Second Baseline Test of the 2-3 GHz GBT Receiver
Project TBASEJRF021202, December 2, 2002

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Setup

This test run was done between 17:00 and 21:00 EST, Monday, December 2 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 except as noted, the receiver polarization was linear, and the spectrometer bandwidth was 200 MHz with 16384 spectral channels. The switching configuration was set to cal off/on, 2 phases. The cal signal was on in phase 2. 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, 68, used the broadband IF noise source as the signal input in place of the receiver to check the IF stability. The scan was 20 minutes long. Figures 1 shows IF channel 1's (recordN - record1) / record1 spectra for records 2, 10, 20, 30, and 40 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 0.4% in 20 minutes with channel 1 being a bit more stable than channel 2. 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, 69, was taken with the receiver connected and the telescope stationary at 77 degrees elevation and 180 degrees azimuth. Figures 4 and 5 show the spectra of (recordN - record1) / record1 for records 2, 10, 20, 30, and 40 corresponding to time intervals of 30 through 1200 seconds. Within the sensitivity of a 30-second integration the difference spectra are reasonably, but not perfectly flat throughout the half-hour period. The main variation was in total power of hannel 2. Note the different vertical scale on Figure 5. A slight waviness and curvature can be seen in the difference spectra after about 10 minutes in both channels. Figure 6 shows the total power integrated in frequency for the 30-second spectra as a function of record number. Channel 1 changed by less than 1% in the 20 minutes, but channel 2's total power drifted by about 9% in this time period. A few bumps in the total power variation are 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 weather was high overcast and about 36 degrees F. The total power change in channel 2 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.

Frequency Test of Spectrum of Continuum Source 2052+3635

The next test was to take 5-minute on-off pairs on the continuum source 2052+3635 at three different first-LO settings corresponding to sky center frequencies of 1940, 1990, and 2040 MHz. This source has a flux density of about 4.3 Jy at 2 GHz. The purpose of the test is to see if the features in the continuum source spectra follow the sky frequency or are fixed in IF frequency. Features that are fixed in sky frequency are presumably introduced in the telescope/receiver system before the first mixer. The results are shown in Figures 7 and 8. Most features are fixed in sky frequency. The exceptions are very near the ends of the spectra, some change in the general slope of the spectra, and possibly a few narrowband birdies that appear as negative spikes in the difference spectra.

Test for Difference in Continuum Source Ta/Tsys

In the November 19 tests we saw roughly a 30% difference in the Ta/Tsys ratio measured in the two receiver channels. To isolate the cause of this discrepancy we measure three on-off scan pairs on the continuum source 2052+3635 with three different receiver configurations. The results are shown in Figure 9. The red spectra in this figure show Ta/Tsys with the receiver in its normal configuration. The green curves are spectra taken with the transfer switch behind the RF amplifiers in the crossed position, and the blue spectra were taken with this RF transfer switch in its normal position and with the two cables between the analog filter rack and the spectrometer samplers swapped. In all three cases Ta/Tsys was measured to be higher in spectra associated with front-end RF channel 2. This suggests that the difference in Ta/Tsys has something to do with the receiver section ahead of the RF transfer switch. However, there is a significant difference in measured Ta/Tsys among the three spectra associated with each RF channel. This indicates that there is probably some non-linearity in the system that needs further investigation.

Ta/Tsys Measurement with Different Sampler Levels

To determine whether the differences in Ta/Tsys measured for each RF channel shown in Figure 9 could be due to an uncompensated non-linearity in the spectrometer samplers, the same receiver configuration was used to measure this quantity using two sampler input levels differing by 3 dB. The red curves in Figure 10 show the measurement results with the samplers run at their normal input levels, and the blue curves show the same measurements with the sampler input levels 3 dB below normal. The bottom two spectra are for channel 1, and the top two are for channel 2. The difference between the two measurements for each channel is considerably less than the range of values for each channel shown in Figure 9, which indicates that a non-linearity exists somewhere else in the receiver amplifier chain.

