Some Q-band Spectral Measurements

R. D. Norrod

September 20, 2005

Introduction

During the maintenance period on September 16, 2005, I ran a series of 60 two-minute scans using the Q-band receiver and the autocorrelation spectrometer. My goal was to study the quality of the spectral baselines over time.

Setup

The GBT was fixed in azimuth at the access elevation. Local time was about 13:00-16:00. Each of the four front-end channels was detected with two ACS high-speed samplers, by using redundant Converter Modules and Sampler/Filter Modules. The ACS was configured in a four bank, two samplers per bank, 800 MHz bandwidth mode. I ran 121 second scans with 10 second integrations. The signal paths are shown in Table 1.

The receiver was at the focus position and observing the sky. The weather was partly cloudy, with temperature about 70F.

Results

To analyze the data, I used glish procedures developed by Fisher, Balser, and myself during the baseline investigation project. The baseline value T_a/T_{sys} is

Table 1: Signal Connections

L1	ODM1	CM1	SF1	Bank A, J1, Sampler 1
	ODM1	CM2	SF2	Bank B, J3, Sampler 1
R1	ODM3	CM5	SF5	Bank A, J2, Sampler 2
	ODM3	CM6	SF6	Bank B, J4, Sampler 2
L2	ODM5	CM11	SF3	Bank C, J5, Sampler 1
	ODM5	CM12	SF4	Bank D, J7, Sampler 1
R2	ODM7	CM15	SF7	Bank C, J6, Sampler 2
	ODM7	CM16	SF8	Bank D, J8, Sampler 2

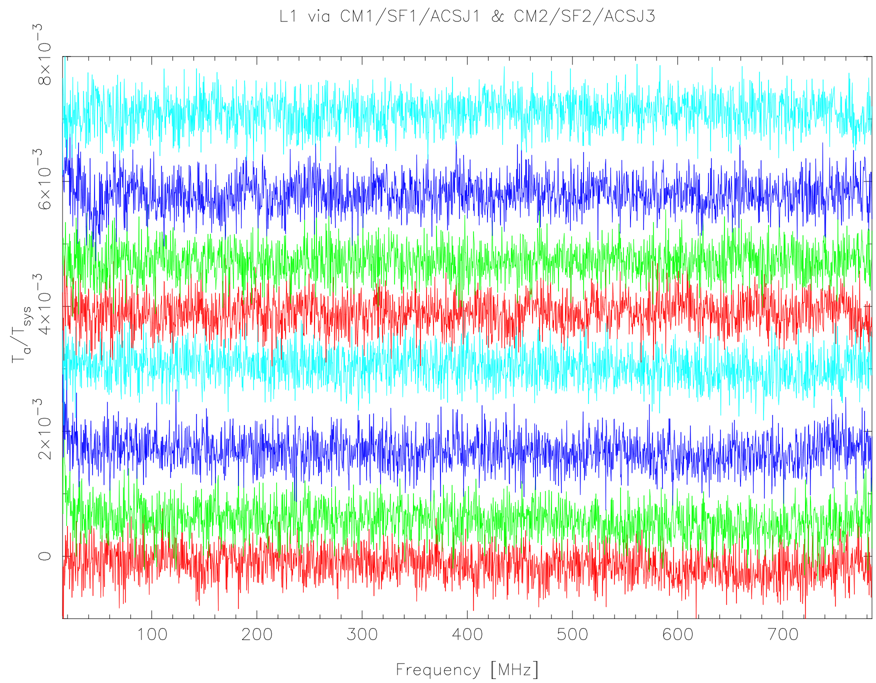

Figure 1: Baseline waterfall plot for Channel L1 during scans 11-15.

calculated on a pair of scans, and corresponds to $(Scan_i - Scan_{i+1})/Scan_{i+1}$. To display the results, baselines for groups of five scans (scans 1-5, 6-10, 11-15, etc.) were plotted and examined, offsetting each trace by 0.001 units for clarity. No mean values are subtracted. On the same plot, the redundant sampler for a channel is plotted, so one sees eight traces. Figure 1 shows an example display for Channel L1 and scans 11-15. Traces of the same color are from the same scan pair, measured on redundant samplers. For an ideal system, traces of the same color will be identical, and all traces will be uniformally spaced by 0.001.

