Sample of Baseline Stability of the 2-3 GHz GBT Receiver
Project TAST_SB_02119, November 19, 2002

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Setup

This test run was done between 18:30 and 22:00 EST, Tuesday, November 19 using the S-band (1.73 - 2.60 GHz) receiver, IF and optical fiber channels 5 and 8, and converter modules 9 and 13. The IF filters were set to a passband of 5840 to 6160 MHz. The sky center frequency was 1990 MHz, the receiver polarization was linear, and the spectrometer bandwidth was 200 MHz with 16384 spectral channels. The switching configuration was set to cal on/off, 2 phases, but for some reason the spectrometer produced data for 4 phases. This may have been due to selecting the external sig/ref in the spectrometer even though its switching setup only showed 2 phases. Only phases 1 and 4 had valid data in the fits files. An unverified 200 MHz spectrometer mode with 2 samplers was used, but the data looked reasonable. Integration times of 30 seconds were used for all measurements.

IF Noise Source Test

The first scan, 2049, used the broadband IF noise source as the signal input in place of the receiver to check the IF stability. The scan was 15 minutes long. Figures 1 shows IF channel 1's (recordN - record1) / record1 spectra for records 2, 10, 20 and 30 in the scan. Figure 2 shows the same sequence for IF channel 2. A plot of the average total powers across the central 90% of each spectrum as a function of record number are shown in Figure 3. The two channels track fairly closely and show a total change of about 0.3% in 15 minutes. All of the difference spectra are flat to a level of less than 0.1% of the total system power.

Sky Drift Scan

The next scan, 2050, was taken with the receiver connected and the telescope stationary at 77 degrees elevation and 179 degrees azimuth. Figures 4 and 5 show the spectra of (recordN - record1) / record1 for records 2, 10, 20, 30, 40, 50, and 60 corresponding to time interval of 30 through 1800 seconds. Within the sensitivity of a 30-second integration the difference spectra are reasonably, but not perfectly flat throughout the half-hour period. The only variation was in total power. Figure 6 shows the total power integrated in frequency for the 30-second spectra as a function of record number. Channel 1 changed by about 0.8% and channel 2 by about 2% in the half hour. Some of the total power variation is correlated between the two channels and could be due to fluctuation in atmospheric noise or common changes to the physical temperature of the receiver amplifiers. The total power change in channel 2 at the beginning of the half hour was considerably larger than anything seen with the IF noise source, so it was probably due to gain changes in the amplifier stages ahead of the mixer.

On-Off Measurement of Continuum Source 2052+3635

The next test was to take two, 5-minute on-off pairs on the continuum source 2052+3635, which has a flux density of about 4.3 Jy at 2 GHz. The results are shown in Figure 7.

Several anomalies are seen in this test. First, the ratio of source antenna temperature to system temperature is about 30% higher in receiver channel 2 than in channel 1. This source has very little polarized flux so that cannot account for the difference. A check of Tsys/Tcal for the two channels shows that channel 1 is about 18% higher than channel 2, which may account for some of the difference in Ta/Tsys. The two values for Tcal at 1990 MHz are 1.60 and 1.64 K for channels 1 and 2, respectively. Second, there is structure in the spectra with a sinusoidal wavelength of about 120 MHz in both receiver channels and a somewhat more irregular sinusoidal wavelength of 10 MHz in channel 2. There is also a weak 2.4 MHz ripple in both channels. The peak to peak amplitudes of the ripples are approximately 4%, 0.5%, and 0.3% of the continuum source flux density at 120, 10, and 2.4 MHz wavelengths. Third, at a baseband frequency of 149 MHz there is a weak dip in the spectrum about 2 MHz wide and 0.5% of the continuum flux deep in receiver channel 1. Fourth, the Tsys/Tcal measurements in the two on-off scan pairs differ by about 1% for channel 1 and about 3% in channel 2. This is probably due to a slightly different total power (gain?) drift between on and off of each scan pair. The drift was larger in channel 2, which is consistent with the relative amplitude of the total power drifts shown in Figure 6. Finally, there are several narrowband negative spikes in all spectra that show up at baseband frequencies of 90, 100, 120, 130, and 160 MHz.

On-Off Measurement of Continuum Source 2340+2220

The next test was to take two, 5-minute on-off pairs on the continuum source 2340+2220, which has a flux density of about 1.7 Jy at 2 GHz. The results are shown in Figure 8.