On-Off Continuum Source Spectra with Subreflector Offsets

Figure 11 shows a comparison of two continuum source on-off spectra with the subreflector displaced +4 centimeters (1/4 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 for a a nearly half-wave phase shift in the weak 10-MHz ripple component of the spectrum. This is best seen in the top spectrum pair (channel 2) in the regions around 1970 and 2080 MHz. This ripple component is not as evident in channel 1 (bottom pair), but some hint of change can seen between the two subreflector positions in this spectrum pair. The large-scale waviness and some of the small-scale features in the spectra do not change with subreflector position and, hence, do not appear to be associated with the telescope optics.

The nominal distances from the feed phase center to the top and bottom edges of the subreflector are 15.9 and 15.1 meters. If their is an interference of the direct and an extra feed-subreflector-feed signal path for a continuum source in the telescope beam, one would expect a spectral baseline ripple of about 9.7 MHz, which is roughly what we see in channel 2 of Figure 11. If there were an interference between the baseline ripples caused by reflections from the top and bottom edges of the subreflector one might expect a modulation envelope on the 9.7 MHz ripple with a period of about 180 Hz. The 200 MHz spectrum is not wide enough nor the observed ripple strong enough to say anything useful about this secondary interference.

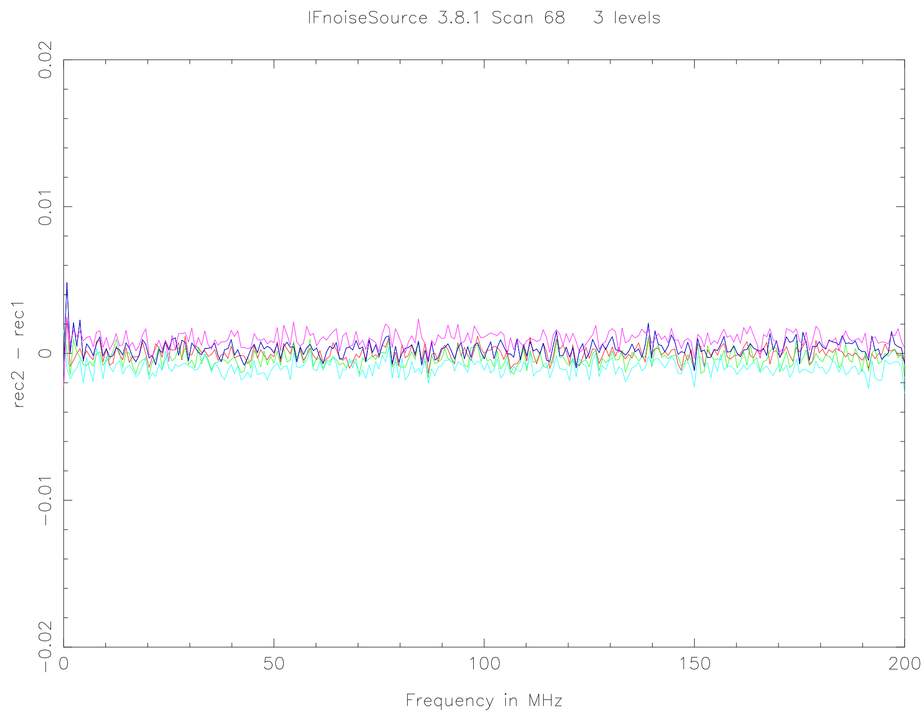

Figure 1: Scan 68, IF channel 1. IF Noise source 30-second spectra of (recordN - record1) / record1 for records 2, 10, 20, 30 and 40 in the scan using colors red, green, dark blue, blue-green, and violet, respectively. The vertical scale is fraction of total power. These spectra have been smoothed by truncating the autocorrelation function to the first 256 lag values.

