Spectrometer Tests with IF Rack Noise Source

Glen Langston, Dana S. Balser, Ronald J. Maddalena, Frank Ghigo

01 September 17

Abstract

Gain stability tests are presented for the GBT IF Chain from the IF-Rack to the Spectrometer, by injecting IF-Rack noise source signals into the IF chain. The electronics gain stability is measured by comparing spectra at different times in the test period, and by measuring the reduction in the RMS noise level as a function of integration time.

We find the IF gain to be stable to better than 1 part in 1000 over a 2 hour time interval in both "polarizations" (both noise source, optical modem, converter module, analog filter, spectrometer sampler chains). For short integration times ($t < 1$ hour), average spectrometer noise decreases with increasing integration time, nearly as $t^{-1/2}$. For integrations of a few hours, the noise level decreases continually, but slightly slower than as $t^{-1/2}$.

1 INTRODUCTION

Electronics gain stability is critical for detection of faint features in long observations. These tests measure the GBT stability by injecting RF noise sources into the GBT IF chain, and comparing the spectra of these noise sources over a 4 hour interval. The spectra were obtained with the GBT spectrometer in the 50 MHz, 16384 lag mode for 8 samplers. This observing configuration would be used to make dual polarization, multi-spectral feature (up to 4) observations at high spectral resolution.

The test setup is described in §2. The normalization and measurements are described in §3. A short summary is given in §4.

2 TEST SETUP

These tests were made on 2001 August 12 and 13. The tests used two GBT IF-Rack wideband noise sources as the input test signals. The IF rack was configured to use optical modems 1 and 3 with the 2840 to 3160 MHz band pass filter inserted before the optical modems. The entire GBT IF chain was set up using glish script `h1Drift.g` in the directory `/home/s2/glangsto/glish`, then touched up with script `noiseSourceConverterRack.g`.

The GBT M&C software was used to set up all hardware. The program `spectrometer` was used to examine the data during and after the tests.

Converter Modules (CM) 1 to 8 were used, with LO values listed in table 1. The spectrometer IF input frequency range was 50 to 100 MHz, and the input signals were transformed into this range via a series of three frequency conversions. The first conversion is a lower sideband up-conversion by the CM LO frequency, followed by a 8.5 to 10.5 band pass filter. Next is a upper sideband down conversion by a fixed frequency of 10.5 GHz. Finally there is an upper sideband down conversion by 0.5 GHz, followed by a 0.05 to 0.100 MHz band pass filter.

The conversion from spectrometer IF input frequency, $\nu_{spectrometer}$, and in the IF rack frequency, ν_{IF}, is dependent on the converter module LO frequency, ν_{CM}, as shown by the equation below:

$$\begin{aligned}\nu_{IF} &= \nu_{CM} - 10.5 + 0.5 + \nu_{spectrometer} \\ &= \nu_{CM} - 10.5 + \nu_{spectrometer}\end{aligned}$$

GHz. The negative sign in front of $\nu_{spectrometer}$ indicates a net lower sideband conversion.

For the 50 MHz bandwidth spectrometer mode, the spectrometer IF frequency range is 50 to 100 MHz. The outputs of the analog filters 1 to 8 were attached to spectrometer low speed sampler inputs 1 to 8.

The spectrometer functioned well during these tests except that occasionally the manager would hang in the "Running" state indefinitely. This problem was overcome by separately running the glish script `abortSpectrometer.g`, which would abort the spectrometer manager if it remained in any one state for longer than 11 minutes.

The spectrometer was configured to perform 30 second integrations in the normal switched calibration mode (Cal_{ON}/Cal_{OFF} mode). The IF-Rack noise sources produce nearly constant intensity outputs, so that the Cal_{ON} spectra are identical to the Cal_{OFF} spectra. For these observations, the scan duration was 10 minutes, therefore each scan contained 20 integrations.

