Qband Baselines
Testing in Equipment Room and on GBT
February 13 and 19, 2004

R. D. Norrod

February 25, 2004

Introduction

This report summarizes spectral line data taken on the Q-band receiver when it was recently located in the Equipment Room and then after reinstallation on the GBT. A brief amount of DCR continuum data is also shown. The data sets were taken under projects TBASERDN040213 and TBASERDN040219.

Testing in Equipment Room

On February 13, the receiver was located in the Equipment Room, and the IF output signals for channels under test were connected via coaxial heliax cable to the RF input ports of two Optical Receiver modules, bypassing the fiber photodiode detectors. Each OR was then connected to two Converter and Sampler/Filter modules and hence to the autocorrelation spectrometer (ACS) samplers. The ACS was configured in a two-bank, two samplers per bank, 800MHz bandwidth mode. Unless noted, the ACS integration period was 10 seconds, with 120 second scans. The frequency axis on spectral plots in this report show the ACS baseband frequency. The “sky” center frequency was 43GHz, and the sky frequency increases toward the left. The connections were:

L1	OR1	CM1	SF1	Bank A, J1, Sampler 1
		CM2	SF2	Bank B, J3, Sampler 3
L2	OR3	CM5	SF5	Bank A, J2, Sampler 2
		CM5	SF6	Bank B, J4, Sampler 4

At certain times, channels R1 and R2 were substituted for L1 and L2, as noted below. A styrofoam box containing absorber foam, with or without liquid nitrogen (LN2), was placed over the feed window.

Equipment Room Results

Figure 1 shows initial results for L1 and L2 with a LN2 load over the feed window. Note the quite close correlation between the two parallel IF paths, for both the large-scale and the short-scale ripples. This probably means the changes causing the baseline ripples originate before the splitters in the Optical Receivers, although temperature, power supplies, and frequency references are also common between the parallel chains.

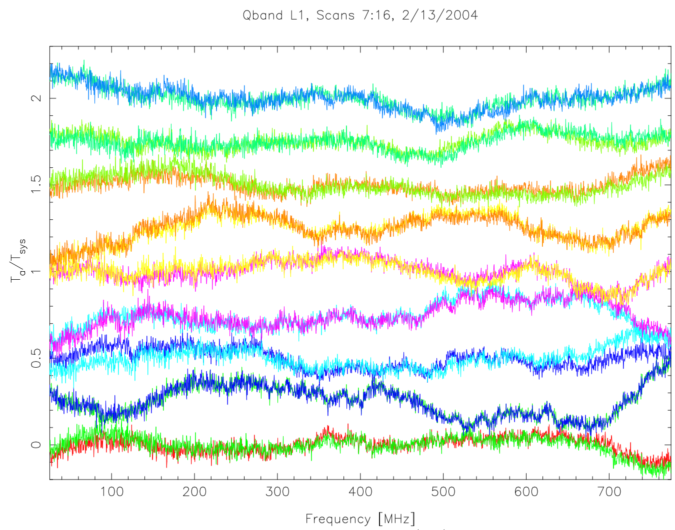
Figure 2 shows initial results for R1 and R2 with a LN2 load over the feed window. Again note the quite close correlation between the two parallel IF paths, for both the large-scale and the short-scale ripples. Noting that the R2 channel exhibits larger amplitude short-term ripples, we plot in Figure 3 the progression of baseline structure for each ten second ACS integration. ("Short-term" loosely refers to ripple periods in the 10-50MHz range.)

We decided to see if adjusting the cryogenic HFET bias in the R2 channel affected the ripple amplitude. The cryo HFET amplifiers in this receiver use InP devices, and those in the first stage come from a wafer referred to as "Cryo3". This wafer typically yields devices that are the lowest noise known, but certain bias irregularities - hysteresis and moding - have been noted at the CDL. Figure 4 shows results for five different combinations of drain voltage and current. From these plots, it certainly appears that the minimum noise bias setting results in much worse baselines. Because of conflicts for access to the ACS and other restraints, the testing on this day then had to be halted.

After some consideration, it was decided to set the bias at one of the settings that provides a compromise in T_{rx}, but away from the T_{min} values. The first stage bias for all four channels was set to $V_{d1} = 1.20V$, $I_{d1} = 1.5mA$. And, because of strong desires to get the receiver into operation and because of the maintenance day scheduling, the receiver was reinstalled on the GBT on February 17.

Testing on the GBT

On February 17, the receiver was reinstalled on the GBT, and on February 19 some test time was available. In addition to checking the receiver's health after the installation, we wanted to try to reproduce the apparent link between HFET bias and baseline ripple seen on the 13th. The ACS was configured in a four-bank, two samplers per bank, 800MHz bandwidth mode. Unless noted, the ACS integration period was 10 seconds, with 60 second scans. The connections were:



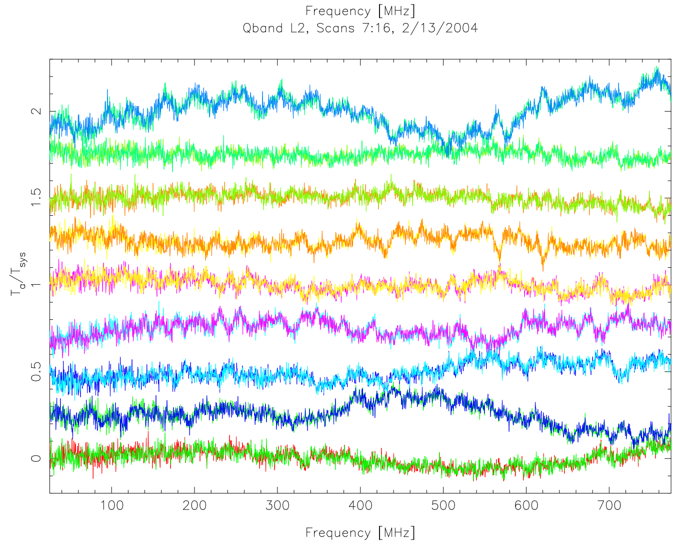


Figure 1: Each of the plots show $(Sig - Ref)/Ref$ taking each of scans 7-15 as Ref and the subsequent scan as Sig. (Scan numbers increase upward.) The vertical scale is multiplied by 100 to express the variations in percent of T_a/T_{sys}, and each trace is offset by 0.25 percent after the mean DC component is subtracted. Data from the parallel IF paths are overlaid in different colors.

