Q-band Spectral Baseline Performance
Project TBASE_051222

Dana S. Balser

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Introduction

During early science observations in Fall 2005 several observers[1] noticed poor spectral baseline performance from the Q-band (40-50 GHz) receiver. Investigation revealed intermittent, irregular baseline structure with ripple periods typically between 10-40 MHz in all channels with L1 having the best baselines and R2 having the worst. This structure sometimes blends with the known 50-60 MHz structure that resides in the equipment room. Inspection of previous Q-band spectral line data revealed that these baseline features did exists but less frequently.

Various tests by Roger Norrod[2] have isolated the baseline structure between the front-end beam switch and the feed. The feeds are cooled and reside within the dewar while the beam switch is at room temperature. The spectral baseline structure at Q-band is qualitatively different than baseline structure that has been previously studied with most GBT receivers. The Q-band baselines are similar to spectral baseline problems that have been detected with the new Ka-band (26-40 GHz) receiver by Brian Mason and Larry Morgan[3], however. Both the Q and Ka-band receivers are unique at Green Bank in that both have cooled feeds. One hypothesis is that the baseline structure is due to reflections between the feed, window, and cryostat walls. To test this hypothesis requires that we move the receiver to the lab for testing.

The goal of this report is to better characterize the baseline structure for astronomical observations. In particular, what is the performance at different bandwidths over longer integrations.

Observations and Results

We performed astronomical observations on cold sky on 22 December 2005 under good weather conditions during the daytime. The Spectrometer was configured in three different modes using bandwidths of 800 MHz (Table 1), 200 MHz

[1]Nissim Kanekar (GBT05C-043) and Jeff Wagg (GBT02A-066).
[2]http://wiki.gb.nrao.edu/bin/view/Projects/QBandUpgradeDesignReview.
[3]See http://wiki.gb.nrao.edu/bin/view/Projects/KaCommSumm_Baselines_05.

Table 1: $BW = 800\,\mathrm{MHz}; N_{\mathrm{chan}} = 2048; \Delta\nu = 390\,\mathrm{kHz}$)

BACKEND	BANK	PORT	FEED	POL	SIDEBAND	SKY FREQ	BANDWIDTH
Spectrometer	A	1	1	L	U	4.30029824e+10	800000000
Spectrometer	A	2	1	R	U	4.30029824e+10	800000000
Spectrometer	B	3	1	L	U	4.30029824e+10	800000000
Spectrometer	B	4	1	R	U	4.30029824e+10	800000000
Spectrometer	C	5	2	L	U	4.30029824e+10	800000000
Spectrometer	C	6	2	R	U	4.30029824e+10	800000000
Spectrometer	D	7	2	L	U	4.30029824e+10	800000000
Spectrometer	D	8	2	R	U	4.30029824e+10	800000000

Table 2: $BW = 200\,\mathrm{MHz}; N_{\mathrm{chan}} = 8192; \Delta\nu = 24.4\,\mathrm{kHz}$

BACKEND	BANK	PORT	FEED	POL	SIDEBAND	SKY FREQ	BANDWIDTH
Spectrometer	A	1	1	L	U	4.30029619e+10	200000000
Spectrometer	A	2	1	R	U	4.30029619e+10	200000000
Spectrometer	B	3	1	L	U	4.30029619e+10	200000000
Spectrometer	B	4	1	R	U	4.30029619e+10	200000000
Spectrometer	C	5	2	L	U	4.30029619e+10	200000000
Spectrometer	C	6	2	R	U	4.30029619e+10	200000000
Spectrometer	D	7	2	L	U	4.30029619e+10	200000000
Spectrometer	D	8	2	R	U	4.30029619e+10	200000000

(Table 2), and 50 MHz (Table 3). All observations used total power position switching on cold sky with a scan duration of 120 seconds (twelve, 10 second integrations) with a total of 24 OffOn pairs for each Spectrometer mode.

The data were reduced with GBTIDL[4]. The antenna temperature is calculated in Kelvins using $\frac{ON-OFF}{OFF}\,T_{\mathrm{sys}}$ where ON and OFF are the total power on and off the target cold sky position and T_{sys} is the total system temperature. Examples of the 800 MHz bandwidth data are shown in Figures 1-2 for each feed and polarization. Consecutive OffOn pairs are plotted from bottom to top. The intermittent behavior is obvious. Channel L1 produces the best baselines.