These data are in directory: `/home/gbtdata/spectralLine_06/Spectrometer/`

Converter Module Frequency (GHz)	IF Min Frequency (GHz)	IF Center Frequency (GHz)	IF Max Frequency (GHz)	Spec. Min Frequency (GHz)	Spec. Center Frequency (GHz)	Spec. Max Frequency (GHz)
13.186	3.086	3.111	3.136	0.050	0.075	0.100
12.979	2.879	2.904	2.929	0.050	0.075	0.100
12.925	2.825	2.850	2.875	0.050	0.075	0.100
12.871	2.771	2.796	2.821	0.050	0.075	0.100
13.075	2.975	3.000	3.025	0.050	0.075	0.100

Table 1: Frequency conversions used in the Noise Source Signal tests. The last line shows that the converter module LO is set to 13.075 GHz, the IF Rack center frequency is placed in the center of the spectrum

3 BAND PASS SHAPES AND STABILITY

Figure 1 shows one pair of the 4 spectral bands measured in these tests. The signal path for these data starts at two independent IF-Rack noise sources, travels through optical modems 1 and 3, converter modules 2 and 6, analog filters 2 and 6 to two low speed spectrometer samplers. This spectral shape is typical of the 50 MHz bands, showing 5-6 extrema in the frequency range. Figure 1 is the average of 1 hour of spectral data. This hour of data is used as the calibration reference for comparing the gain stability of later scans.

The calibration process is required to remove the spectral shape, so that the RMS noise in the integration can be measured. The calibration was done by defining a reference average spectrum, then using this to calibrate other time ranges.

$$Normalized\ Spectrum = \frac{Test\ Spectrum - Average\ Spectrum}{Average\ Spectrum}$$

The RMS noise in 30 second integration minus the 1 hour average was $\pm 2.0 \times 10^{-3}$. The RMS noise in an average of four 30 second integrations minus the 1 hour average was $\pm 9.9 \times 10^{-4}$. Since the noise in the reference 1 hour spectrum is much less than that in the shorter integrations, the noise reduces almost exactly as $t^{-1/2}$, as expected. Figure 2 shows the calibration of a 30 second integration using a 1 hour average of the noise cal from a different time interval.

The RMS noise in a 10 minute scan calibrated using a 1 hour average was $\pm 4.8 \times 10^{-4}$. The RMS noise in an average of 40 minutes (4 scans), relative to the 1 hour average was $\pm 3.1 \times 10^{-4}$. Note that since the 40 minute integration is almost as long as the hour reference, the noise does not decrease as rapidly as $t^{-1/2}$, since the noise in the reference scan is not decreased.

The RMS noise in an average of 1 hour (6 scans), relative to the first 1 hour average was $\pm 2.8 \times 10^{-4}$. The RMS noise in an average of 2 hour (12 scans), relative to the first two hour average was $\pm 2.3 \times 10^{-4}$. The ratio in the two hour and one hour scan noise should be $1./\sqrt{2} \sim 0.7$, but instead only 0.8.

Figure 3 shows the difference of the two 2 hour integrations. Clearly there is systematic difference in the gain over this 4 hour interval. Figure 4 shows the central 25 MHz band. The gain change in the 4 hour interval corresponds to one part in 1 thousand.

4 SUMMARY

The variation in calibration noise source in the IF rack is compared over a four hour interval. The gain stability/stability of the noise source is better than 1 part in 1000 over this period. Further tests will determine the stability over longer integration times.

