

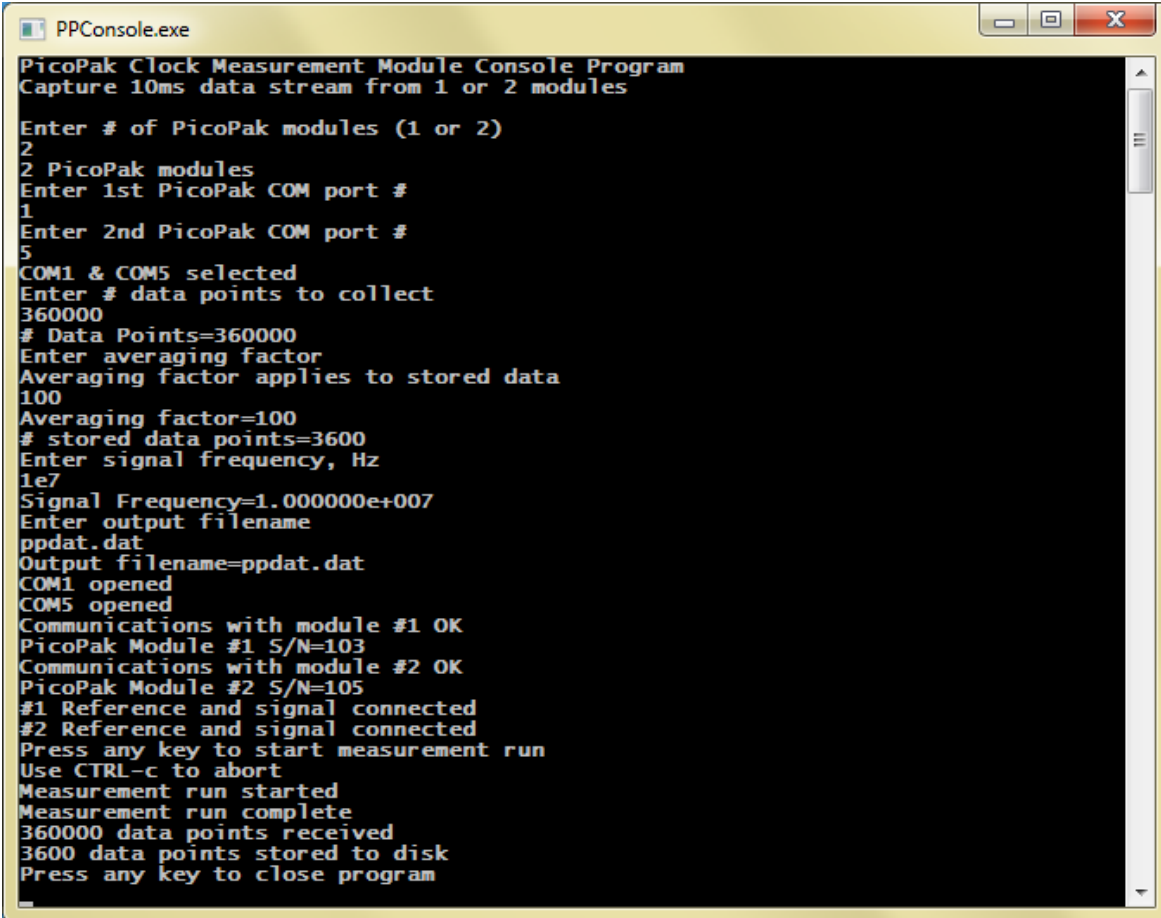
The PPConsole Program

- **Introduction**

PPConsole is a command line program for the PicoPak clock measurement module [1, 2]. It supports capturing the 10 ms data stream from one or two PicoPak modules. Its main application is to collect simultaneous phase data from two modules so that a cross-correlation stability analysis can be performed with a lower noise floor. This program makes collecting such data relatively easy.