Essentially the same spectral features are seen in these spectra as are seen in the Ta/Tsys spectra of 2052+3635 in Figure 7. Fractional difference in Ta/Tsys between channels 1 and 2 is roughly the same as for 2052+3635. Figure 9 shows an over-plot of Ta/Tsys for the first scan pair for the two continuum sources scaled by factors of 4.8 and 1.5, or roughly their relative flux densities. Channel 1's spectra were multiplied by 1.25 to put them on the same scale as those for channel 2. These spectral have been smoothed by truncating their autocorrelation functions by a factor of 8. Except for a slight difference in slope, the two continuum source spectra look quite similar for the same receiver channel. Many of the bumps and wiggles match pretty well.

On-Off Measurement of Cold Sky

The next test was to take two, 5-minute on-off pairs on cold sky using the same observing procedure used on he continuum sources. The results are shown in Figure 10. The last minute of the first scan pair was corrupted by broadband interference, so these data were deleted from the averages. There may be a bit of this interference in the spectra of the first scan pair (red and green spectra in Figure 10). Aside from small DC offsets due to total power drift and the narrow spike in the center of the second set of spectra, the spectral baselines on cold sky look reasonably good. The slight roughness in the high-frequency end of the spectra may be due to some residual interference, since it has the spectral characteristics of the interference seen in the definitely corrupted data.

On-Off Continuum Source Spectra with Subreflector Offsets

Figure 11 shows a comparison of two continuum source on-off spectra with the subreflector displaced +2 centimeters (1/8 wavelength) in the Y direction for one of the two on-off pairs. The spectra are very nearly identical in the two subreflector positions except possibly for a small phase shift in the 10-MHz ripple seen in channel 2. The channel 2 spectra in Figure 8 are essentially identical to the zero-offset spectrum shown in Figure 11. This suggests that the causes of most of the features seen in spectra of continuum sources are in the receiver system rather than the telescope optics. However, this test needs to be repeated with a stronger continuum source (2052+3635 had nearly set when this observation was done), and a larger subreflector offset needs to be tried. (I'm not sure which direction the Y offset is with respect to the telescope since the commanded Y direction was different from the indicated Y direction.)

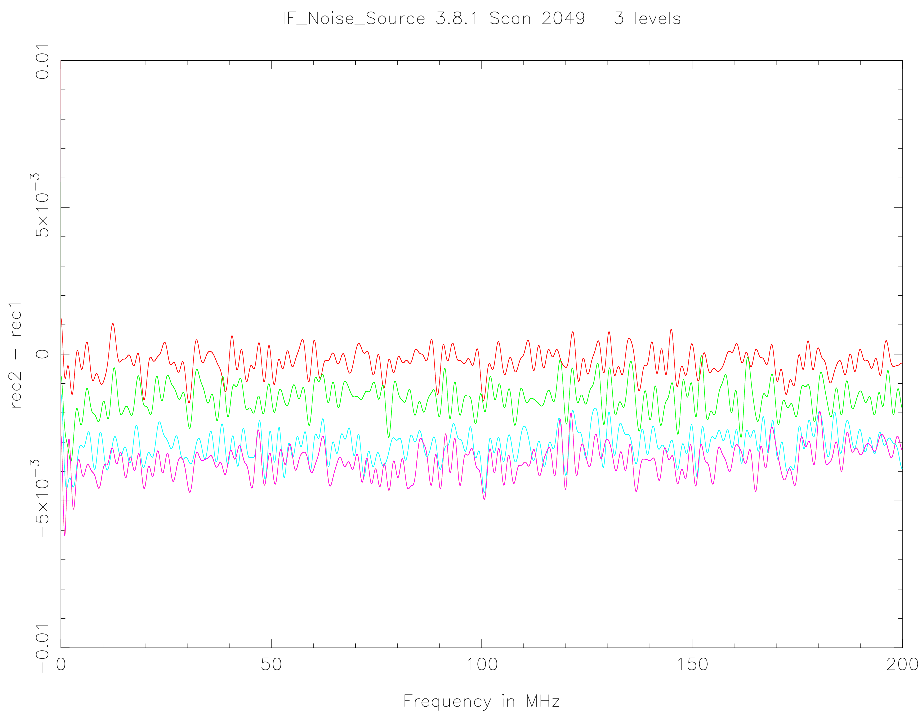

Figure 1: Scan 2049, IF channel 1. IF Noise source 30-second spectra of (recordN - record1) / record1 for records 2, 10, 20 and 30 in the scan using colors red, green, blue-green, and violet, respectively. The vertical scale is fraction of total power. These spectra have been smoothed by truncating the autocorrelation function to the first 200 lag values.

