Phase Data with Discrete Spurs Removed

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This paper shows how the new Stable32 spur removal feature can be used to detect, analyze and remove a pair of discrete spurious components from a set of simulated phase data having underlying white FM noise. The original phase data comprises 5130 $\tau = 1$ second points with two large spurs at 10 and 20 mHz, and white FM noise at a level $\sigma(1) = 1.0$. The analysis uses phase data, L(f) phase noise, and all tau ADEV stability plots to show the effect of removing the spurs with periodogram averaging factors of 1, 2 and 4.

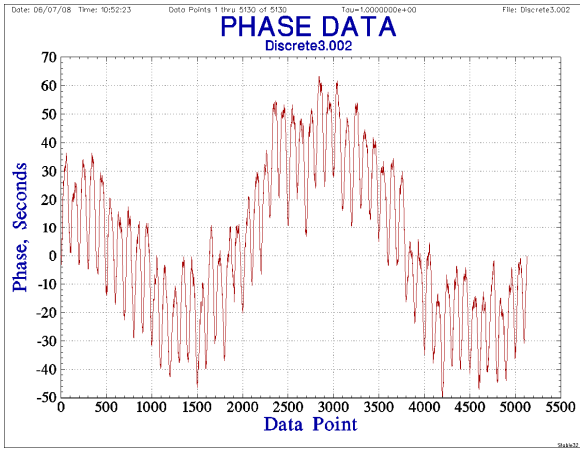

Figure 1a. Original Phase Data with 2 Discrete Spurs

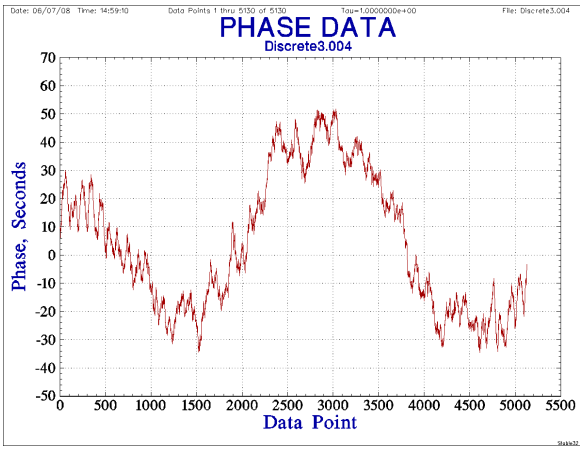

Figure 1b. Corrected Phase Data with Spurs Removed Using AF = 1

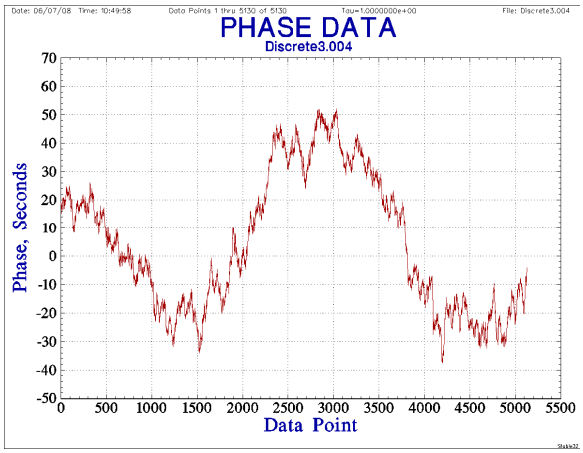

Figure 1c. Corrected Phase Data with Spurs Removed Using AF = 2

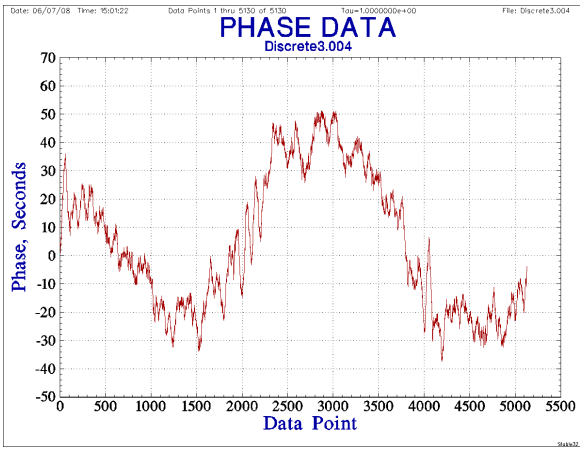

Figure 1d. Corrected Phase Data with Spurs Removed Using AF = 4

Phase Data Plots for Original and Corrected Data

Strong periodic components are more visible in phase than frequency data because the noise is smoothed. The most obvious component in the uncorrected data has a period of 100 seconds (100 τ =1 sample intervals). The phase data corrected by using AF = 2 has the least residual periodic ripple.

