Application Note AN2002

How to optimally work with external references using the APPH

Purpose

This application note focuses on the phase noise measurement of very low noise reference sources and explains why external references can be very useful to speed up measurement.

Introduction

The efficient use of the APPH with crosscorrelator and external references is highlighted to benefit from faster measurement speed when measuring ultra-low SSB phase noise of DUTs.
When using Anapico's APPH signal source analyzer, one has the choice to use
- standard internal references
- option LN: close to carrier ultra low noise internal references
- voltage tunable external references.

Figure 1 illustrates the phase noise sensitivity of the APPH for a single correlation (16 sec measurement time) for a 10 MHz DUT signal. The phase noise sensitivity indicates how low at a given offset from the carrier the DUT phase noise can be to be measured accurately. A DUT having a phase noise below the phase noise sensitivity requires either additional correlations (increasing measurement time) or cannot be measured at all.

Figure 2 shows the phase noise sensitivity after 1000 correlations (and approx. 5 hours measurement time).

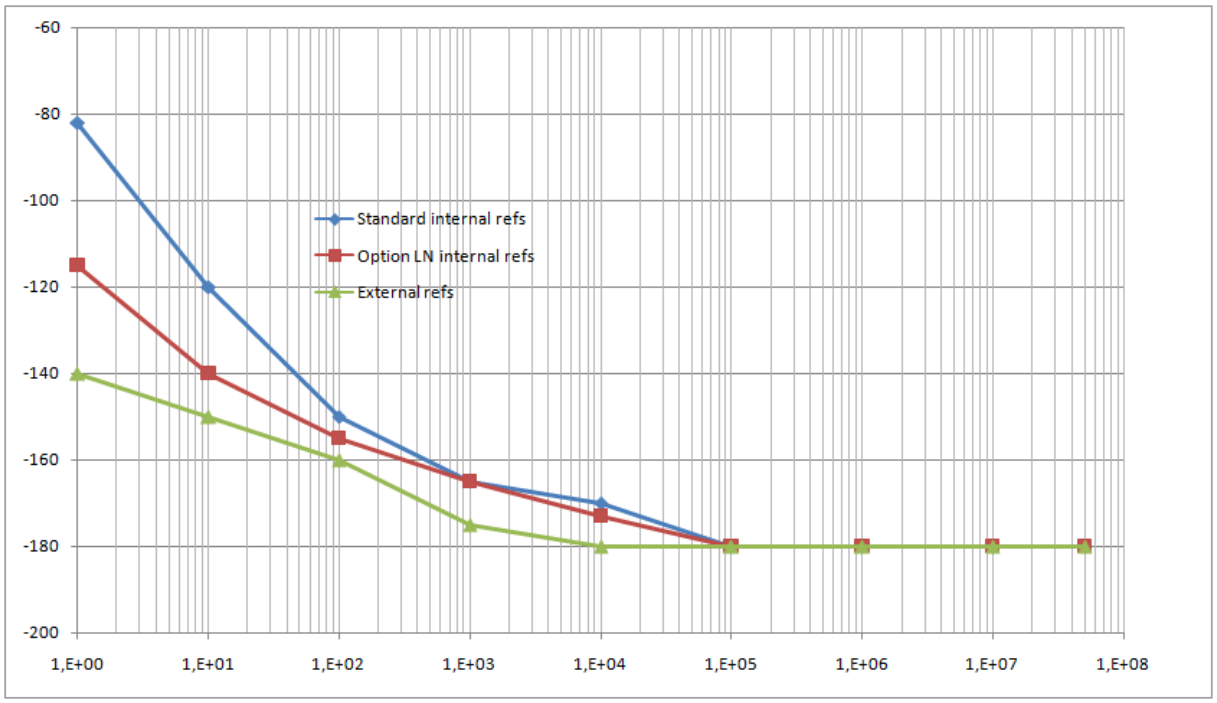

Fig. 1: Phase noise sensitivity of APPH system with different measurement options (1 correlation, 10 MHz, 16 seconds measurement time)

