November 22, 2002

Summary Report
Project ID TBASErdn021121

On November 21, Galen Watts and Roger Norrod used the DCR and a laboratory noise source injected at various points in the Equipment Room IF system to characterize and isolate out-of-the-ordinary IF gain fluctuations. The Analog Filter Rack 200/800MHz SF modules 1-8 and the Converter Racks' CM 1-16 were evaluated.

The test source consisted of a diode noise source, transistor amplifier, and a passive four-way power splitter. The source outputs were connected into Input 3 (J3) of SF1 – SF4.

Scan Summary:

tau=1sec, BW=200MHz, T = 300sec. DCR Mode TPwCal. Recording SF1-SF4 TP outputs. Times given in UTC.

Scans 1-12: 13:44:09 to 14:45:18

Moved source outputs to inputs of SF5 – SF8. Recording SF5-SF8 TP outputs.

Scans 13-24: 14:49:01 to 15:50:09

Changed BW to 800MHz in SF5-SF8.

Scans 25-26: 15:56:34-16:06:42

Changed tau->0.1sec, T->60sec, DCR mode to TPnoCal.

Scan 27-28: 16:09:55 to 16:12:03

Moved test source outputs to CM 1-4, and tuned LO2 to 10700 MHz (tunes 1100 MHz to 900MHz, center of SF 200MHz sampling band). tau->1sec, BW->200MHz, T->300sec, DCR mode remains TPnoCal, recording SF1-SF4 TP outputs.

Scan 29-31: 16:32:47 to 16:48:05

Increased CM attenuator by 1dB.

Scan 32-33: 16:49:18 to 16:59:26

Moved test source outputs to CM9-12. Still recording SF1-SF4.

Scan 34:37: 17:08:13 to 17:28:37

Moved test source outputs to CM5-8. Recording SF5-SF8.

Scan 38-41: 18:14:00 to 18:29:17

Moved test source outputs to CM18-16. Recording SF5-SF8.

Problems with scan 42; rebooted DCR.

Scan 43-45: 18:55:19 to 19:10:36

Swapped noise source cables: CM13 <-> CM14, CM15 <->CM16.

Scan 46-47: 19:15:24-19:25:34

Discussion of Tests:

To evaluate the health of the receiver chain, it is helpful to return to the radiometer equation (Wollack, *Rev. Sci. Inst.,* v66, Aug 1995, pp4305-4312):

$$\left(\frac{\Delta T_{rms}}{T_{sys}}\right)^2 = \frac{1}{B\tau} + \left(\frac{\Delta G}{G}\right)^2 + \left(\frac{\Delta T_{sys}}{T_{sys}}\right)^2 \qquad (1)$$

The first right-hand term is due to Gaussian (thermal) fluctuations in the input signal and sets the best receiver sensitivity that can be obtained. For the conditions used in most of the tests above,

$$\frac{1}{B\tau} = \frac{1}{(200x10^6)(1)} = 5x10^{-9}$$

By comparing the measured total power fluctuations to this limit, it should be possible to determine the maximum bandwidth and integration time product at which gain and system temperature fluctuations begin to dominate. In the discussion below, it is assumed that $\Delta T_{sys} = 0$, although it is not generally possible to separate these fluctuations from gain fluctuations.

Continuum detection in the GBT is done in the following fashion. The signal to be detected is input to a square-law detector. The detector output goes to a DC to ~20kHz amplifier to boost the mean voltage to nominally one volt, and then to a V/F converter which produces pulses at the nominal rate of 1MHz/Volt. The V/F pulses are transmitted over multimode fiber to the DCR, which contains sixteen programmable counters. The DCR counts the pulses for the specified integration time and writes the resulting counts to disk. In the analysis used below, the samples for each recorded channel are normalized by:

$$C_i^N = \frac{C_i - \overline{C}}{\overline{C}} \qquad (2)$$

where $\overline{C}$ is the mean of the samples over the analyzed period, typically 10 minutes. Measured variance is calculated by squaring the standard deviation of (2) for the analyzed period.

We found that the test noise source was quite sensitive to movement and probably temperature. The data showed a more-or-less linear drift of 0.2% to 0.9% over ten minutes that was obviously correlated in all four channels. For the time being, I assume that all the measured linear drift is due to drift of the test source, although we will work to better stabilize the source and repeat these tests. A linear baseline was fit and subtracted from each measurement. The variance of the data after the linear baseline was subtracted is tabulated below as V_L.

It is clear from examining the fitted plots that most of the short-term data fluctuations are also correlated between the four channels. That is to be expected as the same amplified noise source is injected into all four channels under test, and the output fluctuations should be correlated if the source "thermal" fluctuations dominate the output fluctuations. (That's our goal!) Of course, there are mechanisms (e.g. power supply fluctuations) that could also produce gain fluctuations correlated across the channels. Regardless, I carried the analysis one step further by calculating a sample-by-sample average across two to four of the channels, and subtracted this average from all four. That removes correlated fluctuations and the residual variance should be due to uncorrelated gain fluctuations. Using this method, several suspect modules were identified. The variance after this average subtraction is tabulated below as V_A.

Table 1
Measured Variances

Scans	Modules	$V_L x10^9$	$V_A x10^9$
9-10	SF1	8.3	1.0
9-10	SF2	7.2	0.3
9-10	SF3	8.8	0.5
9-10	SF4	7.7	0.4
13-14	**SF5**	**25.3**	**20.5**
13-14	SF6	9.6	0.4
13-14	SF7	11.5	0.3
13-14	SF8	11.2	0.4
32-33	**CM1->SF1**	**116**	**68**
32-33	CM2->SF2	40	4.0
32-33	CM3->SF3	14.4	11.7
32-33	CM4->SF4	44.1	5.2
36-37	CM9->SF1	52.9	3.7
36-37	CM10->SF2	28.9	6.7
36-37	CM11->SF3	57.6	3.0
36-36	CM12->SF4	40.0	2.0
40-41	CM5->SF5	36.1	18.0
40-41	CM6->SF6	12.1	0.8
40-41	CM7->SF7	12.1	0.8
40-41	CM8->SF8	16.9	5.3
43-44	CM13->SF5	--	30.6
43-44	CM14->SF6	--	3.7
43-44	CM15->SF7	--	1.2
43-44	CM16->SF8	--	2.7

Conclusions:

SF5, CM1, and to a lesser extent, SF1 stand out with poorer stability. These will be pulled from the system as soon as possible, and units with better performance moved into those heavily used slots. It is also clear that the converter modules generally dominate the CM-SF cascades' fluctuations, except when SF5 is used. This may be 1/f noise in the microwave amps in these modules, but further investigation will be needed.

We need to better package the test noise source equipment to improve its stability. I find this testing technique is quite useful to isolate bad modules. An obvious follow-up is to inject into the SF modules and use the Spectrometer to take data.

R. Norrod
11/22/2002