IF Noise Source Spectra
Project TBASEJRF030211 and TBASEJRF030213, 11/13 February 2003

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Introduction

These two observing sessions were used to take an inventory of the baseline variations in all channels of the GBT IF system used with 800 MHz bandwidth. Some of the baseline ripples with periods of 50 to 70 MHz are known to be originating in the IF's and they have been found to be sensitive to GBT equipment room temperature. These measurements present a quantitative correlation of baseline ripple amplitude with room and IF rack temperature. A likely cause of IF baseline ripples is signal reflections at the ends of cables between IF modules and variations in the electrical lengths of these cables with temperature. An analysis of this effect can be found in

http://www.gb.nrao.edu/gbt/baseline/subpages/reports/IFLINgw030203.

The Setups

Tables 1 and 2 show the signal connection paths from the IF noise source to the spectrometer samplers. Half of the IF modules were sampled in each measurement run. Notice that one fiber optics channel is common to two converter/filter/sampler module sets, which can help isolate the origin of baseline effects by looking for common effects in two spectra. Optical modulators 1-5 and 7 are the original external laser modulators, modulator 6 is the one modified for lower 2.4-MHz ripple, and modulator 8 is a direct modulator.

The DCR was run simultaneously with the spectrometer. The DCR sampled the signals at the output of the IF racks where the signals enter the optical modulators and at the output of the analog filter racks where the signals go to the spectrometer samplers. Table 3 lists the DCR channel assignments.

The spectrometer was the master for switching signals and was set up as if there was a receiver with four cal/sig/ref phases in beam-switching mode, but all four phases will be from the same IF noise source connection. One long scan of more than five hours duration was taken each night using 6000 MHz IF frequency, 30-second integration times, 800 MHz bandwidth, 4 banks,

Table 1: IF Noise Source to Spectrometer Connection Matrix on 11 February 2003

ODM	CM	SF	AC Sampler	AC bank	AC spectrum
2	1	1	0	A	1
2	3	3	4	C	1
4	5	5	1	A	2
4	7	7	5	C	2
6	10	2	2	B	1
6	12	4	6	D	1
8	14	6	3	B	2
8	16	8	7	D	2

Table 2: IF Noise Source to Spectrometer Connection Matrix on 13 February 2003

ODM	CM	SF	AC Sampler	AC bank	AC spectrum
1	2	2	2	B	1
1	4	4	6	D	1
3	6	6	3	B	2
3	8	8	7	D	2
5	9	1	0	A	1
5	11	3	4	C	1
7	13	5	1	A	2
7	15	7	5	C	2

8 samplers, in spectrometer modes 1W2-001-800, 1W2-123-800, 1W2-245-800, and 1W2-367-800. The GBT equipment room temperature and the temperature at about eye level inside of converter rack A were recorded every ten seconds throughout each run.

Ripple Period Correlations with Cable Length

This analysis is looking for changes in the noise spectra from all of the IF channels as a function of time. The assumption is that something in the system is drifting over time scales of minutes to tens of minutes. Figure 1 shows an example of a noise spectrum change between the 2^{nd} 30-second record and the 30^{th} record on the first night's observing. The ripple that is most evident on the high frequency side of this spectrum is the effect we are measuring. To quantify the amplitude and isolate different ripple periods we take the Fourier transform of this spectrum with the noisy end-points deleted as shown on Figure 2. This is on of the worst examples of ripple measured in this data set with three strong ripple components that are not obviously harmonically related. Figures 3 and 4 show the the spectrum and periodogram of one of the weakest and simplest ripples detected in the 30-second record differences. All IF channels show some detectable ripple in the differences of spectra taken less than 5 minutes apart during the 5 hours of monitoring, but at times the spectra were stable for periods considerably longer than 5 minutes.

Figures 5 and 6 show summaries of the ripple periods seen throughout the

Table 3: DCR Connections on 11 and 13 February 2003

DCR Channel	Connection	Date (Feb.)
1	ODM 1	13th
2	ODM 2	11th
3	ODM 3	13th
4	ODM 4	11th
5	ODM 5	13th
6	ODM 6	11th
7	ODM 7	13th
8	ODM 8	11th
9	SF 1	11th and 13th
10	SF 2	11th and 13th
11	SF 3	11th and 13th
12	SF 4	11th and 13th
13	SF 5	11th and 13th
14	SF 6	11th and 13th
15	SF 7	11th and 13th
16	SF 8	11th and 13th

five-hour runs of 11 and 13 February, respectively. Each of the top eight rows corresponds to an IF channel as designated in the last two columns of Tables 1 and 2. If a ripple period appeared relatively strongly sometime during the five-hour run, it is shown with a filled square. Most strong ripples were present much of the time. Weaker and often less frequently detected ripple features are shown as open squares. The bottom three rows in these two figures show the locations of the strongest periodogram features from the Roger's and Galen's tests of inducing ripples by changing cable lengths at three places in the IF system using modules OR1, CM1, SF1, and sampler HSS0. The periodograms of Roger's spectra are shown in Figures 7, 8, and 9. Channel A1 in Figure 5 corresponds most closely to the IF components used in Roger's and Galen's tests.