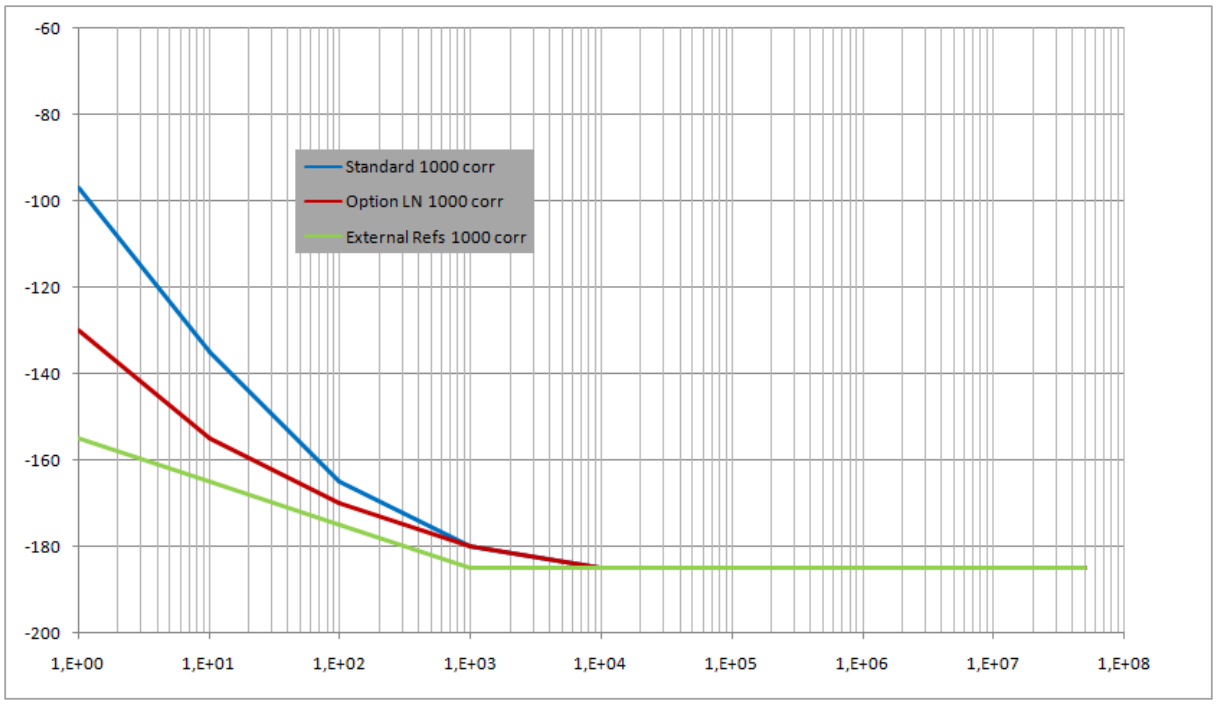

Fig. 2: Phase noise sensitivity of APPH system with different measurement options (1000 correlation, 10 MHz, 5 hours measurement time)

In this example, a 10 MHz low phase noise OCXOs with an expected phase noise of around -105 dBc/Hz at 1 Hz offset is to be measured.
It becomes very obvious that even after 1000 correlations It will be difficult to measure such a device with standard internal references.

The limitations of standard internal references

Figure 3 shows the corresponding results after 1 (green trace) and 200 correlations (red trace). For offsets 100 Hz and more the traces are identical. However, for offsets below 100 Hz the measurement is limited by the phase noise sensitivity of the APPH using standard internal references. Even after 200 correlations and 1.5 hours measurement time, the 1 Hz offset has not reached the expected value. Additional correlations and hours of measurement time is needed to obtain the actual result.