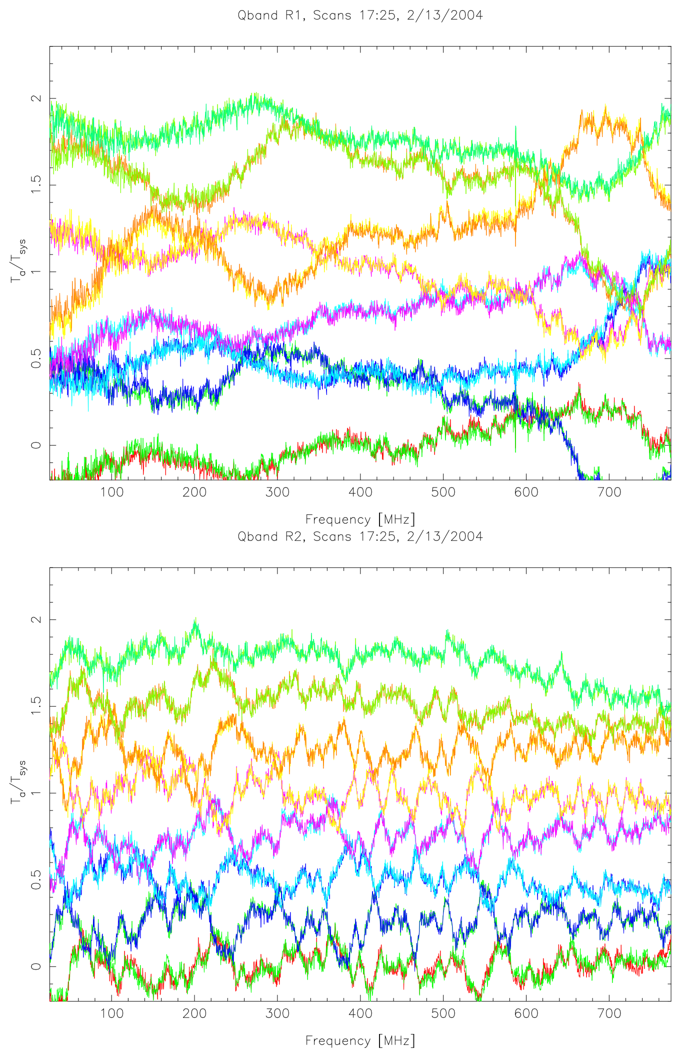


Figure 2: Each of the plots show $(Sig - Ref)/Ref$ taking each of scans 17-24 as Ref and the subsequent scan as Sig. (Scan numbers increase upward.) The vertical scale is multiplied by 100 to express the variations in percent of T_a/T_{sys}, and each trace is offset by 0.25 percent after the mean DC component is subtracted. Data from the parallel IF paths are overlaid in different colors.

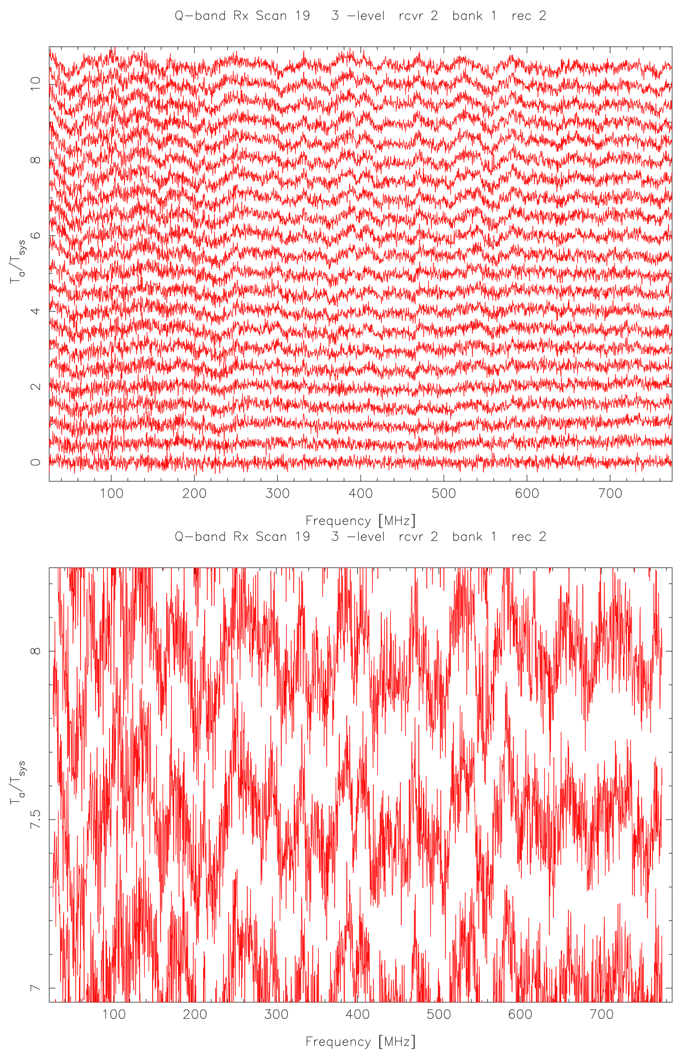
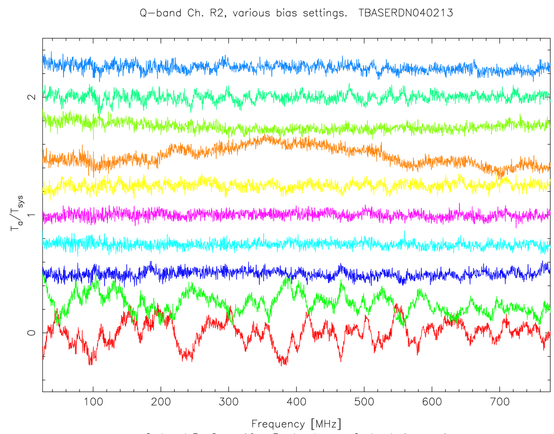