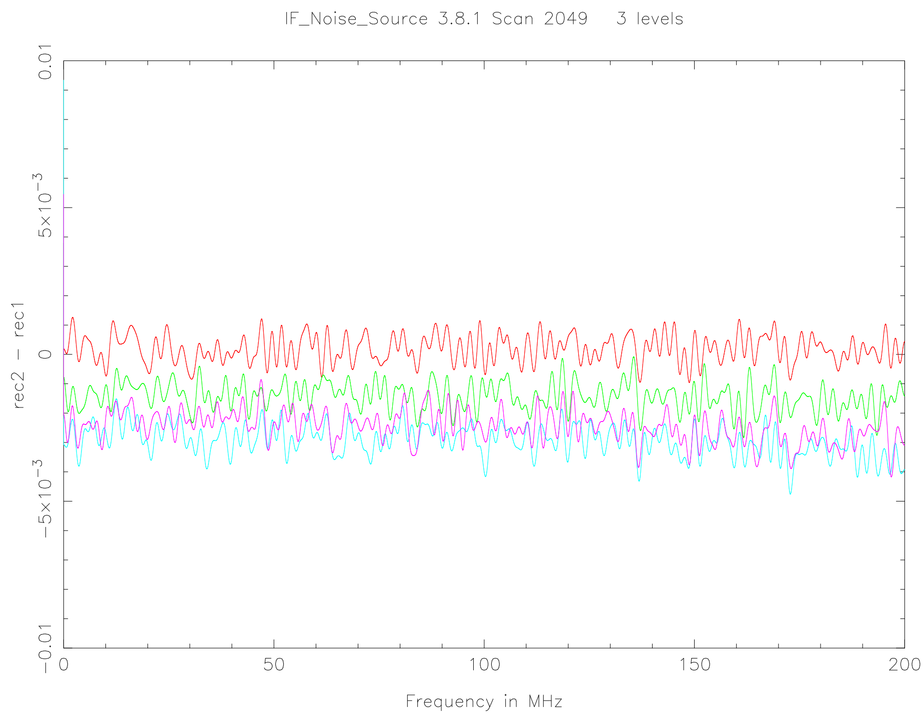

Figure 2: Scan 2049, IF channel 2. IF Noise source 30-second spectra of (recordN - record1) / record1 for records 2, 10, 20 and 30 in the scan using colors red, green, blue-green, and violet, respectively. The vertical scale is fraction of total power. These spectra have been smoothed by truncating the autocorrelation function to the first 200 lag values.