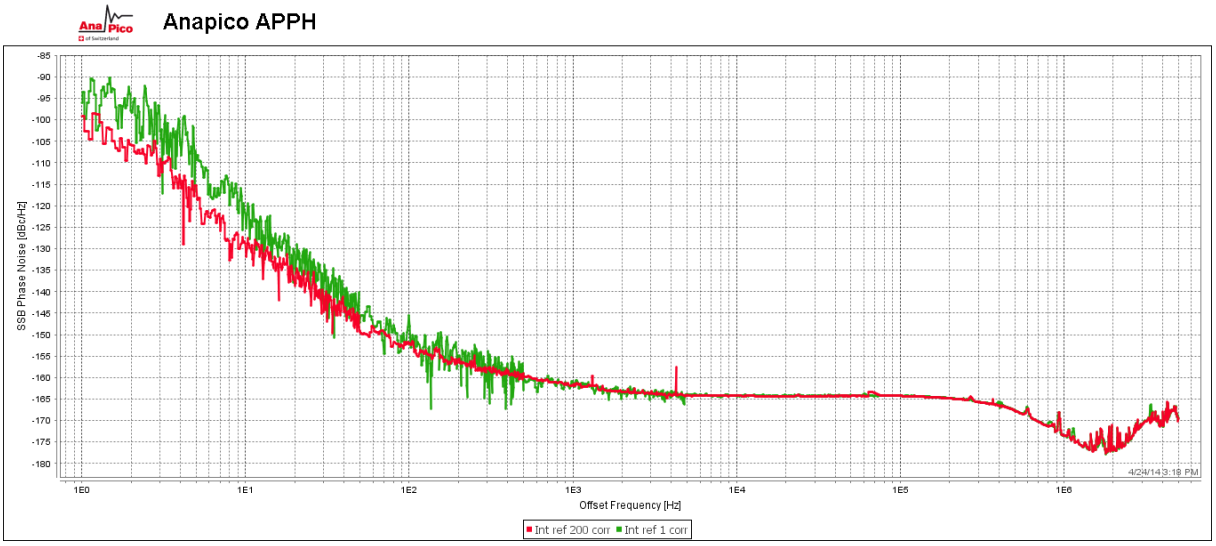

Fig. 3: Phase noise measurement of low-noise 10 MHz OCXO after 1 correlation (green trace) using standard internal references and after 200 correlations (red trace, 90 minutes measurement time).

The measurement setup using external references

Alternatively, external references can be used that result in a substantially lower phase noise sensitivity at low offset frequencies.

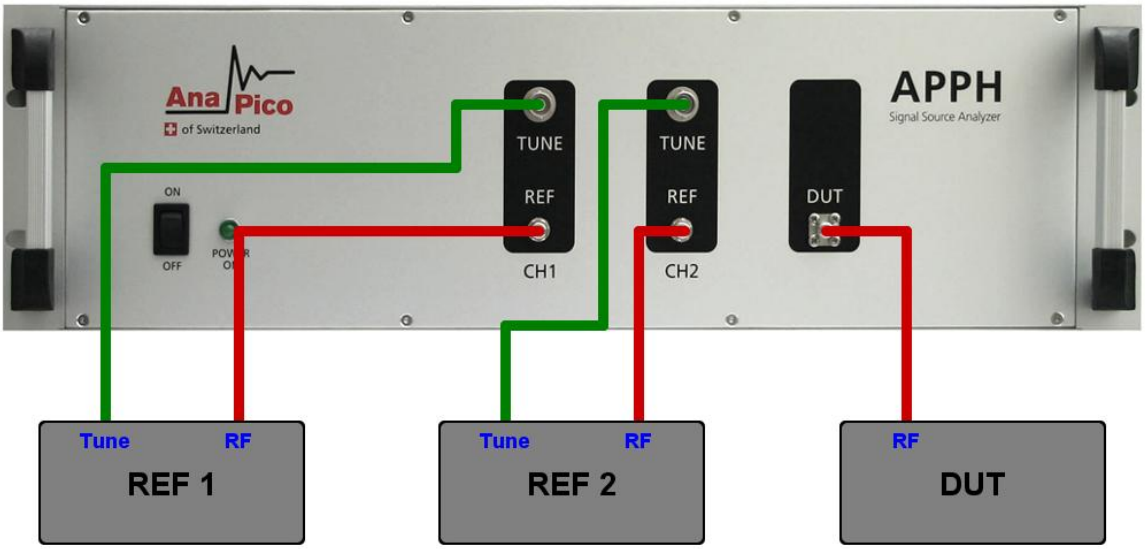

Fig.4: Connectivity block diagram as provided by the APPH GUI software.