The most obvious correlation seen in Figures 5 and 6 is the prevalence of ripples with periods near FFT channel 13, which corresponds to a period of 800/13=62 MHz. This matches Roger's period of 63 MHz that resulted from a change in the length of the cable between the optical receiver module and the converter module. No obvious correlation is found with the 23- and 21-MHz periods created in the cable-length-change tests. The OR to CM cable carries a 6 GHz signal in the tests being described here while the CM to SF and SF to HSSx cables carried 0.8-1.6 GHz signals so one might expect a greater sensitivity to cable length changes with temperature at 6 GHz. However, one would also expect the longer lengths of the other two cable bundles to have larger absolute changes in length for a given temperature change that nearly compensates for the difference in frequency. The CM to SF and SF to HSSx cables are roughly three times as long as the OR to CM cables. The temperature environments of these three cable sets are not obviously different from visual inspection. Maybe the mismatches at the ends of the 6 GHz cable are somewhat worse than those seen by the lower frequency cables.

The ripples seen in FFT channels 7-10 and 17-45 are quite real and appear to have no counterpart in the cable length change tests.

Ripple Amplitude Correlations

Figure 10 shows a clear correlation between the amplitude of the FFT channel 13 (62 MHz) ripple of IF channel A1 with converter rack A internal air temperature. The correlation with GBT equipment room air temperature is less obvious. Figure 11 shows the FFT channel 13 (62 MHz) ripple amplitude as a function of time for all IF's measured on 11 February. Some channels are a lot less stable at this ripple period than others. several pairs of channels are well correlated, and others are not. There doesn't appear to be a strong connection between the variations within one converter rack, but some details do seem to match.

Figure 12 shows the amplitude variations in ripples with periods in three adjacent FFT channels of A1 periodogram of 11 February. The correlation between channels 11 and 13 is pretty weak. The ripple pattern shown in Roger's cable length test report is quite complex so very likely there is more than one effect contributing to the ripple pattern. Figure 12 suggests that these effects may have different sensitivities to time and/or temperature or that they are driven by somewhat forcing mechanisms.

Figure 13 shows a case where adjacent channels and even a widely separated channel in a series of periodograms are very well correlated. The fact that channel 30 is well correlated with channels 13, 14, and 15 suggests a harmonic relationship (double cable reflection?), although channel 28 would have been a better match.

One could continue to look for temporal correlations between amplitudes of various ripple periods, but at this point it's probably better to attack the 63 MHz ripple and reduce it below detectability. Then we can go back and look for the next layer of ripple effects in the IF system using similar diagnostics.

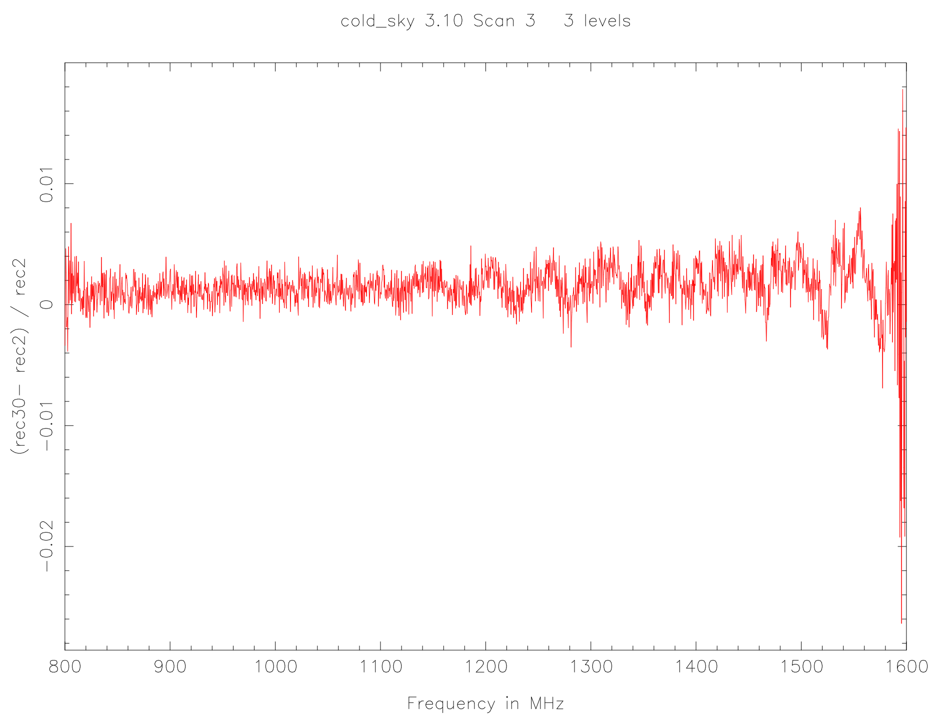

Figure 1: (record30 - record2) / record2 for spectrometer channel B1 form the 11 February run. The frequency scale is for the signal presented to the spectrometer 3-level sampler.

