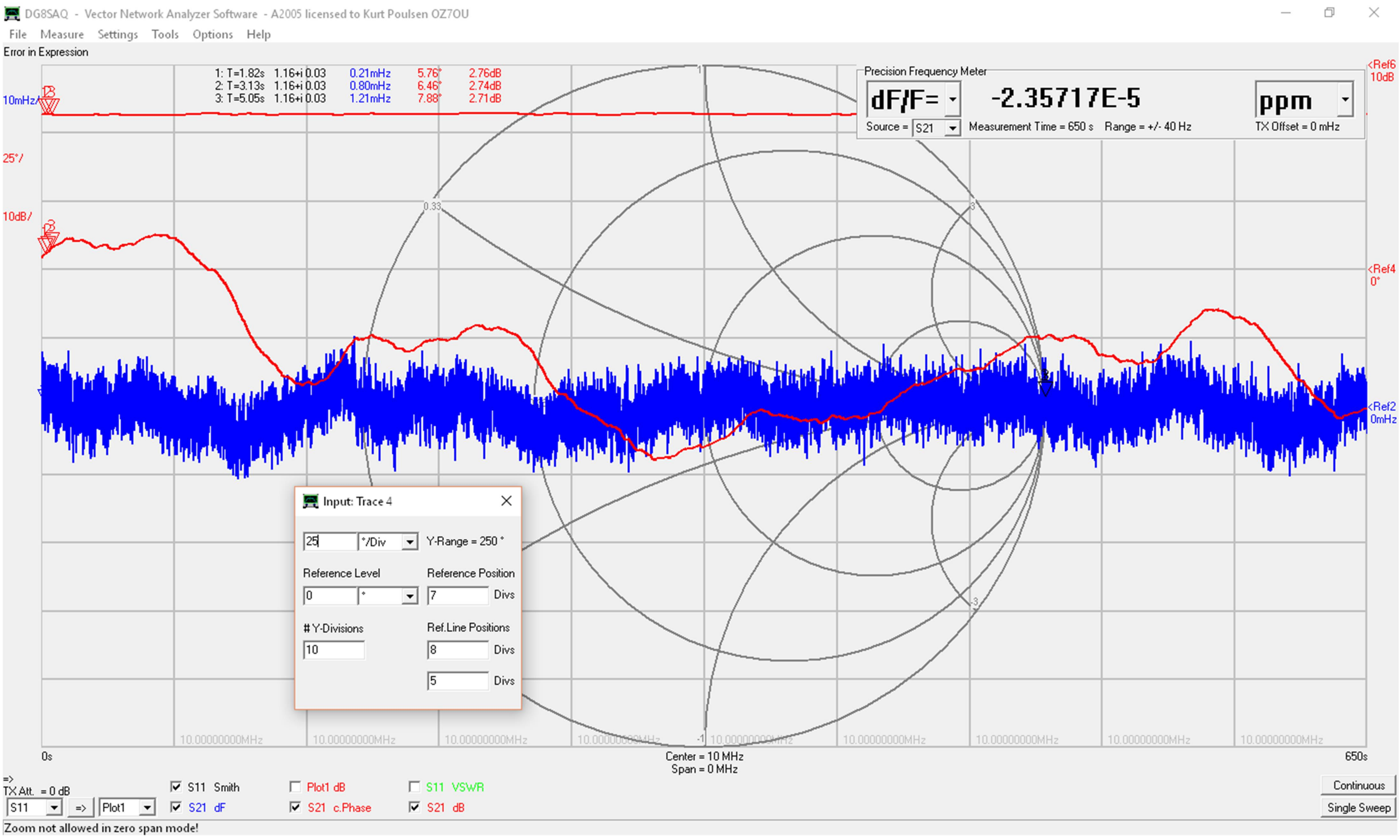




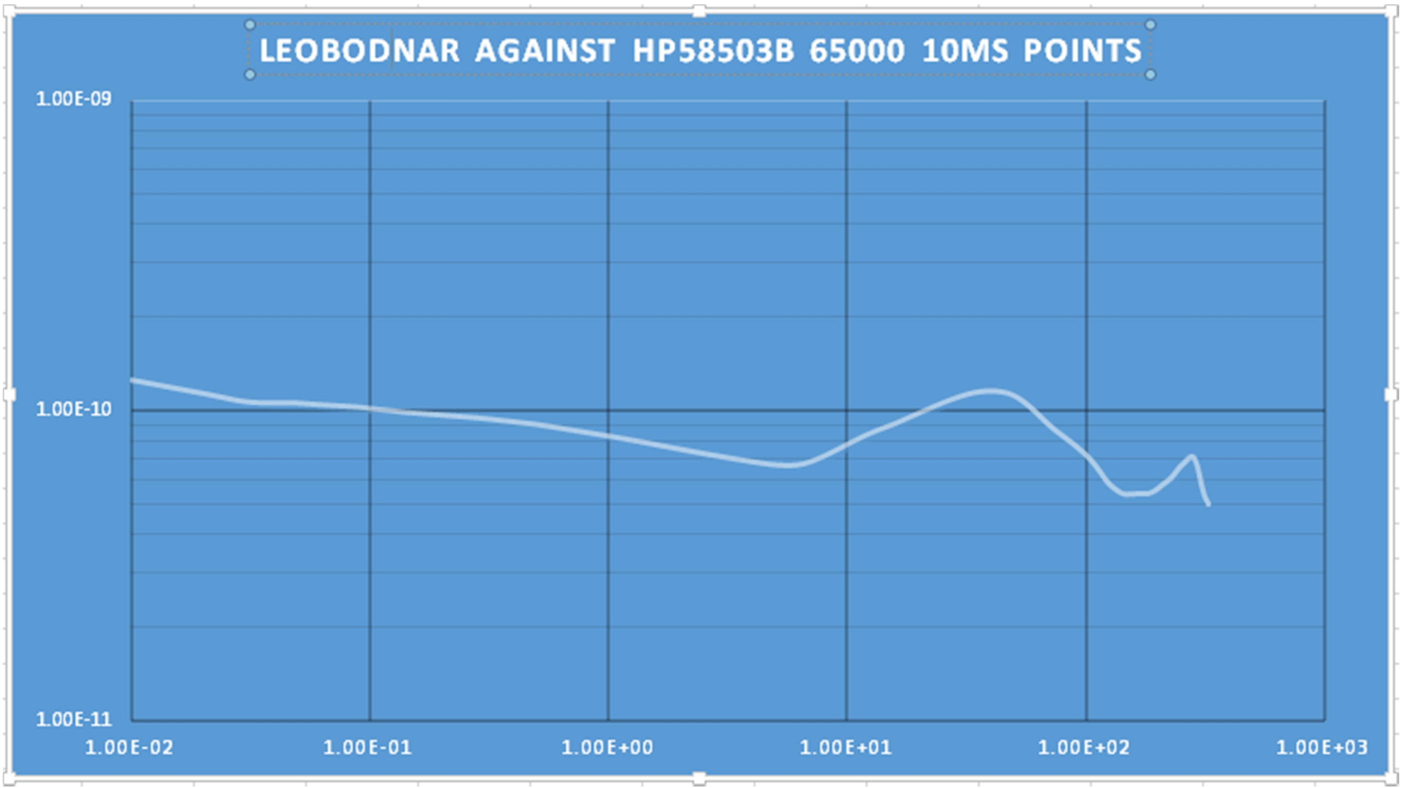
Below trace demonstrates the time it takes to reach a stable 10MHz reference after a cold start which is less than a minute. An output reached within 10 second



Below demonstrates the result when time per point changed to 10ms for 65000 points which is maximum for a single VNWA sweep. However it is possible to autosave multiple sweeps.