Averaged data are shown for channel R2 in Figures 3, 5, and 7 for bandwidths of 800 MHz, 200 MHz, and 50 MHz, respectively. Plotted are data averaged over 1, 4, 16, and 24 OffOn pairs from bottom to top. Clearly the baseline structure integrates down with time even though some baseline structure always remains. The lower panel in each figure shows the power spectrum, indicating the plethora of signals above 10 MHz. Figure 4 plots the observed rms noise with the expected theoretical noise versus integration time. The three panels plot the rms over the entire 800 MHz band, the inner 200 MHz, and the inner 50 MHz from top to bottom. The noise does integrate down with time but the rms values are typically a factor of two larger than expected after 1.6 hours. Channel L1 has the best performance while channel R2 has the worst performance. Figures 6 and 8 show similar plots for the 200 MHz and 50 MHz spectrometer mode data. The data have not been smoothed. The spectral resolution is better in these

[4]Currently the data are Hanning smoothed.

Table 3: $BW = 50\,\mathrm{MHz}; N_{\mathrm{chan}} = 4096; \Delta\nu = 12.2\,\mathrm{kHz}$

BACKEND	BANK	PORT	FEED	POL	SIDEBAND	SKY FREQ	BANDWIDTH
Spectrometer	A	9	1	L	L	4.30029373e+10	50000000
Spectrometer	A	10	1	L	L	4.30029373e+10	50000000
Spectrometer	A	13	1	R	L	4.30029373e+10	50000000
Spectrometer	A	14	1	R	L	4.30029373e+10	50000000
Spectrometer	B	17	1	L	L	4.30029373e+10	50000000
Spectrometer	B	18	1	L	L	4.30029373e+10	50000000
Spectrometer	B	21	1	R	L	4.30029373e+10	50000000
Spectrometer	B	22	1	R	L	4.30029373e+10	50000000
Spectrometer	C	25	2	L	L	4.30029373e+10	50000000
Spectrometer	C	26	2	L	L	4.30029373e+10	50000000
Spectrometer	C	29	2	R	L	4.30029373e+10	50000000
Spectrometer	C	30	2	R	L	4.30029373e+10	50000000
Spectrometer	D	33	2	L	L	4.30029373e+10	50000000
Spectrometer	D	34	2	L	L	4.30029373e+10	50000000
Spectrometer	D	37	2	R	L	4.30029373e+10	50000000
Spectrometer	D	38	2	R	L	4.30029373e+10	50000000

data with many more channels across the 200 MHz and 50 MHz bands. Hence the rms values are better with many more channels between the 10-40 MHz baseline structure.

Conclusions

The spectral baselines at Q-band have been characterized under typical astronomical conditions. Intermittent, irregular baseline structure with scales between 10-40 MHz persists in all channels. Because this baseline structure changes on short timescales the noise does integrate down close to theoretical values; although the baseline structure always remains at some level over at least 1.6 hours. Astronomical observations with spectral features with a known center frequency and with line-widths less than 10 MHz are possible with the current system.