- **Program Description**

Figure 1 shows the PPConsole screen for a two-module measurement run. The same signal and reference inputs are applied to both modules, and they are both connected to the PC running the PPConsole program. The COM port numbers for two PicoPak modules (COM1 and COM5), the desired number of 10 ms data points (360000), the stored data averaging factor (100), the nominal signal frequency (10 MHz) and the data filename (foo.dat) are all entered. This will result in 3600 1-second (1 hour) of simultaneous data being stored, as shown in the partial data file listing of Figure 2 (note that zero values are replaced by 1e-99 to avoid them being treated as gaps by Stable32). One can see that the phase values for the two modules advance similarly, but not exactly the same, due to the frequency offset between the two sources, the modules noise, and modulo their data quantization.



```
PPConsole.exe
PicoPak Clock Measurement Module Console Program
Capture 10ms data stream from 1 or 2 modules

Enter # of PicoPak modules (1 or 2)
2
2 PicoPak modules
Enter 1st PicoPak COM port #
1
Enter 2nd PicoPak COM port #
5
COM1 & COM5 selected
Enter # data points to collect
360000
# Data Points=360000
Enter averaging factor
Averaging factor applies to stored data
100
Averaging factor=100
# stored data points=3600
Enter signal frequency, Hz
1e7
Signal Frequency=1.000000e+007
Enter output filename
ppdat.dat
Output filename=ppdat.dat
COM1 opened
COM5 opened
Communications with module #1 OK
PicoPak Module #1 S/N=103
Communications with module #2 OK
PicoPak Module #2 S/N=105
#1 Reference and signal connected
#2 Reference and signal connected
Press any key to start measurement run
Use CTRL-c to abort
Measurement run started
Measurement run complete
360000 data points received
3600 data points stored to disk
Press any key to close program
```

Figure 1. PPConsole Screen

```

PPConsole Data File
Column 1=PicoPak Module S/N 103
Column 2=PicoPak Module S/N 105
Tau: 1.000000e+000
Start=Mon Mar 30 17:34:40 2015
End=Mon Mar 30 18:34:40 2015
Phase, seconds
# Header End
8.911133e-010 9.033203e-010
1.782227e-009 1.782227e-009
2.661133e-009 2.661133e-009
3.527832e-009 3.552246e-009
4.431152e-009 4.455566e-009
5.358887e-009 5.346680e-009
6.225586e-009 6.225586e-009
7.116699e-009 7.141113e-009
8.032227e-009 8.032227e-009
8.923340e-009 8.947754e-009

```

Figure 2. PPConsole Data File

The PPConsole program opens the two COM ports, verifies the communication paths to the modules, reads the module S/Ns, verifies that their signals and references are connected, and the operator then starts the measurement run. The two 10 ms data streams are, after averaging by a factor of 100 to 1 second, very nearly simultaneous (within better than 1%) and are therefore suitable for a cross-correlation stability analysis [3]. The PPConsole program stores the 1-byte incremental phase data from each module to PC memory during the run and then integrates, down-samples and stores them to a disk file at the end of the run. Each row of the two data columns in the data file correspond to a near-simultaneous phase measurement by the two modules, which can be read into Stable32 for a cross-correlation Allan deviation analysis.

- **Cross-Correlation Analysis**

The cross-correlation Allan deviation, Cross sigma or “# ADEV [4] is calculated exactly like the normal one except that the products of separate x[] array values are used instead of the square of values from a single array. The resulting sigma can have either sign (suppressed). If the same data are in both arrays, the result will be the same as the overlapping Allan deviation. Calculation of the cross-correlation Allan deviation, # ADEV, is supported by the Stable32 program for phase data. Two phase data files having the same number of points representing data from simultaneous measurements using two separate measuring systems whose noise will be partially cancelled by the cross-correlation process are read into Stable32 and stored in the first two phase data tabs. Cross sigma is selected as the variance type in the Run function, and is calculated from those two data sets.

The individual and cross-correlation noise floors with coherent signal and reference inputs for two PicoPak modules are shown in Figures 3-5. The cross-correlation technique reduces the noise floor by a factor of about x10 at short tau.