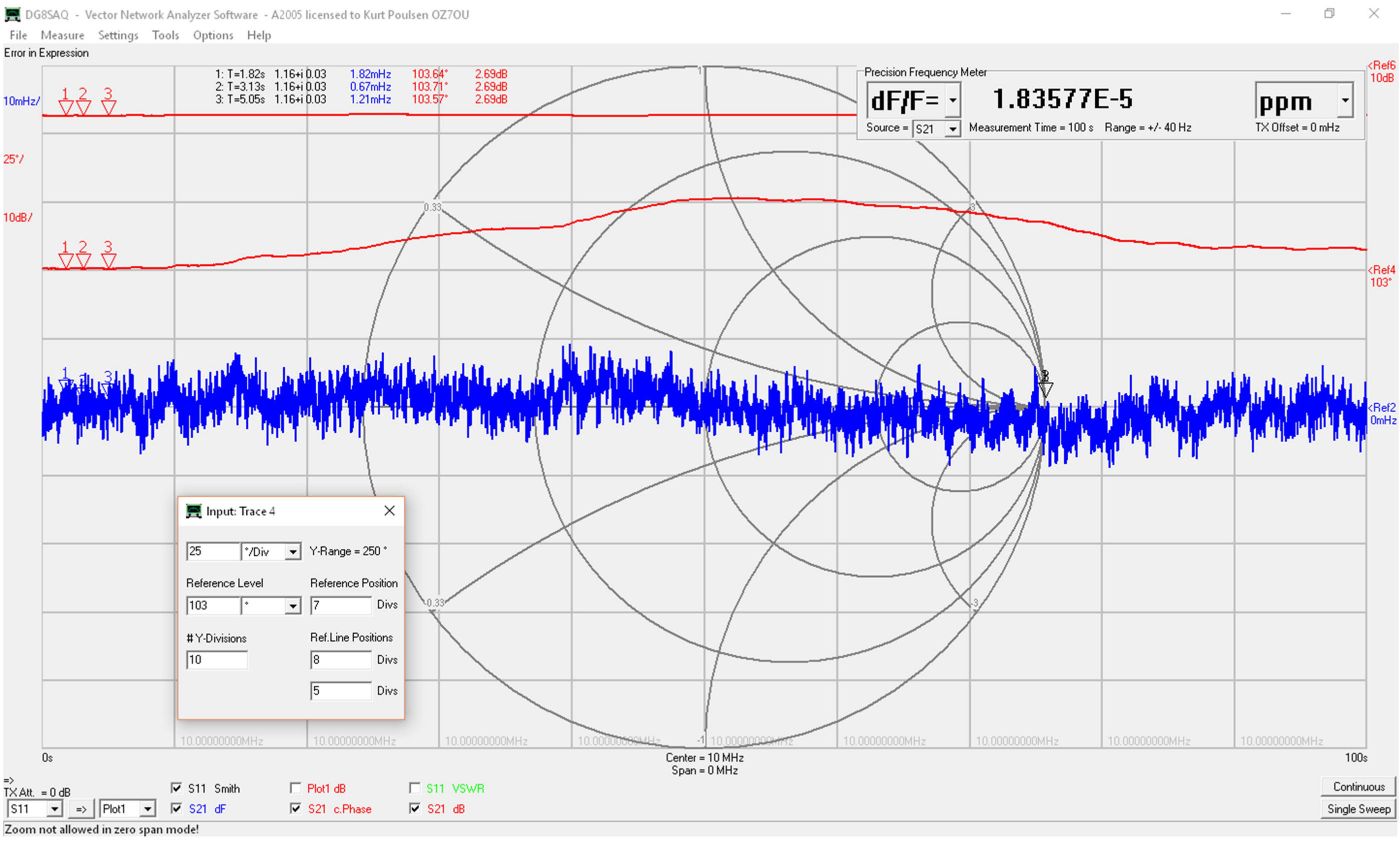


Above Leobodnar GPSDO against HP58503B GPSDO 65000 10ms points

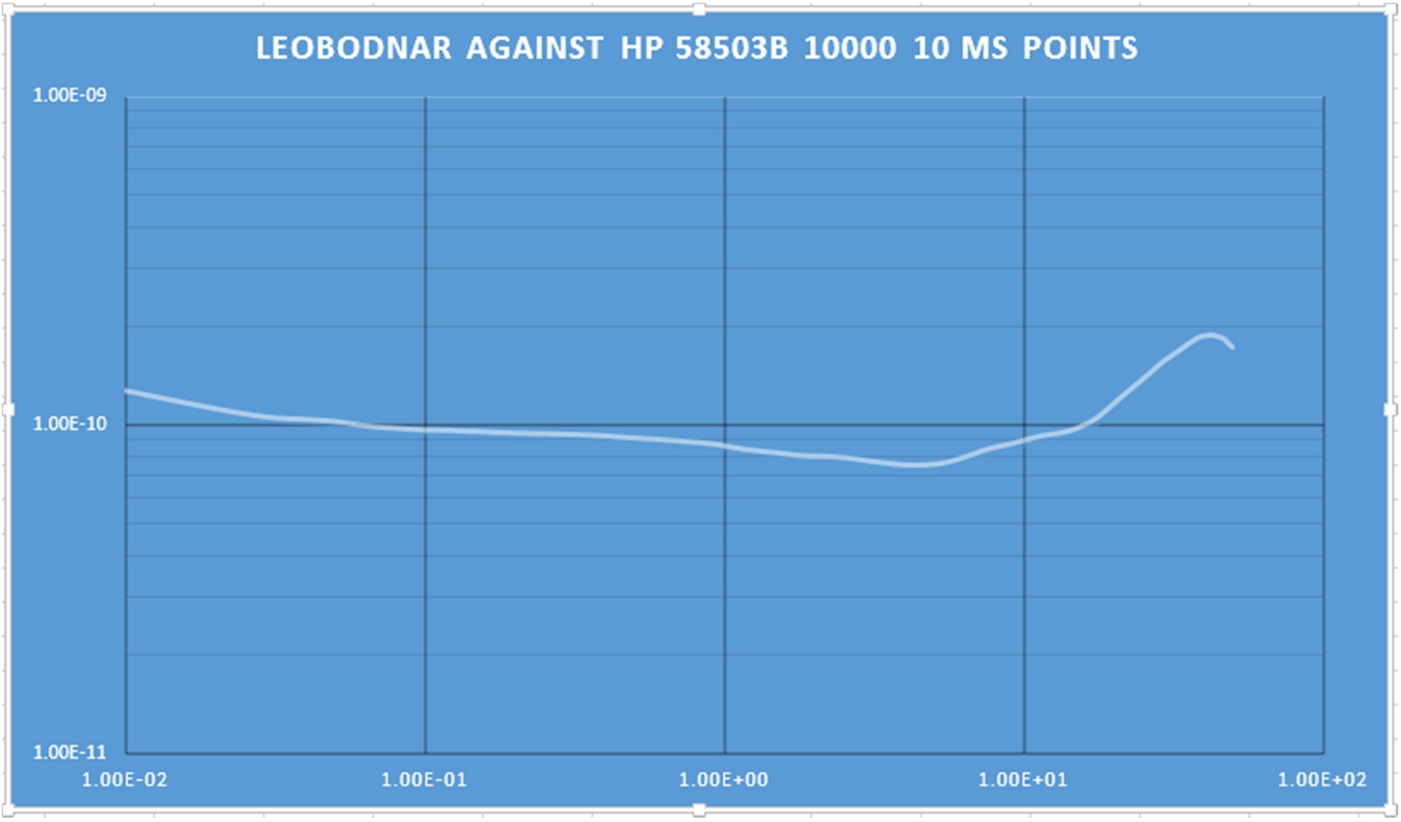


Allan Deviation for Leobodnar GPSDO against HP58503B GPSDO 65000 10ms points

Below a repeated test as above for 10000 10mS points

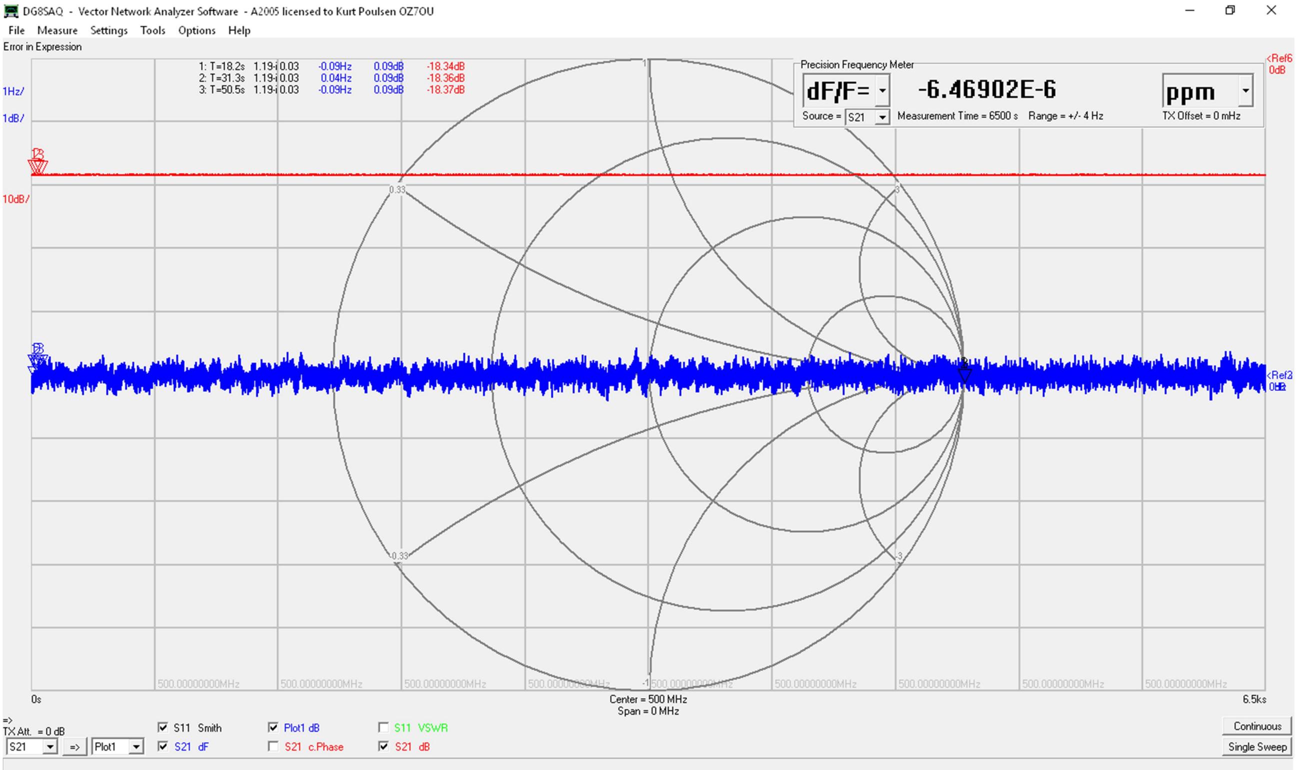


Above Leobodnar GPSDO against HP58503B GPSDO 10000 10ms points demonstrates repeated test not exacctly identical