The block diagram of the measurement setup is shown in Figure 4. Two 10 MHz OCXO have been used as external tunable references. Both references, here through hole mounted on test fixtures, are supplied using the two internal supplies of the APPH. Each reference OCXO output is connected to the RF IN port of one APPH reference input, and each tuning port of the OCXO is connected to the corresponding tuning output port of the APPH. Therefore, the external references are fully controlled (biased, and tuned) via the APPH.
The DUT signal is fed into the DUT port. The actual measurement setup is shown on the photograph in Figure 5.

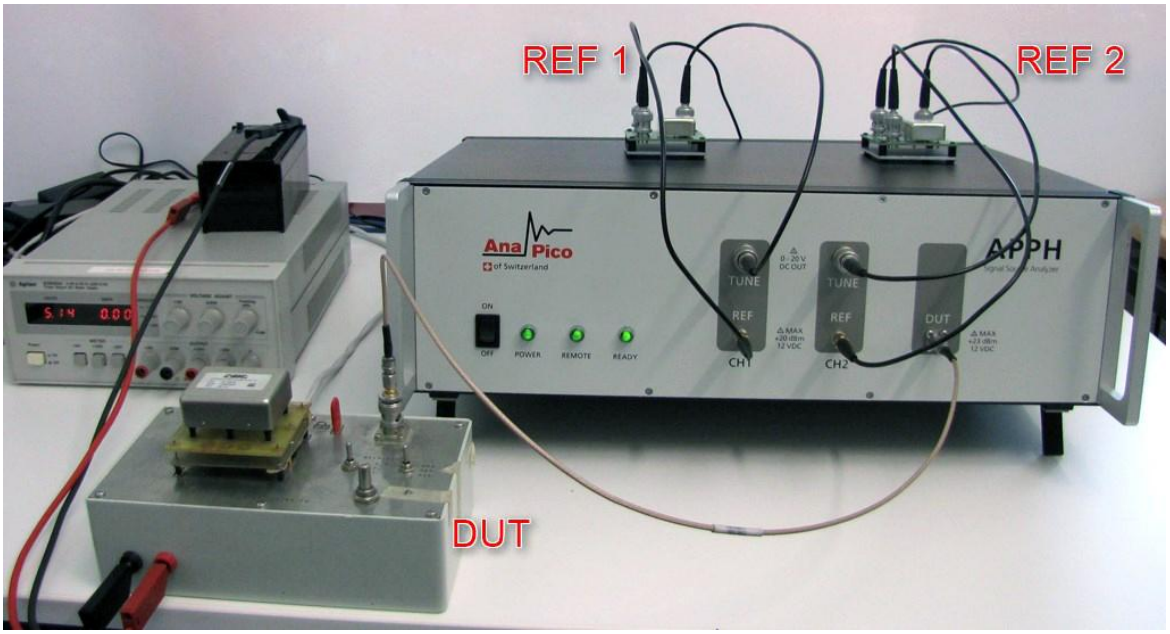

Fig 5: Photograph of measurement setup

The GUI setup

In the APPH GUI, the setup is straightforward. First, and only if desired, enable low-noise internal power supplies to power the external references. As shown in Figure 6, in the **Supply Configuration** menu both supplies have been enabled and set to 5.1V and supply a current of more than 550 mA per channel during startup of the OCXO.
Alternatively, the external references may be powered from external power supplies.