Figure 3: The upper plot shows $(Sig - Ref)/Ref$ taking the first ten-second record of scan 18 (channel R2) as Ref and each records 2-12 of scan 18 and records 1-12 of scan 19 as Sig. (Time progresses upward.) The lower plot is a zoomed portion of the upper. The vertical scale is multiplied by 100 to express the variations in percent of T_a/T_{sys}, and each trace is offset by 0.25 percent after the mean DC component is subtracted.



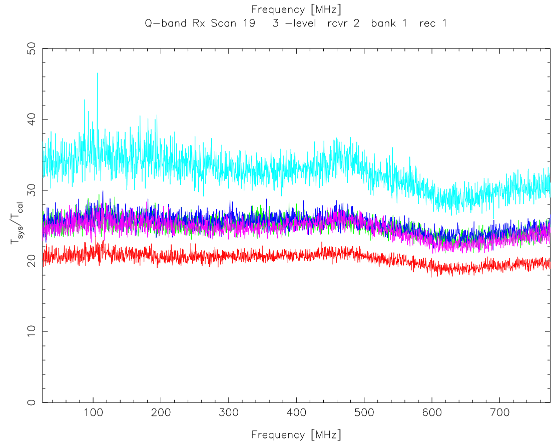


Figure 4: The upper plot shows $(Sig - Ref)/Ref$ for two minute scan pairs with various bias settings on the first stage HFET in channel R2. Baselines from two pairs for each setting are plotted, to give some sense of variations for undisturbed settings. From the bottom, the bias settings were: $V_{d1} = 0.88V$, $I_{d1} = 2.1mA$ (red, green); $V_{d1} = 1.5V$, $I_{d1} = 2.1mA$ (blue, cyan); $V_{d1} = 1.7V$, $I_{d1} = 2.1mA$ (red,yellow); $V_{d1} = 1.70V$, $I_{d1} = 1.0mA$ (brown, green); $V_{d1} = 1.20V$, $I_{d1} = 1.5mA$ (teal,blue). The vertical scale is multiplied by 100 to express the variations in percent of T_a/T_{sys}, and each trace is offset by 0.25 percent after the mean DC component is subtracted. The lower plot shows T_{sys}/T_{cal} for the same set of bias settings. The lowest trace (red) is for the $V_{d1} = 0.88V$, $I_{d1} = 2.1mA$ setting, as recommended by CDL for minimum noise; the upper trace (cyan) is for the $V_{d1} = 1.70V$, $I_{d1} = 1.0mA$ setting. The other three settings yielded similar values between the extremes. To arrive at the receiver temperature, multiply the left scale value by $T_{cal} = 5.5K$, and subtract the LN2 load temperature, about $79K$. Hence, 20 corresponds to $31K$, and 30 to $86K$.

L1	ODM1	OR1	CM1	SF1	Bank A, J1, Sampler 1
			CM2	SF2	Bank B, J3, Sampler 3
R1	ODM3	OR3	CM5	SF5	Bank C, J5, Sampler 5
			CM6	SF6	Bank D, J7, Sampler 7
L2	ODM5	OR5	CM11	SF3	Bank A, J2, Sampler 2
			CM12	SF4	Bank B, J4, Sampler 4
R2	ODM7	OR7	CM15	SF7	Bank C, J6, Sampler 6
			CM16	SF8	Bank D, J8, Sampler 8

Results on the GBT

Figures 5 and 6 show baselines for initial scan sequences taken with the ambient load paddle in place over the feed window. As described in the figure caption, the data for channel R2 was taken at two different bias settings. There appears to be no relationship between the baseline character and the bias settings, unlike the apparent link seen on the 13th.

We then retracted the load paddle so that the receiver was looking at the sky. Figures 7 and 8 show the results. The large structures beginning in scan pair 42-43 and continuing thru scan pair 48-49 appears in similar fashion in all four channels. That may indicate the cause lies with the sky, the weather, or the antenna structure. One notes that the short-period ripples tend to be more prominent during this period also, which is interesting and may be a hint worth pursuing. The Tsys during this sequence of scans is plotted in Figure 9. The two values of Tsys in the R2 channel are due to the different bias settings on the cryo HFET stage 1.

Results Tracking the Sky

We then used a glish procedure to do an off/on pair of scans, on an arbitrary sky position. Each scan was 300 seconds long. The results are shown in Figures 10 and 11. It is clear that the noise does integrate down, but for long integrations the sensitivity in most cases will be limited by the baseline structure.

Finally, we did a few five-minute DCR scans tracking, two in total power with cal mode, and two in switched power with cal. The results are plotted in Figures 12 and 13. The FFT data in Figure 12 clearly shows the 1.2 Hz refrigerator frequency, but the level is probably not significant for most purposes. Comparing the total power and the switched power data in Figure 13, the beam switching does remove some drift, but the L1-L2 data exhibits some bleedthrough. That may be due to gain imbalance before the beam switch, but we did not have time on this day to investigate whether improving the balance (which can be adjusted remotely) would improve the switching performance.