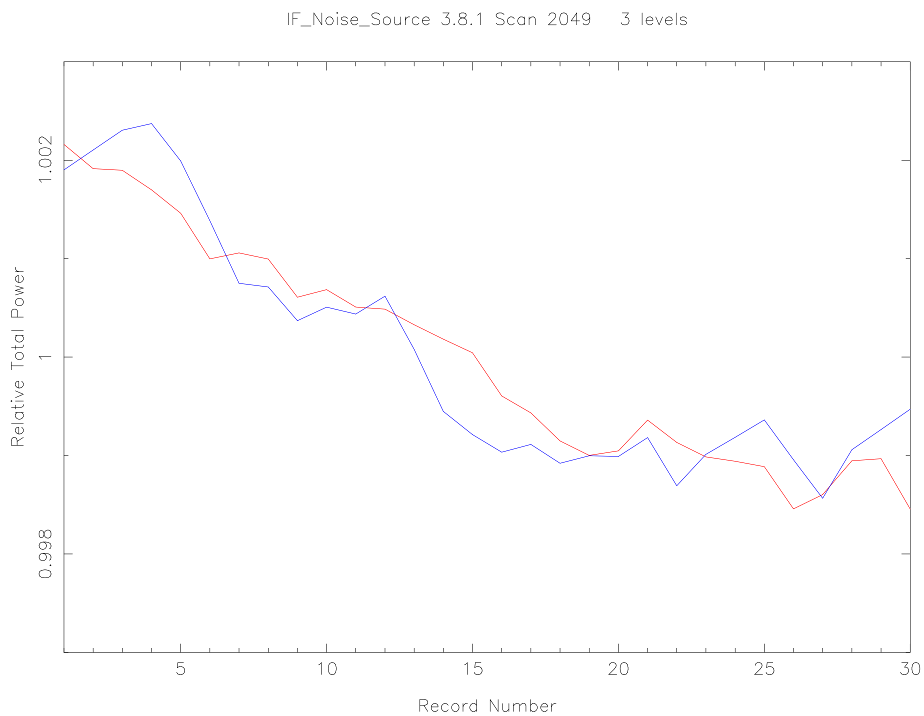

Figure 3: Scan 2049, IF Noise source total power as a function of record number. Each record is 30 seconds long. IF channel 1 is the red line, and IF channel 2 is the blue line.

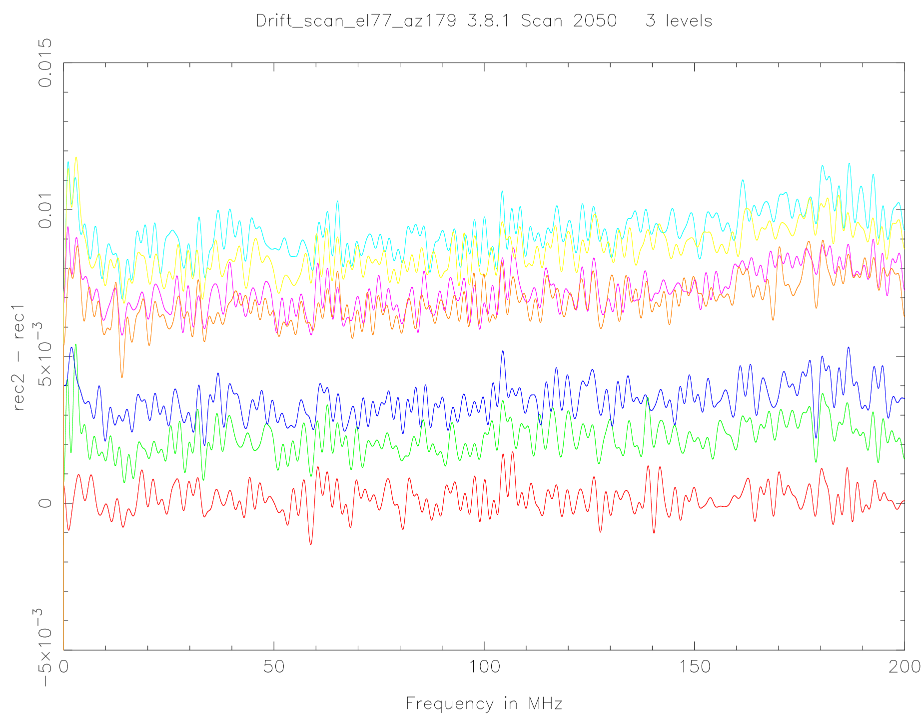

Figure 4: Scan 2050, IF channel 1. Sky drift scan 30-second spectra of (recordN - record1) / record1 for records 2, 10, 20, 30, 40, 50 and 60 in the scan using colors red, green, dark blue, blue-green, violet, yellow, and orange, respectively. The vertical scale is fraction of total power. These spectra have been smoothed by truncating the autocorrelation function to the first 200 lag values.