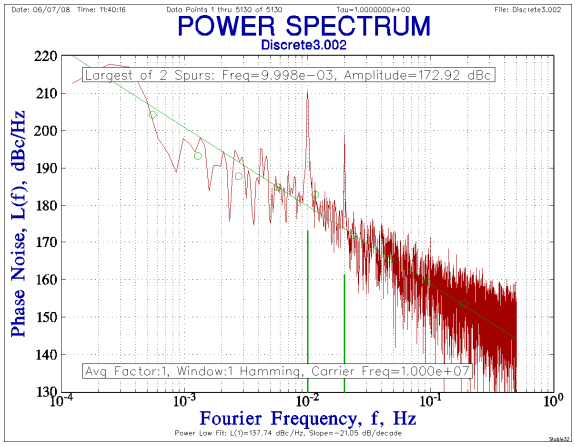

Figure 2a. Original PSD Plot

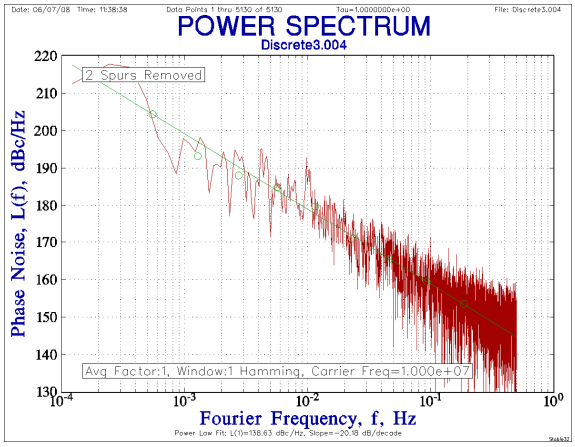

Figure 2b. Corrected PSD Using AF = 1

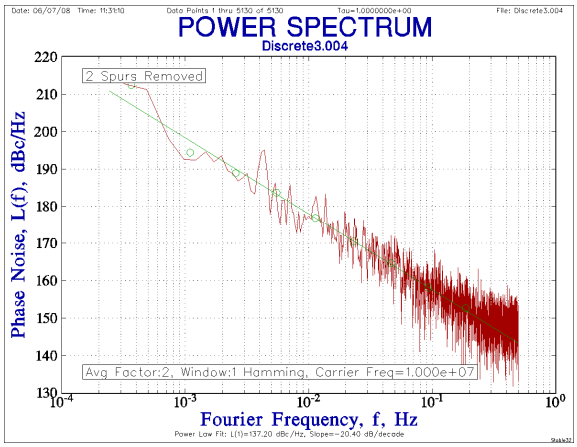

Figure 2c. Corrected PSD Using AF = 2

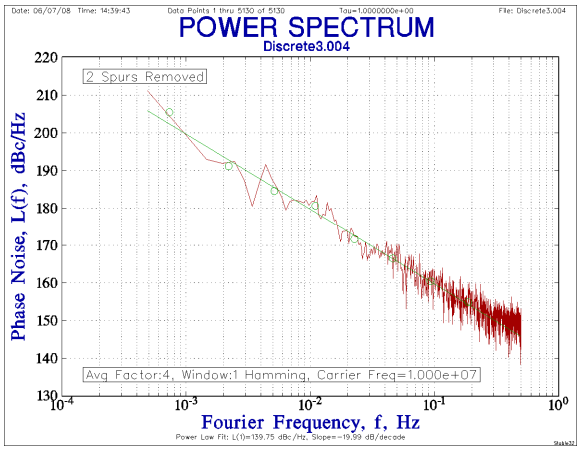

Figure 2d. Corrected PSD Using AF = 4

PSD Plots for Original and Corrected Data

The spur removal is best at AF = 2. The original spurs at 10 and 20 mHz are nearly absent in all of the corrected PSD plots. In the AF = 1 PSD plot, the energy near that Fourier frequency is actually somewhat above and below it, where no correction was applied for the 20 dB spur threshold that was used. The excess energy near 4 mHz in the AF = 2 PSD plot is probably an artifact of the removal process. A lower spur threshold of 15 dB was needed to remove the smaller 20 mHz spur for AF = 4.