I will now discuss several classes of "disturbances" seen in the baselines.

Converter Rack Ripple

Some baselines showed noticable 60MHz ripple, almost certainly due to variations in the Converter Rack temperature, and previously shown to be due to reflections around the 4-way dividers in the Optical Receiver modules. Figure 2 shows one of the worst instances of this effect. Note that the ripple shows in both samplers.

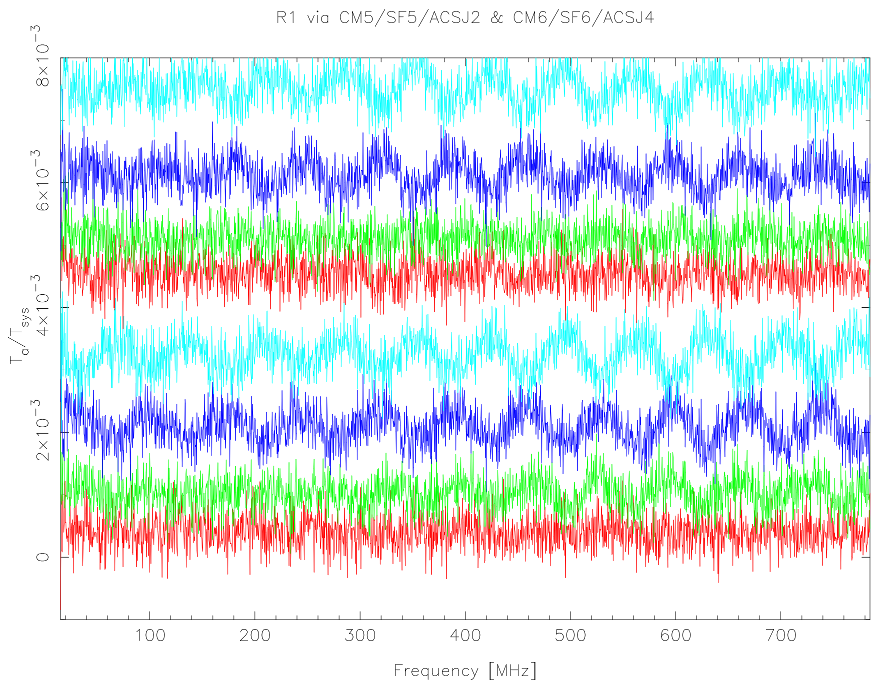

Figure 2: Baseline waterfall plot for Channel R1 during scans 21-25. The ripple with period about 60MHz is due to reflections in the Converter Rack impacted by fluctuations in temperature.

Table 2: Bad ACS Lags

Scan 4	Bank B	Rcvr 2	Phase 2	Integration 6
Scan 30	Bank B	Rcvr 1	Phase 2	Integration 5
Scan 41	Bank B	Rcvr 1	Phase 1	Integration 3
Scan 58	Bank B	Rcvr 1	Phase 2	Integration 10

Bad ACS Lags

Four instances of bad ACS lags were seen during the two hours of taking data. The instances are tabulated in Table 2.

Figure 3 shows the first instance, occuring in the second sampler on Channel R1 during scan 4. The bad lag manifests itself as high frequency ripple in both baselines calculated using scan 4. At the scale plotted, a casual inspection might conclude that the noise level of these two baselines simply increased, yet the autocorrelation function spike near lag 1230 is easily seen in lag space. Figure 4 shows the effect of dropping integration 6 from the baseline calculation. Figure 5 shows another of the bad lag instances.

We are dealing with small number statistics, but it may be worth noting that all the bad lags occurred in bank B. The effects of lag spikes will tend to be reduced as many integrations are averaged, but that also makes it harder to detect the effect in the spectral domain. One might conclude that the noise is simply somewhat higher than expected. We should also note that the baseline ripple period depends on the bad lag number, which I presume could occur anywhere in lag space.

8MHz Ripple in L2

There were three periods of 2-3 scans during which strong ripple appeared in both L2 detectors. Figure 6 shows one instance. The FFT of the L2 baseline shows strong spectral content centered near 8MHz. The FFT of the R2 channel for the same scan pair is also plotted for comparison.

