VSRT MEMO #064

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To: VSRT Group
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Subject: Measurements of system noise changes at 11 GHz during heavy rain.

A compact fluorescent lamp (CFL) installed on the “test” ozone spectrometer located at Haystack is currently under test as a automated method of calibrating the spectrometer. The objectives of these tests are as follows:

1. Evaluate the stability and reliability of the CFL microwave output for calibrating a radiometer.
2. Compare various methods of calibrating the spectrometer.

Figure 1. Ozone spectrometer at Haystack with CFL lamp for calibration tests.

Figure 1 show the setup of the ozone spectrometer and the CFL. Initial tests made by Sai Tenneti as part of his REU research used a 12volt 3V CFL (Bright Light SDC-M3W). While these results were promising they were carried in good weather, so that there was little variation in the system noise, and the data were noisy owing to interference from the Haystack radar. Sai measured the equivalent output of CFL to be 7 K. This result is reasonable given the geometry in which the CFL is on the edge of the LNBF beam at a point which is about -10dB relative to the on axis response. Unfortunately the CFL failed after about 1000 on/off cycles. The CFL is turned on and off in a 3 minute cycle. This is a weak point in the CFL design which has been largely corrected in some newer designs. So far the replacement of CFL (Solsum ESL 12v 7w) has been running for more than 10 days or 5,000 cycles.

A model for the system noise T_{sys}, is as follows:

$$T_{sys} = T_{cmb} e^{-(\tau_a + \tau_r)} + T_{atmos}\left(1 - e^{-(\tau_a + \tau_r)}\right) + T_{LNA} + T_{spill} + T_{CFL} e^{-\tau_r}$$

T_{cmb} = 3 K cosmic background

$T_{atmos} \sim$ 295 K

T_{LNA} = 30 K (~0.4 dB NF)

T_{spill} = 40 K spillover

T_{CFL} = 30 K CFL effective temperature

τ_a = 11 GHz atmospheric opacity at 8 degrees elevation ~ 0.1 under typical conditions

τ_r = opacity at 11 GHz due to rain on the feed's hydrophobic cover.

Methods of calibration

1. Y factor measurement with absorber.

$$Y_{load} = \left(T_{LNA} + T_{amb}\right) / T_{sys}$$

where T_{amb} = ambient temperature ~ 295 K

If we measure Y_{load} and assume a value for T_{LNA}, obtained by other means, we can calculate T_{sys}. If we then assume the radiometer gain is constant we can keep track of the T_{sys} vs time using

$$T_{sys}(t) = T_{sys}(t_y) P(t) / P(t_y)$$

where $P(t)$ = the current total power

$P(t_y)$ = total power at time of Y factor

2. CFL calibration

If the CFL is used to measure a Y factor

$$Y_{CFL} = \left(T_{sys} + T_{CFL}\right) / T_{sys}$$

$$T_{sys}(t) = T_{CFL} \Big/ \left(Y_{CFL}(t) - 1 \right)$$

where the T_{CFL} has been determined from $T_{CFL} = T_{sys}(t_y)\left(Y_{CFL}(t_y) - 1\right)$

Figure 2 shows T_{sys} vs time from the first method, which assumed the radiometer gain is stable and $T_{CFL}(t)$ from $T_{CFL}(t) = T_{sys}(t)\left(Y_{CFL}(t) - 1\right)$.