Summary

There are several points that seem worth noting:

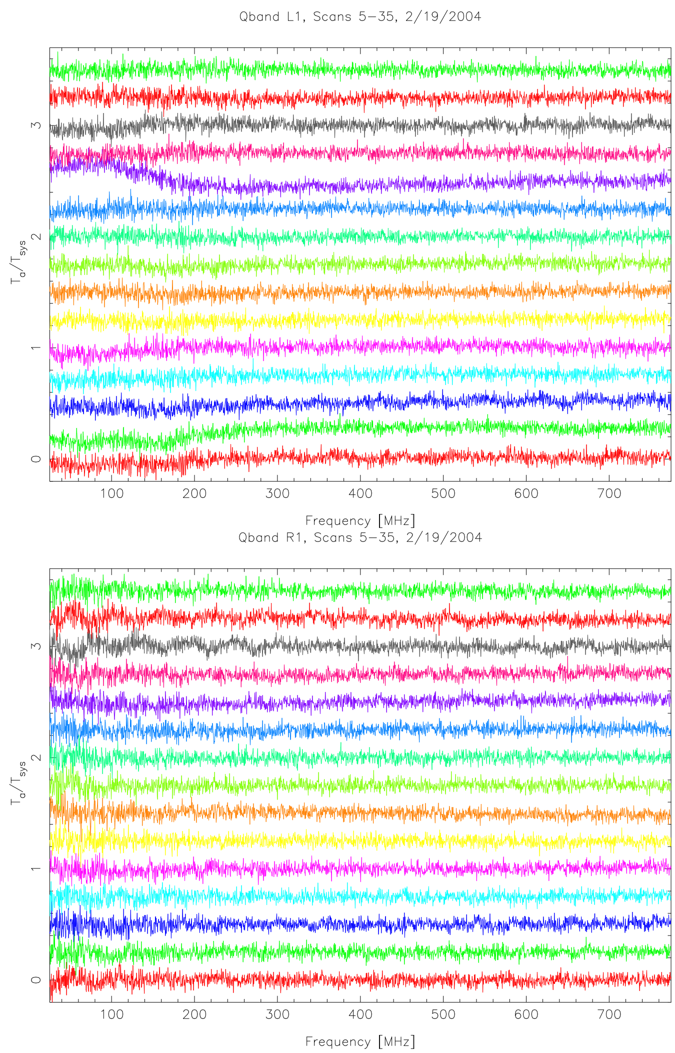


Figure 5: Each of the plots show $(Sig - Ref)/Ref$ taking odd-numbered scans as Ref and the subsequent even numbered scan as Sig. (Scan numbers increase upward.) The vertical scale is multiplied by 100 to express the variations in percent of T_a/T_{sys}, and each trace is offset by 0.25 percent after the mean DC component is subtracted. The receiver ambient load was over the feed window. The top panel is channel L1 and the lower panel is channel R1.

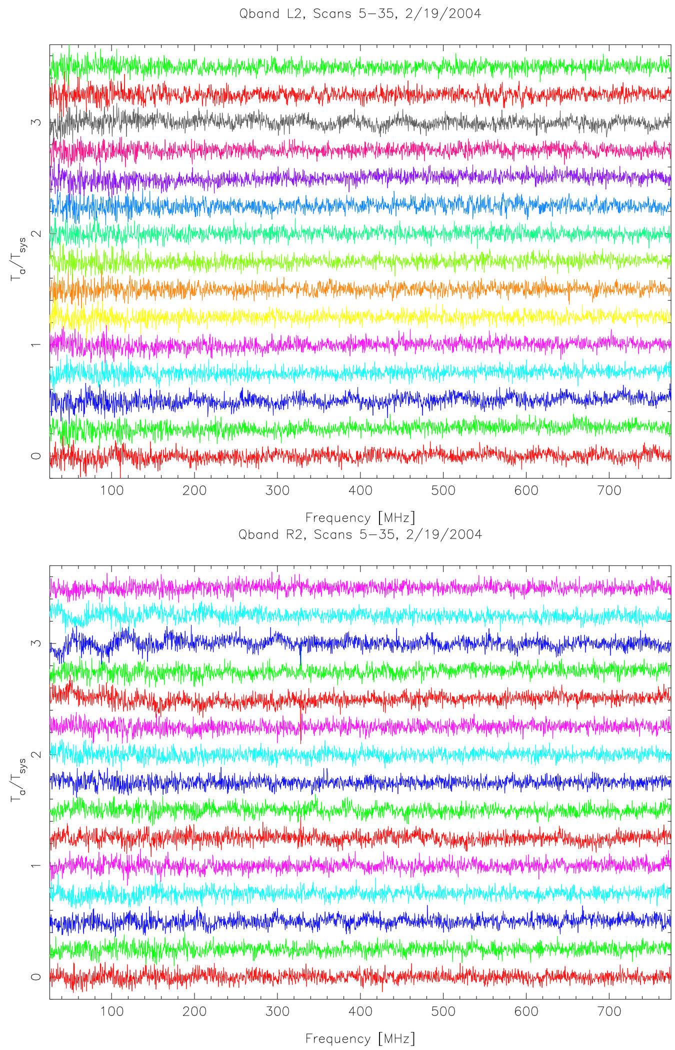


Figure 6: Each of the plots show $(Sig - Ref)/Ref$ taking odd-numbered scans as Ref and the subsequent even numbered scan as Sig. (Scan numbers increase upward.) The vertical scale is multiplied by 100 to express the variations in percent of T_a/T_{sys}, and each trace is offset by 0.25 percent after the mean DC component is subtracted. The receiver ambient load was over the feed window. The top panel is channel L2 and the lower panel is channel R2. The R2 data was taken with two different bias settings. The bottom five traces with $V_{d1} = 1.20V$, $I_{d1} = 1.5mA$; the middle five traces with $V_{d1} = 0.89V$, $I_{d1} = 2.1mA$; and the top five with the first settings again.

