The Dependence of ATA System Gain Stability on Temperature of the PAX Box.

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This is a gain stability study of an ATA receiver front-end in which the PAX box temperature is varied and the resulting total power is recorded. The ATA front end consists of a log-periodic feed coupled to a refrigerated LNA followed by a Post Amp Module (PAM). The PAM drives the optical fiber modulator that feeds the single mode fiber carrying the 0.5 - 11 GHz band to the lab. The LNA is inside a dewar cooled to a regulated 62 K. The PAM and fiber driver are inside an enclosure, the PAX box, that is regulated to 20.1± 0.1 ºC. The fiber is carried to the laboratory through an underground PVC pipe in which the temperature is stabilized. The question that we address is the dependence of the front-end gain on the temperature of the PAX box.

For the test we used antenna 2c pointed in a northerly direction at an elevation of about 45º. It's fiber coming into the lab was coupled to a PAM unit with an input fiber diode detector. The output of this PAM unit was coupled to a power detector through a high pass filter. The filter, consisting of a length of x-band waveguide, transmitted only frequencies above about 7 GHz. The filter was chosen to eliminate the received lower frequencies at the antenna which are more plagued with interference. The lab PAM unit was wrapped in a thermally insulating cloth to slow its temperature drifts due to the cycling of the Liebert cooler in the lab. Because lab temperature drifts are of the order of a degree, we are only able to measure a lower limit to the stability of the amplifiers on the front end in this test. To test the PAX temperature dependence, we arranged to be able to turn off the regulator of the PAX box, a thermoelectric cooler (TEC), observe the drift of total power with PAX temperature and then turn the regulator back on again.

The upper panel of Figure 1 shows the power output from the lab PAM unit as a function of time. One large tick is 0.1 dB. The lower panel shows three temperatures on the same time scale: the black line is the PAX case temperature; the green curve is its heat exchanger temperature; the red curve is the temperature of the air blown into the PAX case and over the heat exchanger from the underground PVC pipe. The PAX case temperature is also plotted in the upper panel, inverted to emphasize the correlation. The regulator was turned off at 16.6 hours. When the temperature had risen by 5 degrees, the regulator was turned back on because the temperature sensor ceases to be linear beyond 5 degrees difference from its normal operating value of 20.1 degrees C. Then the regulator was turned off and on one more time. In Figure 2 the case temperature is further scaled to emphasize the close correlation between the case temperature and the total power.

