

To: VLBI2010 Broadband Development Group
From: Brian Corey
Subject: Modulation during first hour of 2008 May 23 GGAO-Westford BBD test

This memo presents additional information beyond that in an earlier memo about the nature of the 1/20-Hz modulation observed in the phase cal and sample state statistics for Westford during the first hour of the test.

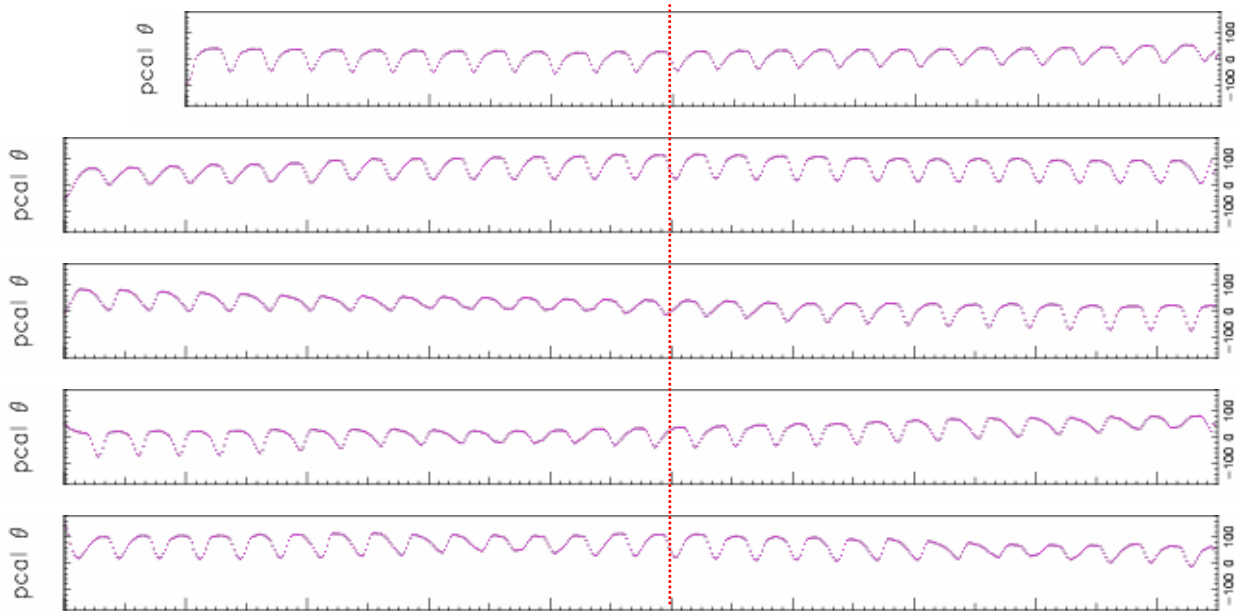


Figure 1. Phase of 8892 MHz phase cal tone (4 MHz tone in LSB baseband channel X4L) in Westford L-pol signal, as extracted at correlator, vs. time. Each panel is snipped from a fringe plot for a single scan. The scans are in time order, from top to bottom: 144-1641, 144-1650, 144-1700, 144-1710, and 144-1720. Each time axis runs from zero to 9 minutes 30 seconds after the 10-minute mark, except for the first scan, where it runs from 1 minute to 9 minutes 30 seconds after the mark. Altogether the five time series completely cover the interval from 16:41:00 to 17:29:30 except for four 30-second breaks between scans. Major tick marks are every 1 minute. Each point is a one-second average. The vertical dashed red line intercepts each time series at epochs precisely 10 minutes apart.