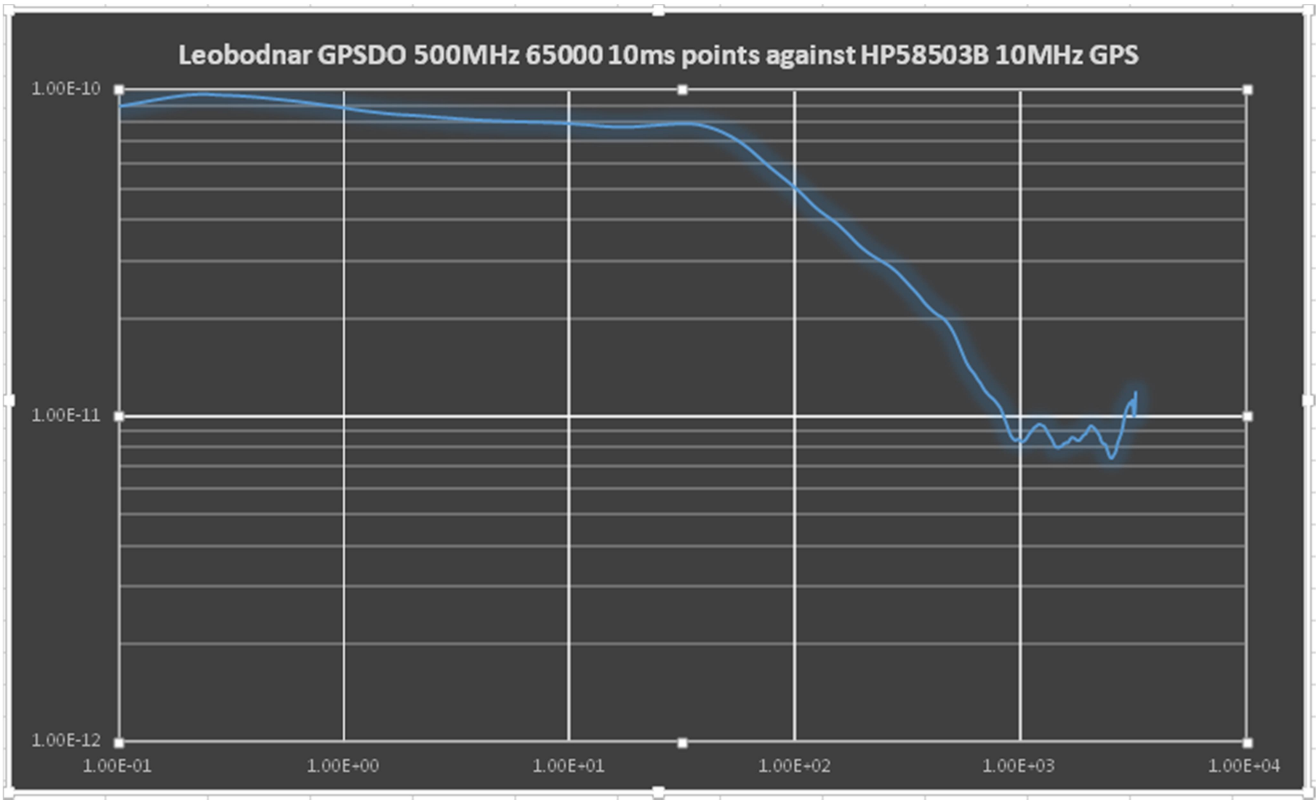


Allan Deviation for Leobodnar GPSDO against HP58503B GPSDO 10000 10ms points

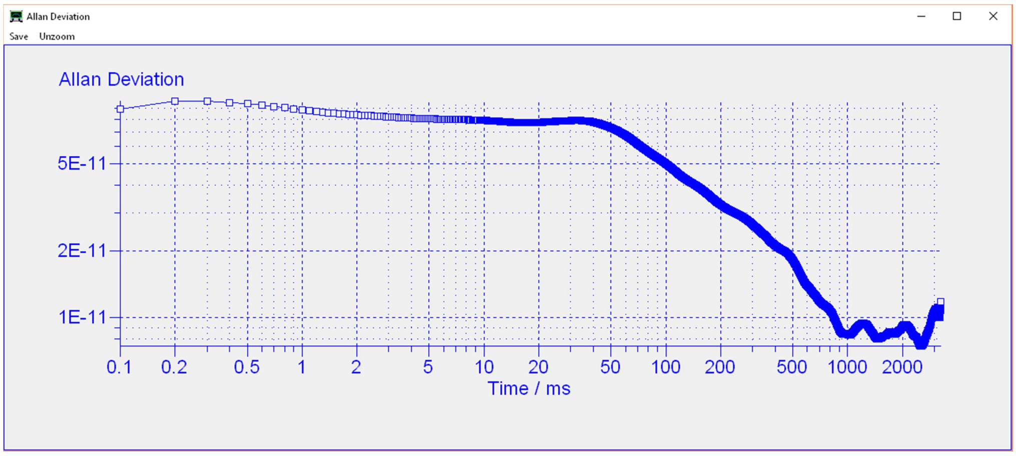
Finally the Leobodnar GPSDO was connected to an outdoor GPS antenna with 360 degree view and measured over 65000 100ms points where the average dF/F stability was -6.47E-12. The test frequency was 500MHz and the result showed a spot peak deviation less than 0.5Hz at 500MHz being 1E-9. The Multipliers must be increased to provide higher output to the mixer at 500MHz and in his case to x18.



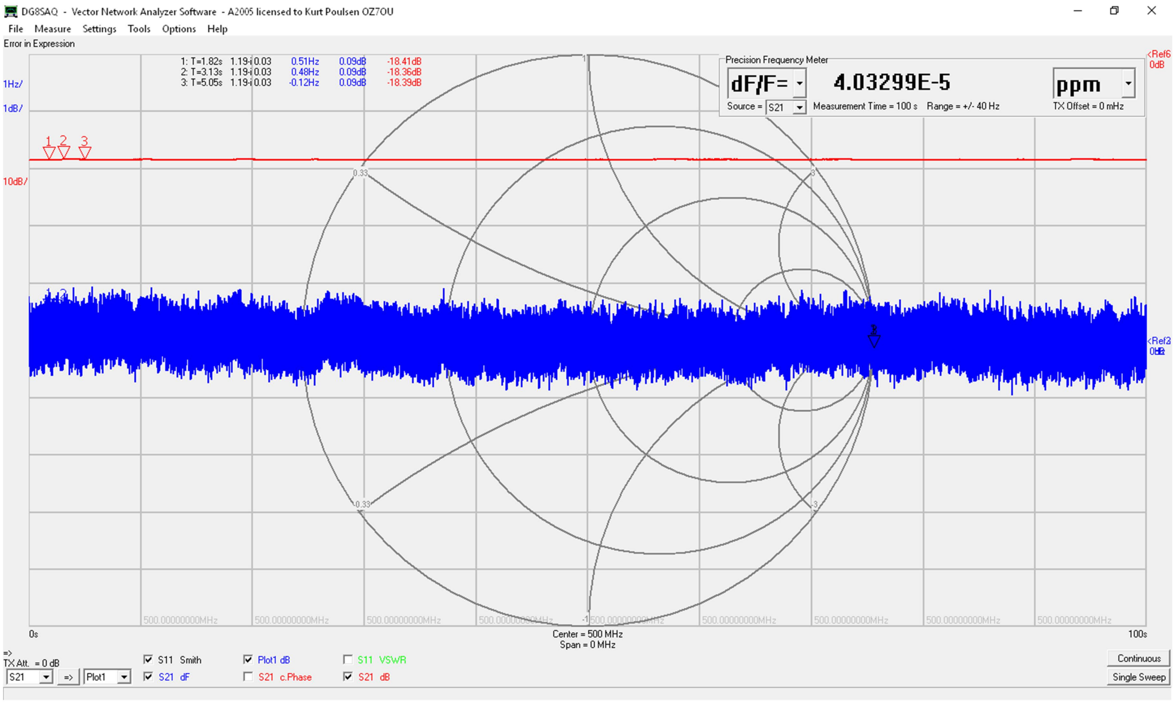
Leobodnar GPSDO measured for 65000 100mS points against the HP 58503B GPS disciplined 10MHz reference. Use of the outdoor marine GPS antenna has caused a more stable trace with less ripple compared to the previous measurement made with the supplied small magnet antenna also placed outdoor, but not with complete 360 degree view.