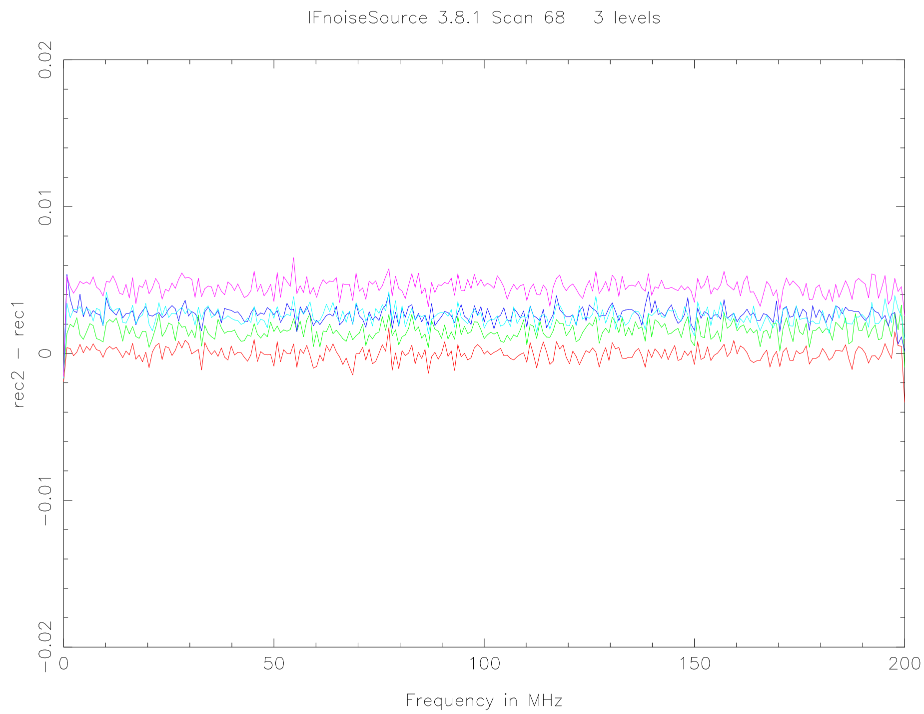

Figure 2: Scan 68, IF channel 2. IF Noise source 30-second spectra of (recordN - record1) / record1 for records 2, 10, 20 30, and 40 in the scan using colors red, green, dark blue, blue-green, and violet, respectively. The vertical scale is fraction of total power. These spectra have been smoothed by truncating the autocorrelation function to the first 256 lag values.

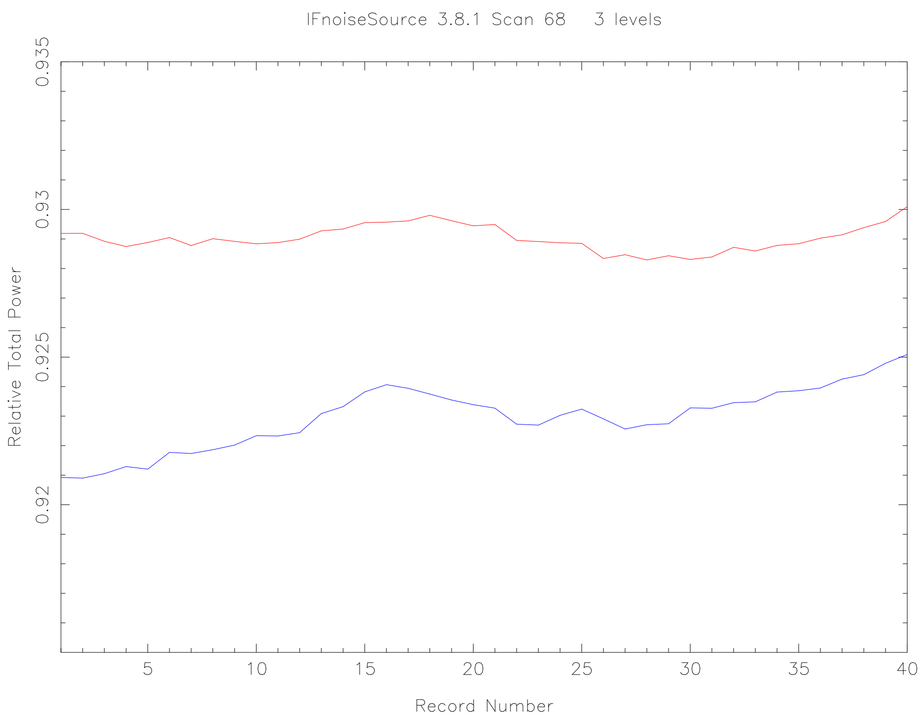

Figure 3: Scan 68, IF Noise source total power as a function of record number. Each record is 30 seconds long. IF channel 1 is the red line, and IF channel 2 is the blue line.