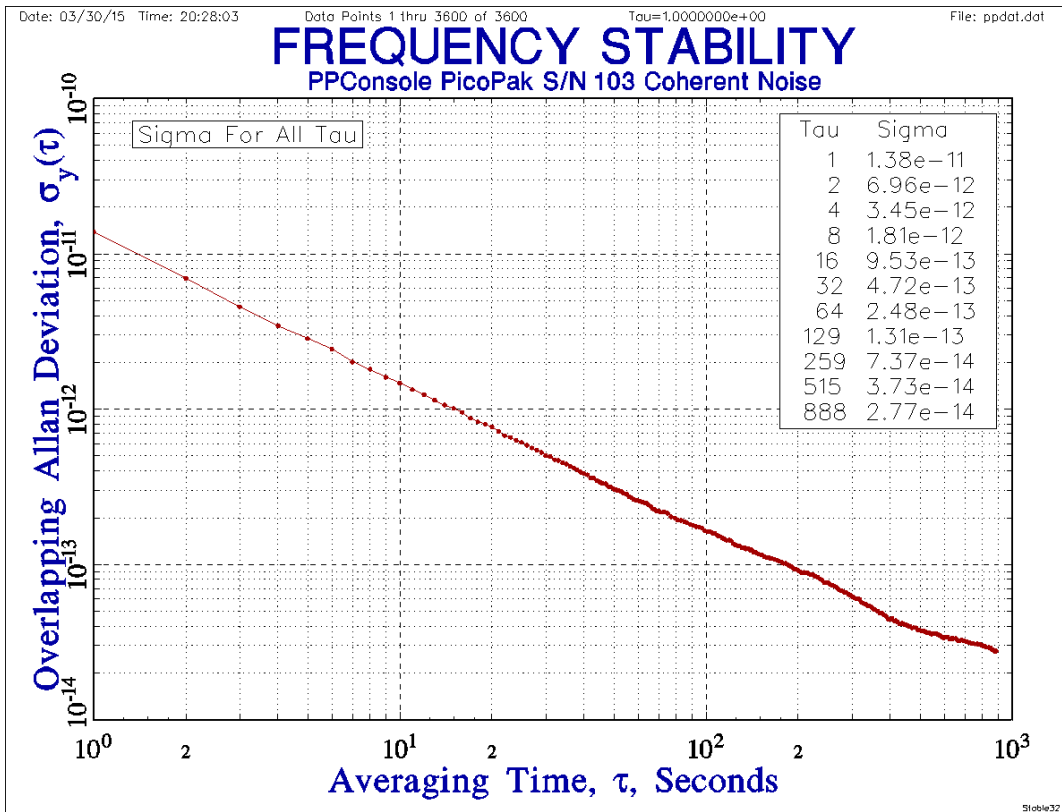


Figure 3. PicoPak S/N 103 Noise Floor

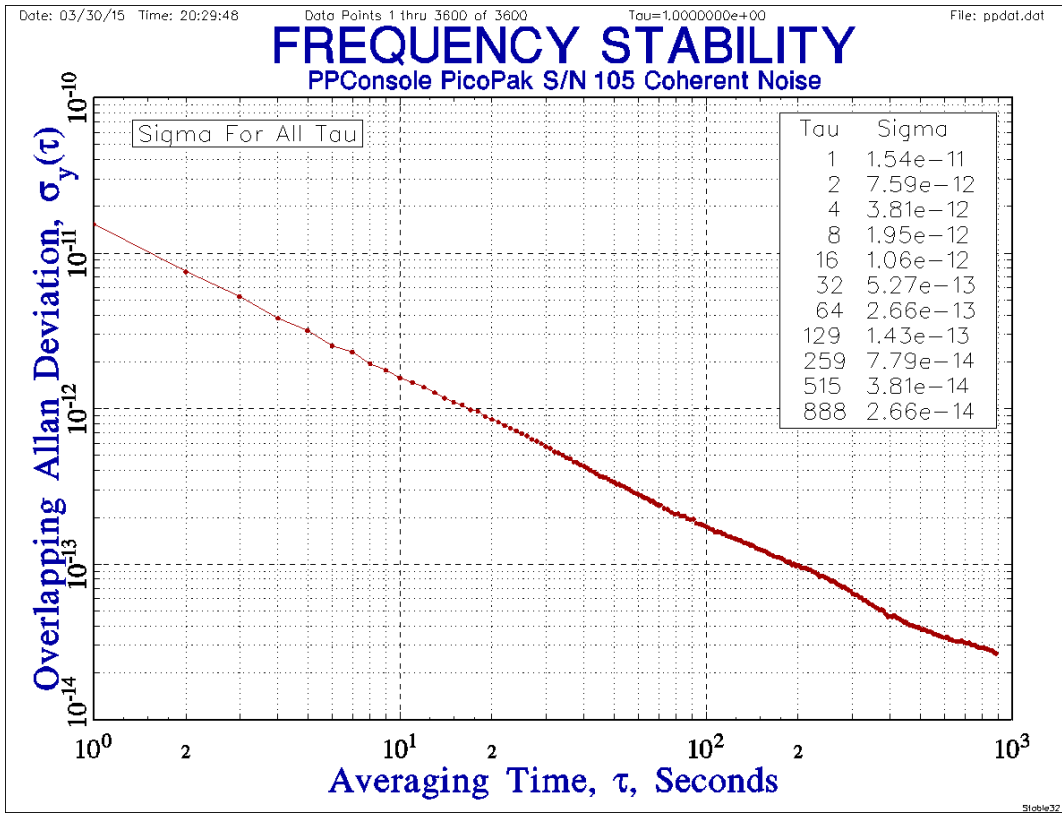


Figure 4. PicoPak S/N 105 Noise Floor

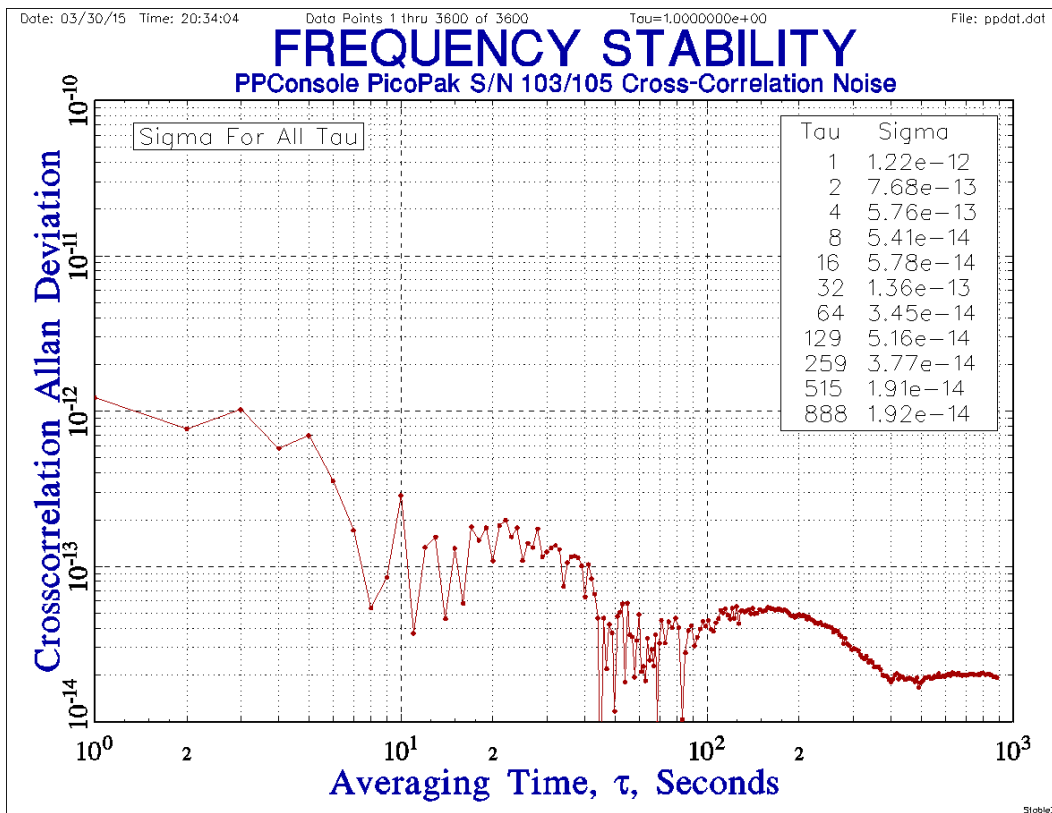


Figure 5. PicoPak S/Ns 103 and 105 Cross-Correlation Noise Floor

The cross-correlation technique can be applied for the measurement of a pair of Rb oscillators. The measurements with either PicoPak module alone have excess white PM noise in the short term region As shown in Figures 6 and 7. A white FM $\tau^{-1/2}$ is expected for these sources but the measured data shows excess white PM τ^{-1} quantization noise from the measurement modules.

The cross-correlation ADEV results in Figure 8 have a lower measurement system noise floor and can be used to estimate the actual white FM noise level of the sources, as shown by the green $\tau^{-1/2}$ fit to the 1-200 second cross-correlation data.