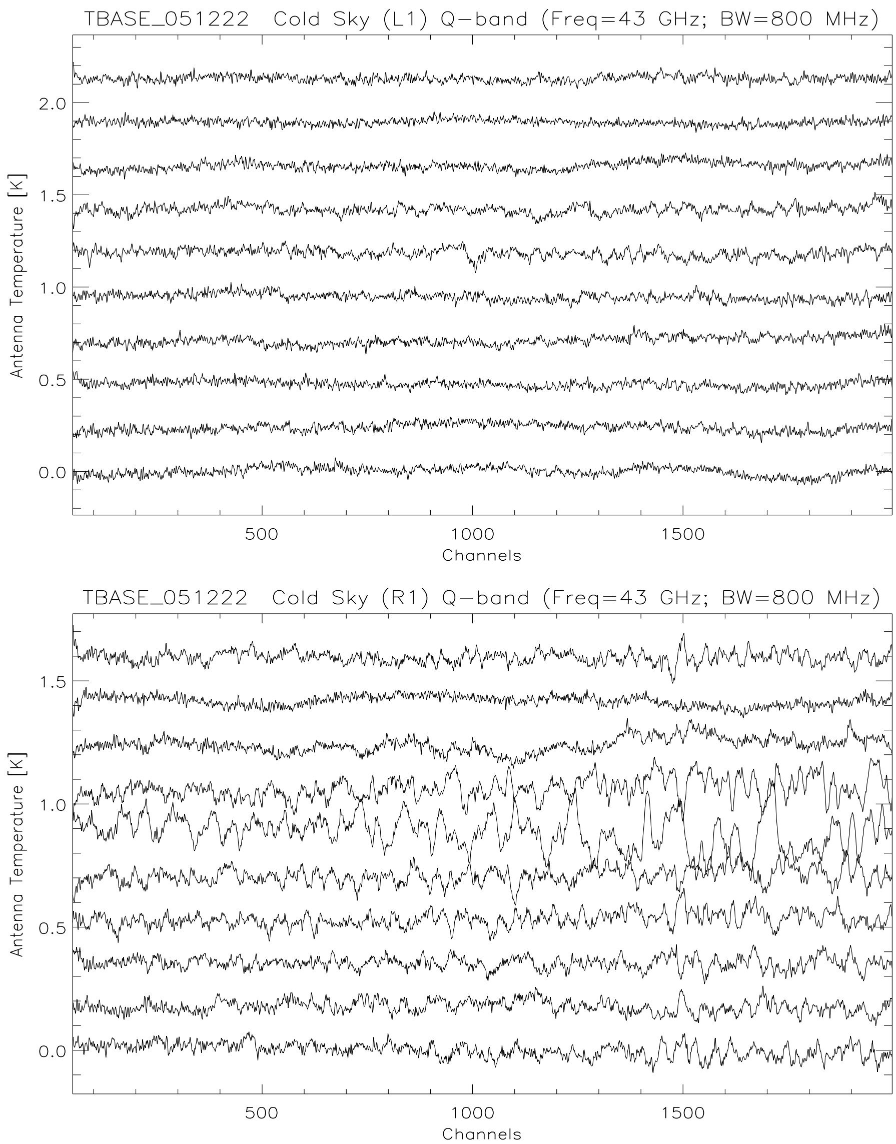

Figure 1: Waterfall plots of the antenna temperature for consecutive OffOn pairs using the 800 MHz bandwidth Spectrometer mode. Data are plotted from bottom to top. Upper panel: channel L1. Lower panel: channel R1.