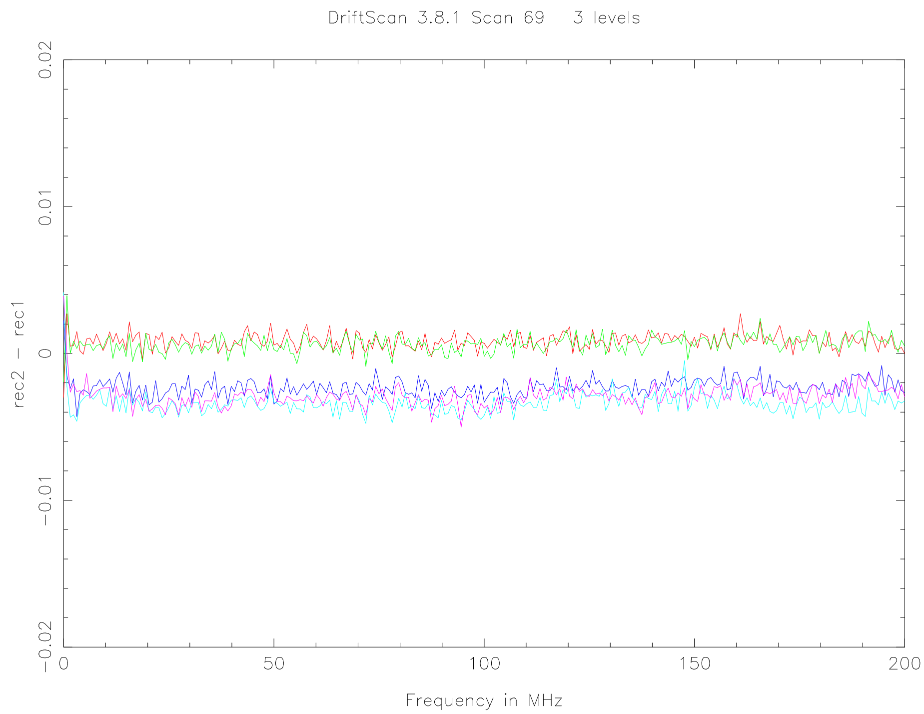

Figure 4: Scan 69, IF channel 1. Sky drift scan 30-second spectra of (recordN - record1) / record1 for records 2, 10, 20, 30, and 40 in the scan using colors red, green, dark blue, blue-green, and violet, respectively. The vertical scale is fraction of total power. These spectra have been smoothed by truncating the autocorrelation function to the first 256 lag values.