1. Evidence from phase cal

Figure 1 is an extended version of the pcal phase plot in figure 8 of my June 8 memo on the BBD test. The new figure displays the phase time series of a representative pcal tone for all five full-length scans during which the modulation was present. The gradual waveform changes that were visible in the single-scan time series in the earlier memo (which is reproduced in the bottom

panel of figure 1) are obviously not unique to that scan. A new feature only detectable with the extended time series is that the modulation period is slowly decreasing over the 48+ minutes of figure 1. By observing the phase of the waveform at the points where it is intersected by the dashed vertical red line, which is drawn at an arbitrary set of epochs spaced 10 minutes apart, one can see that the phase is accelerating from one scan to the next, i.e., the period is decreasing. I find the period decreased from ~ 20.0 seconds at the start to ~ 19.7 seconds by the end.

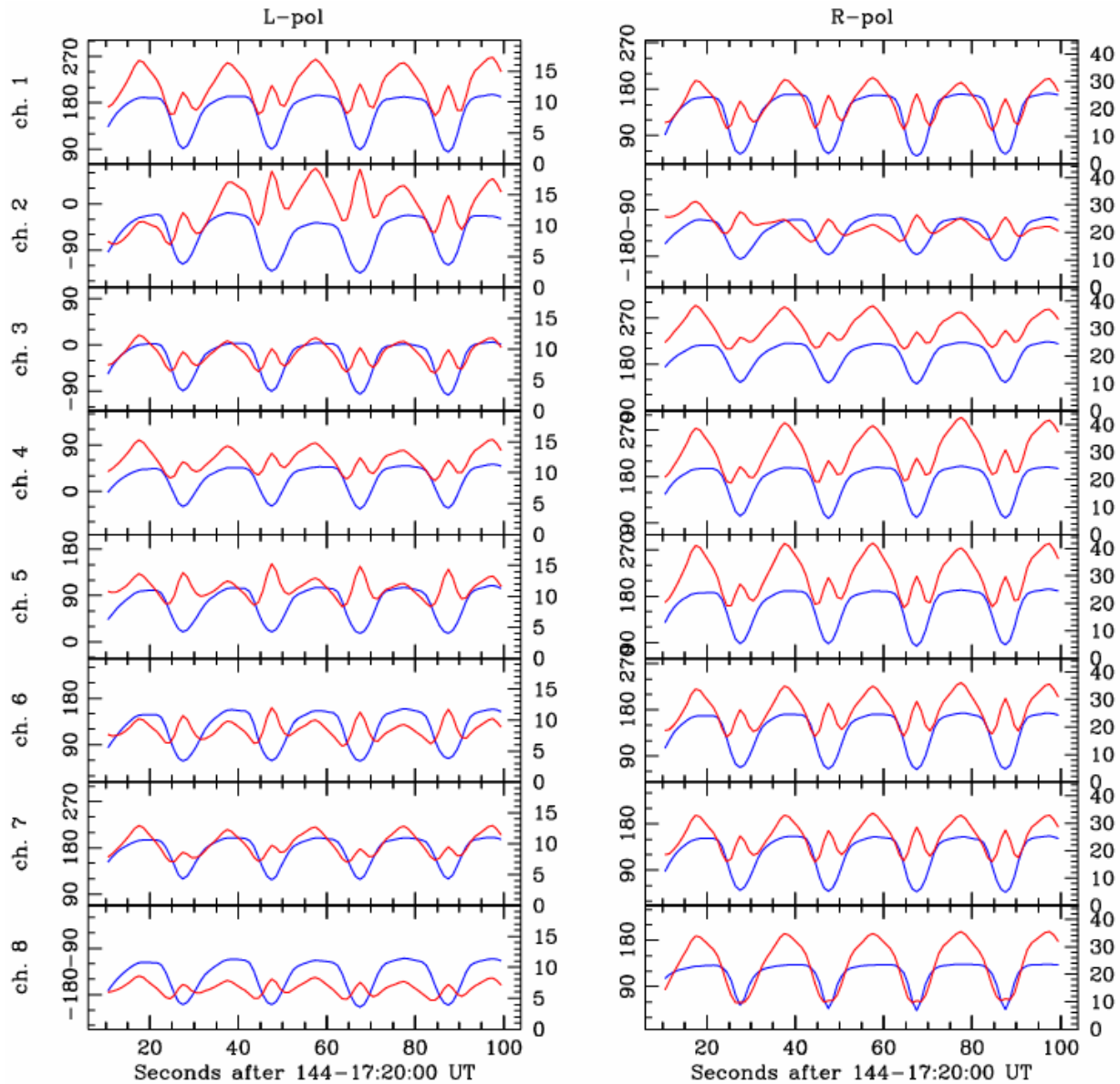


Figure 2. Westford phase cal phase (blue line and lefthand scale) and amplitude (red line and righthand scale) time series for the 4-MHz tone in each frequency channel for both polarizations. Time span runs from 10 to 100 seconds after the start of scan 144-1720. Data are one-second averages. Amplitudes have been multiplied by 1000. In order to simplify comparing phases between channels, the max-min span of all the phase ordinates is held fixed at 240° .

Additional phase cal evidence not available on a fringe plot is provided by the pcal amplitudes. In figure 2 are plotted the Westford pcal amplitudes and phases at the start of scan 144-1720. The amplitudes are obviously strongly modulated in synchrony with the phases. (The somewhat aperiodic behavior of the amplitudes and phases in channel 2 is probably related to what appears to be severe contamination by spurious signals. This contamination is more obvious after 144-1740, when the 1/20-Hz modulation was gone.)

The fact that the pcal amplitudes are strongly modulated rules out simple LO phase modulation in the UDC as the cause.