Figure 7 shows a second instance. The lower panel plots the FFT of each baseline in the scan sequence 42-47 to give some sense of the time characteristics of the ripple. You can see that the scan 42-43 baseline (red) is normal, then three pairs show strong ripple, and then the 46-47 pair baseline (magenta) returns to normal.

At the moment I have no idea what caused this type of disturbance. The ripple appeared three times during the two hour observation, and affected 2-3 scans each time. I have found no evidence it is related to the ACS. It showed on one sampler on two different banks simultaneously. Since it was always on the L2 channel it probably originated in the Receiver Room or possibly the fiber IF link.

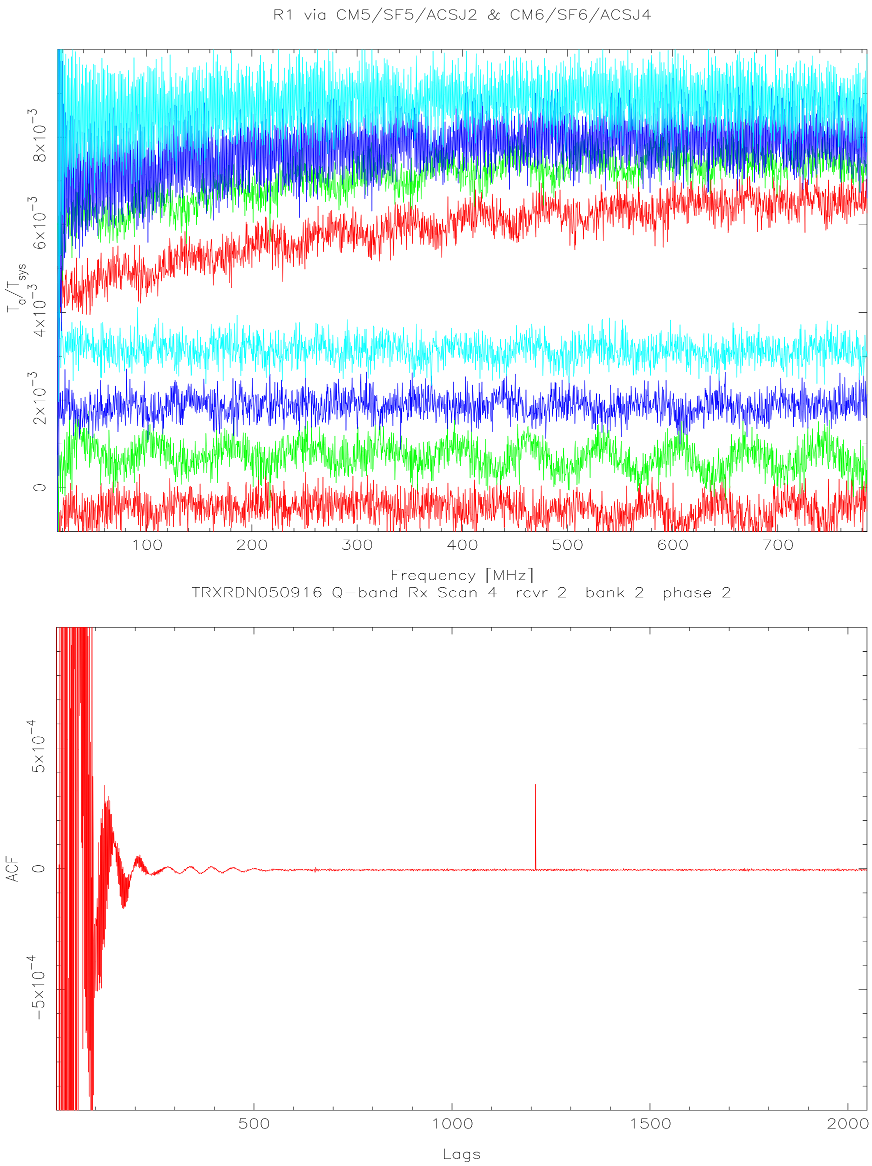

Figure 3: The upper panel shows the baselines for Channel R1 during scans 1-5. The apparent increase in noise in the top two baselines is actually due to a bad lag in scan 4, integration 6. The curvature in the upper set of baselines is not related, and is thought to be simply warm-up of the electronics after the system was configured. The lower panel shows the bad lag during one integration of scan 4.