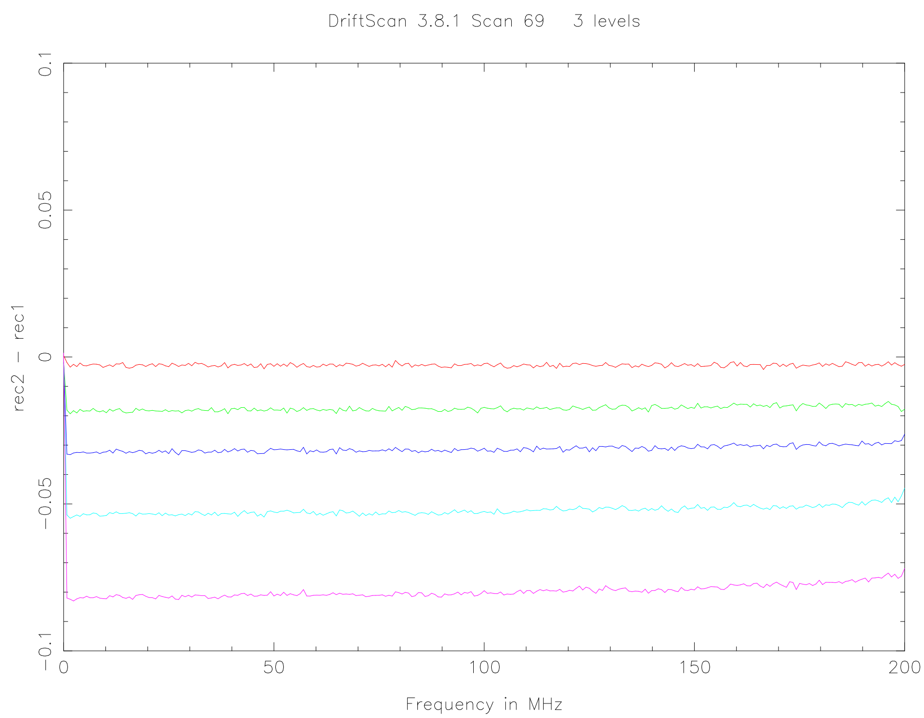

Figure 5: Scan 69, IF channel 2. Sky drift scan 30-second spectra of (recordN - record1) / record1 for records 2, 10, 20, 30, and 40 in the scan using colors red, green, dark blue, blue-green, and violet, respectively. The vertical scale is fraction of total power. Note the scale difference compared to Figure 4. These spectra have been smoothed by truncating the autocorrelation function to the first 256 lag values.

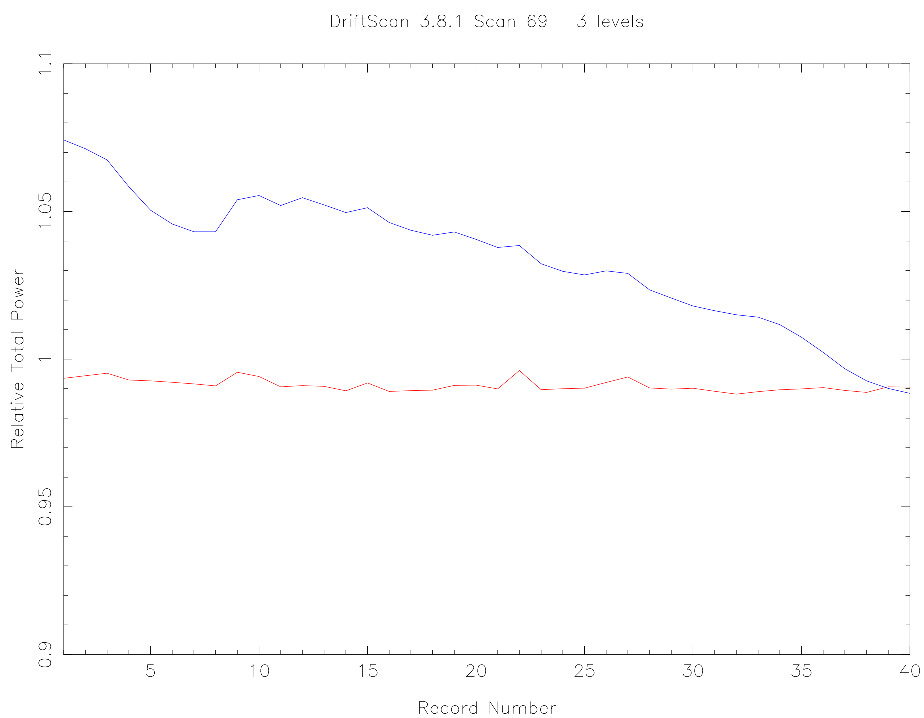

Figure 6: Scan 69, Sky drift scan total power as a function of record number. Each record is 30 seconds long. IF/receiver channel 1 is the red line, and IF/receiver channel 2 is the blue line.