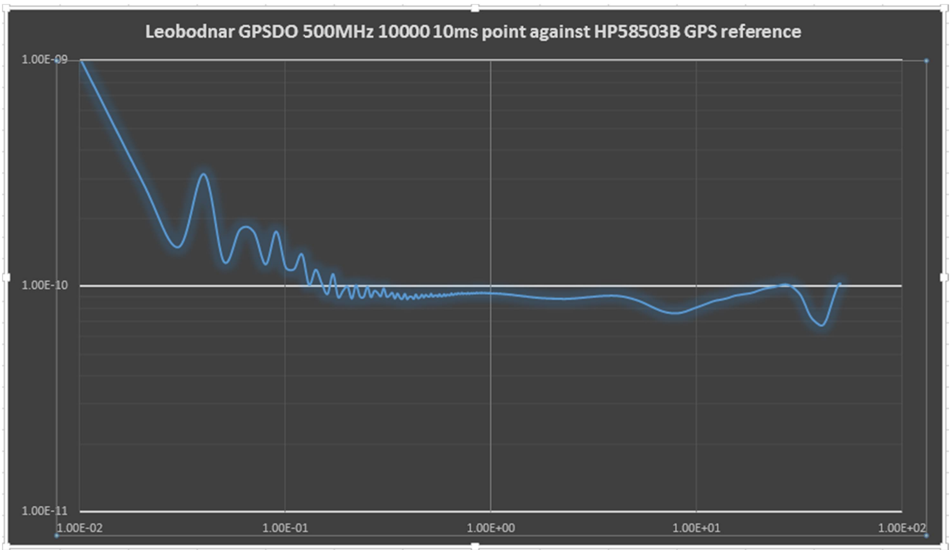


Allan deviation for Leobodnar GPSDO measured for 65000 100mS points at 500MHz against the HP 58503B GPS disciplined 10MHz reference. (Please note an error in the header line not 10ms but 100ms. Below identical plot created by VNWA



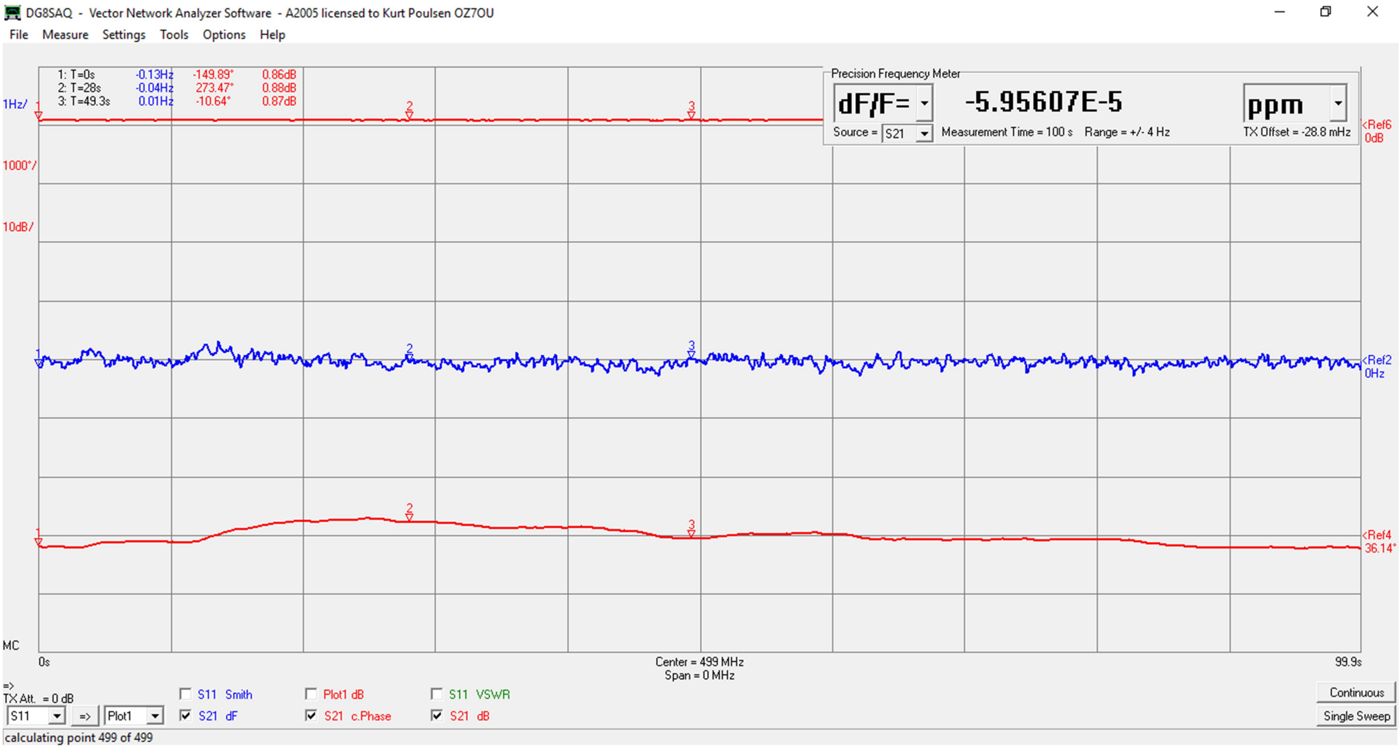
Below measurements made for 10000 100mS points at 500MHz average stability calculated to 4.03E-11



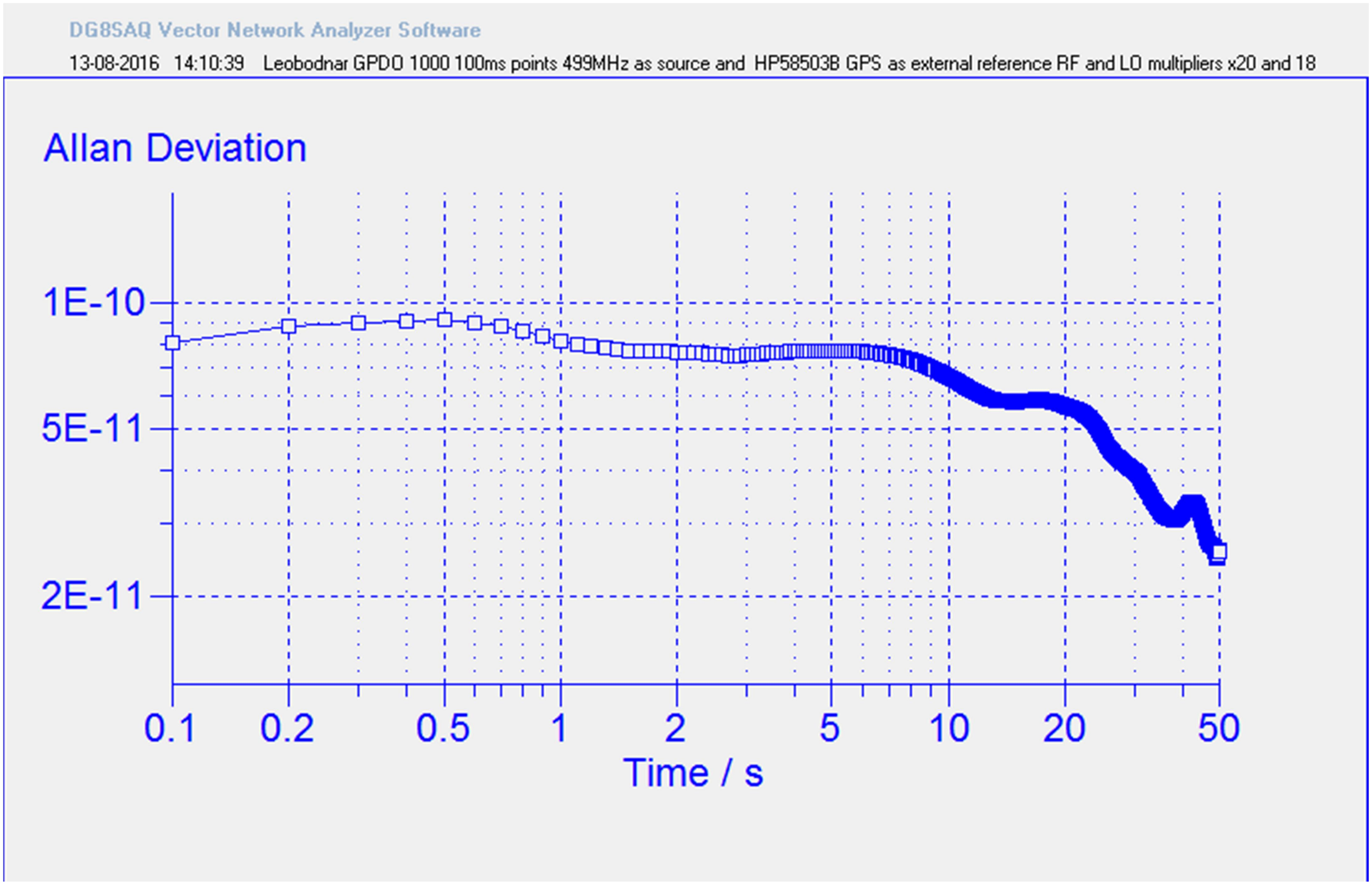


Allan Deviation for 10000 10mS points at 500MHz and same result as before with slightly more stable frequency due to outdoor marine GPS antenna