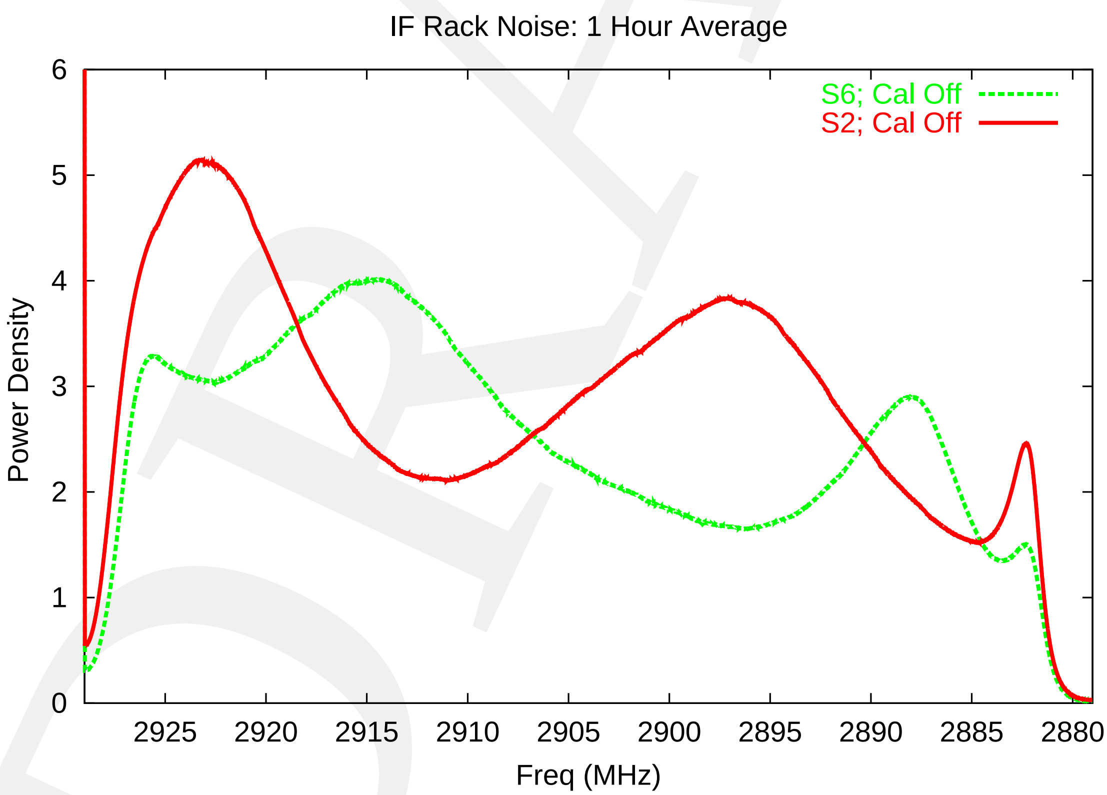

Figure 1: Average of 1 Hour of scans of IF Rack Noise Source. The Optical Modem 1 data is red, Optical Modem 3 data is green.

.