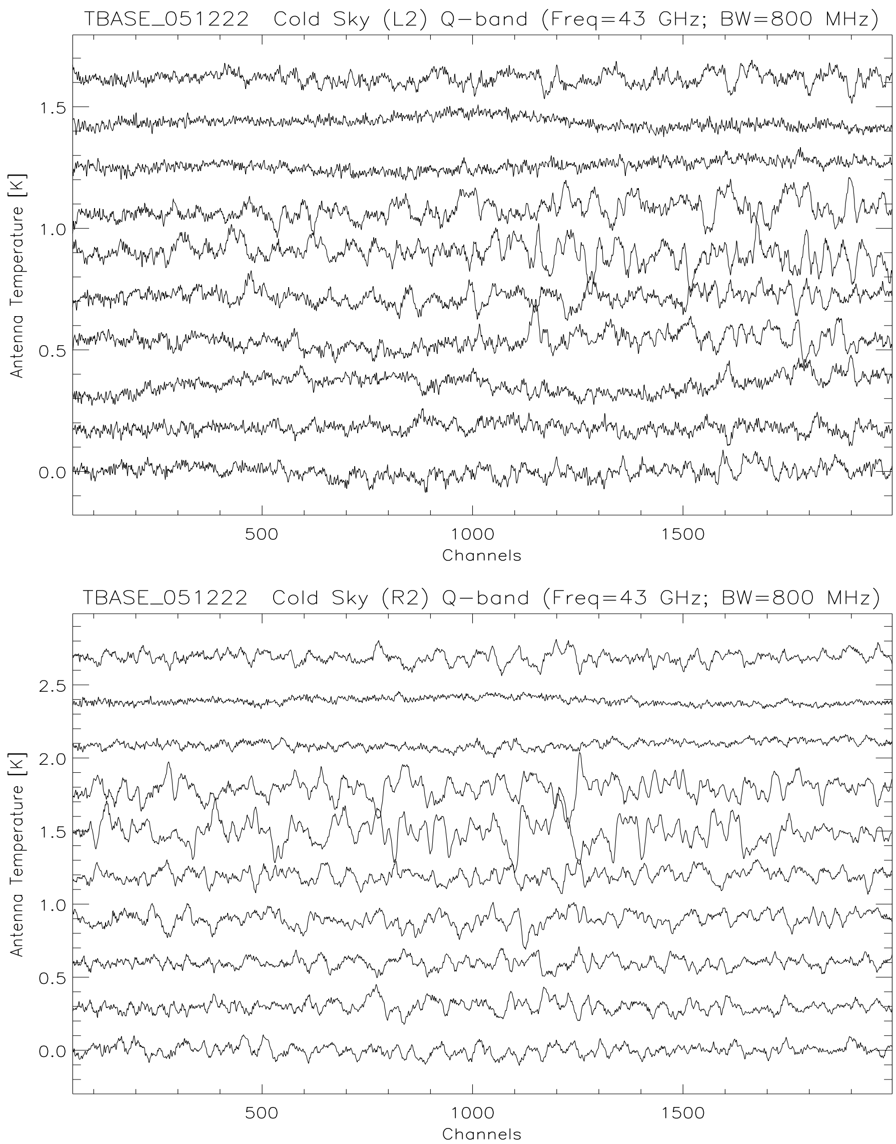

Figure 2: Waterfall plots of the antenna temperature for consecutive OffOn pairs using the 800 MHz bandwidth Spectrometer mode. Data are plotted from bottom to top. Upper panel: channel L2. Lower panel: channel R2.