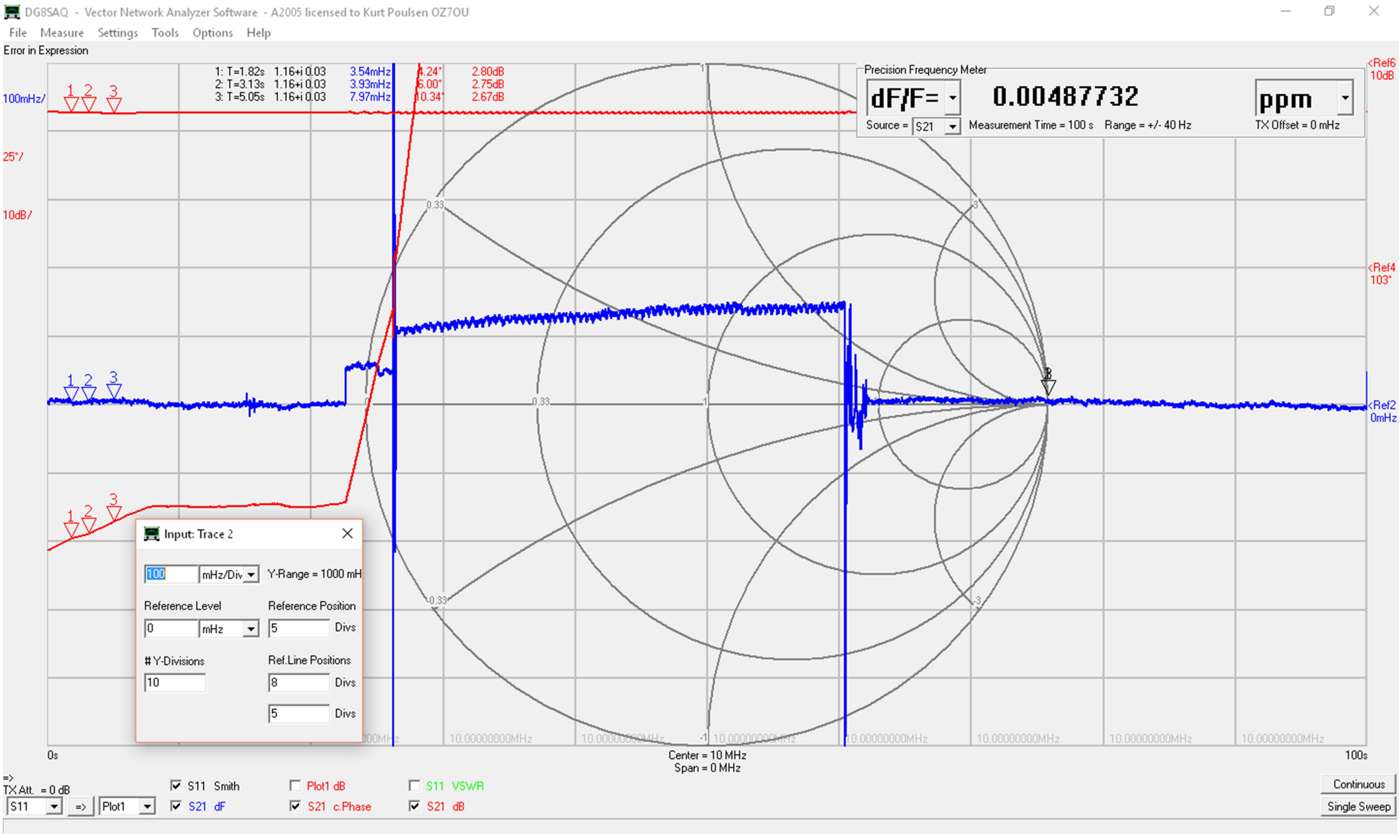
A repeated test at 499MHz for 1000 100ms points and RF multiplier at x18 and LO multiplier at x20 providing higher signal level to the mixer.



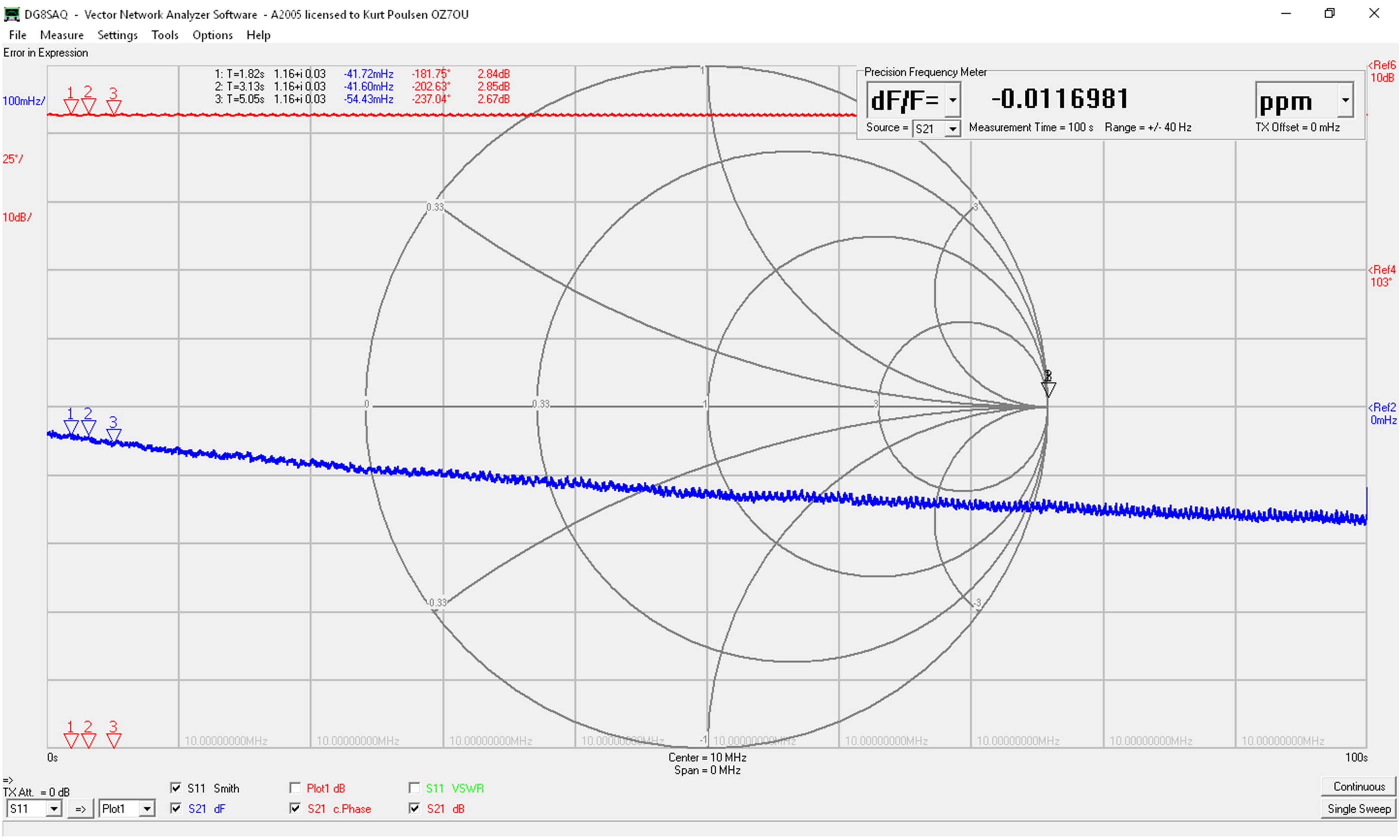
Below Allan deviation for above measurement



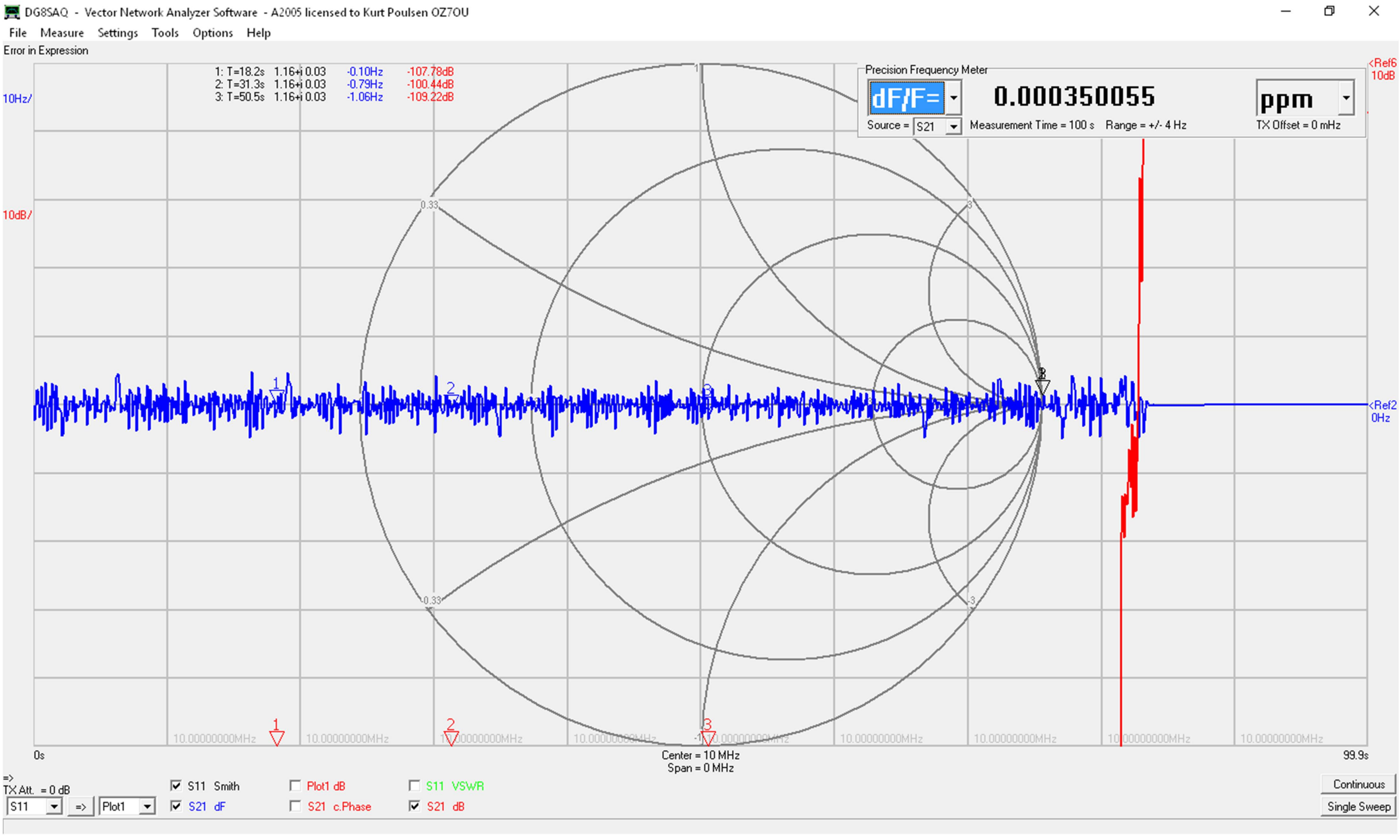
Below a test where the GPS antenna disconnected and shortly after reconnected