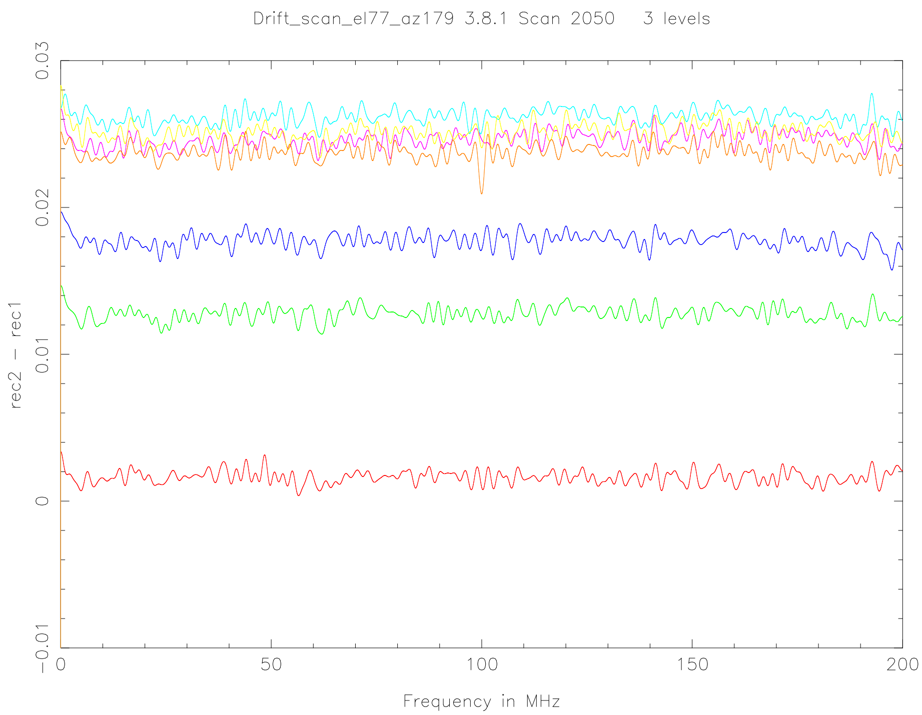

Figure 5: Scan 2050, IF channel 2. Sky drift scan 30-second spectra of (recordN - record1) / record1 for records 2, 10, 20, 30, 40, 50 and 60 in the scan using colors red, green, dark blue, blue-green, violet, yellow, and orange, respectively. The vertical scale is fraction of total power. Note the scale difference compared to Figure 4. These spectra have been smoothed by truncating the autocorrelation function to the first 200 lag values.

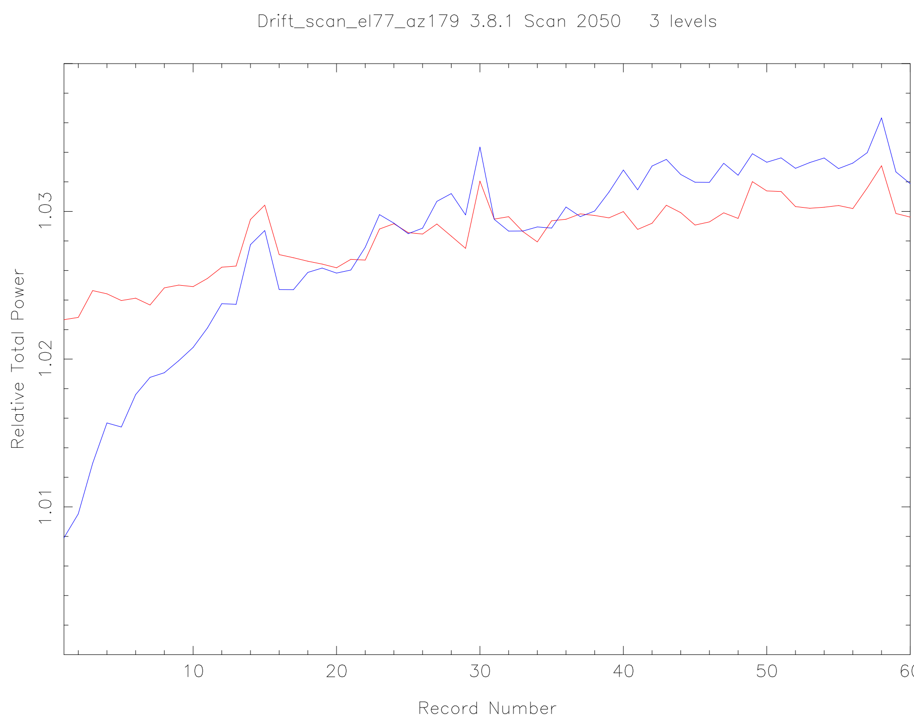

Figure 6: Scan 2050, Sky drift scan total power as a function of record number. Each record is 30 seconds long. IF/receiver channel 1 is the red line, and IF/receiver channel 2 is the blue line.