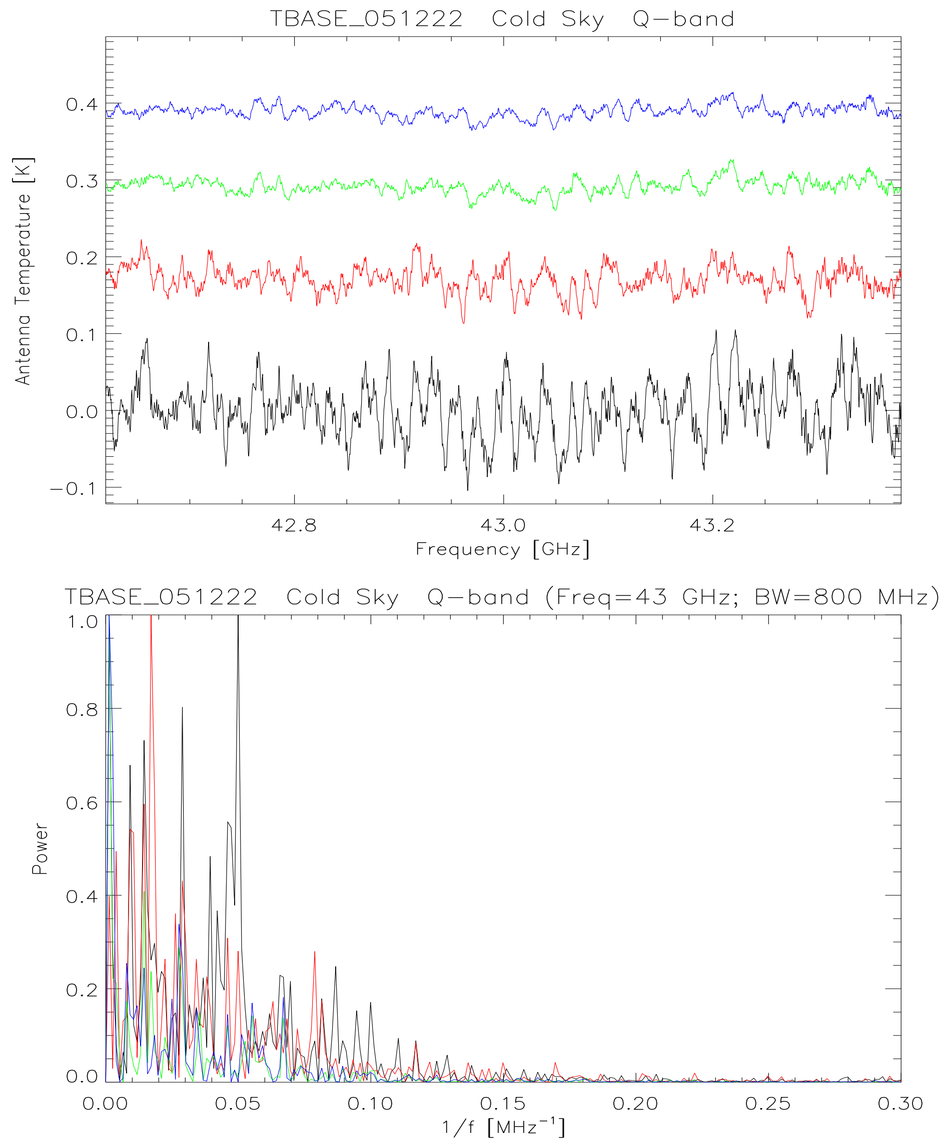

Figure 3: Averaged spectra using the 800 MHz bandwidth spectrometer mode. Upper panel: antenna temperature averaged over 1 (black), 4 (red), 16 (green), and 24 (blue) OffOn pairs plotted from bottom to top. The rms noise across the entire band, neglecting the edges, is 36 mK, 17 mK, 9.5 mK, and 8.3 mK from bottom to top. Bottom panel: power spectra for the spectra in the top panel.