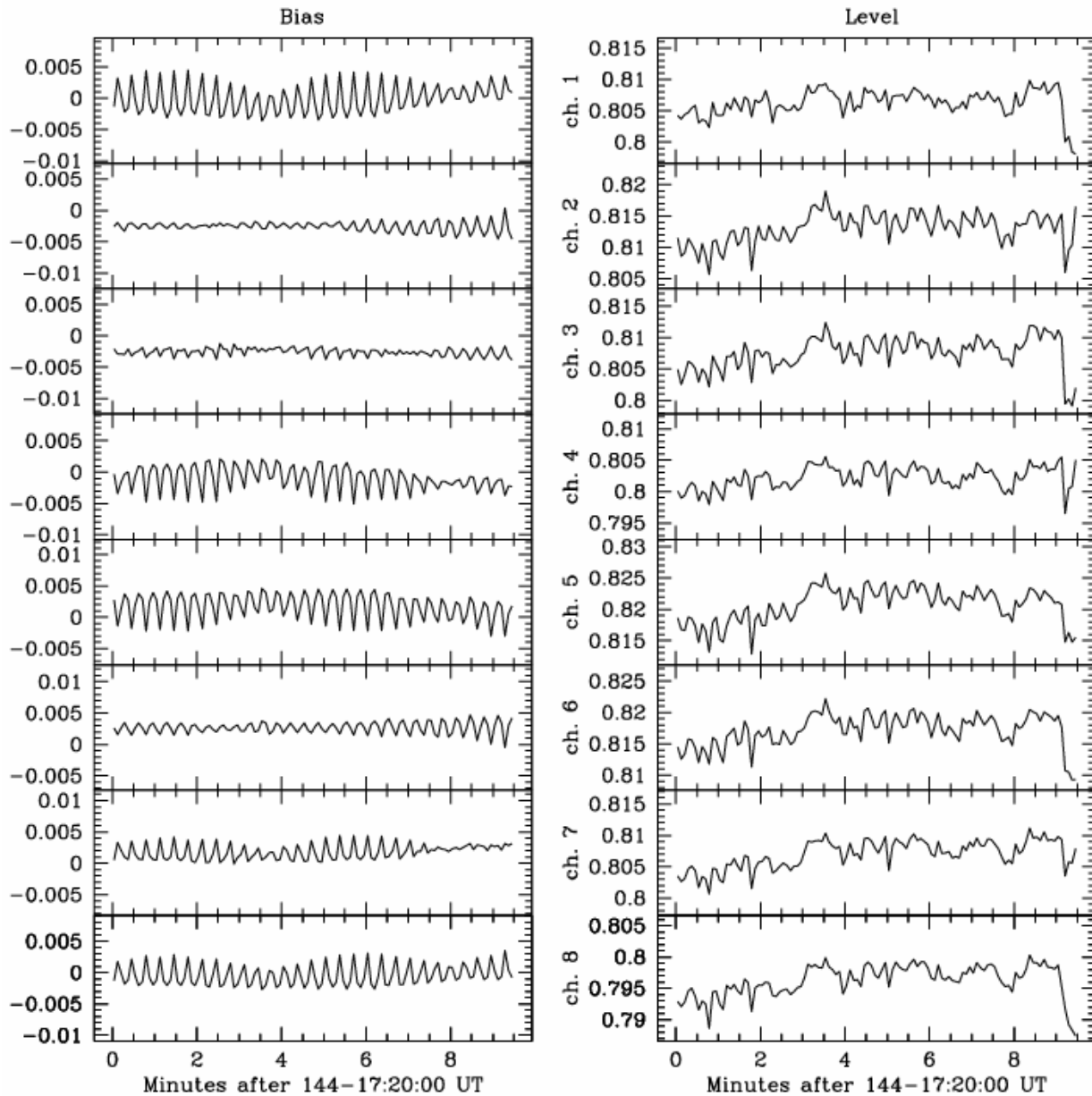


Figure 3. Westford L-pol state statistics time series for all frequency channels in scan 144-1720. Lefthand panels labeled Bias show the fraction of all samples by which positive samples outnumber negative. Righthand panels labeled Level show the fraction of samples in the low-magnitude state. All ordinates have a max-min span of 0.02. Data are five-second averages.

2. Evidence from state statistics of 2-bit samples

As noted in the June 8 memo, the preponderance of positive samples over negative, or *bias*, also exhibits a distinct 1/20-Hz modulation. It turns out that the fraction of all samples with low magnitude, or *level*, does as well, although only very weakly – see figures 3 and 4. The 1/20-Hz oscillations in the L-pol levels are masked to some degree by variations on other time scales, but there is no mistaking the oscillations in the R-pol levels for some channels. The levels shown in the figures are also typical of those observed in the earlier scans and later on as well, after the modulation disappeared.