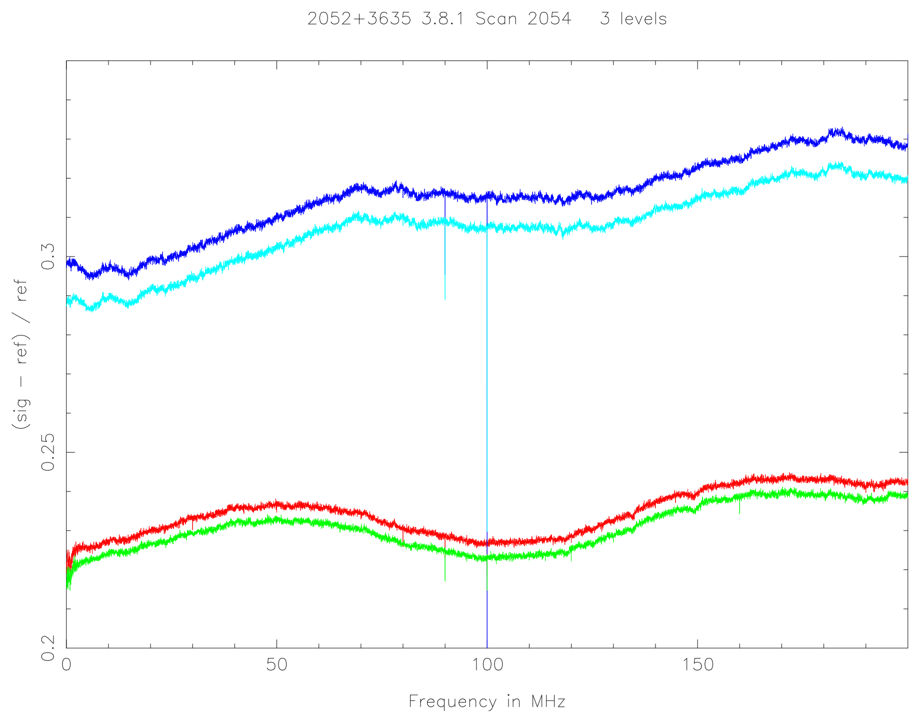

Figure 7: Scans 2053-6. Each spectrum is 5 minutes on, 5 minutes off for the continuum source 2052+3635. The red and green spectra are (on - off) / off for IF/receiver channel 1 using scans 2053/2054 and 2055/2056, respectively. The dark blue and blue-green spectra are the same scan pairs for IF/receiver channel 2. The spectra are Hanning smoothed.

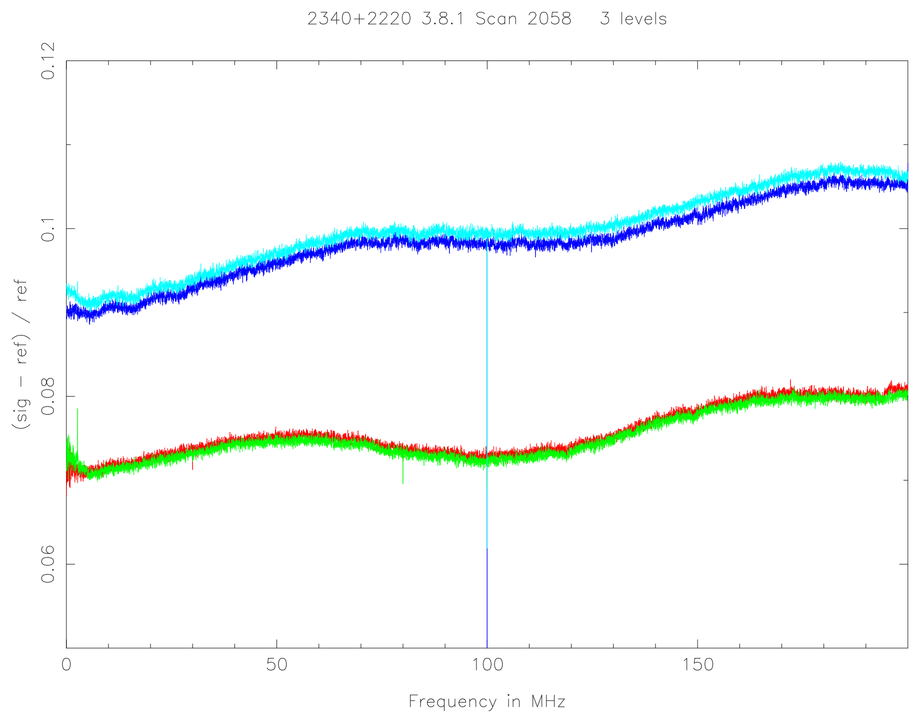

Figure 8: Scans 2057-60. Each spectrum is 5 minutes on, 5 minutes off for the continuum source 2340+2220. The red and green spectra are (on - off) / off for IF/receiver channel 1 using scans 2057/2058 and 2059/2060, respectively. The dark blue and blue-green spectra are the same scan pairs for IF/receiver channel 2. The spectra are Hanning smoothed.