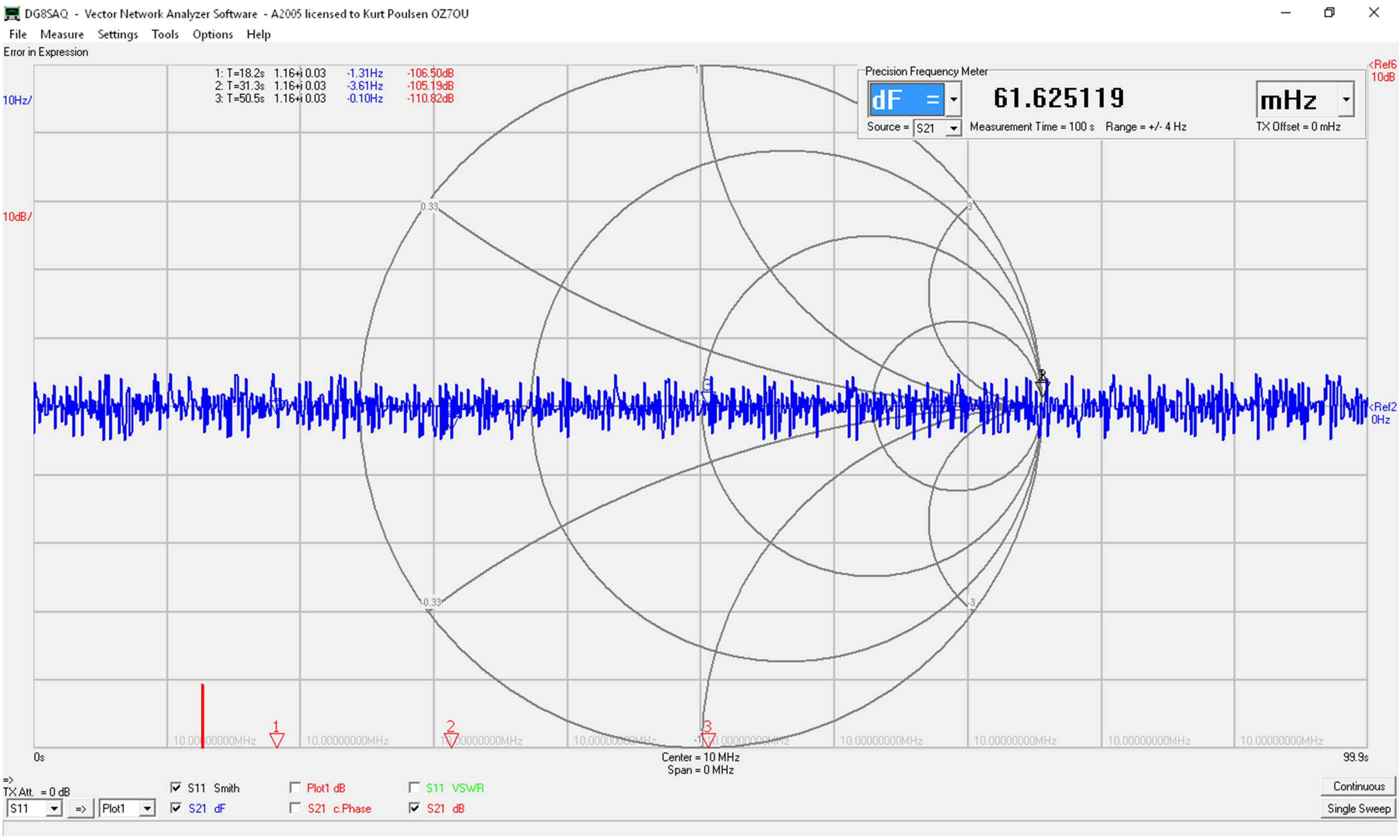
Above Leobodnar GPSDO against HP58503B GPSDO 10000 10ms points GPS Antenna disconnected and reconnected



Above shown drift as when GPS antenna disconnected



Above when power interrupted, antenna disconnected and power reapplied with antenna connected after 82sec. Sweep 1000 100ms points. Observe the scale setting for dF changed to 10Hz/div



Power interrupted, antenna disconnected and power reapplied. Frequency pretty accurate with noise. Observe dF scale setting 10Hz/div. So a valid GPS signal important for reducing the noise level and if antenna disconnected after a GPS fix the much less noise. Sweep 1000 100ms points.

Output power measurements seen below and some deviations found pending method of measurement

According to specification the output power of the fundamental are as follows
Output power level (measured at 10MHz, fundamental power channel):
+13.3dBm, drive setting 32mA
+12.7dBm, drive setting 24mA
+11.4dBm, drive setting 16mA
+7.7dBm, drive setting 8mA

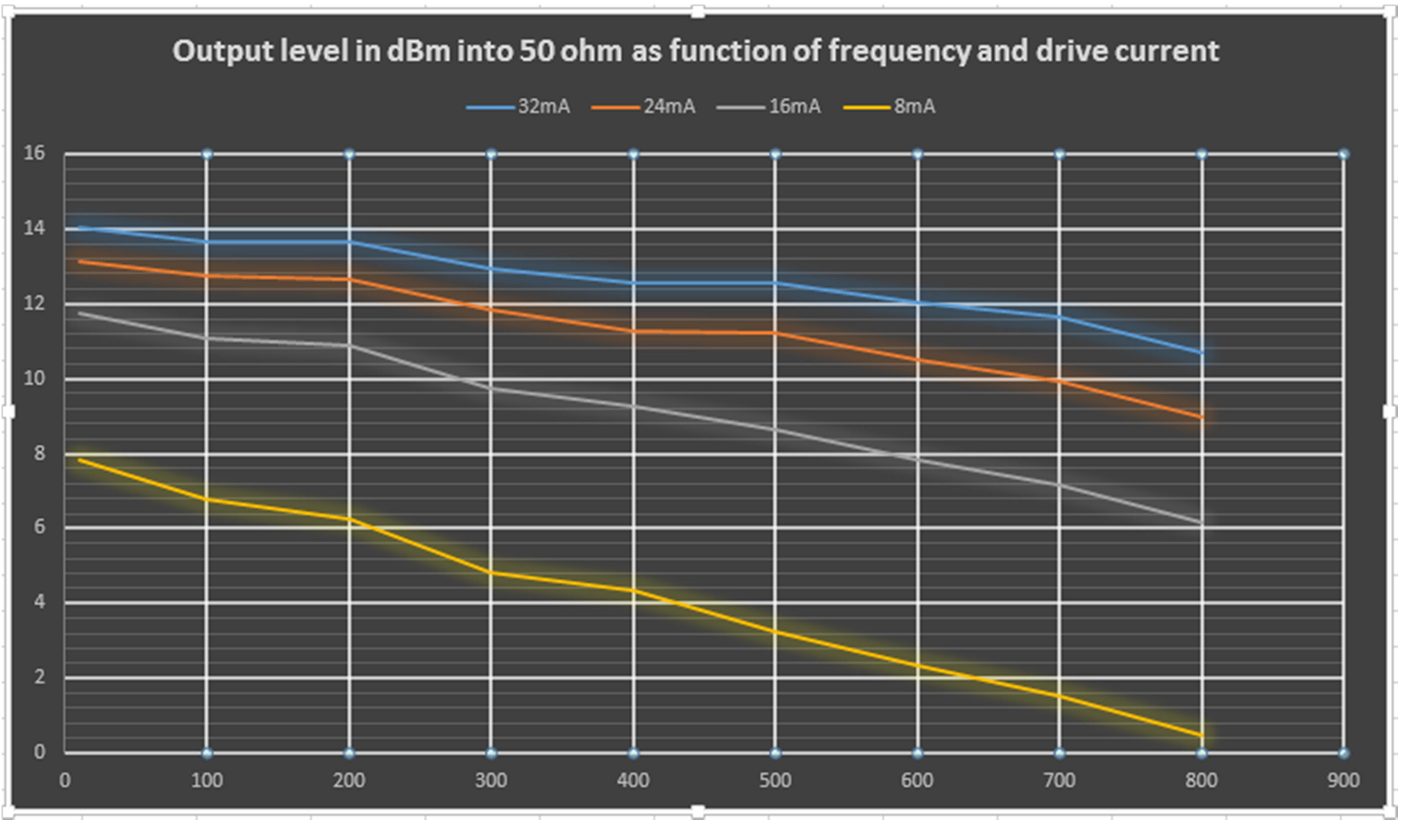
Measured with my HP Spectrum analyzer 8559A
Output power level (measured at 10MHz, fundamental power channel):
+14.0dBm, drive setting 32mA
+13.4dBm, drive setting 24mA
+11.0dBm, drive setting 16mA
+7.0dBm, drive setting 8mA

Measured power level with the HP 437E power meter, **which includes the harmonics**
Output power level (measured at 10MHz incl. harmonics):
+14.33dBm, drive setting 32mALP filter
+13.59dBm, drive setting 24mA
+12.18dBm, drive setting 16mA
+8.72dBm, drive setting 8mA

Output power level by HP 437E power meter at 200MHz with 200MHz LP filter , fundamental power Channel):
+12.9dBm, drive setting 32mA
+12.44dBm, drive setting 24mA
+11.49dBm, drive setting 16mA
+8.77dBm, drive setting 8mA