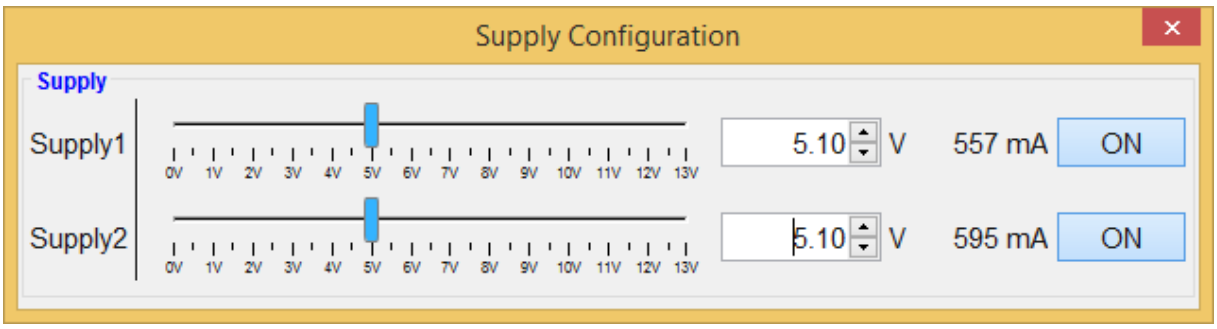

Fig 6: Supply configuration menu. Both supplies are set to 5.1V and during OCXO startup, draw about 550 mA per channel.

Next, the external references require a short calibration sequence of the external references to determine the tuning constant. In the **Advanced Measurement Configuration** menu, the tuning voltage range is set for each channel. In this case we use a tuning range from 0 to +10 V. The "Meas" button will then execute the calibration measurement. In out example, the calibration reveals respective 2.60 Hz/V and 2.57 Hz/V tuning sensitivities on the two channels.
Note that this calibration must be performed only once during the setup. Only if a reference is replaced, the corresponding calibration step must be repeated.