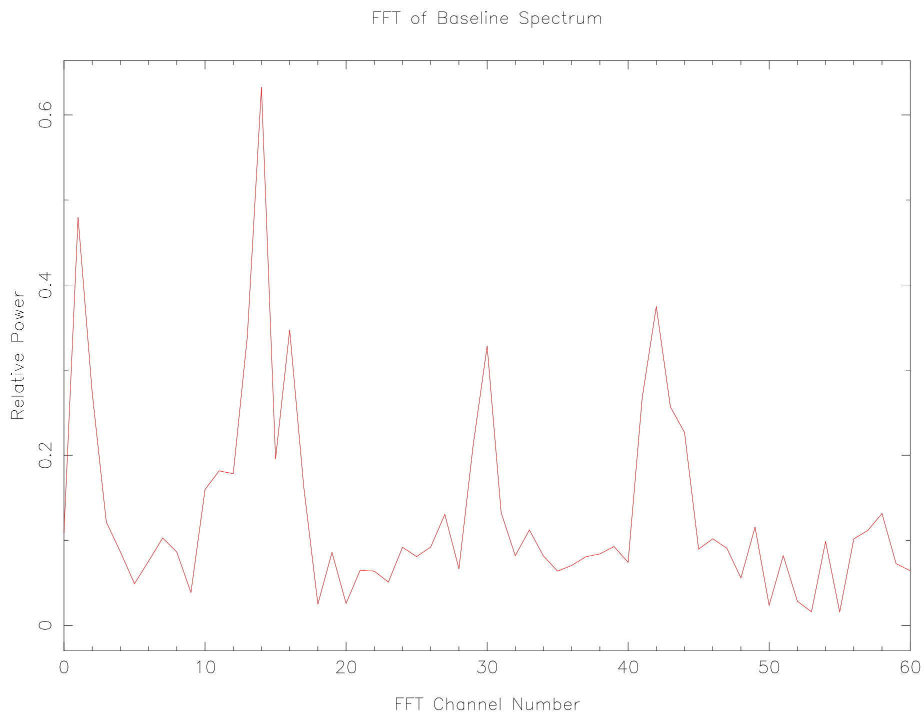

Figure 2: FFT of the spectrum shown in Figure 1. The horizontal axis is the FFT channel. The ripple period, in MHz, is 800 MHz divided by the channel number, and the electrical length of cable that would cause this ripple period is 18.75 cm times the channel number.

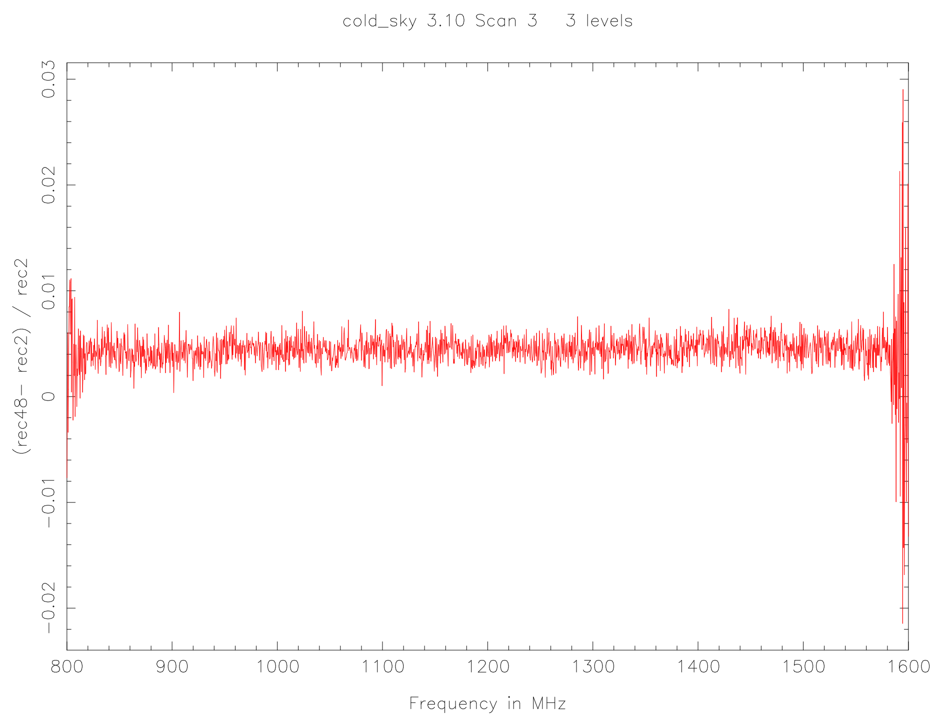

Figure 3: (record48 - record2) / record2 for spectrometer channel A1 form the 11 February run. The frequency scale is for the signal presented to the spectrometer 3-level sampler.