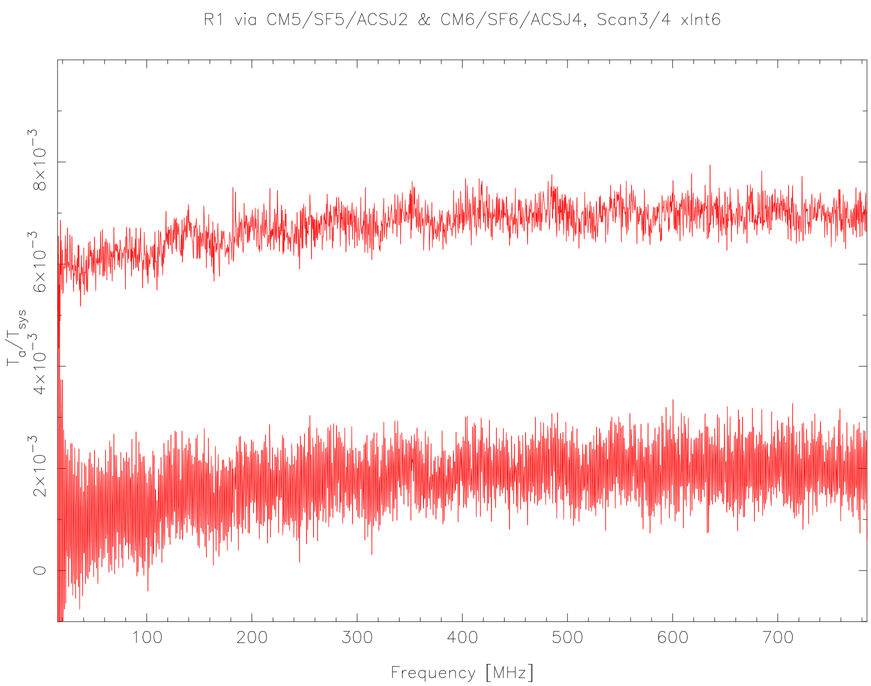

Figure 4: The upper trace is the baseline of scans 3 and 4, with the bad integration omitted. The lower trace includes the bad integration.