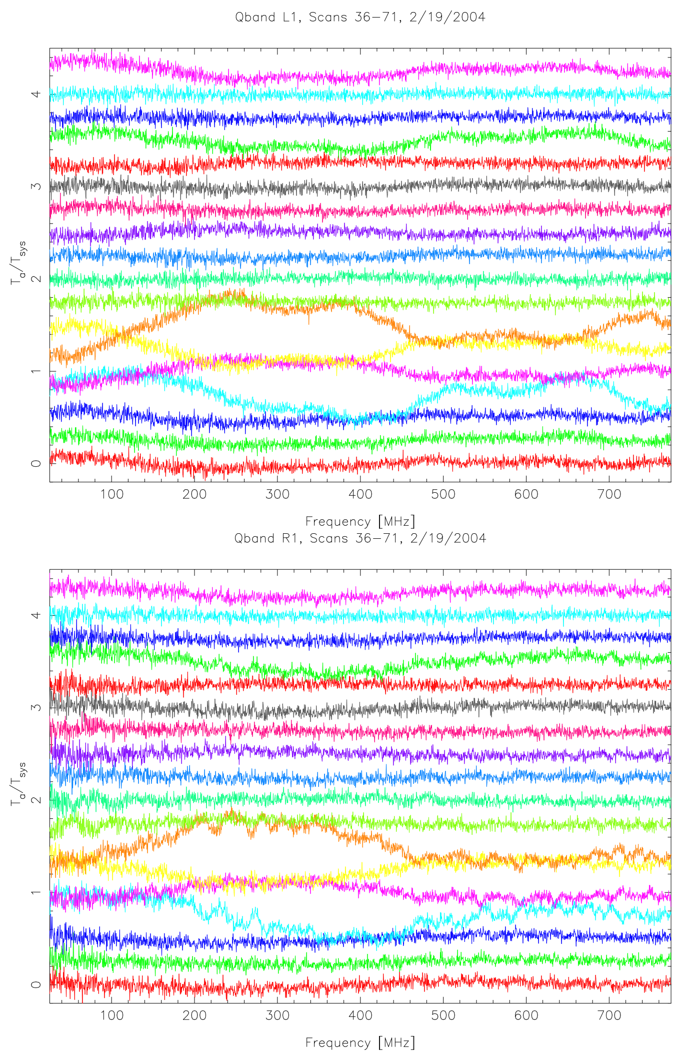


Figure 7: Each of the plots show $(Sig - Ref)/Ref$ taking odd-numbered scans as Ref and the subsequent even numbered scan as Sig. (Scan numbers increase upward.) The vertical scale is multiplied by 100 to express the variations in percent of T_a/T_{sys}, and each trace is offset by 0.25 percent after the mean DC component is subtracted. The ambient load paddle was retracted so the receiver was looking at the sky at the access elevation of 77 degrees. The top panel is channel L1 and the lower panel is channel R1.

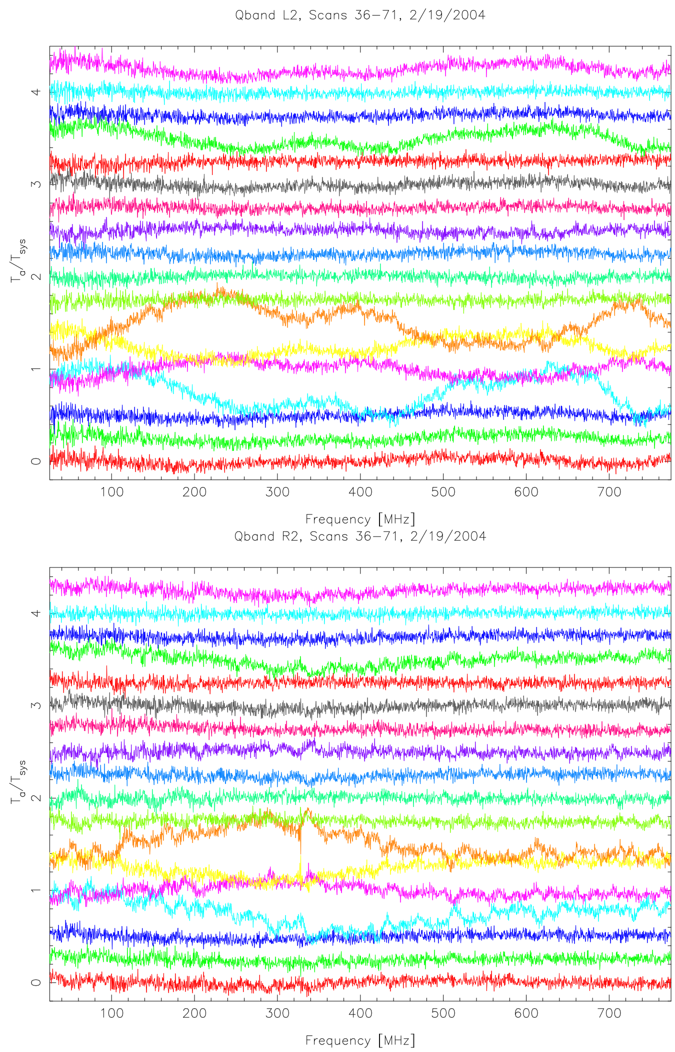


Figure 8: Each of the plots show $(Sig - Ref)/Ref$ taking odd-numbered scans as Ref and the subsequent even numbered scan as Sig. (Scan numbers increase upward.) The vertical scale is multiplied by 100 to express the variations in percent of T_a/T_{sys}, and each trace is offset by 0.25 percent after the mean DC component is subtracted. The ambient load paddle was retracted so the receiver was looking at the sky at the access elevation of 77 degrees. The top panel is channel L2 and the lower panel is channel R2. The R2 data was taken with various bias settings. The bottom five traces with $V_{d1} = 1.20V$, $I_{d1} = 1.5mA$; the next four traces with $V_{d1} = 0.89V$, $I_{d1} = 2.1mA$; the next two traces with $V_{d1} = 0.89V$, $I_{d1} = 2.6mA$; and the top seven traces with the first settings again.