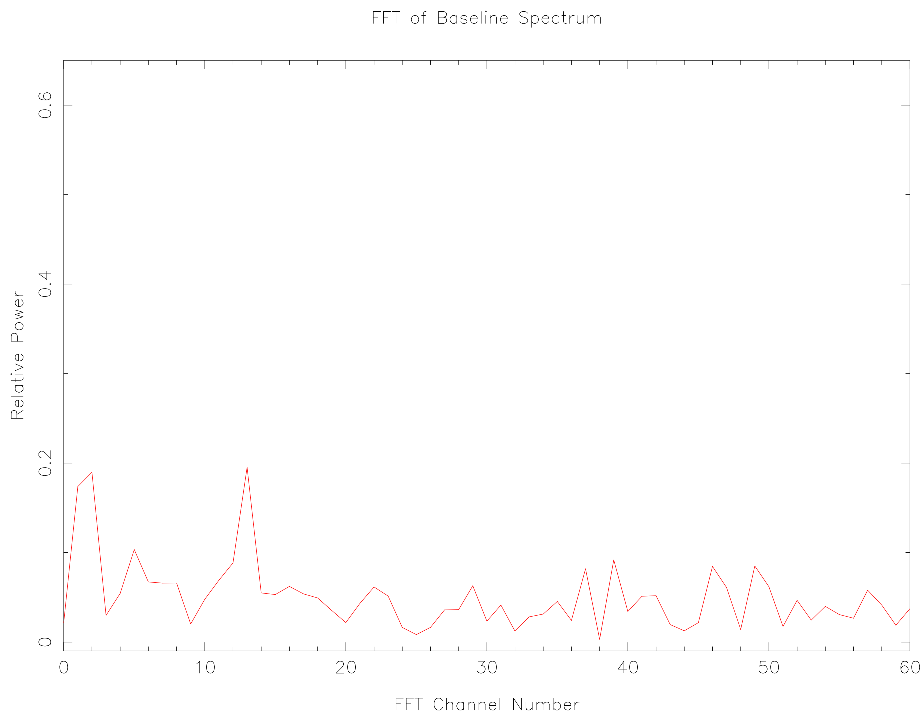

Figure 4: FFT of the spectrum shown in Figure 3. The horizontal axis is the FFT channel. The ripple period, in MHz, is 800 MHz divided by the channel number, and the electrical length of cable that would cause this ripple period is 18.75 cm times the channel number.

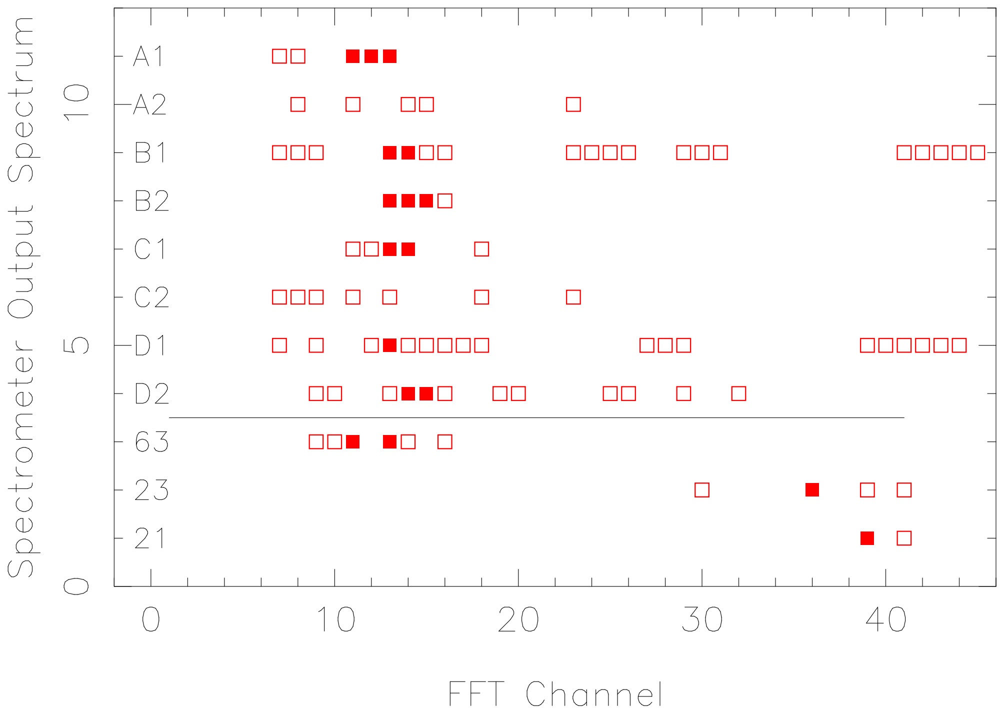

Figure 5: Ripple periods found in 11 February 2003 data. The horizontal scale is FFT channel number. The ripple period, in MHz, is 800 MHz divided by the channel number, and the electrical length of cable that would cause this ripple period is 18.75 cm times the channel number. The rows are for different IF channels using the spectrum designations given in the last two columns of Table 1. The bottom three rows show equivalent results for the FFT's of spectra obtained by changing IF cable lengths as reported in TBASErdn030221. Rows "63", "23", and "21" refer to the 63, 23, and 21 MHz ripple periods pointed out by Roger in this report. (See Figures 7, 8, and 9.)