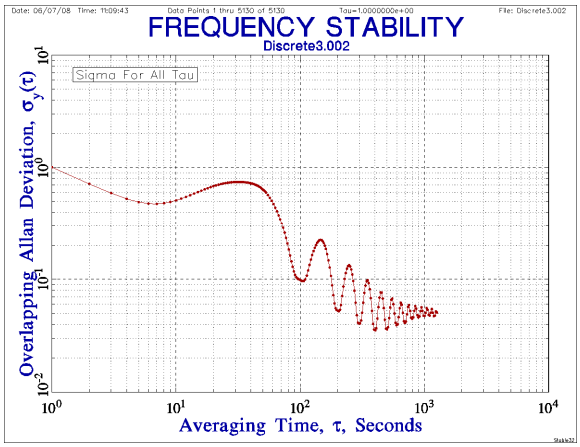

Figure 3a. Original ADEV Plot

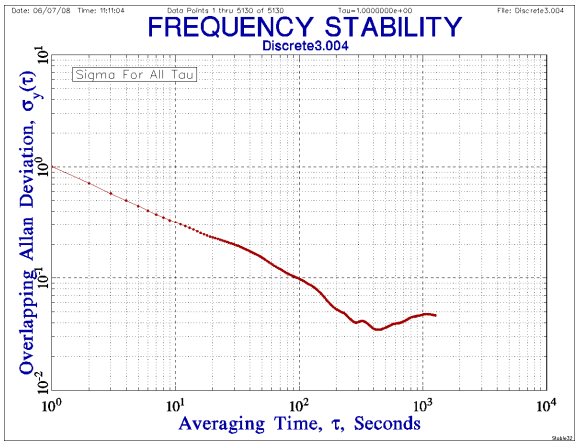

Figure 3b. Corrected ADEV Using AF = 1

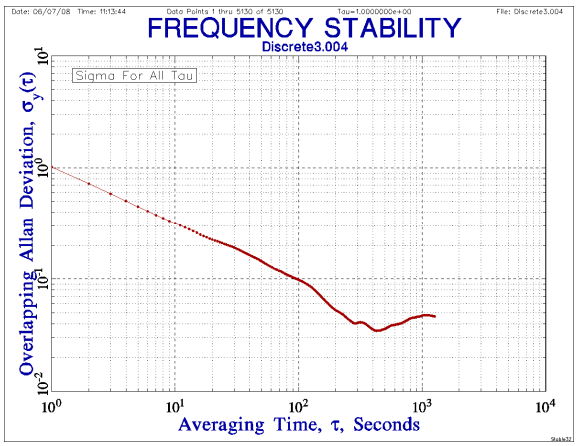

Figure 3c. Corrected ADEV Using AF = 2

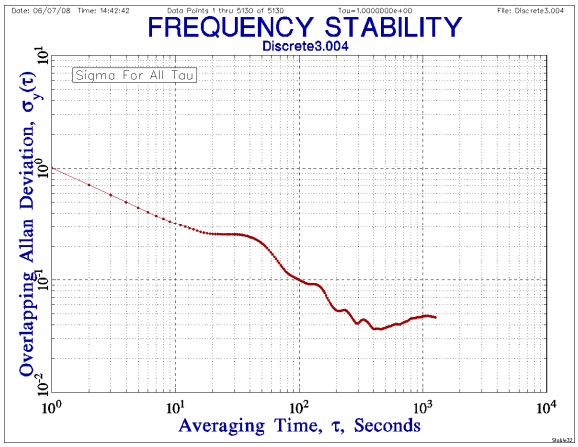

Figure 3d. Corrected ADEV Using AF = 4

All Tau ADEV Plots for Original and Corrected Data

All cases have the same σ(1), and all corrected cases have similar ADEV plots, but the corrected data and stability are not identical. The AF = 1 and 2 averaging factors are best, probably because, with more averaging than that, the spurs are removed from relatively small FFT data sections. All of the corrected stability plots follow the general trend of the lower envelope of the uncorrected all tau ADEV results. The first minimum of the uncorrected stability plot is at t = 100 seconds, the period of the largest 10 mHz spur.