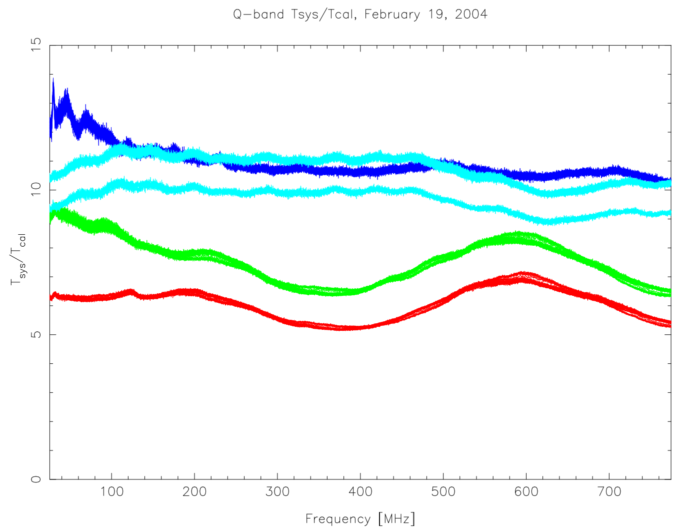


Figure 9: T_{sys}/T_{cal} for all scans 36-71 are overlaid in this plot. Channel L1 (red), L2 (green), R1 (blue), and R2 (cyan). The separated values of R2 are due to the different bias settings used during the scan sequence.

- The generally poor baselines seen in the Equipment Room looking at a LN2 load may indicate that load instabilities dominated, since the baselines were much improved looking at the ambient load or the sky.
- The short period (less than 50MHz period) structure at first suspected to be related to HFET bias could not be reconfirmed on the antenna, so for now I assume they are not related.
- Data taken on the sky did exhibit long period variations from time to time (Figures 7 and 8), and these appeared to be correlated in all four channels. That may indicate they were related to the sky, the weather, or the antenna structure. As shown in Figure 14, the air temperature was fairly stable during the test period, but the wind was gusty. Could feedarm sway due to wind gusts affect the baselines in the way seen?
- The short period baselines on the sky seemed to get more prevalent in scans with the long period structure. However, the short period features tend to be more bothersome, and probably will ultimately limit the spectral sensitivity.
- There is remarkable correlation in baseline structure between parallel IF channels (parallel after the splitters in the Optical Receivers). This was seen both on the GBT and in the Equipment Room (when the IF Rack and fiber links are not in play). That implies that the baselines originate in the front-end.

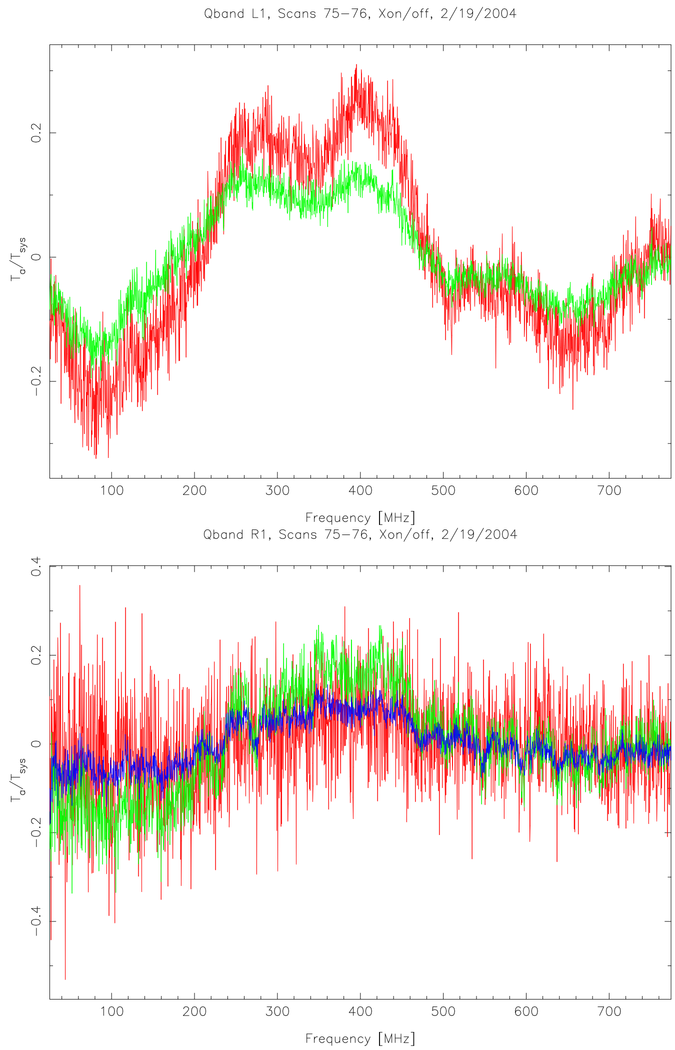


Figure 10: $(Sig - Ref)/Ref$ taking scan 75 as Ref and scan 76 as Sig. The vertical scale is multiplied by 100 to express the variations in percent of T_a/T_{sys}, and the mean DC component is subtracted. The GBT was tracking J2000 position 01:31:00, 47:00:00 (on scan). In the upper panel (channel L1), the red trace is calculated using only the first minute of data from each scan, while the green trace uses all five minutes. In the lower panel, the red trace uses only the first ten seconds from each scan, the green trace the first minute, and the blue trace all five minutes of data. Note that the vertical scale is different in the two panels.

