Asymmetric Singleband Delay Functions

Roger Cappallo
24 May 2019

Since the advent of the wideband digital systems we have been seeing some oddly asymmetric singleband delays (sbd) functions on fringe plots (see figure 1). Note also the S-shaped phase signature (in red) of the Xpower Spectrum plot, which is causing the asymmetry. By tracking back through experiments, Mike Titus and I have found that the pattern appears to show up only when the wideband sampled systems are cross-correlated with datastreams that have been sampled on a narrowband basis, such as the Mk4 and VLBA formatter produces. It seems likely that the cause is a phase signature of the narrow band anti-aliasing filters, which when cross-correlated against a similar system cancels out, but which is evident when correlated against narrow channels that have a wideband origin, as their phase is likely flat. When the wideband systems (vgos, dbbc, cdas) are correlated against one another, there is no large phase signature present.

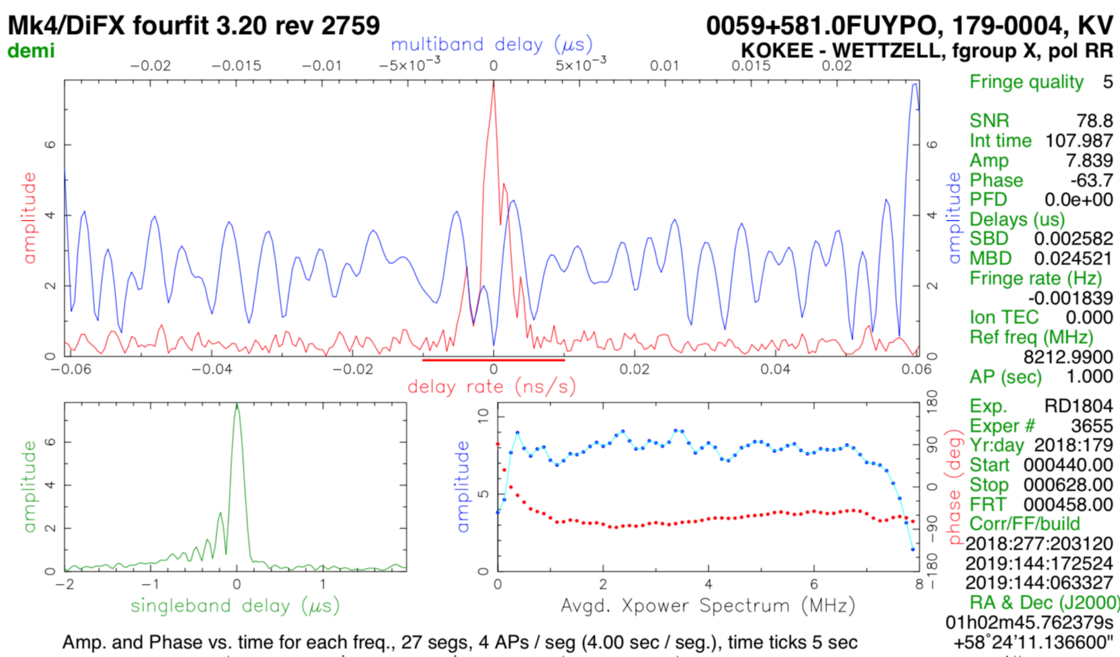

Figure 1

I have done some experimentation on a possible remedy within fourfit, in which we would correct the single-channel bandpasses identically within each channel for afflicted baselines. The intent is to increase coherence across frequency within each channel, and in so doing increase the scan snr.

I imported the cross-spectral phase data from the scan in figure 1 into MATLAB, and have experimented with correcting the phase by fitting a variety of models to the data. I've found that a good fit can be had by a cubic polynomial plus a 1/f term for the rapid phase change near DC, viz.

$$\varphi(f) = af^3 + bf^2 + cf + d + e/f$$

In figure 2 the cross-spectral phase is plotted in red, whereas the fit function is shown in blue. The rms phase residual to the blue curve is 4.1°.