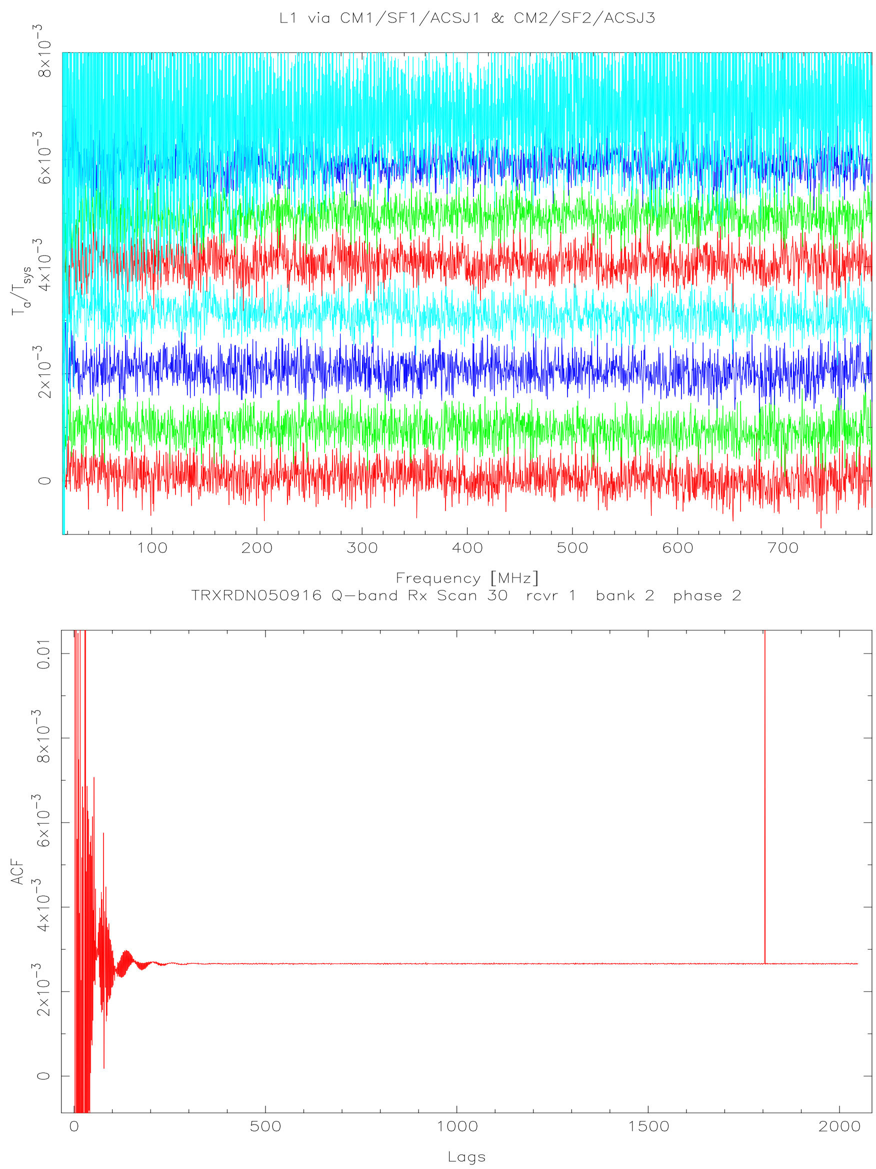

Figure 5: Another bad lag and its impact on the baseline.