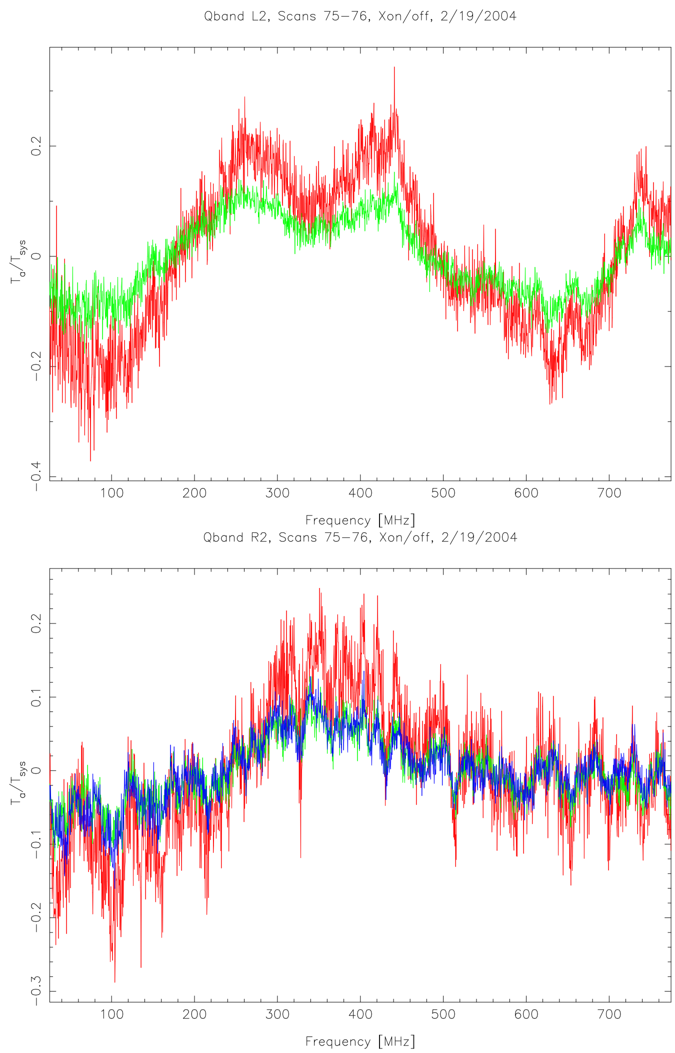


Figure 11: $(Sig - Ref)/Ref$ taking scan 75 as Ref and scan 76 as Sig. The vertical scale is multiplied by 100 to express the variations in percent of T_a/T_{sys}, and the mean DC component is subtracted. The GBT was tracking J2000 position 01:31:00, 47:00:00 (on scan). In each panel, the red trace is calculated using only the first minute of data from each scan, while the green trace uses all five minutes. The blue trace in the R2 panel is the baseline from data taken through the parallel IF path (via CM16).

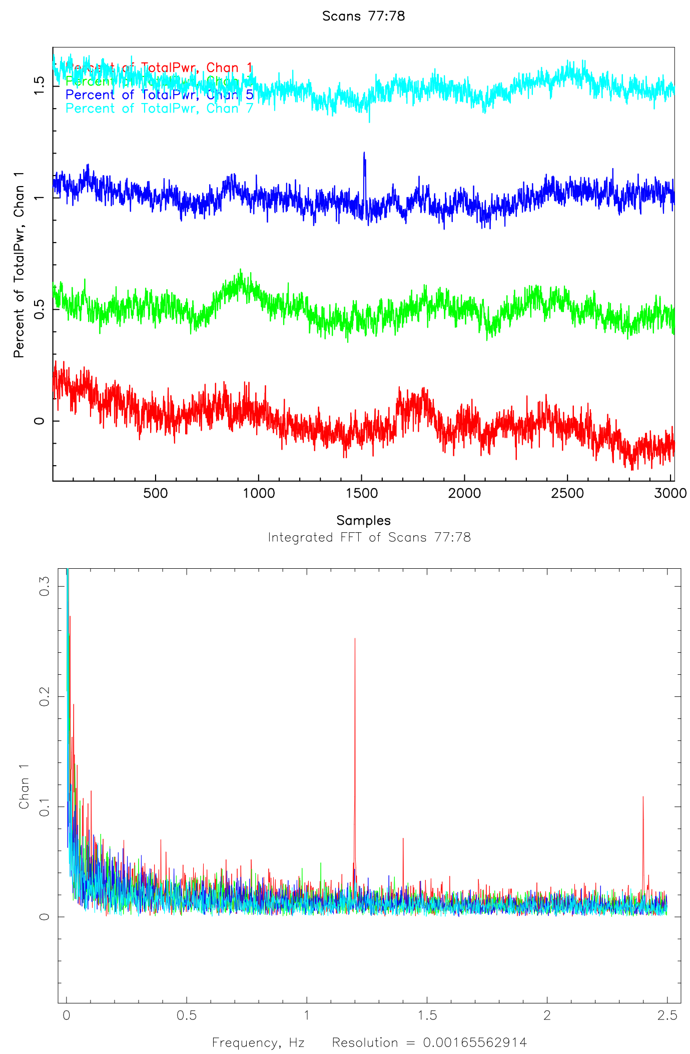


Figure 12: DCR continuum data as the GBT tracked. Channel L1 (red), R1 (green), L2 (blue), and R2 (cyan). In the upper panel, $100(TP - Mean)/Mean$ is plotted where TP is the average of the Cal On and Cal Off phases for each sample, and $Mean$ is taken over the entire 10 minute period. The traces are offset by 0.5 for clarity. The integration period is 0.2 seconds, and the RF detected bandwidth is 1280MHz. The DCR mode was TPwCal. The lower panel shows the same data transformed by the FFT.