However, a much better method is as follows:
With the 10 to 18GHz power sensor HP8481A and HP 437E power meter calibrated to it internal 35MHz 0dBm reference, and controlled to be within 0.01dBm using the 50MHz reference of another HP435B power meter, the output level for the signal generator HP8664A is measured directly at it N female output connector. With a high quality short N male to Male SMA the signal generator output is feed to a Minicircuit ZFSC 10-1500MHz power combiner to port 1 and to port 2 is feed the signal from the Leobodnar GPSDO via a precision 10.0dB 18GHz SMA inline attenuator.
The sum of the port 1 and 2 signals at port S is then connected to the 10MHz to 21GHz HP8559A spectrum analyzer. The frequency from the HP signal generator is programmed to be 1 MHz higher than the GPSDO, and on the SA display set to linear Y display the precision step attenuator of the HP 8664A is adjusted until the two signal on the SA screen are of same magnitude.The power loss in the power splitter and the Spectrum analyzer level accuracy has no influence on the measurements.
Thus the output of the GPSDO is found with an accuracy of better than 0.2dB, as the power combiner has no more than 0.03dB amplitude unbalance, the HP signal generator output measured at 0dBm with the HP 437E power meter with less than 0.1dB accuracy, and the step attenuator for the HP 8664A signal generator are with 0.1dB resolution, and within + - 0.05dB (tested with powermeter), and cable loss measured with the VNWA to be virtually 0dB for the frequencies in question. Levels in the table below are corrected for HP8664A Error (specs are + - 1dB so well within)
These are the values found for my version of the Leobodnar GPSDO

Frequency MHz	dBm @ 32mA	dBm @ 24mA	dBm @ 16mA	dBm @ 8mA	HP8664A Error
10	14.04	13.14	11.74	7.84	0.34
100	13.67	12.77	11.07	6.77	0.17
200	13.67	12.67	10.87	6.27	0.27
300	12.94	11.84	9.74	4.84	0.24
400	12.58	11.28	9.28	4.33	0.28
500	12.54	11.24	8.64	3.24	0.34
600	12.03	10.53	7.83	2.33	0.43
700	11.65	9.95	7.15	1.55	0.35
800	10.68	8.98	6.18	0.48	0.48

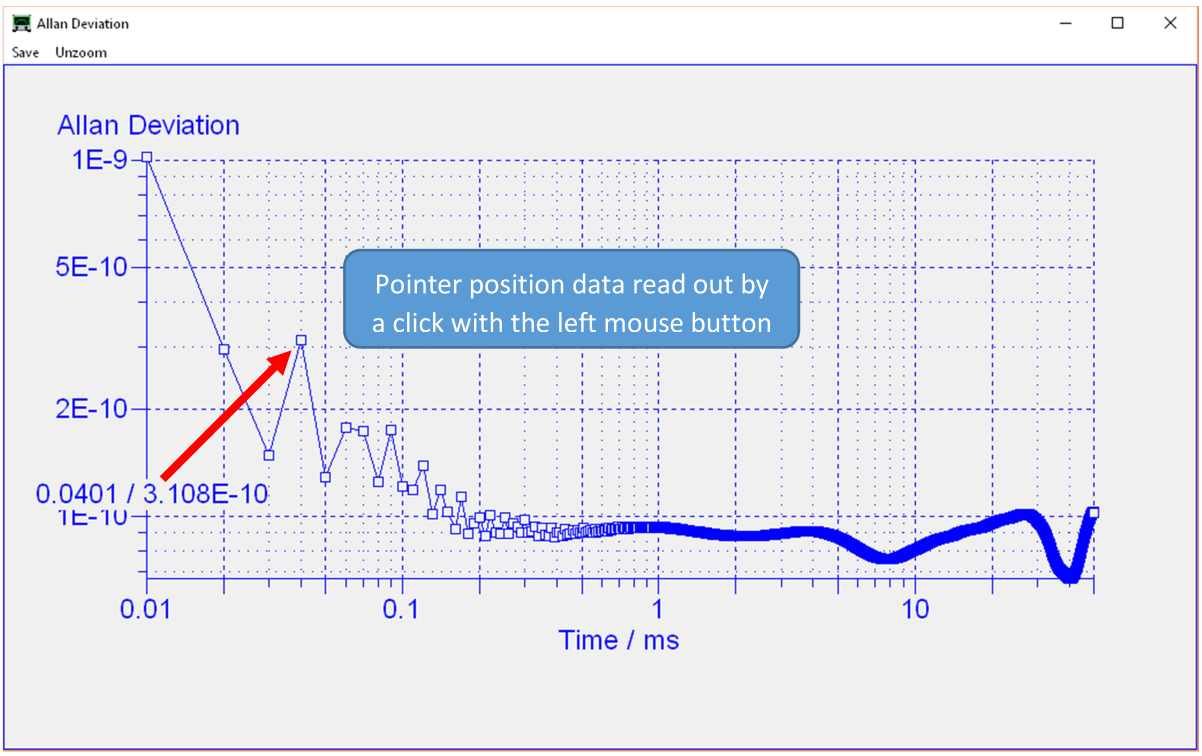


The graphical representation show the effect of the step attenuators 0.1dB resolution and the estimation of + - 0.2dB accuracy seems fair. An averaging/smoothing could be made. The 35 and 50MHz reference signals in the two power meters are to be trusted as correct.

This concludes the testing so far and later on will probably be added some phase noise documentation.
Find on next page the documentation found about phase noise from the manufacturers homepage.

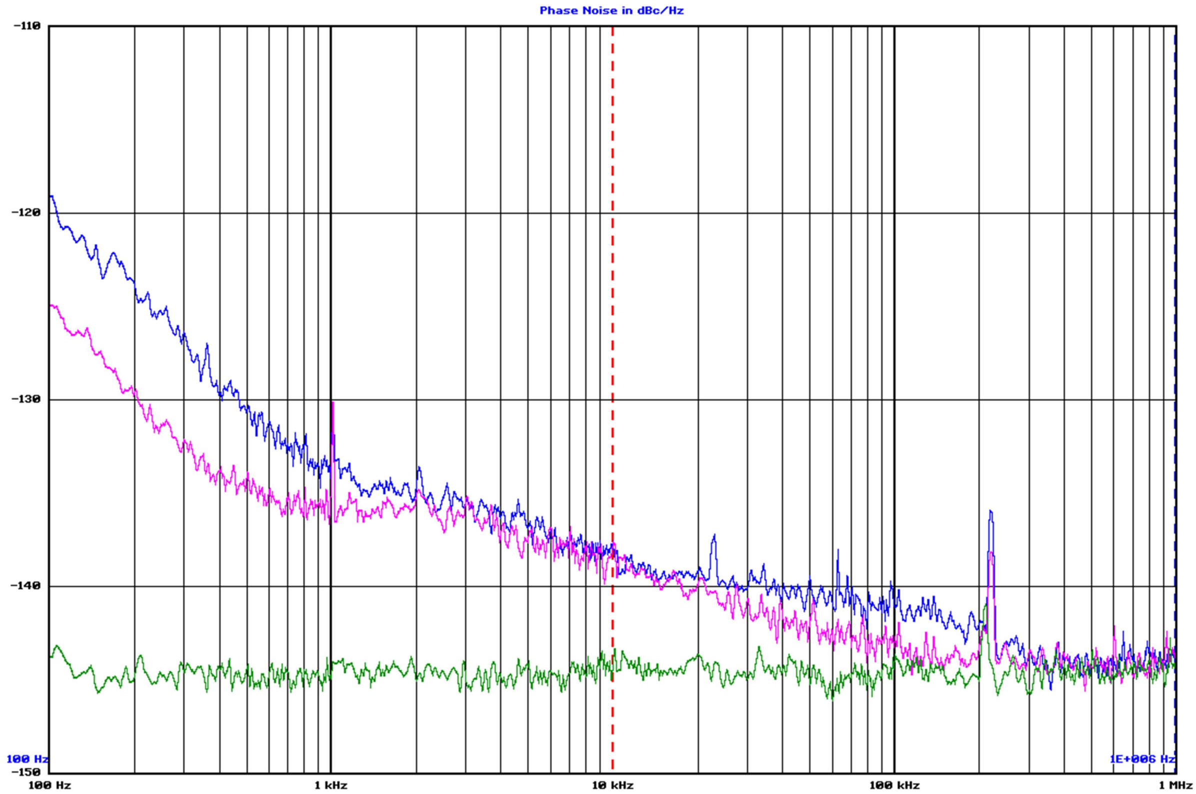
July 17 2016 Kurt Poulsen (with some additions August 12 2016)

On July 18 DG8SAQ Tom Baier as told released an experimental version 36.6.9.u of the VNWA software which directly draws the Allan Deviation graph ☺ What a time saver !!! **and now improved version 36.6.9.v**
See below the Allan Deviation for Leobodnar GPSDO against HP58503B GPSDO 10000 10ms points



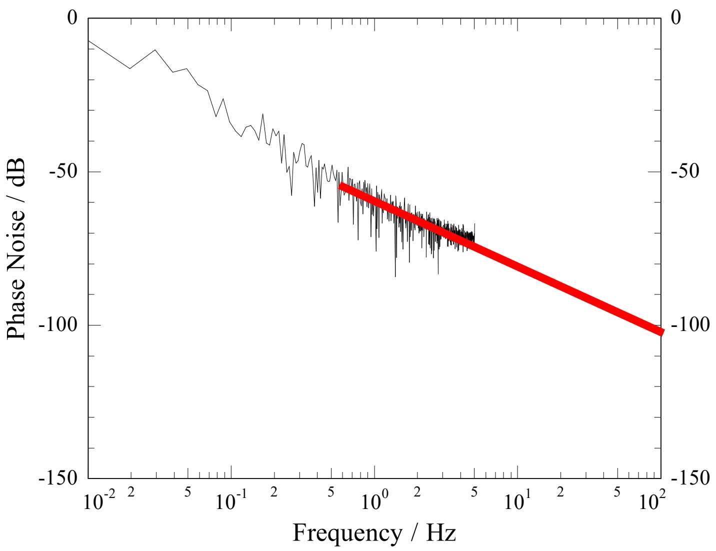
From the manufacturer homepage
http://www.leobodnar.com/shop/index.php?main_page=product_info&cPath=107&products_id=234
following info about phase noise found.