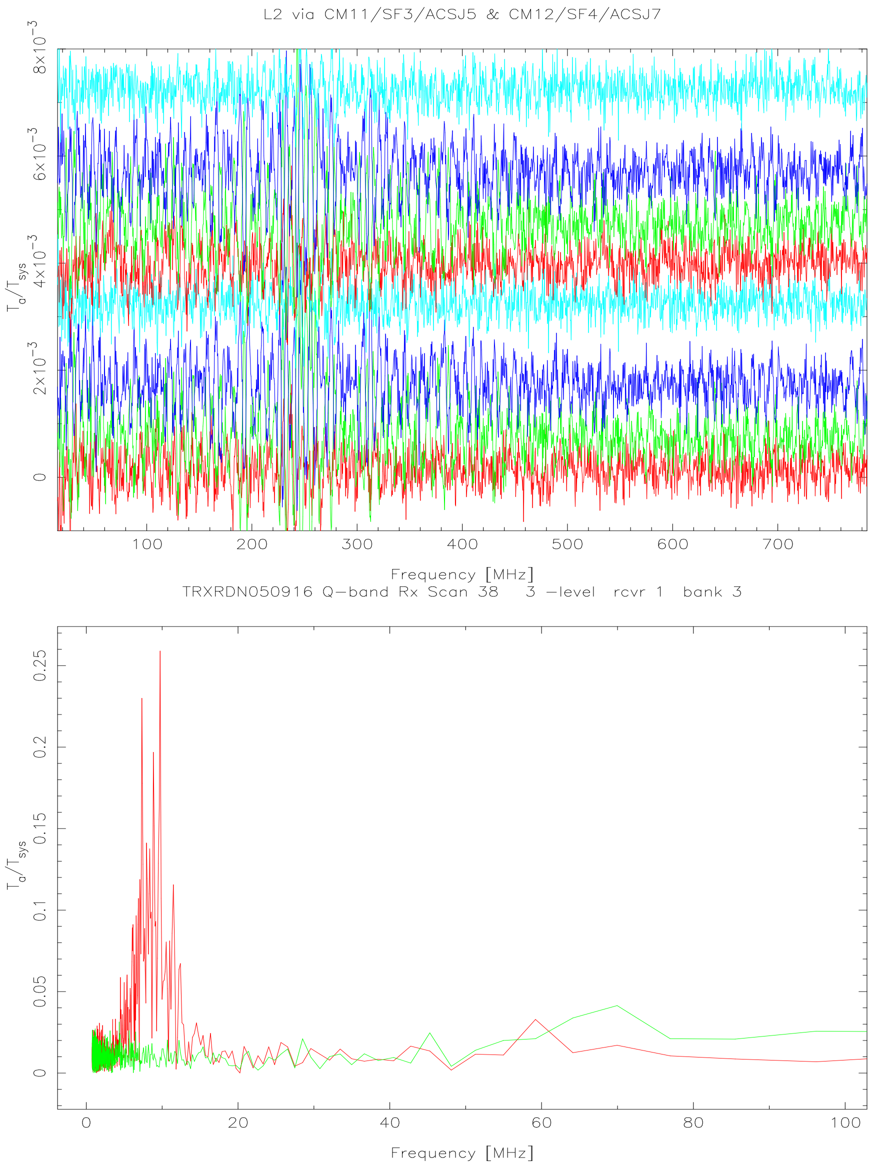

Figure 6: Channel L2 baselines during scans 36-40 are shown in the upper panel. Note spurious ripple shows in both L2 detectors. The lower panel shows FFTs of the scan 37-38 baseline for one L2 sampler (red) and one R2 sampler (green).

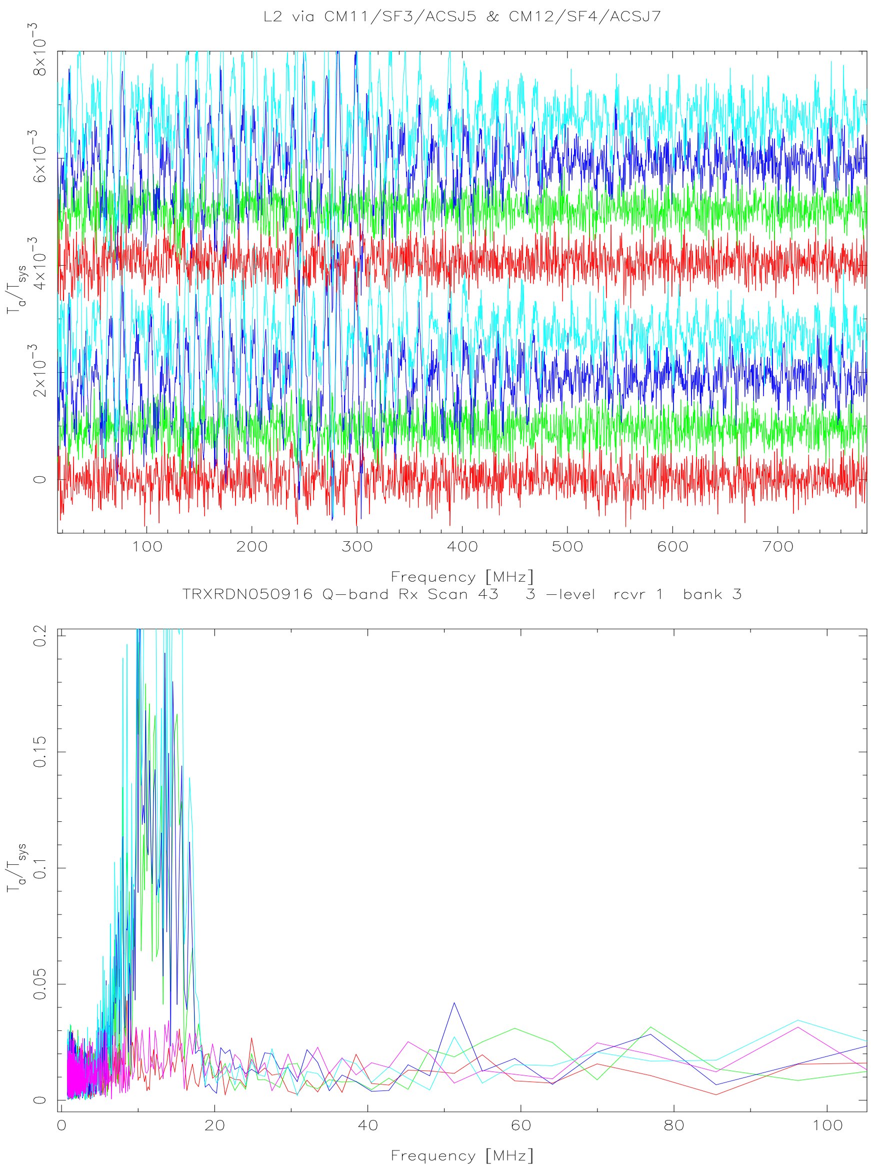

Figure 7: Channel L2 baselines during scans 41-45 are shown in the upper panel. The lower panel shows a sequence of FFTs of the baselines of scans 42-47.