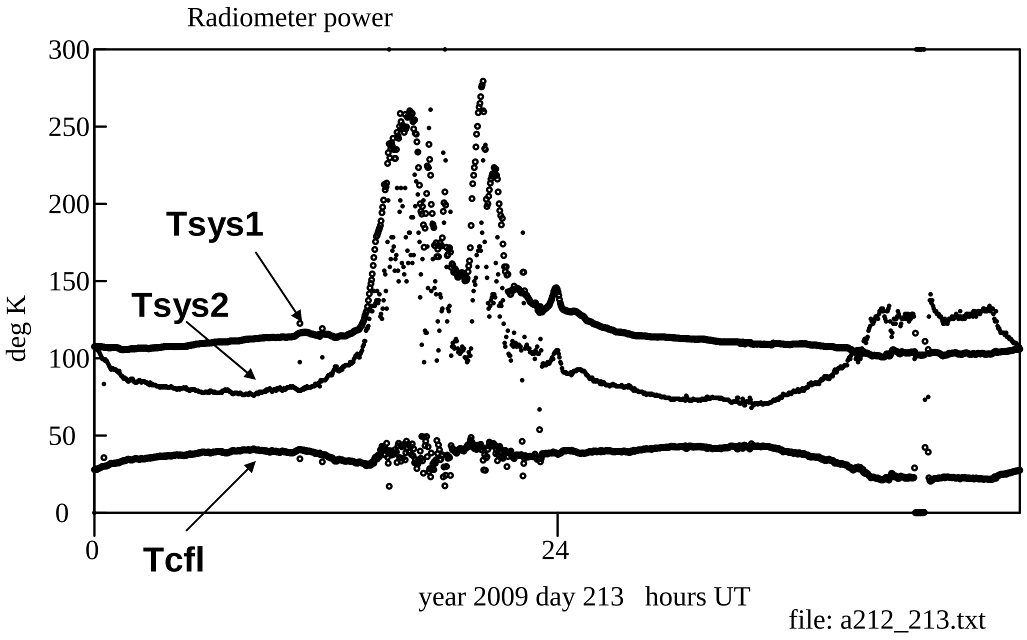

Figure 2. System temperature from method 1 ($T_{sys}1$) and method 2 ($T_{sys}2$) along with T_{CFL}.

Also shown in figure 2 is T_{sys} vs time from the second method. The T_{sys} from the second method is noisy and suffers from variability in the CFL microwave output with temperature. The problem is mainly due to the CFL startup. In order to achieve a greater life time under frequent on/off cycles as would be present in a motion sensitive light the electronics preheats the lamp before bringing the lamp to full intensity. The problem could be ameliorated by using a much longer calibration cycle time.

An encouraging aspect of figure 2 is that it looks like the first method works extremely well as the gain is extremely stable. Another interesting feature is the derived CFL temperature, except for very brief occasions, is not effected by heavy rain on the LNBF. This means that the large increase in system temperature during rain is mainly due to losses in the atmosphere and not due to a layer of water on the LNBF feed cover. Apparently the plastic cover on the LNBFs are extremely hydrophobic and are probably more effective than a radome in preventing signal loss due to rain.

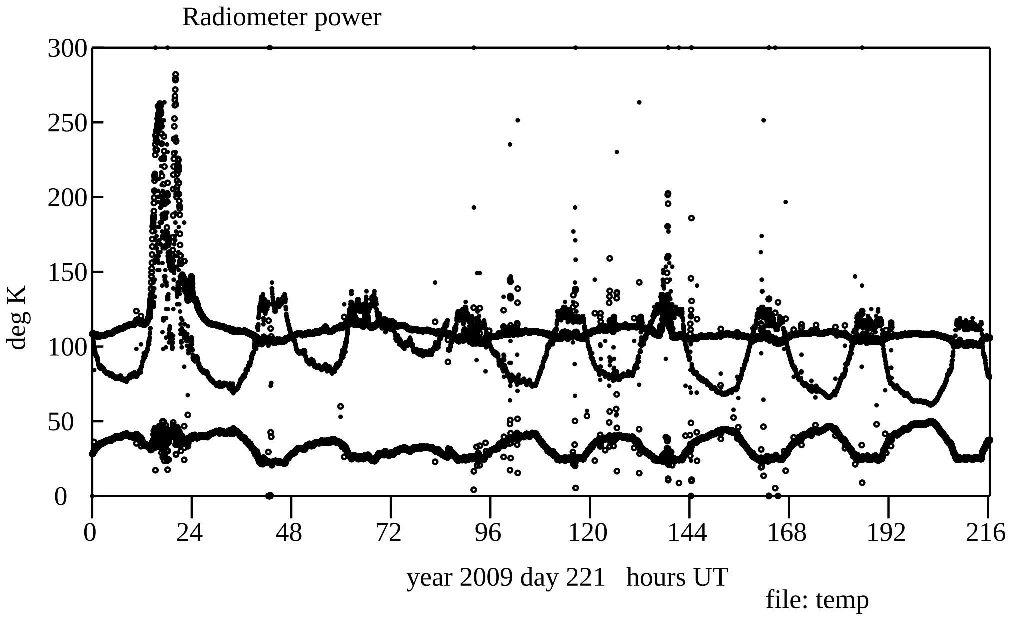

Figure 3. shows the results from a longer time span in which the diurnal variations in CFL output are quite evident.