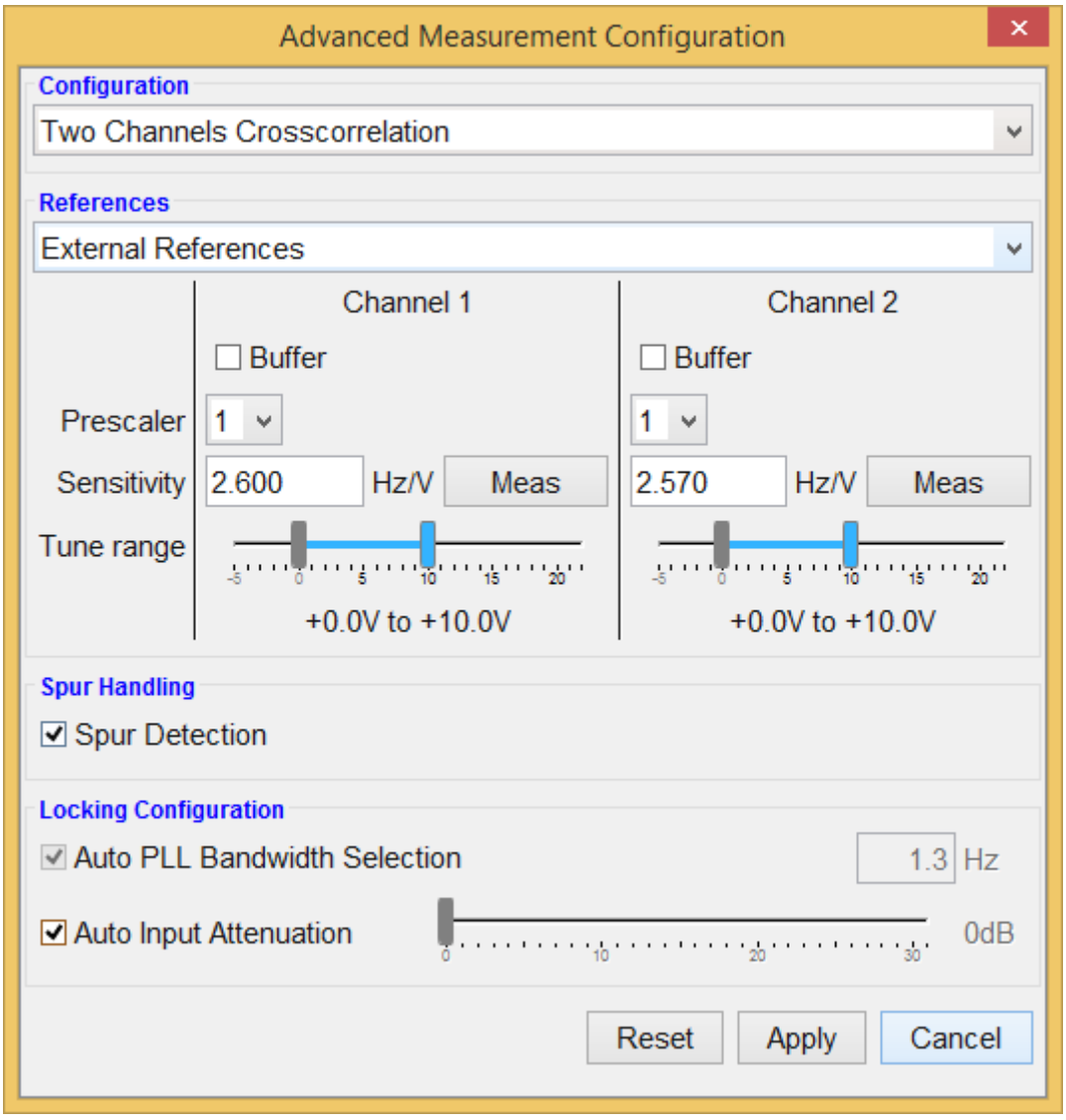

Fig. 7: APPH GUI setup to enable and calibrate external references.

The measurement results

Once the calibration is completed, a click on the measurement button will start the measurement. In our example we have set the offset range from 1 Hz to 5 MHz and a total of 10 correlations. Figure 8 shows the phase noise trace after the first correlation, and Figure 9 the same after 10 correlations completed. Comparing the results after 1 resp. 10 correlations shows a very good agreement. The longer measurement time for 10 correlation just lead to a "smoother" trace.

Finally, the measurement results using internal and external results are compared in Figure 10. As expected, measurements using internal references

(green trace after 1st correlation, red trace after 200 correlations) are in exact agreement with the purple trace (external references, 10 correlations) for offsets larger 100 Hz. For offsets below 100 Hz, using external references yield the correct result after just a few correlations.