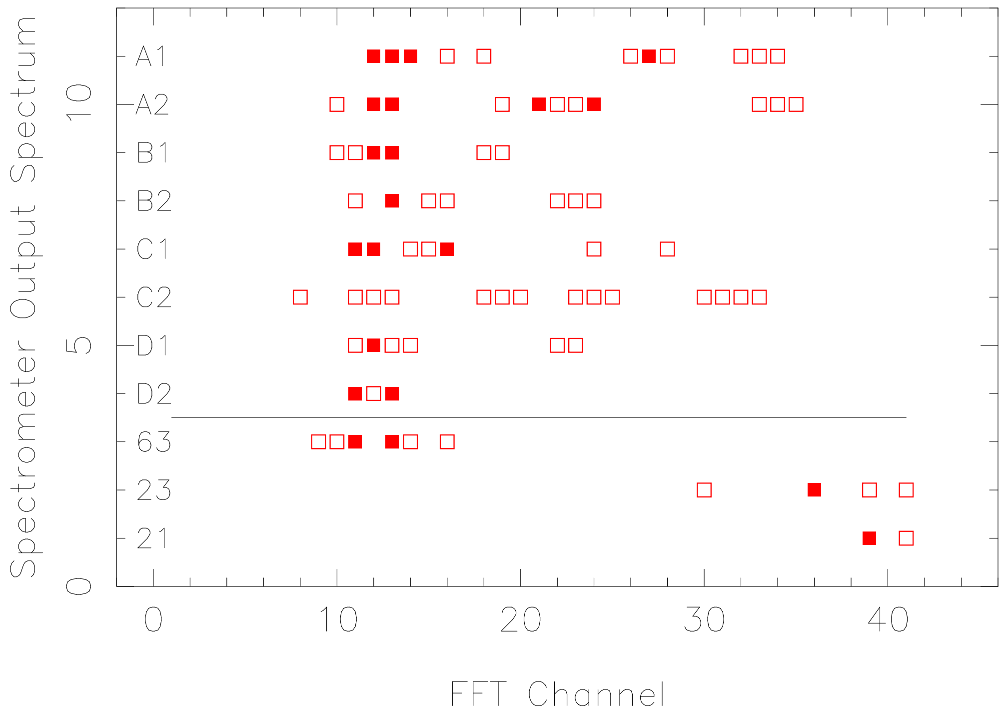

Figure 6: Ripple periods found in 13 February 2003 data. The horizontal scale is FFT channel number. The ripple period, in MHz, is 800 MHz divided by the channel number, and the electrical length of cable that would cause this ripple period is 18.75 cm times the channel number. The rows are for different IF channels using the spectrum designations given in the last two columns of Table 2. The bottom three rows show equivalent results for the FFT's of spectra obtained by changing IF cable lengths as reported in TBASErdn030221. Rows "63", "23", and "21" refer to the 63, 32, and 21 MHz ripple periods pointed out by Roger in this report. (See Figures 7, 8, and 9.)

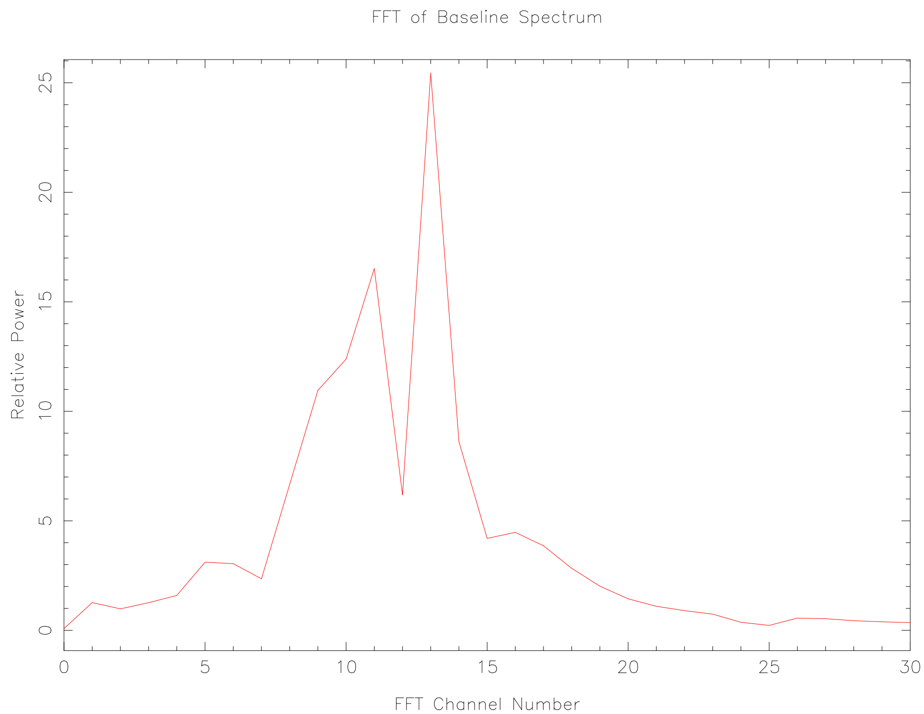

Figure 7: FFT of the spectrum shown in Figure 1 of Roger's report on changing IF cable lengths (TBASErdn030221/report.ps). The horizontal axis is the FFT channel. The ripple was induced by changing the length of the cable between OR1 and CM1 by a small amount. The ripple period, in MHz, is 800 MHz divided by the channel number, and the electrical length of cable that would cause this ripple period is 18.75 cm times the channel number.