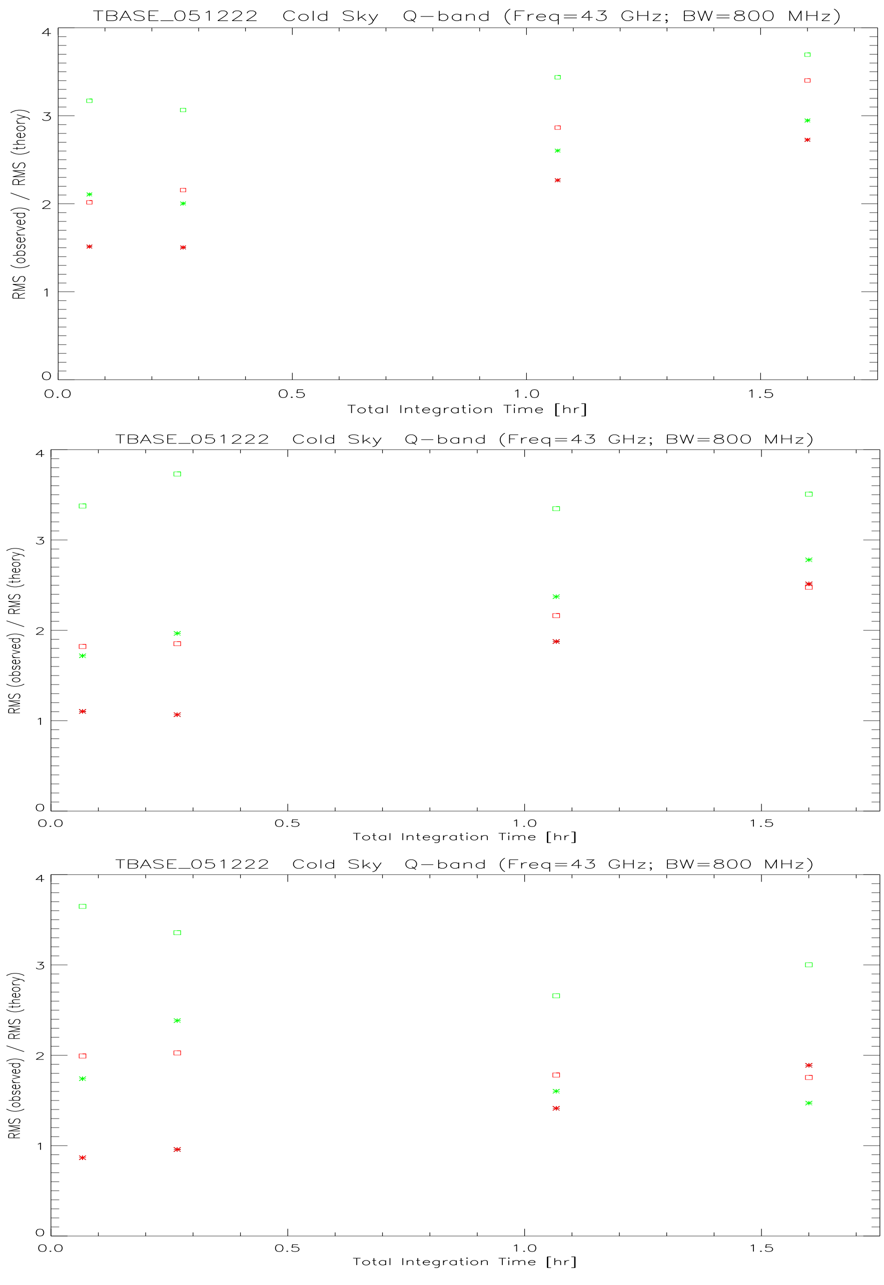

Figure 4: Ratio of the observed rms noise to the theoretical noise as a function of time for the 800 MHz bandwidth mode. All four channels are plotted: L1 (red star), R1 (green star), L2 (red square), and R2 (green square). The rms values are calculated over the full 800 MHz band (top panel), the inner 200 MHz (middle panel), and the inner 50 MHz (bottom panel).