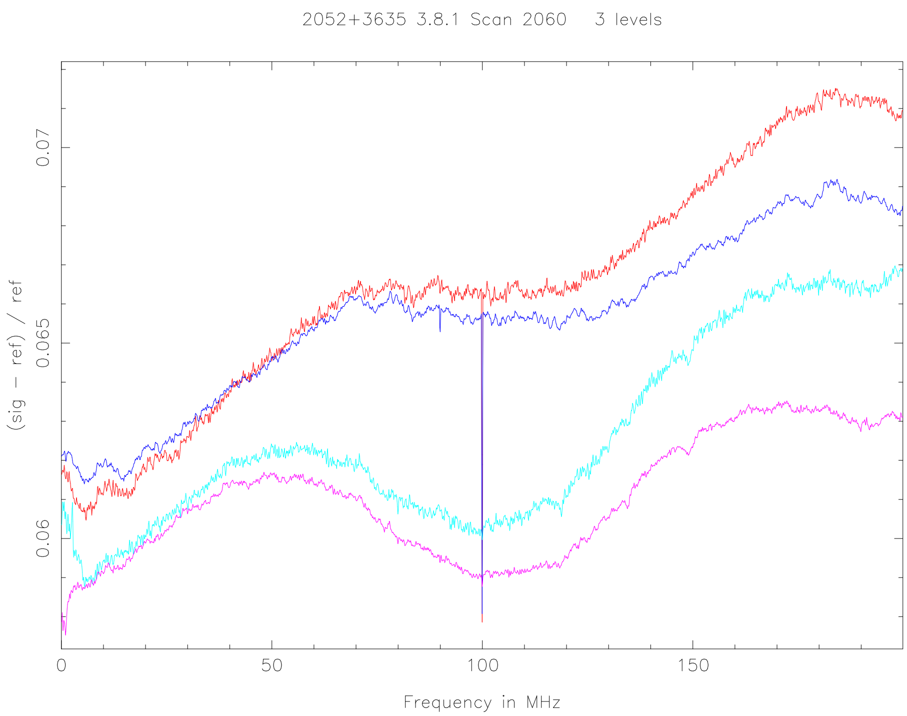

Figure 9: Scans 2053/4 and 2057/8. Ta/Tsys for two continuum sources, 2052+3635 and 2340+2220. Each spectrum is the first 5-minute-on, 5-minute-off pair shown in Figures 7 and 8. The violet spectrum is channel 1 of 2052+3635. The blue-green spectrum is channel 1 of 2340+2220. The dark blue spectrum is channel 2 of 2052+3635. The red spectrum is channel 2 of 2340+2220. To get the spectra on the same scale, they have been scaled by 1/4.8 and 1/1.5 to account for the difference in source flux densities and 1.25 to account for the apparent difference in calibration between the the two receiver channels. The spectra have been smoothed by truncating the autocorrelation functions to 2048 lags then Hanning convoled.