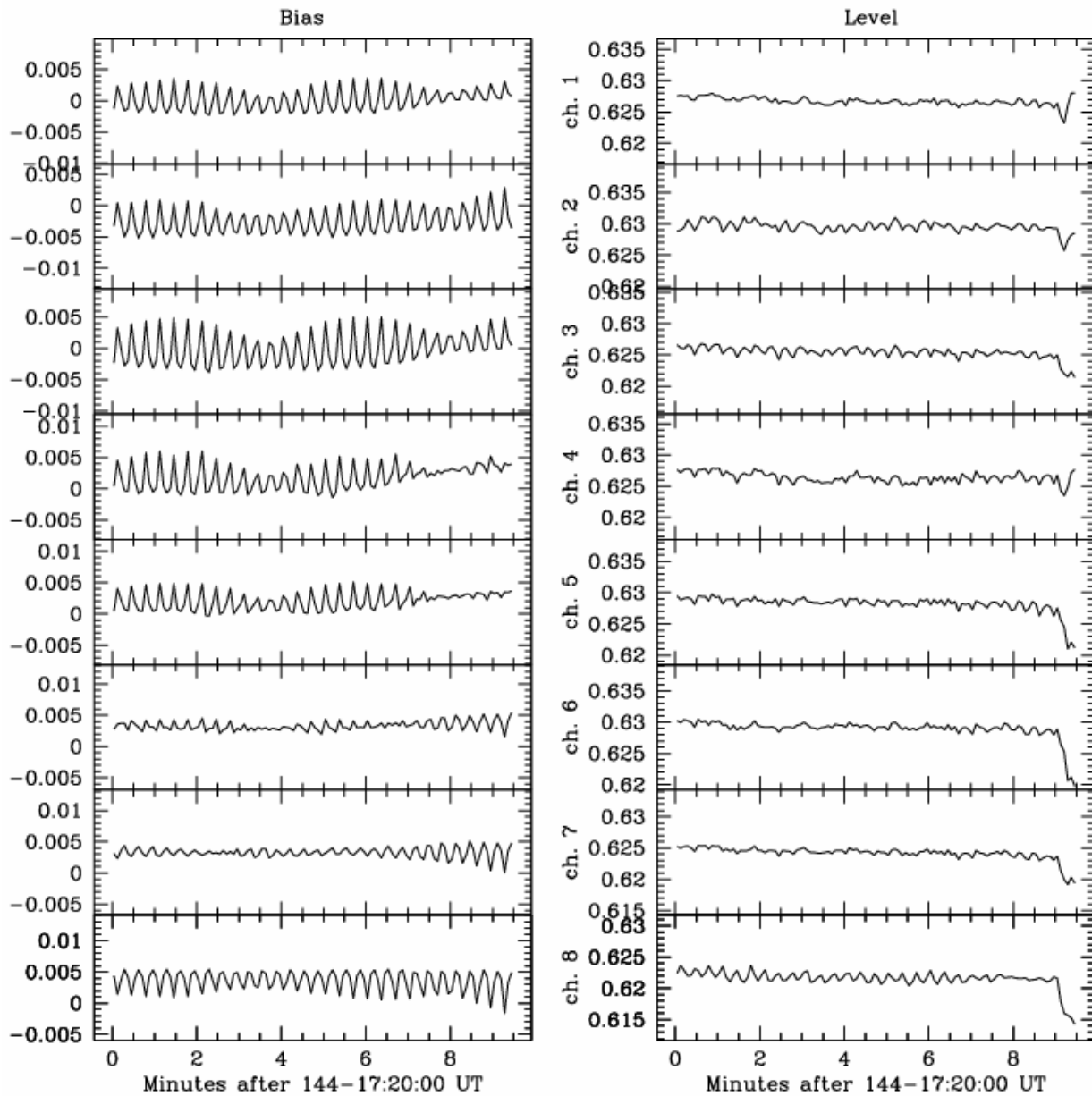


Figure 4. Same as figure 3 except that samples are R-pol.

3. Speculations

As mentioned above, LO modulation does not appear to be a viable explanation for the modulation. Still alive as possibilities are:

1. (complex) gain variations in an amplifier near saturation (the latter condition is necessary to explain the sample bias and pcal amplitude variations), and
2. varying RFI that is periodically overdriving an amplifier, with AM-to-PM conversion causing the pcal phase modulation.

The 1/20-Hz frequency of the modulation is far smaller than the typical 60-Hz-harmonic frequencies caused by defective power supplies. The low frequency is more consistent with a mechanical system of some sort, like a scanning radar antenna. Perhaps someone could check with the Millstone operators to see whether either the 440 or 1295 MHz radar was active during the test.

Before any explanation that involves fluctuations in signal levels can be accepted, the relative weakness of the sample level variations must be understood. Yes, the levels do exhibit 1/20-Hz variations, but they are far smaller than the pcal amplitude or bias variations. Either the putative overdriven amplifier is *so* far overdriven that its output level barely changes as the input level changes, or there is an AGC circuit with time constant <20 seconds somewhere in the system. According to Chris B. and Alan H., there is no AGC in the receiver/UDC/DBE part of the signal path. Mark E. is investigating whether the fiber optic system has one.