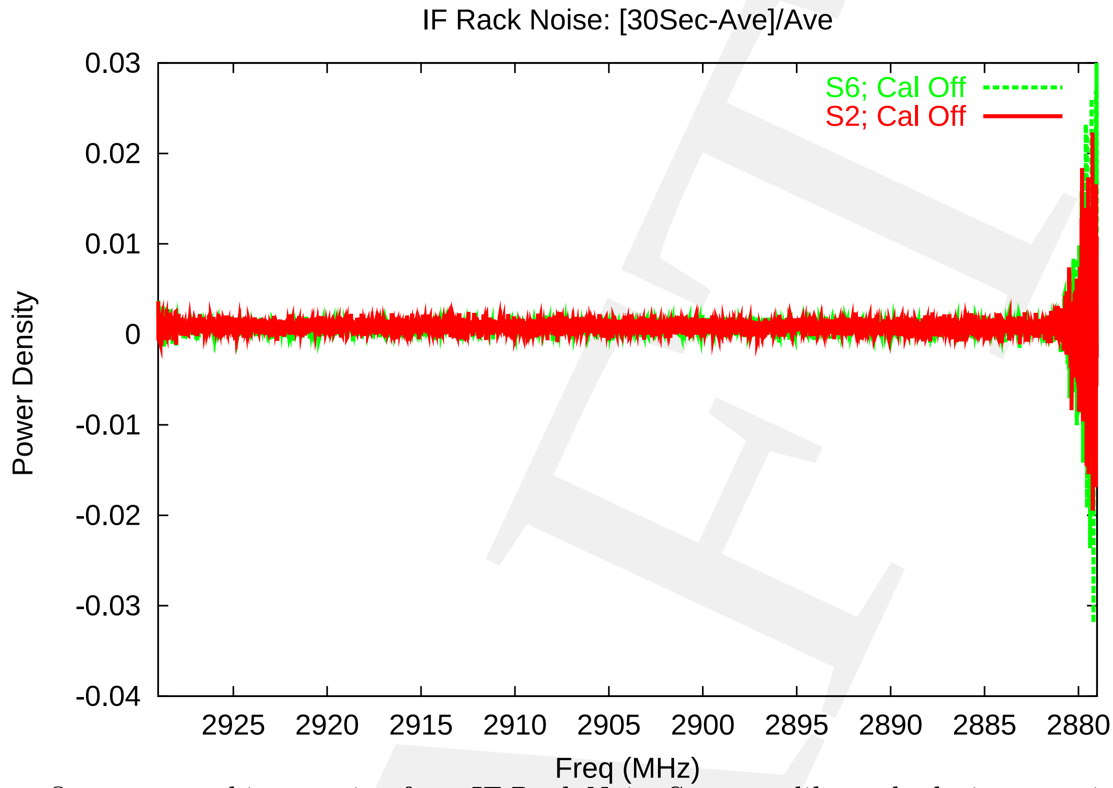

Figure 2: One 30 second integration from IF Rack Noise Source calibrated relative to an independent one hour average scan. Spectrum shows (Integration$_{30second}$ - average$_{1Hour}$)/average$_{1Hour}$.

