The Strange Case of a Pseudo Flicker Floor

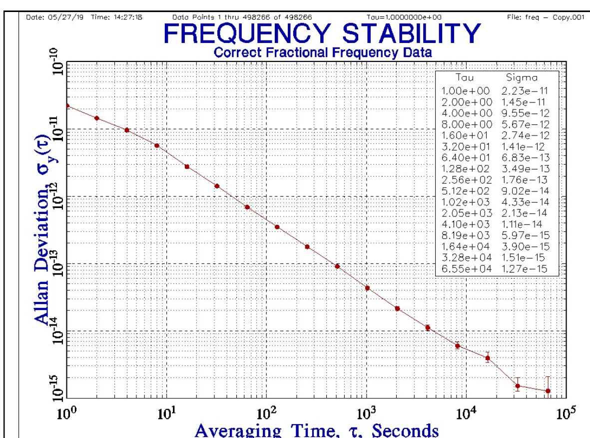
W.J. Riley
Hamilton Technical Services
Beaufort, SC 29907 USA

Adding a constant to frequency data should not change the resulting Allan deviation (ADEV) since it is based on 1st differences. In other words, normalizing raw frequency data in hertz by dividing those values by the nominal frequency, i.e., f / f_0, should produce the same ADEV results as properly converting the raw frequency data into fractional frequency values, i.e., $y = (f - f_0) / f_0$. But not always!

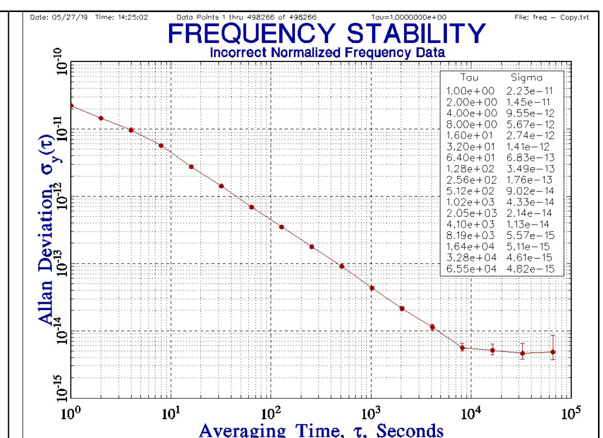
Most frequency stability analyses of frequency data (e.g., with Stable 32) are performed using fractional frequency values. A common error made by a novice Stable32 user (its documentation not withstanding) is to perform a stability analysis with raw frequency data in hertz. Recently, I received a query about strange ADEV results using Stable32, and it turned out that the user had simply divided his raw frequency readings by their nominal value, f / f_0. Now f / f_0 is $[(f - f_{0)} / f_0] +1$, so, compared with proper fractional frequency data, his analysis was conducted on values with 1 added to them.

Adding a constant to the input data should not change the results of an ADEV analysis. But it can significantly stress the dynamic range of the ADEV calculation. Instead of a value like (say) $1x10^{-12}$, one must deal with $1 + 1x10^{-12}$ or 1.000000000001. Even with double-precision (16-digit) arithmetic that can affect the ADEV results, especially at longer tau where they tend to become smaller. In the case of our novice analyst, the data represented the noise floor of a stability measuring system, a rather worst-case for this situation since one typically has small white PM noise deviations that should become lower as 1/tau.

The ADEV results for our new users' data are shown below for the two cases of correct fractional frequency data and incorrect normalized frequency data.



Correct ADEV Results for $(f - f_0) / f_0$



Wrong ADEV Results for f / f_0

The results with the improper f / f_0 normalization are confusingly plausible. They are OK (identical to the proper fractional frequency case) at shorter tau up to about 2000 seconds, but appear to have a "flicker floor" of about $5x10^{-15}$ at tau greater than about 10,000 seconds. It would be easy to be confused by that, or to attribute it to the device being measured.

Note that this problem only occurs with certain data sets and analysis conditions, and depends on the selected analysis function and many internal Stable32 program details. For example, in this case the overlapping ADEV shows the wrong slope and some functions completely fail. Improperly-normalized data can potentially affect many aspects of the program, generating wrong, and in some cases strange, results.

In this case, if the fractional deviations were larger by a factor of x10 or more, the double-precision dynamic range is adequate for these data and a correct ADEV result is obtained for f / f_0 normalization. But one should always use fractional frequency data.

Dynamic range issues are rare in frequency stability analysis and are generally associated with long-term phase data for a highly-stable source with a large frequency offset. In this case it the frequency data had a huge apparent frequency offset caused by improper data format.

I have to admit that, in many years of providing advice regarding frequency stability analysis, I have not, as obvious as it is, met this problem before. The chances of a new analyst seeing this warning before encountering this pitfall are vanishingly small, but I thought it was nevertheless worth documenting.

I express my thanks to the (anonymous) novice analyst for bringing this to my attention.

File: The Strange Case of a Pseudo Flicker Floor.doc

W.J. Riley
Hamilton Technical Services
May 28, 2019