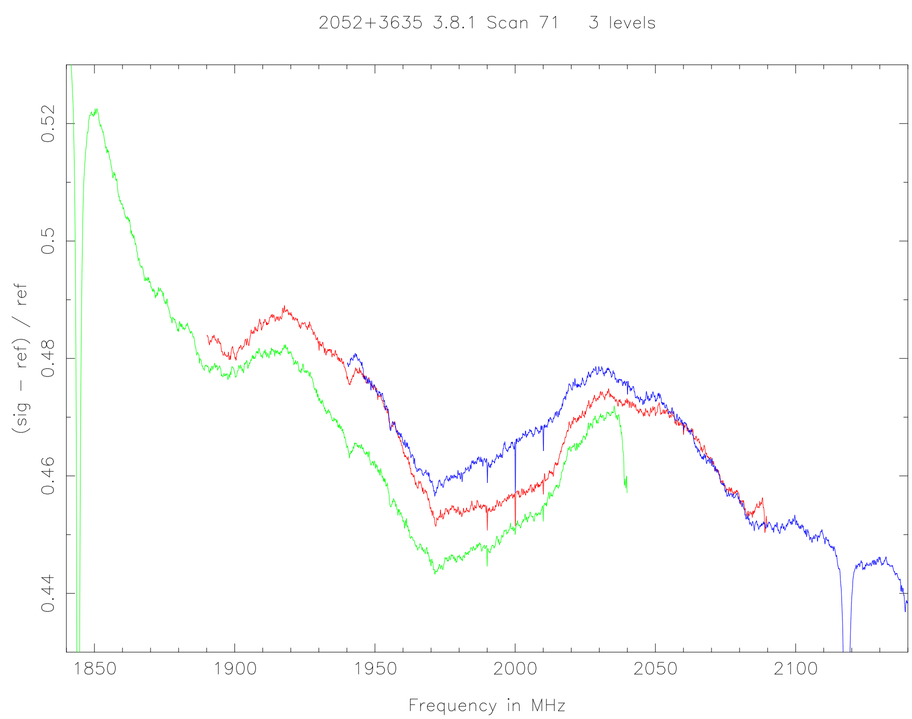

Figure 7: Scans 70, 71, 74, 75, 78, and 79, Channel 1. Each spectrum is 5 minutes on, 5 minutes off for the continuum source 2052+3635. The green, red and blue spectra are (on - off) / off or Ta/Tsys for IF/receiver channel 1 using sky center frequencies of 1940, 1990, and 2040 MHz, respectively, by changing the first LO frequency to 7940, 7990, and 8040 MHz. The spectra have been smoothed by truncating the autocorrelation functions to 2048 lags then Hanning convolved.

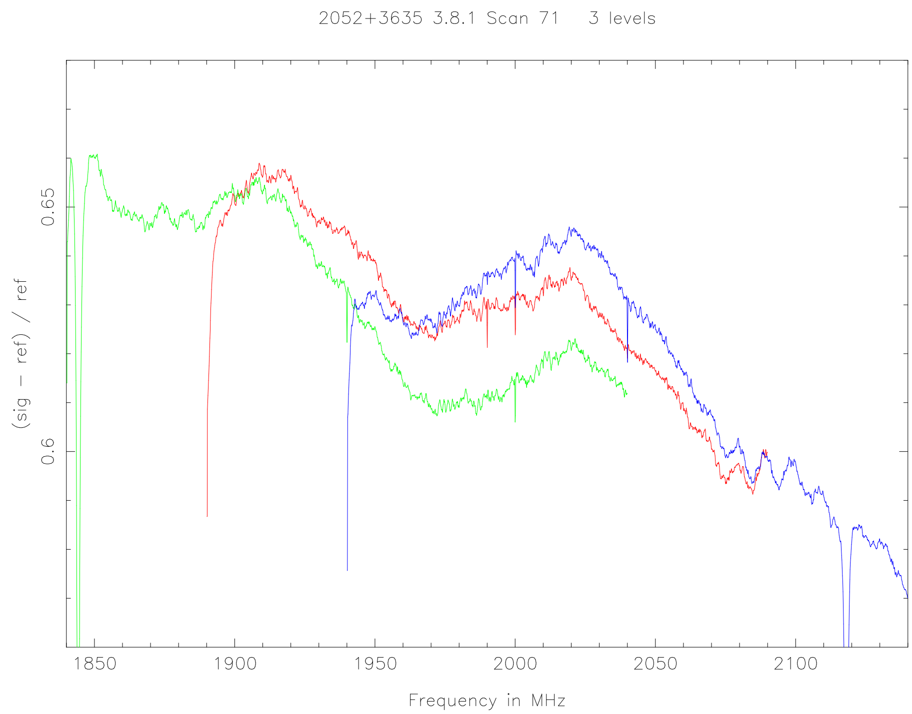

Figure 8: Scans 70, 71, 74, 75, 78, and 79, Channel 2. Each spectrum is 5 minutes on, 5 minutes off for the continuum source 2052+3635. The green, red and blue spectra are (on - off) / off or Ta/Tsys for IF/receiver channel 2 using sky center frequencies of 1940, 1990, and 2040 MHz, respectively, by changing the first LO frequency to 7940, 7990, and 8040 MHz. The spectra have been smoothed by truncating the autocorrelation functions to 2048 lags then Hanning convolved.