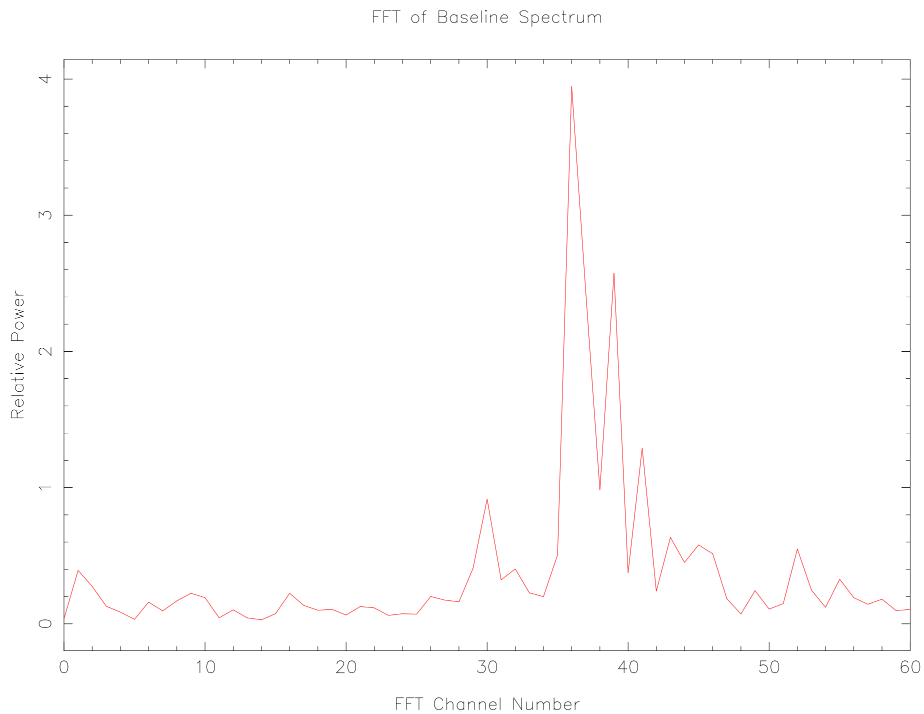

Figure 8: FFT of the spectrum shown in Figure 3 of Roger's report on changing IF cable lengths (TBASErdn030221/report.ps). The ripple was induced by changing the length of the cable between SF1 and sampler HSS0 by a small amount. The horizontal axis is the FFT channel. The ripple period, in MHz, is 800 MHz divided by the channel number, and the electrical length of cable that would cause this ripple period is 18.75 cm times the channel number.

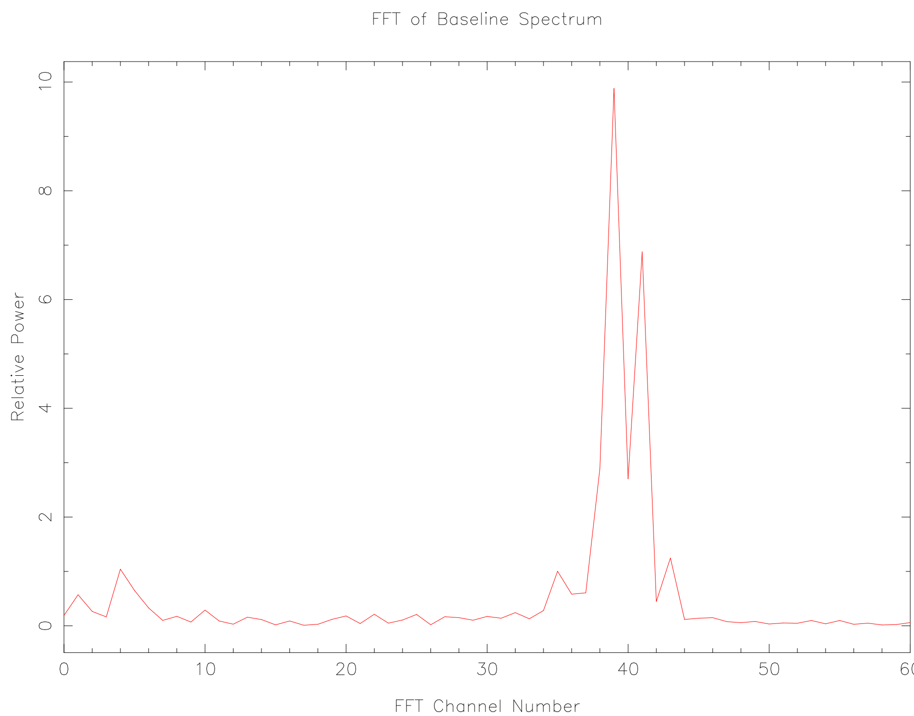

Figure 9: FFT of the spectrum shown in Figure 2 of Roger's report on changing IF cable lengths (TBASErdn030221/report.ps). The horizontal axis is the FFT channel. The ripple was induced by changing the length of the cable between CM1 and SF1 by a small amount. The ripple period, in MHz, is 800 MHz divided by the channel number, and the electrical length of cable that would cause this ripple period is 18.75 cm times the channel number.