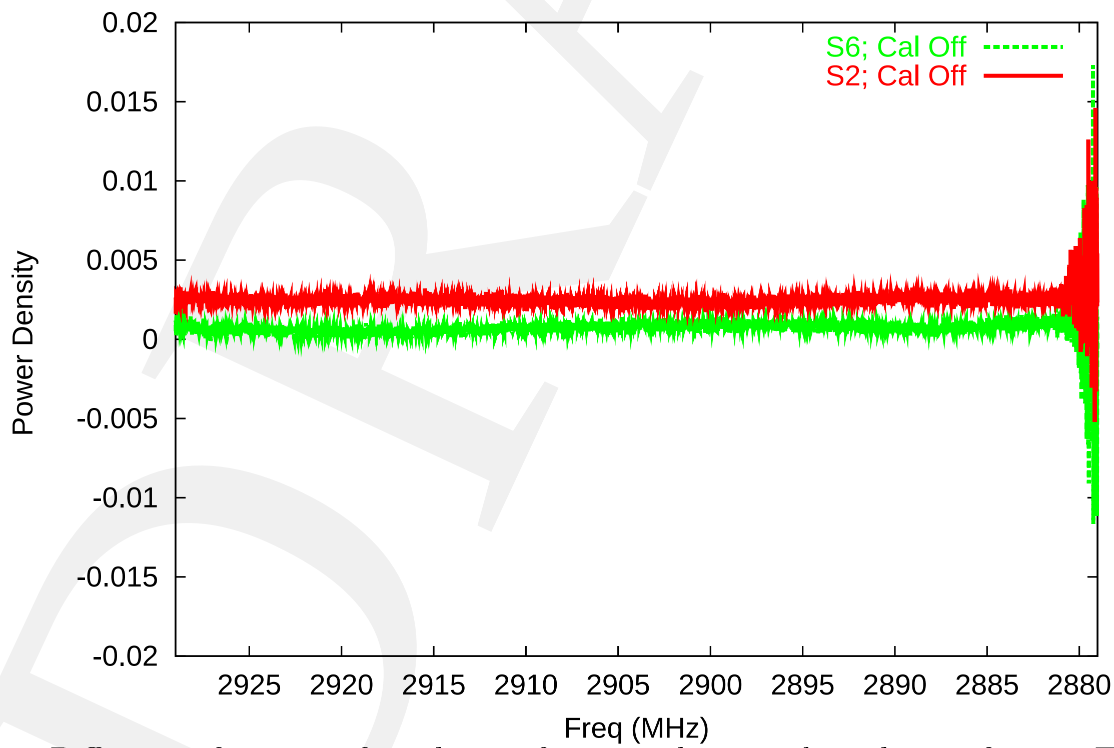

Figure 3: Difference of average of two hours of scans and a second two hours of scans. The Optical Modem 1 data is red (top), Optical Modem 3 data is green (bottom).

.

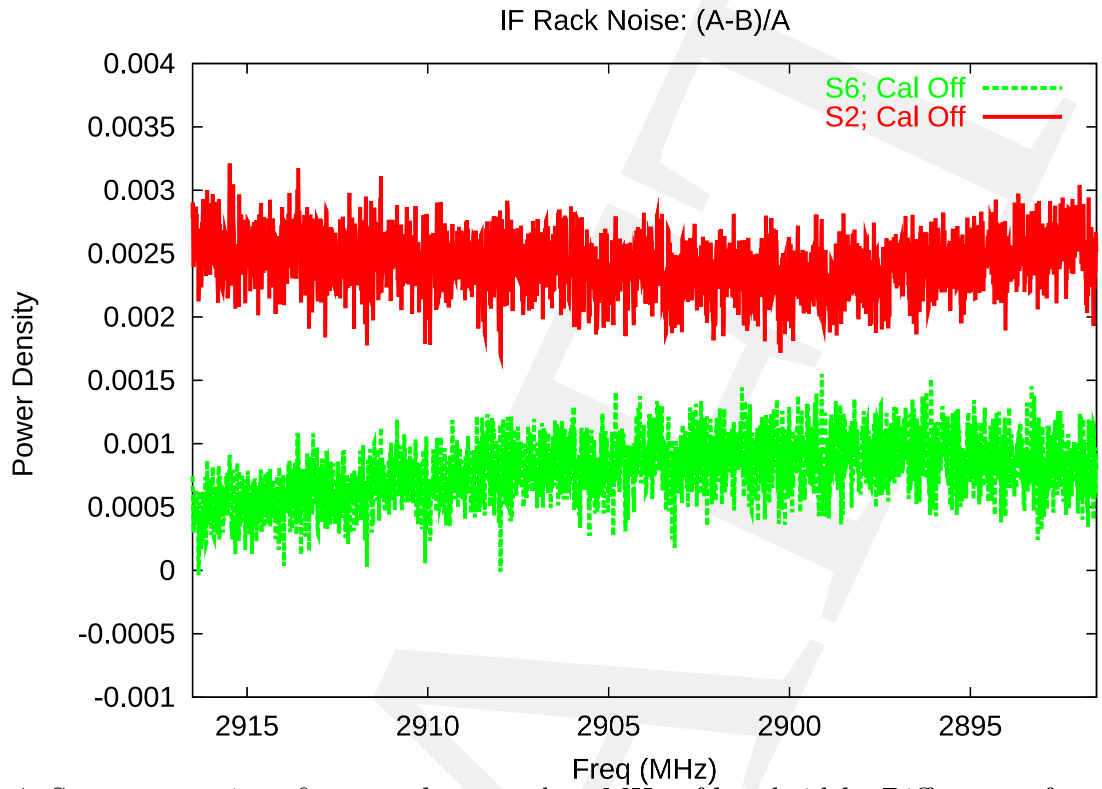

Figure 4: Same as previous figure, only central 25 MHz of bandwidth. Difference of average of two hours of scans and a second two hours of scans. The Optical Modem 1 data is red (top), Optical Modem 3 data is green (bottom).