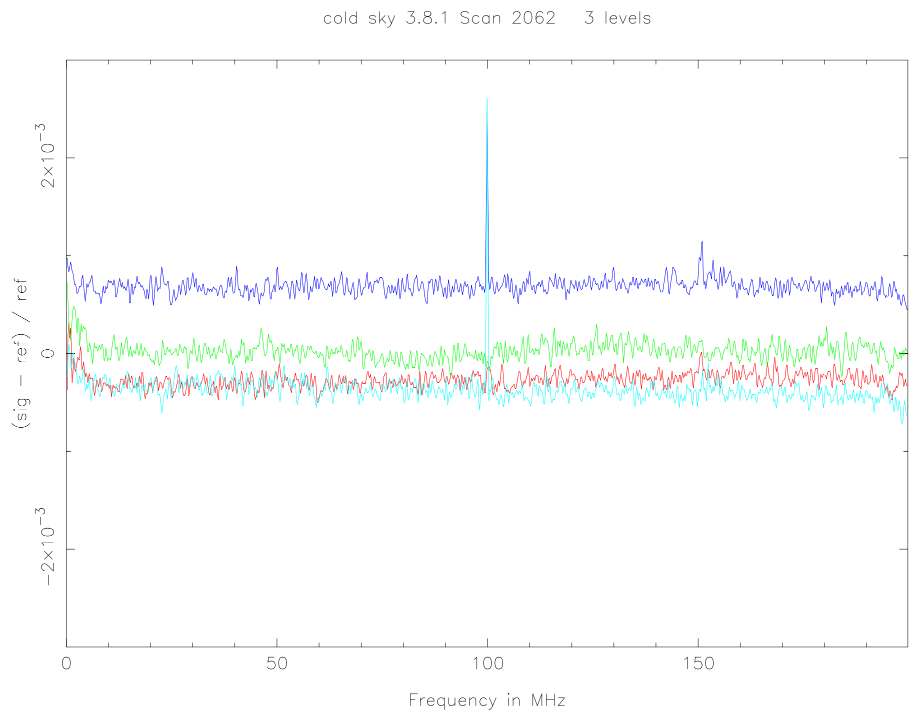

Figure 10: Scans 2061/2 and 2063/4. Each spectrum is 5 minutes on, 5 minutes off for blank sky in the same manner as the continuum source on-off measurements. The red and green spectra are (on - off) / off for IF/receiver channel 1 using scans 2061/2062 and 2063/2064, respectively. The dark blue and blue-green spectra are the same scan pairs for IF/receiver channel 2. The spectra were smoothed by truncating the autoorrelation functions to 1024 lags and then Hanning convolving the resulting spectrum. The last minute of scan 2062 was corrupted by wideband interference so these data were deleted.

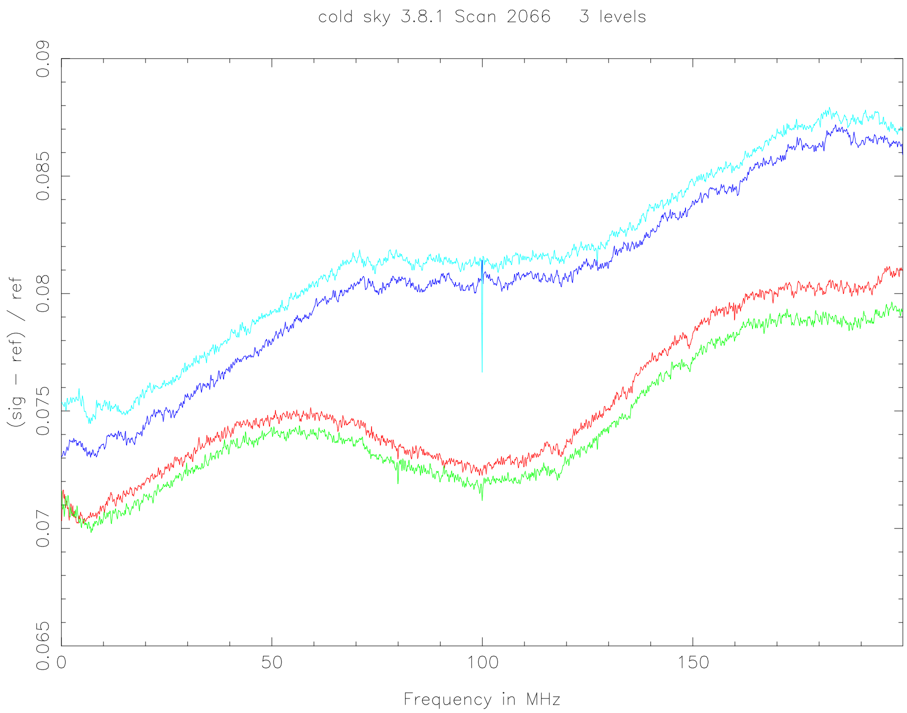

Figure 11: Scans 2065/6 and 2067/8. Each spectrum is 5 minutes on, 5 minutes off the continuum source 2340+2220 as in scans 2057-60 shown in Figure 8. The difference between on-off pairs 2065/6 (red and dark blue) and 2067/8 (green and blue-green) is that the subreflector was offset by +2 centimeters in the Y direction for the first pair. The red and green spectra are (on - off) / off for IF/receiver channel 1. The dark blue and blue-green spectra are the same scan pairs for IF/receiver channel 2. The spectra were smoothed by truncating the autoorrelation functions to 2048 lags and then Hanning convolving the resulting spectrum.