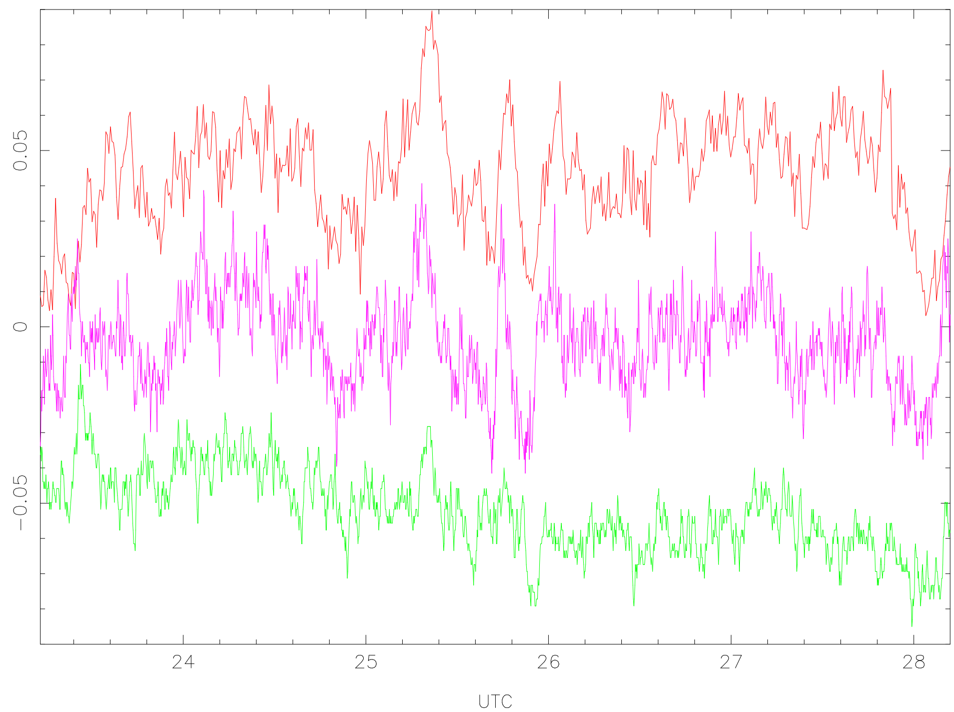

Figure 10: Correlation of the 62-MHz ripple period amplitude in IF channel A1 of the 11 February data (red curve) with converter rack A internal air temperature (violet) and GBT equipment room air temperature (green). The temperature values have been multiplied by 0.2 and given an arbitrary zero offset to allow easier visual comparison with the ripple amplitude curve.

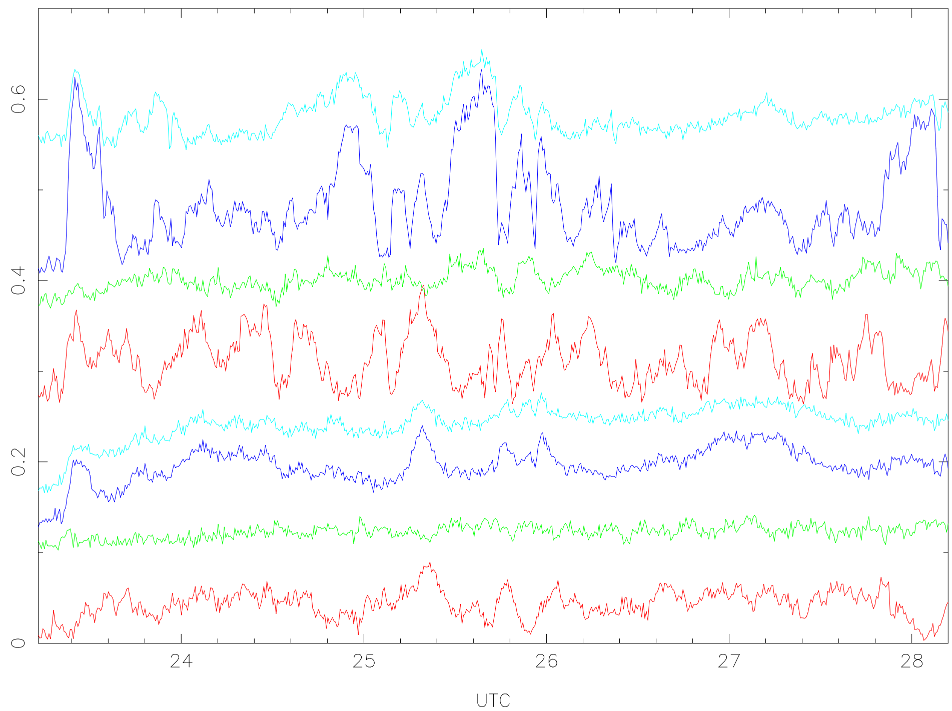

Figure 11: FFT channel 13 (62-MHz ripple period) amplitude of 11 February for IF channel A1 (bottom red), A2 (bottom green), B1 (bottom dark blue), B2 (bottom blue-green), C1 (top red), C2 (top green), D1 (top dark blue), and D2 (top blue-green). The red and green curves are for converter modules in rack A, and the blue and blue-green are in rack B.