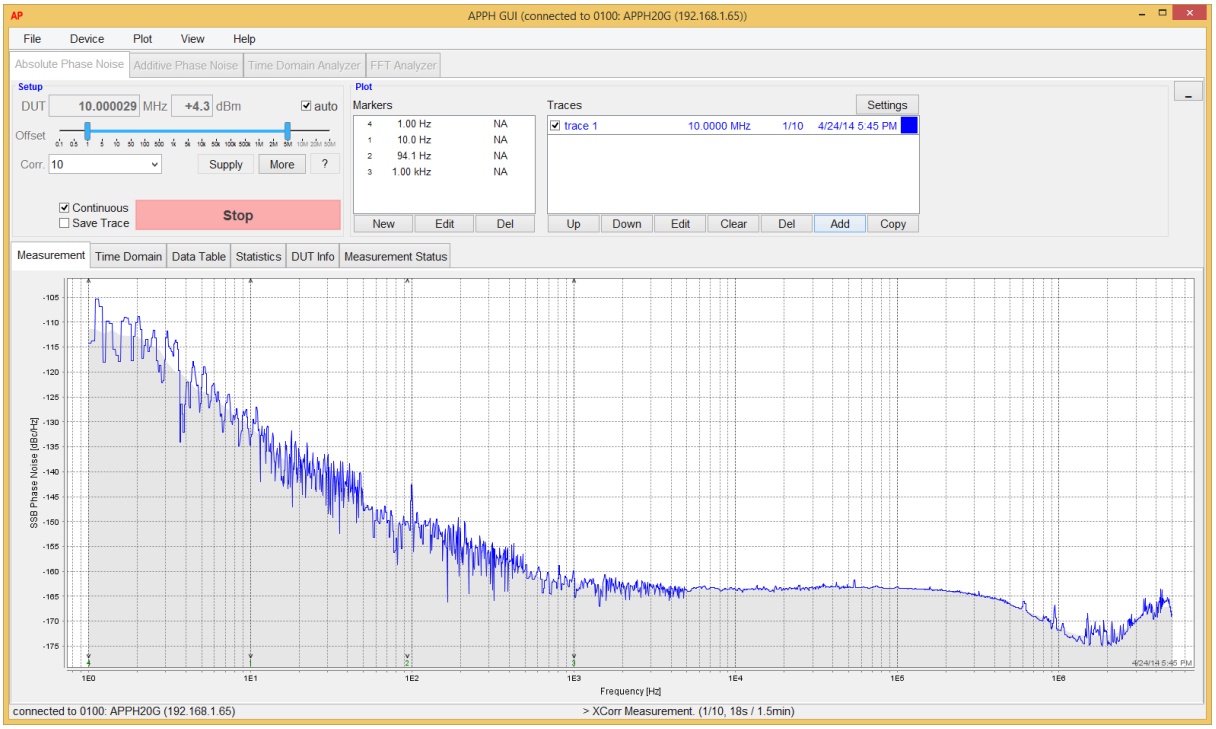

Fig 8: Blue trace shows measurement result after first correlation (16 seconds measurement time).

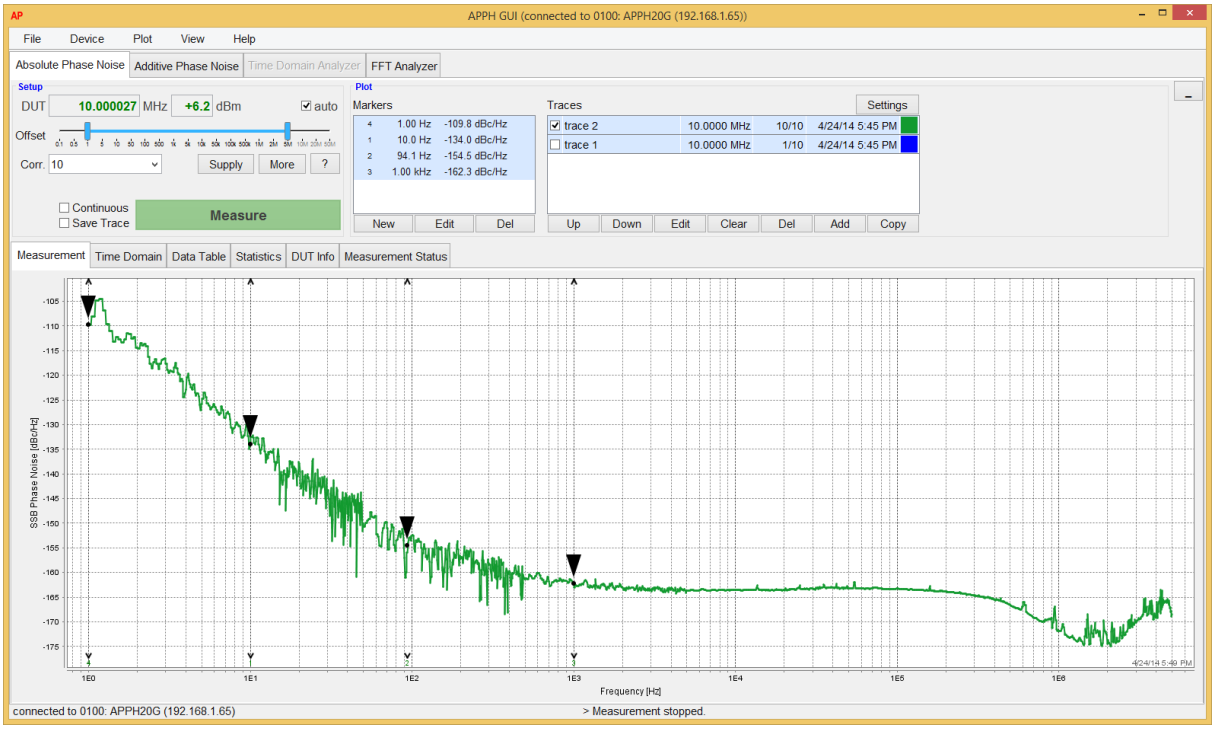

Fig 9: Final measurement after just 10 correlation (160 seconds measurement time).