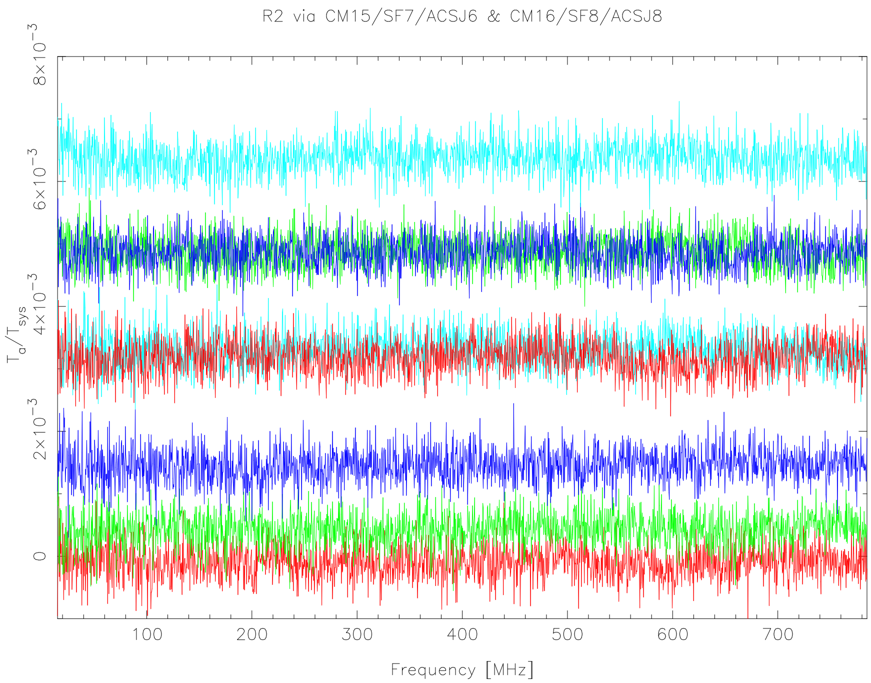

Figure 8: A waterfall plot for channel R2 during scans 11-15. Note the baseline zero offsets vary by about 0.1%.

Baseline Mean Offsets

The final class of disturbances I will illustrate are zero offsets in the mean baseline value. Figure 8 shows an extreme case, the R2 channel during scans 11-15. As noted previously, in an ideal system, the mean value of each baseline is zero - since we plot each subsequent trace offset by 0.001 units, the mean values should fall at multiples of 0.001 on the vertical scale. It can be seen that the offset ranges up to 0.001 during these scans.

The offsets can be caused by several things, including changes in the continuum noise level coming in the feed, changes in the effective receiver noise temperature, or changes in the system gain over the 4 minute period of two scans. In examining the data, we see changes that are correlated between the redundant detectors, and some that are not. I saw no instances of offsets greater than about 0.1%.

Summary

Two hours of spectral line data was taken with the Q-band receiver and analyzed. Several classes of baseline imperfections were seen and discussed in this report. The cause of two classes are known: the 60MHz ripple due to Converter

Rack temperature, and the lag spikes sometimes seen in ACS data. Research is on-going into possible hardware fixes of the 60MHz ripple. There is hope the bad ACS lags will be eliminated by the new LTA design, but in the meantime it seems important for spectral line observers to closely examine their data in lag space. I believe an automated flagging process for this fault is available.

I am not sure how important the baseline zero offsets are to a typical observer. I think it will be difficult to eliminate these completely, and we have no organized investigation into the problem planned.

The 8MHz ripple events in the L2 channel is of unknown cause, and affected about 15% of the two minute scans. Further investigation is probably warranted.