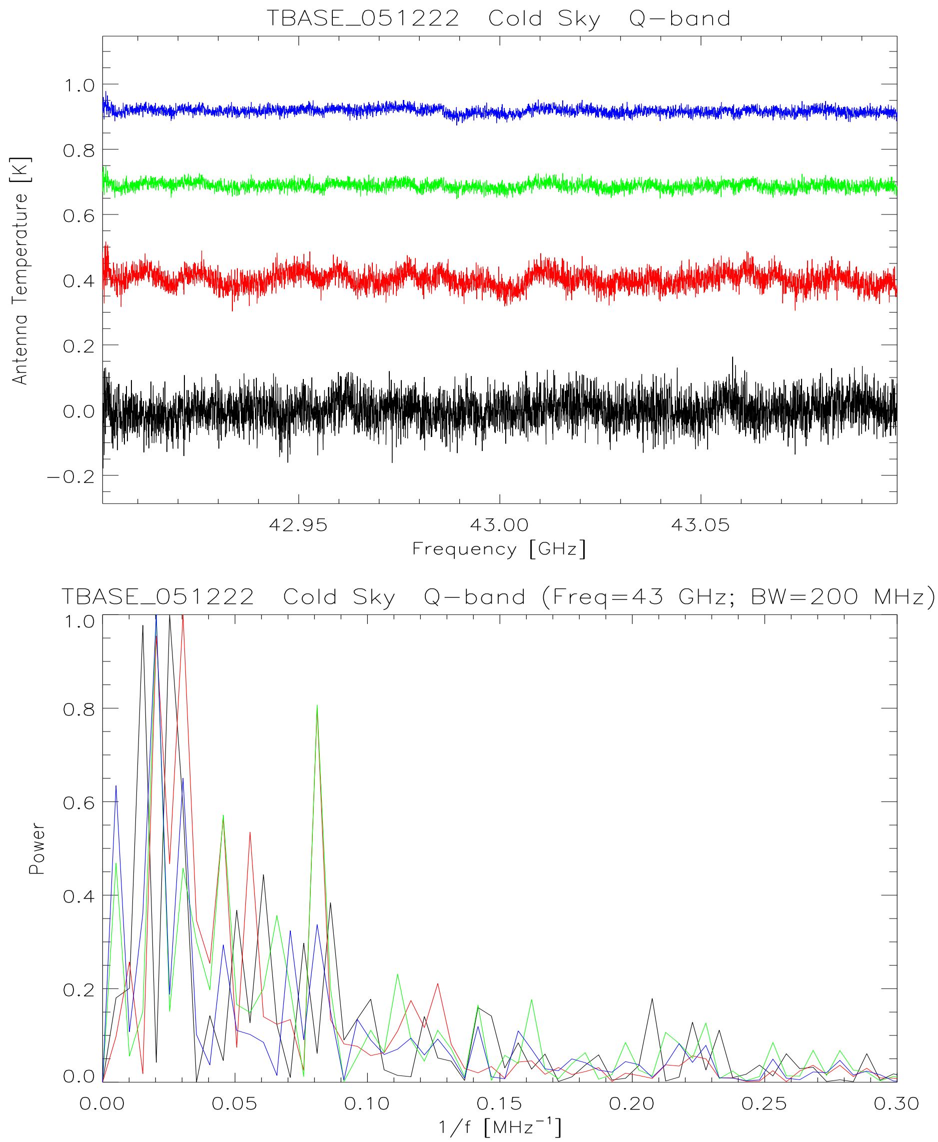

Figure 5: Averaged spectra using the 200 MHz bandwidth spectrometer mode. Upper panel: antenna temperature averaged over 1 (black), 4 (red), 16 (green), and 22 (blue) OffOn pairs plotted from bottom to top. The rms noise across the entire band, neglecting the edges, is 43 mK, 26 mK, 12 mK, and 11 mK from bottom to top. Bottom panel: power spectra for the spectra in the top panel.

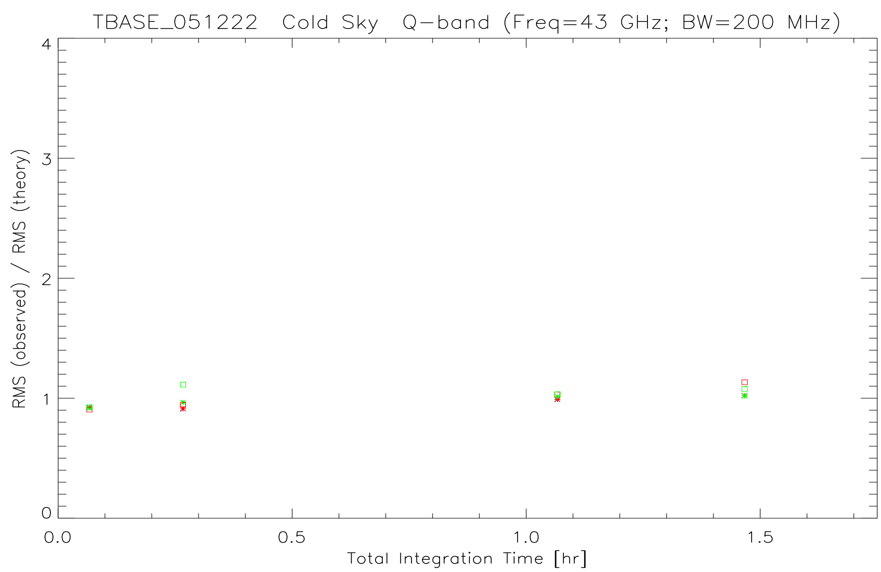

Figure 6: Ratio of the observed rms noise to the theoretical noise as a function of time for the 200 MHz bandwidth mode. All four channels are plotted: L1 (red star), R1 (green star), L2 (red square), and R2 (green square).