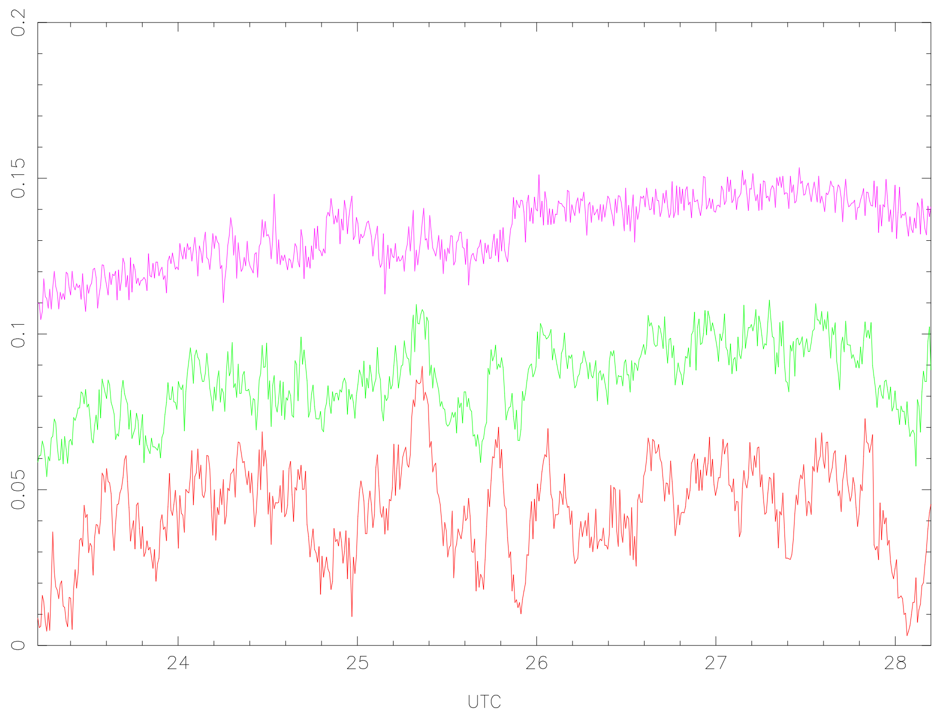

Figure 12: Ripple amplitudes as a function of time for FFT channels 11 (73-MHz period, violet), 12 (67 MHz, green), and 13 (62 MHz, red) in IF channel A1 of the 11 February run. The green and red curves are offset by 0.05 and 0.1, respectively, for clarity.

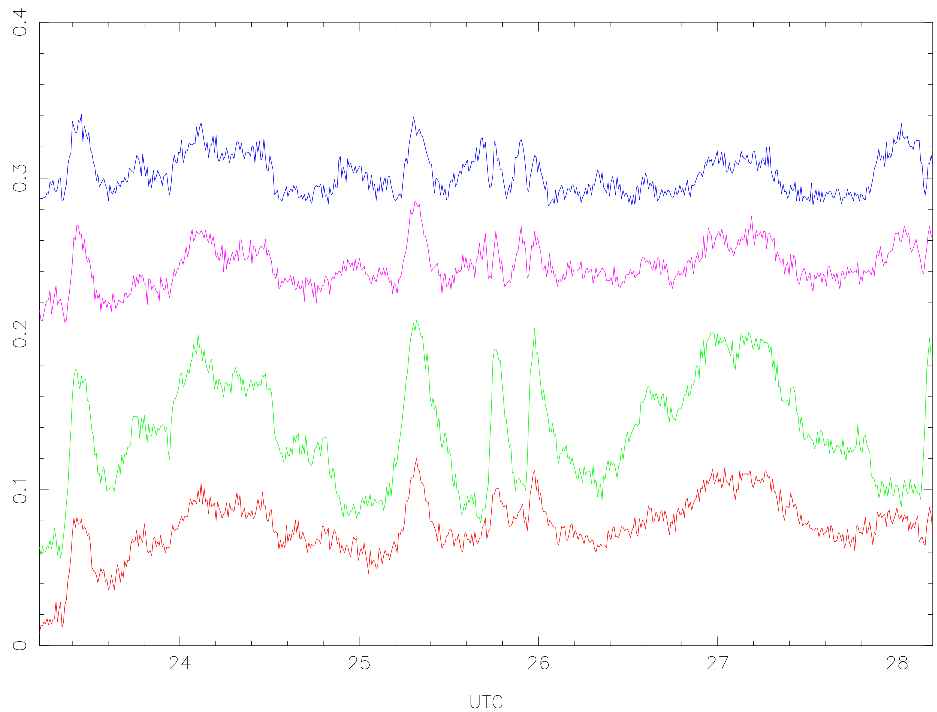

Figure 13: Ripple amplitudes as a function of time for FFT channels 13 (62-MHz period, red), 14 (57 MHz, green), 15 (53 MHz, violet), and 30 (27 MHz, blue) in IF channel B1 of the 11 February run. The green, violet, and blue curves are offset by 0.05, 0.2, and 0.28, respectively, for clarity.