Phase noise plots have been acquired with HP E4406A signal analyser using notch filter method. The measured phase noise approaches the noise level of E4406A and therefore might be lower than presented here.

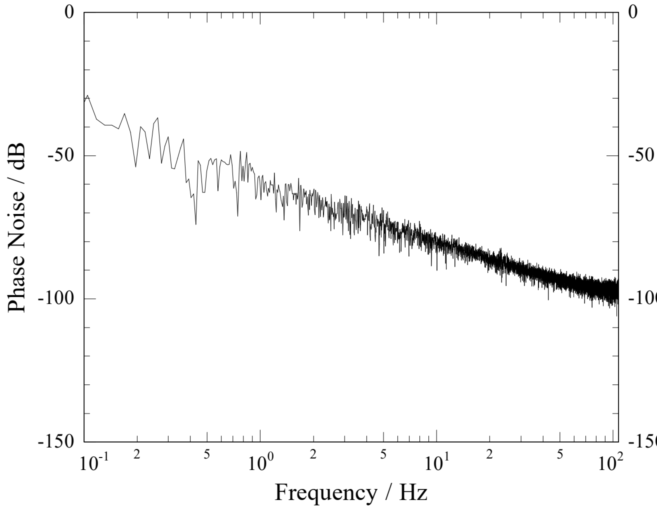


Trace	Carrier Hz	Carrier dBm	dBc/Hz at 10000 Hz	Residual FM Hz	RMS Noise Rads	RMS Jitter	SSB C/N dB	Sweep	Instrument
Standard GPS clock (TCXO)	11 997 628	4.35	-138.3	5.18E+001	1.04E-004	1.4E-012 s	-82.7	438s	E4406A
Custom GPS clock (crystal)	11 997 627	4.35	-137.7	5.13E+001	9.52E-005	1.3E-012 s	-83.4	471s	E4406A
Measurement setup noise floor	11 997 624	4.35	-143.3	4.88E+001	8.46E-005	1.1E-012 s	-84.5	439s	E4406A

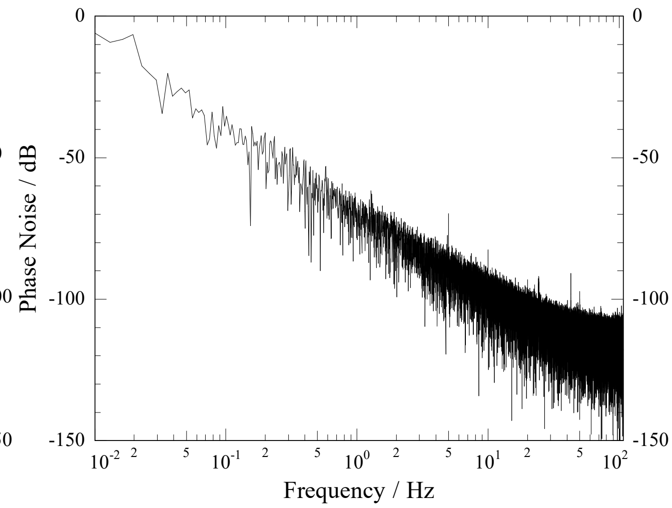
It is now possible to produce phase noise measurement with the VNWA by saving continuous phase *.dat files and process the in a program called Genplot. A separate document available at the link
http://hamcom.dk/VNWA/How to measure phase noise using the VNWA Frequency meter and the GenPlot software_rev3.pdf
Please study this separately and below I only shown some measurement for the Leobodnar GPSDO for various conditions. The phase noise is a supplement to the normal 0 beat method seldom possible at lower frequencies than 20Hz and above manufacturer measurements start at 100Hz. These measurements are limited to about 200Hz at the maximum as the shortest time per point is 1.33 ms for the VNWA which due to the Nyquist criteria leads to 1/(2x1,33ms) Hz =376Hz, but quite a noisy affair ☺.



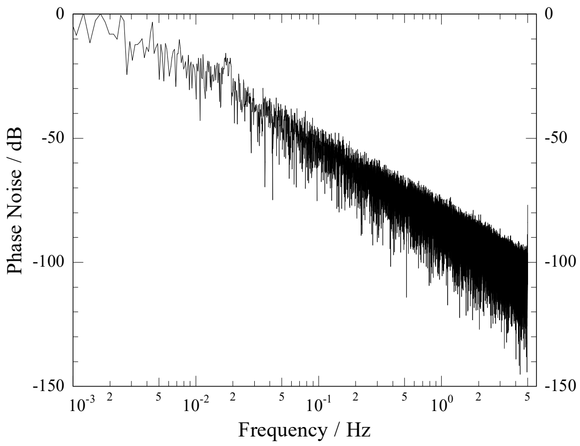
1000 100mS points at 11.9MHz and if a linear curve it will hit about -100dB



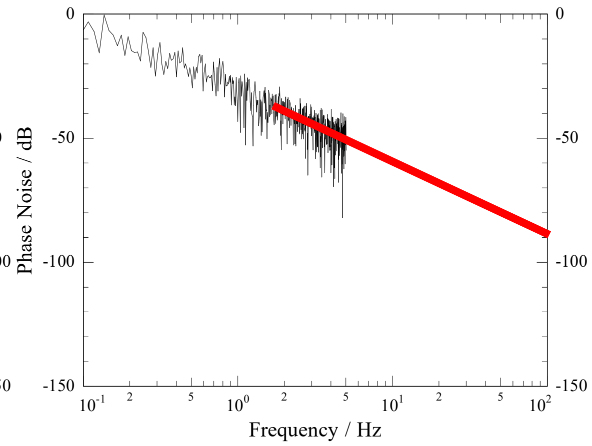
10000 4.67ms point at 10MHz



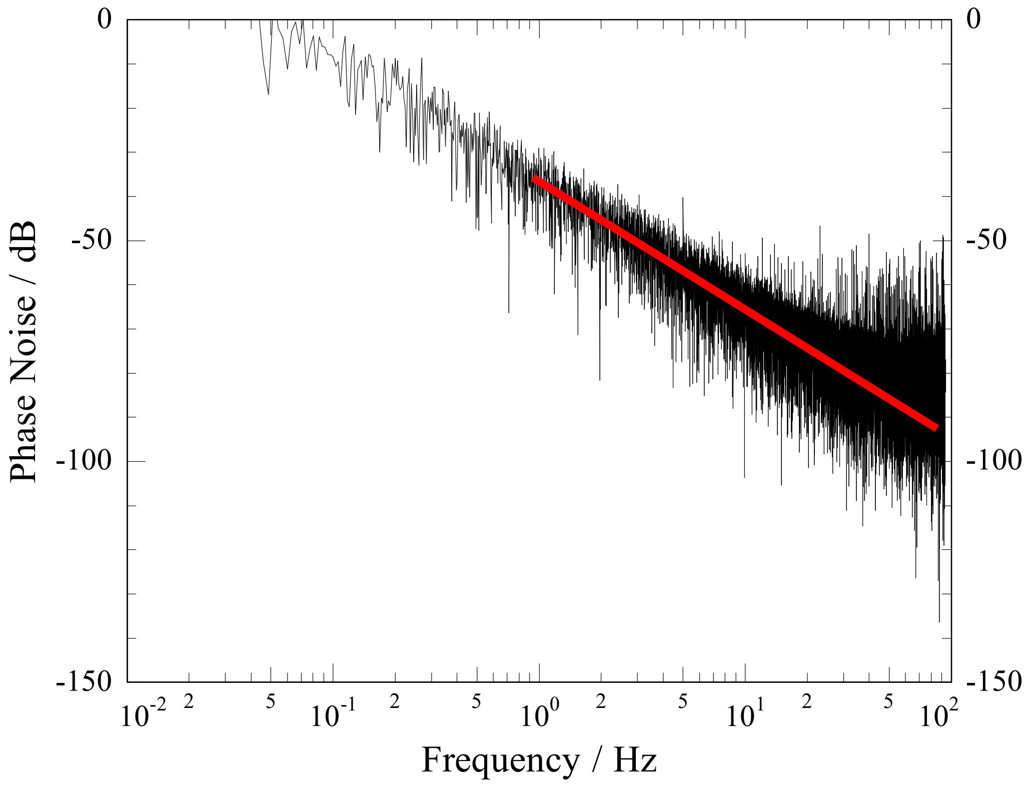
65000 4.67ms points at 10MHz



65000 100mS point at 10MHz (max 5Hz possible)



1000 100mS points at 599MHz



65000 5.33ms points at 499MHz

Quite interesting that the VNWA also has such applications and the Loebodnar GPSDO behaves very well
end of report August 12 2016 Kurt Poulsen