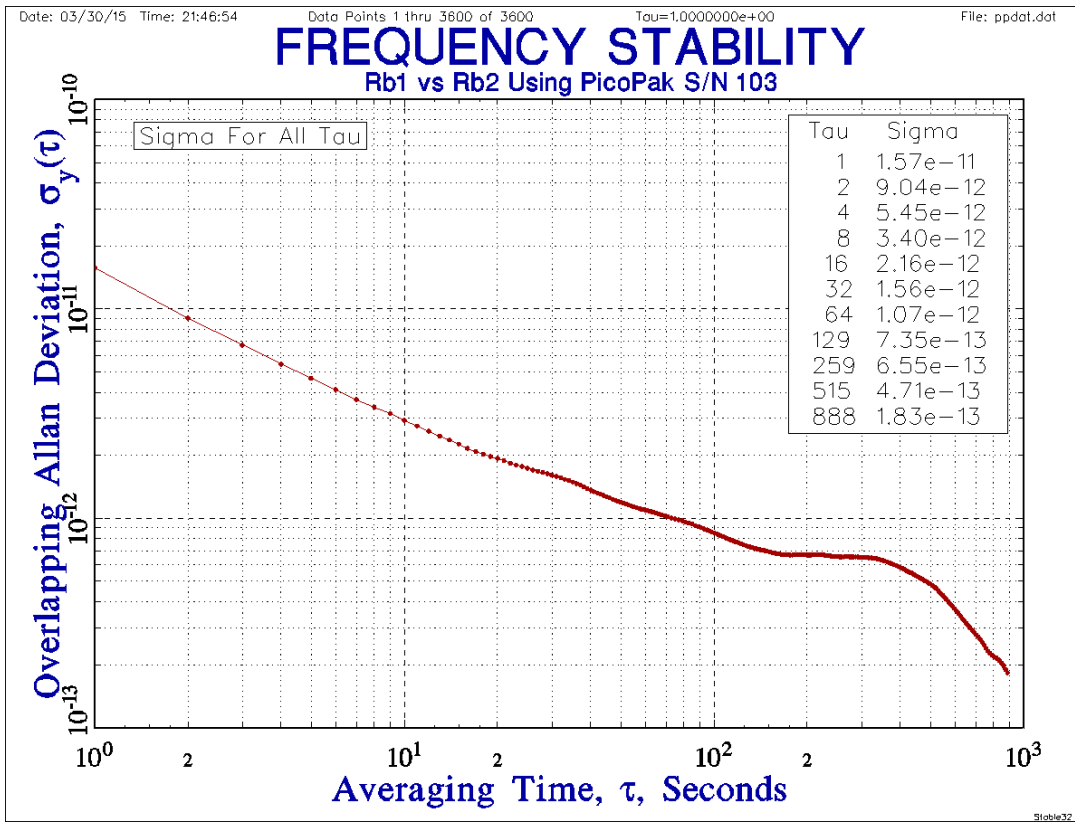


Figure 6. Rb Oscillator Stability Using PicoPak Module S/N 103

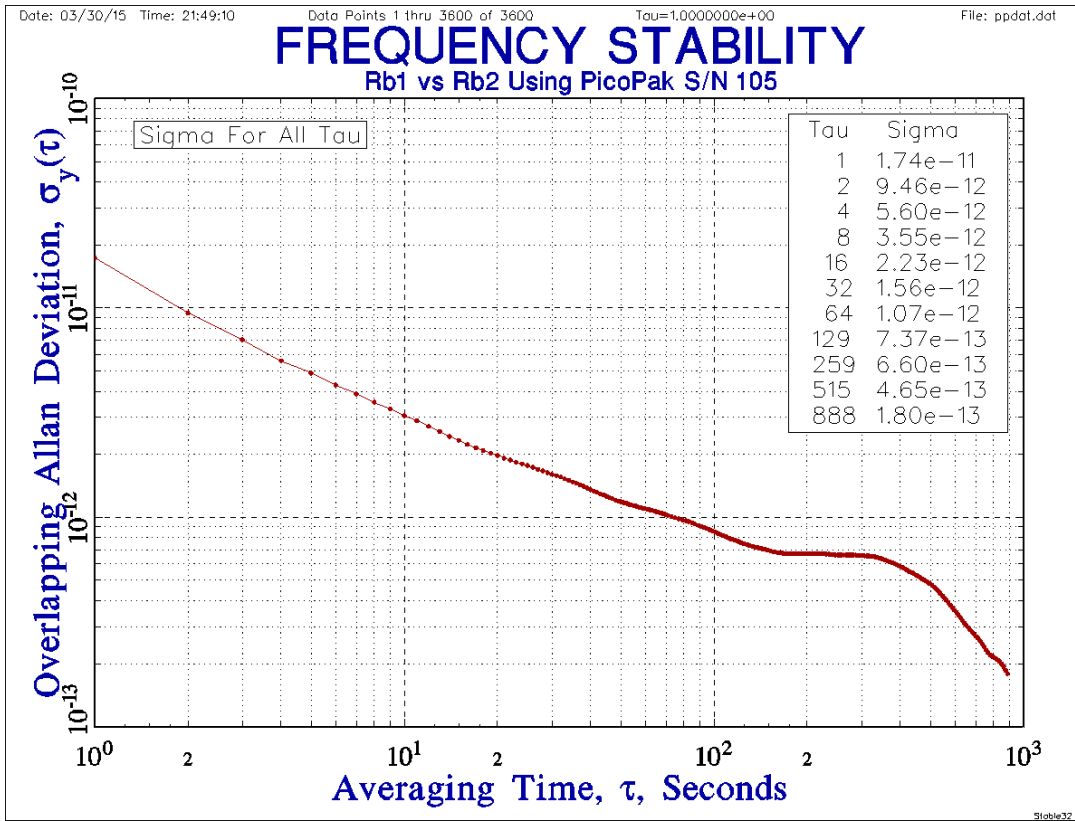


Figure 7. Rb Oscillator Stability Using PicoPak Module S/N 105

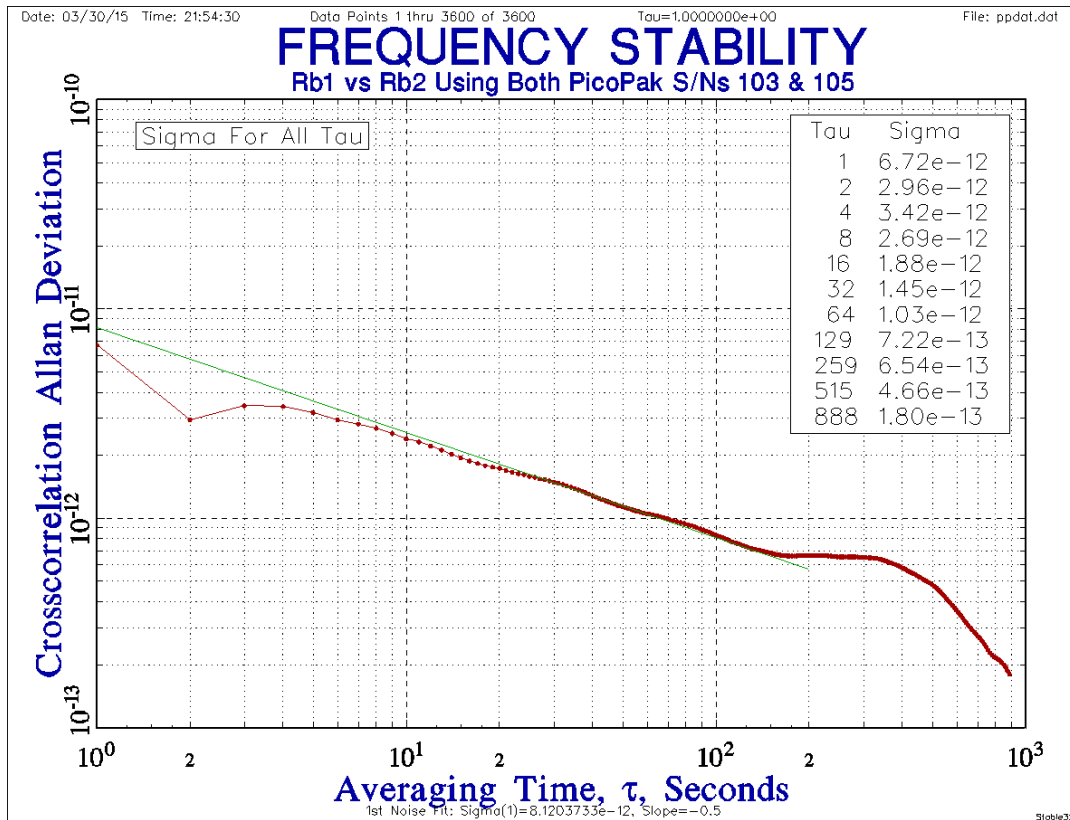


Figure 8. Rb Oscillator Stability Using Both PicoPak Modules and Cross-Correlation

• **References**

1. W.J. Riley, "The PicoPak Clock Measurement Module", Hamilton Technical Services, Beaufort, SC 29907 USA, March 2015.
2. The PPConsole program was written in C using the Win32 API and Microsoft Visual C/C++ 5.0, and is supplied with the PicoPak clock measurement module hardware.
3. T. Van Baak, private communication, 03/20/15.
4. A. Lepek and F.L. Walls, "Cross Correlation Analysis Improves Time Domain Measurements", *Proc. 1993 IEEE Freq. Ctrl. Symp.*, pp.312-320.

File: The PPConsole Program.doc
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Hamilton Technical Services
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