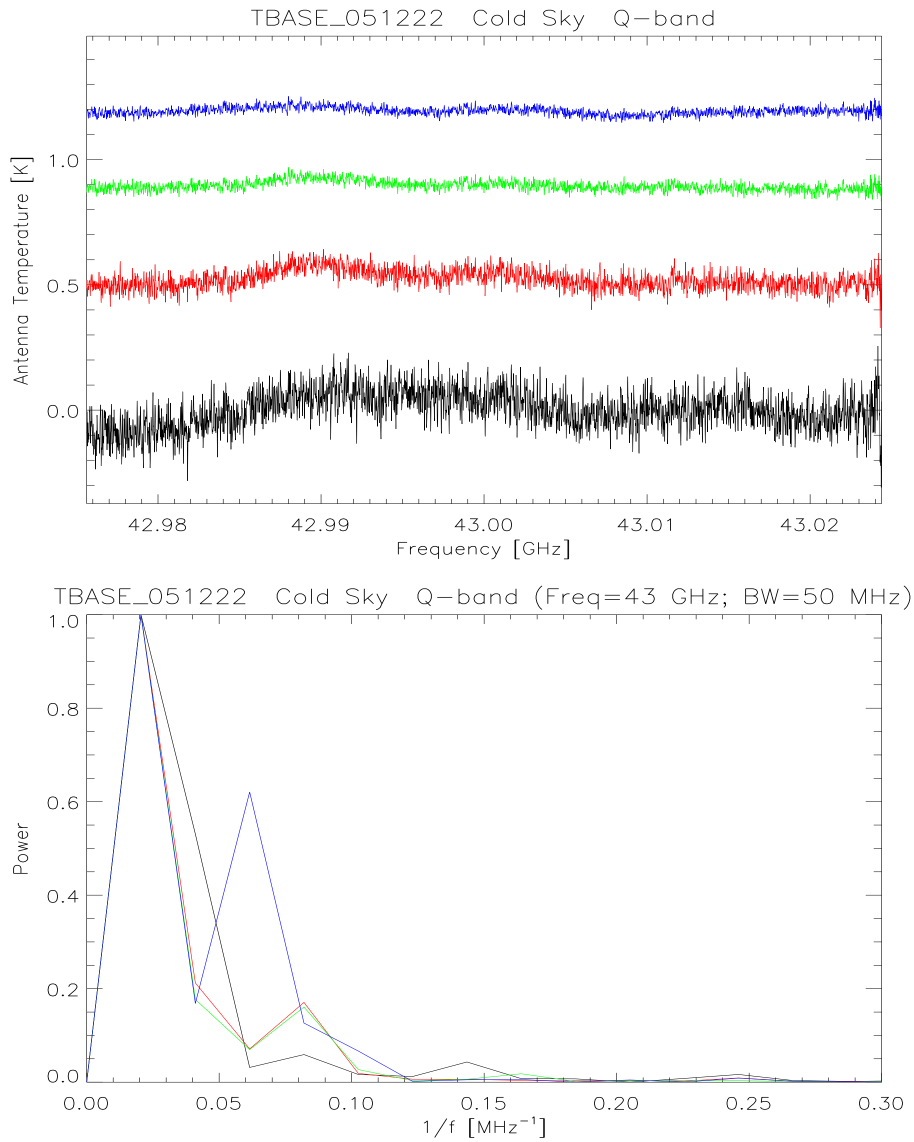

Figure 7: Averaged spectra using the 50 MHz bandwidth spectrometer mode. Upper panel: antenna temperature averaged over 1 (black), 4 (red), 16 (green), and 24 (blue) OffOn pairs plotted from bottom to top. The rms noise across the entire band, neglecting the edges, is 73 mK, 38 mK, 19 mK, and 15 mK from bottom to top. Bottom panel: power spectra for the spectra in the top panel.

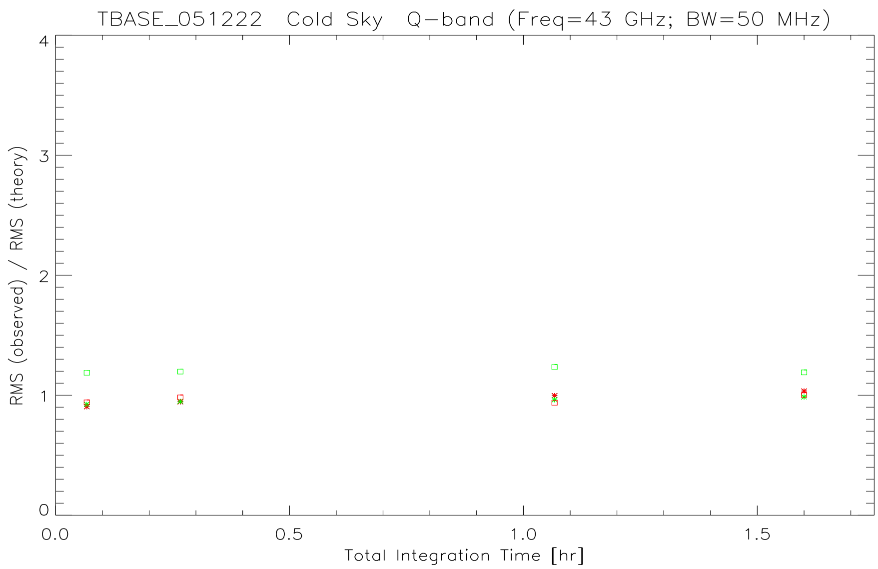

Figure 8: Ratio of the observed rms noise to the theoretical noise as a function of time for the 50 MHz bandwidth mode. All four channels are plotted: L1 (red star), R1 (green star), L2 (red square), and R2 (green square).