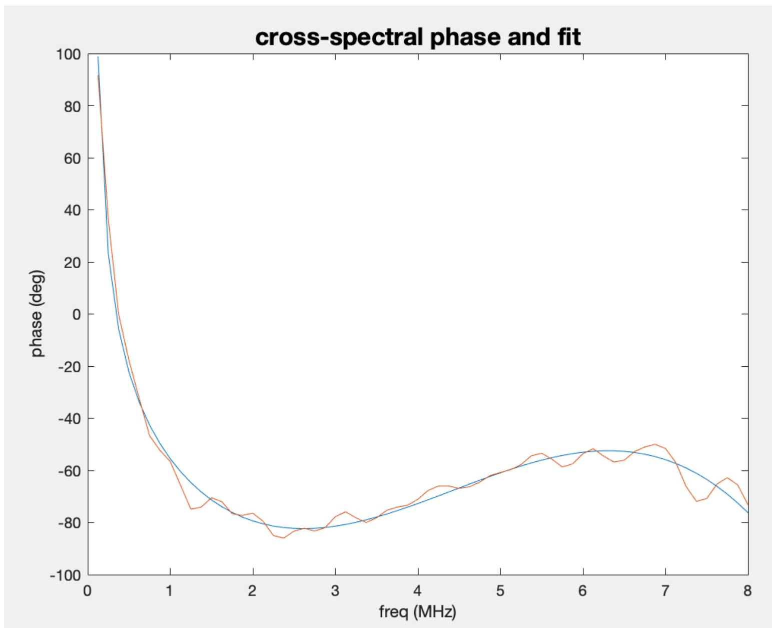

Figure 2

I've then used the resulting coefficients (a..e) for a correction function within fourfit, to better align the phases across frequency. This was done in a very ad hoc proof-of-concept fashion, by hardwiring code into the norm_fx routine. The upper portion of the resulting fringe plot can be seen in figure 3. As can be seen in comparison to figure 1, which was fourfitted in identical fashion other than the channel passband correction, the asymmetry has been largely removed. Also the snr has increased by a little over 6%.

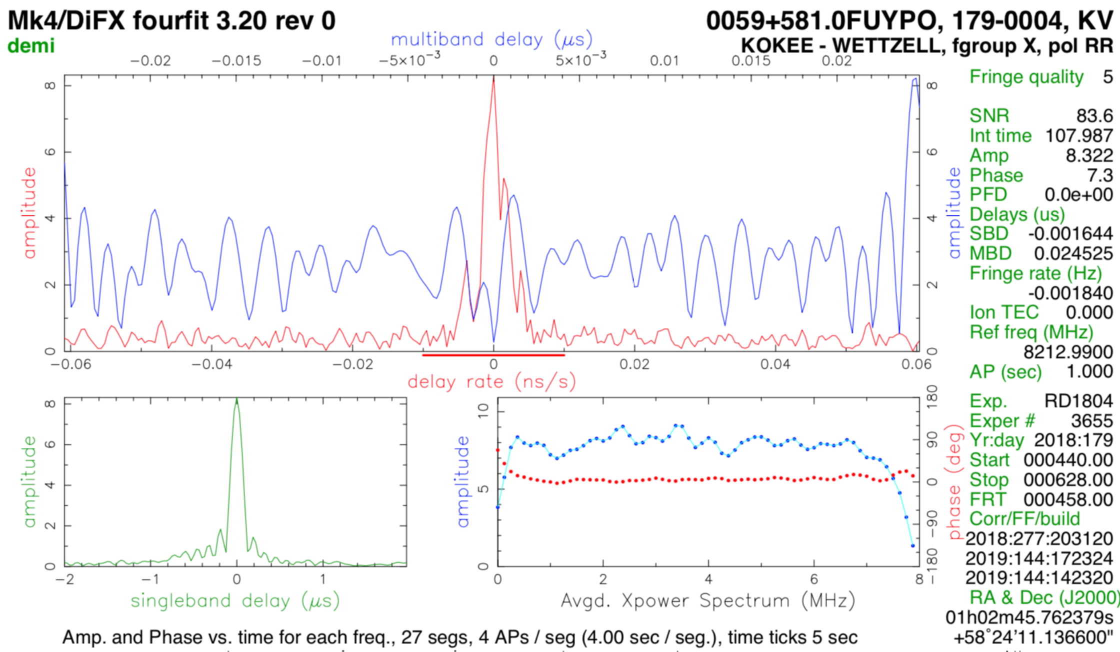

Figure 3

The question now is whether or not it is worthwhile to add this feature into fourfit in a more general fashion. The lifetime of the narrowband systems are presumably limited, and it is really just during this transition time when a mixture of systems is being used that the feature would be of most help. It may happen, though, that there are occasional circumstances in which such a feature would be useful even in the wideband systems.