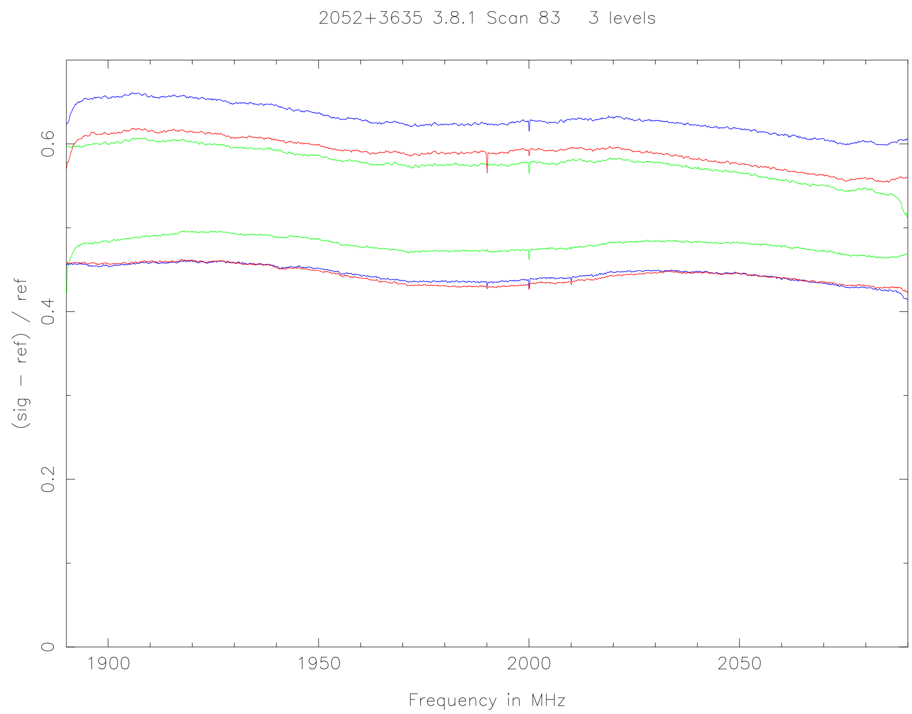

Figure 9: Scans 82, 83, 86, 87, 90, and 91. Ta/Tsys for continuum source 2052+3635 with the normal receiver configuration (red spectra), with the front-end transfer switch crossed (green spectra), and the signal lines to the spectrometer samplers reversed (dark blue spectra). The lowest three spectra in this plot correspond to sky channel 1, and the highest three are for sky channel 2. Each spectrum is 5 minutes on, 5 minutes off integrations. The spectra have been smoothed by truncating the autocorrelation functions to 2048 lags then Hanning convolved.