The spur removal in the plots above inserts zeros at those Fourier frequencies where spurs were detected above a selected threshold. Extending the spur removal range by ±2 FFT points improves the spur suppression, especially for AF = 1 as shown in Figure 4 below.

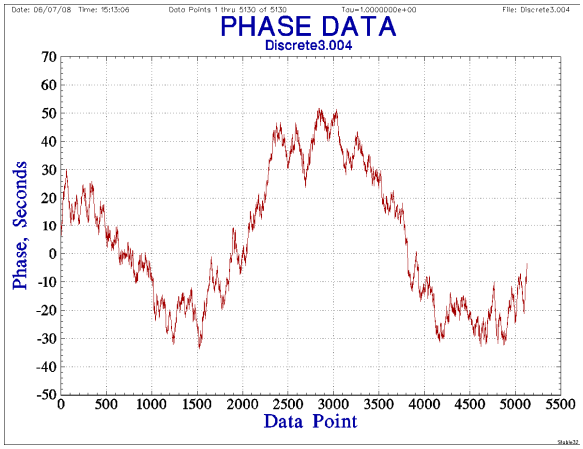

Figure 3a. Phase Data Plot

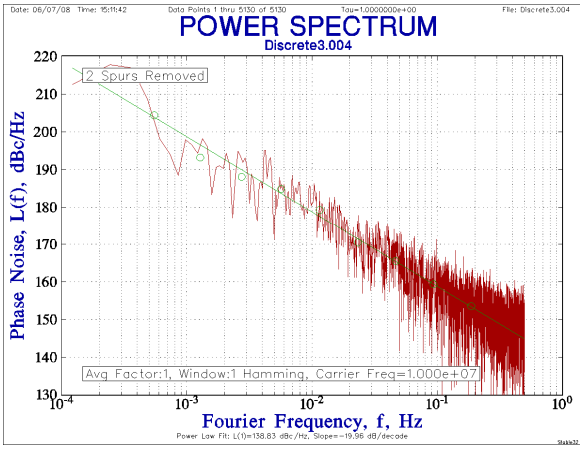

Figure 3b. PSD Plot

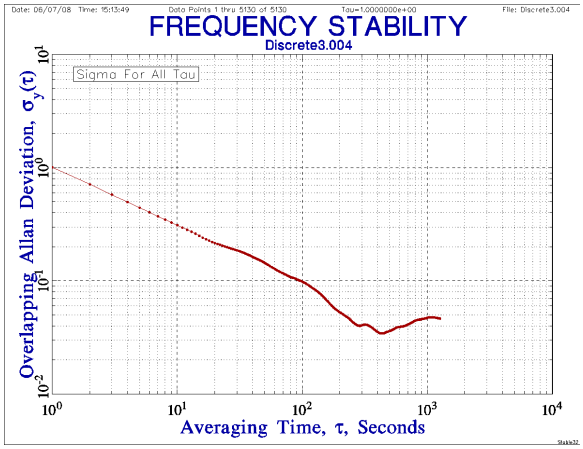

Figure 3c. ADEV Plot

Virtually all spur energy is removed from this PSD plot. The data and ADEV plots, however, are not significantly different. Stable32 uses extended spur removal as its default when the FFT array size is 512 or larger to improve its AF = 1 spur removal. The number of additional FFT points removed on each side of the detected spur can be set by the ExtendSpurRange setting in the [Preferences] section of the Stable32.ini configuration file.

AF = 1 Plots for ±2 FFT Point Extended Spur Removal

Spur removal can be a useful technique to analyze clock data that is badly contaminated by discrete spurious components. It is possible to remove such interference while preserving the essential noise and drift characteristics of the underlying data. But this technique should be used with discretion, preferring uncontaminated data whenever possible. The spur removal process involves FFT and inverse FFT processing of zero padded time domain data when the original record length is not an exact power-of-two. This produces more time domain data points than the original record that are truncated to the original length. Clearly the subsequent analysis is performed on altered data.