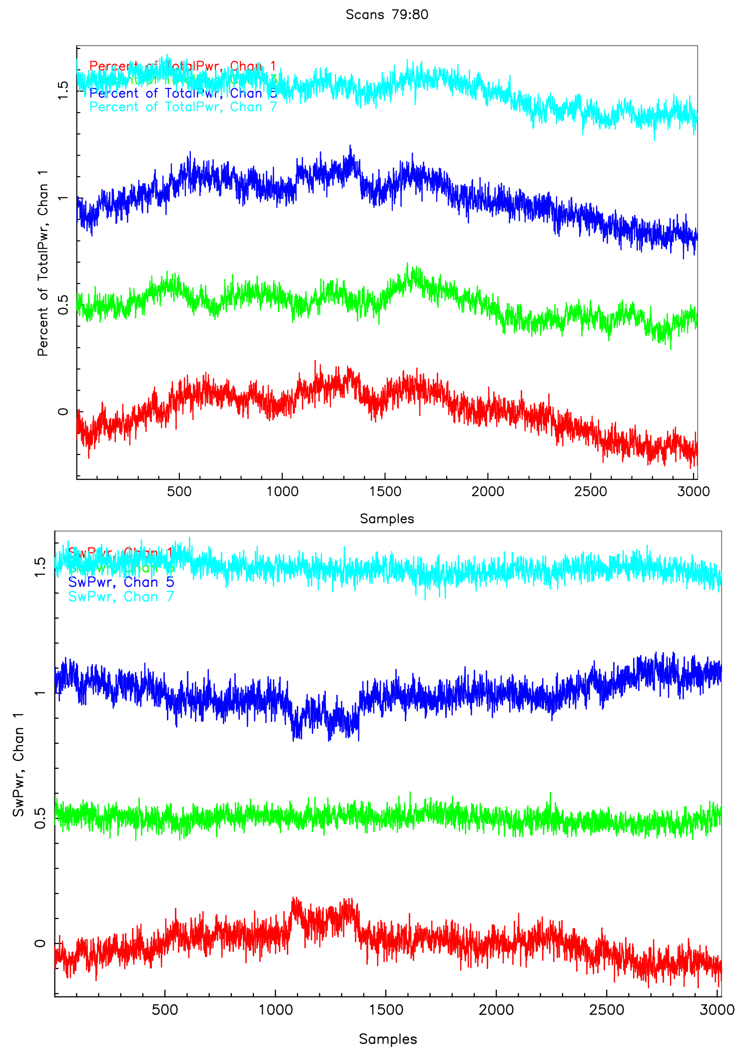


Figure 13: DCR continuum data as the GBT tracked. Channel L1 (red), R1 (green), L2 (blue), and R2 (cyan). In the upper panel, $100(TP - Mean)/Mean$ is plotted where TP is the average of the four phases for each sample, and $Mean$ is taken over the entire 10 minute period. The traces are offset by 0.5 for clarity. The integration period is 0.2 seconds, and the RF detected bandwidth is 1280MHz. The DCR mode was SwPwrCal (the receiver beam switches were running). The lower panel shows the switched power data during the same period.

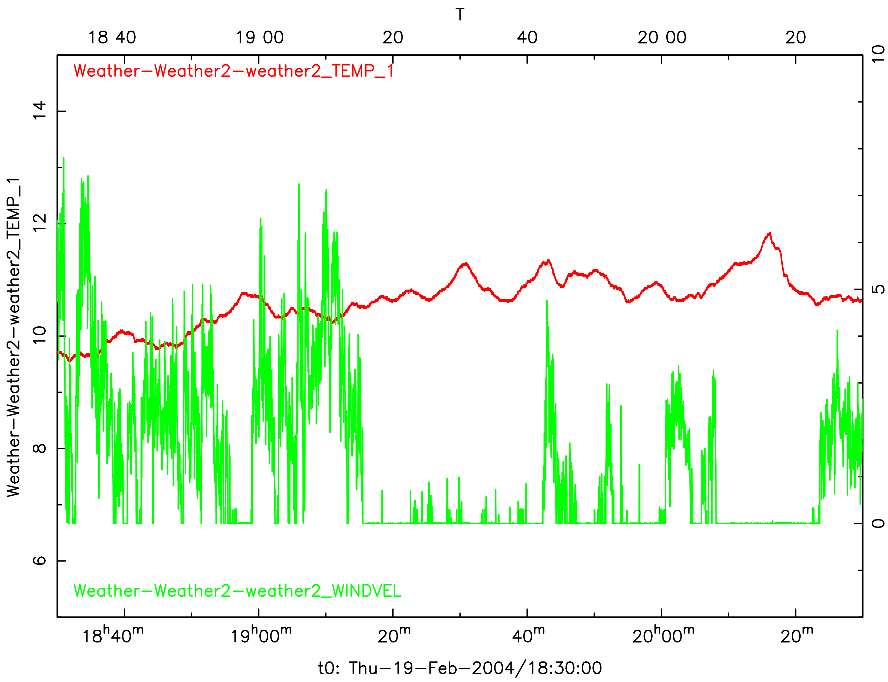


Figure 14: The air temperature (C) and wind speed (m/s, right axis) measured near the GBT during the period of the measurements taken on the sky.

Before our work in February on the receiver, we used the fact a couple of channels were consistantly much worse than the others to determine that a problem lay within the dewar. We replaced a LO Multiplier and cleared a couple of other problems, and now all four behave similarly. Further progress will be difficult.