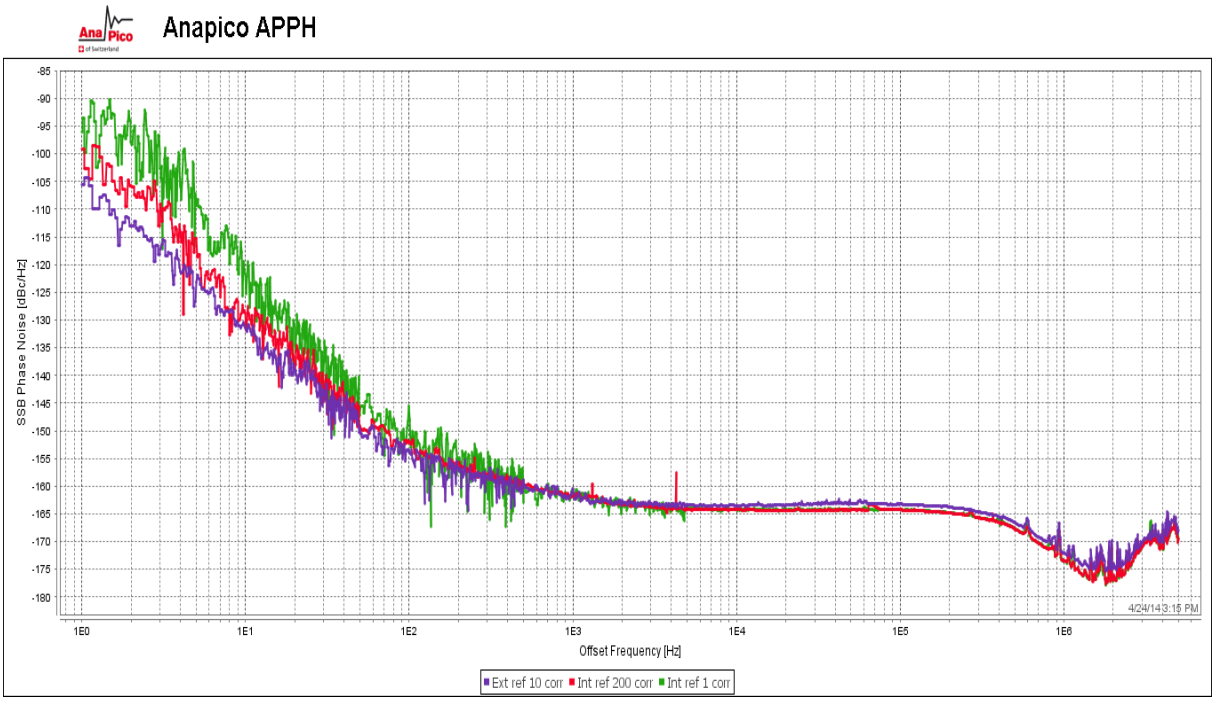

Fig. 10: Phase noise measurement of low-noise 10 MHz with internal references (green and red trace) and external references (purple trace, 10 correlations, 160 seconds measurement time).

Conclusion

In conclusion, the APPH offers great flexibility in configuring your measurement to the required performance level.

For most phase noise measurement applications, the use of the standard configuration with the internal references is the ideal choice providing easy to use reliable measurements.

For measurements of very low phase noise DUTs (especially close to the carrier below 10 Hz offset), the low-noise option of the internal references (option LN) or external references will offer lower instrument noise floors and substantially reduced measurement times.

With the help of the APPH GUI, the setup and calibration of external references is greatly simplified, offering an alternative way to perform ultra-low phase noise measurements in short amount of time.