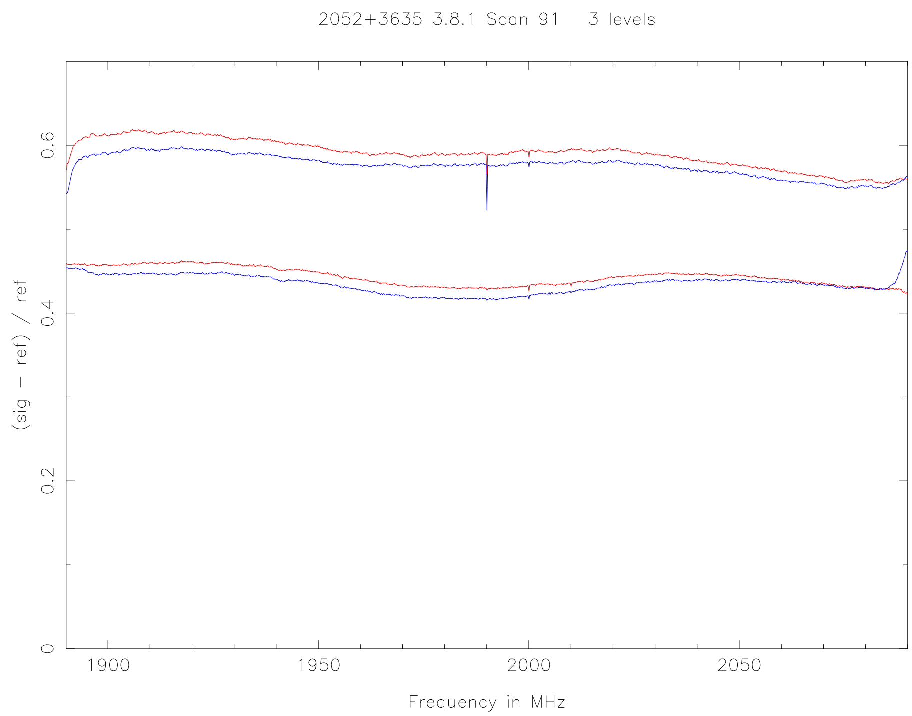

Figure 10: Scans 90, 91, 92, and 93. Ta/Tsys for continuum source 2052+3635 using different spectrometer sampler input levels. Each spectrum is 5 minutes on, 5 minutes off integrations. The red spectra are for normal sampler input levels and the blue spectra are for input levels 3 dB below normal. The lowest two spectra correspond to IF/receiver channel 1, and the top two spectra are for channel 2. The spectra were smoothed by truncating the autocorrelation functions to 2048 lags and then Hanning convolving the resulting spectrum.

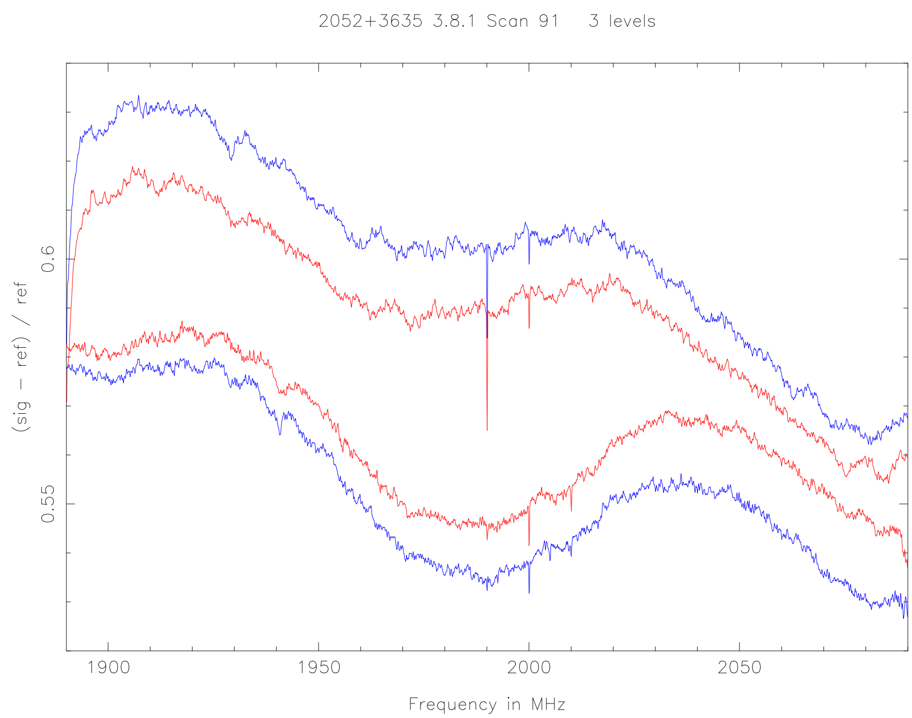

Figure 11: Scans 90, 91, 94, and 95. Each spectrum is Ta/Tsys for an observing pair of 5 minutes on, 5 minutes off the continuum source 2052+3635. The red spectra are with the subreflector in its normal focus position, and the blue spectra are with the subreflector displaced by 4 cm (about 1/4 wavelength) in the positive Y direction The lowest two spectra correspond to IF/receiver channel 1, and the top two spectra are for channel 2. Three of of the spectra have had their intensities scaled to get them close together on the same plot. The spectra were smoothed by truncating the autoorrelation functions to 2048 lags and then Hanning convolving the resulting spectrum.