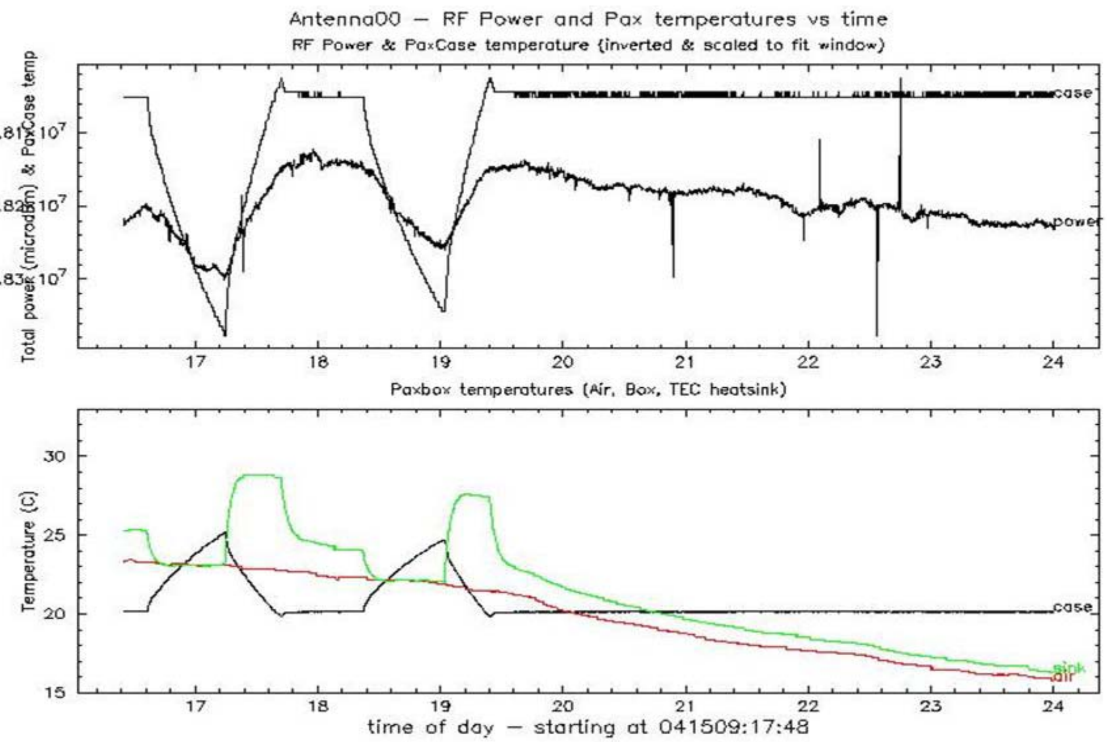

Fig 1. Changing the Pax Box temperature produces a clear change in the total power.

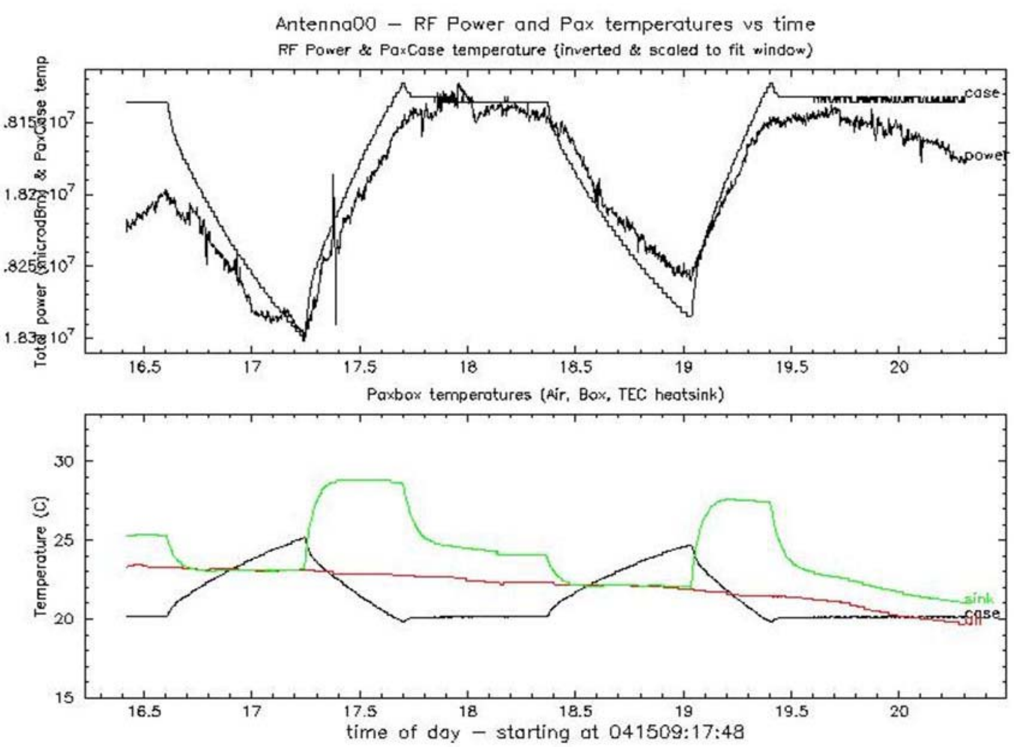

Fig 2. Further rescaling the temperature emphasizes the close correlation.

Evidently, the total power dropped by 0.1 dB as a result of the 5 degree temperature increase of the PAX case.   0.1 dB is a gain drop of 2.3%. This gain change is .02 dB per degree. It agrees well with measurements in the laboratory of one PAM unit: .02dB/degree. It is interesting that there were no apparent additional gain changes associated with the optical fiber drivers. These units have additional temperature regulation which appears to have remained stable during the 5 degree case temperature change.

Figures 3, 4, and 5 show the measured temperatures of the PAX boxes in nodes 1, 2, and 3 on July 8, 2008. During the middle part of the day, nearly all of the individual antenna PAX boxes are out of regulation. Because of the saturation of the temperature sensors, it is not possible to know how far the actual PAX temperatures drifted away from the 20.1 C regulation point or whether they reached a fixed error at any time. From the result of the experiment described here, we may expect gain drifts of the order of a few percent during any day like July 8, 2008. The time scales are evidently slow due to the thermal inertia of the PAX Box. With the box temperature regulated, gain fluctuations appear to be not more than about 0.2% over time scales of the order of 20 minutes.

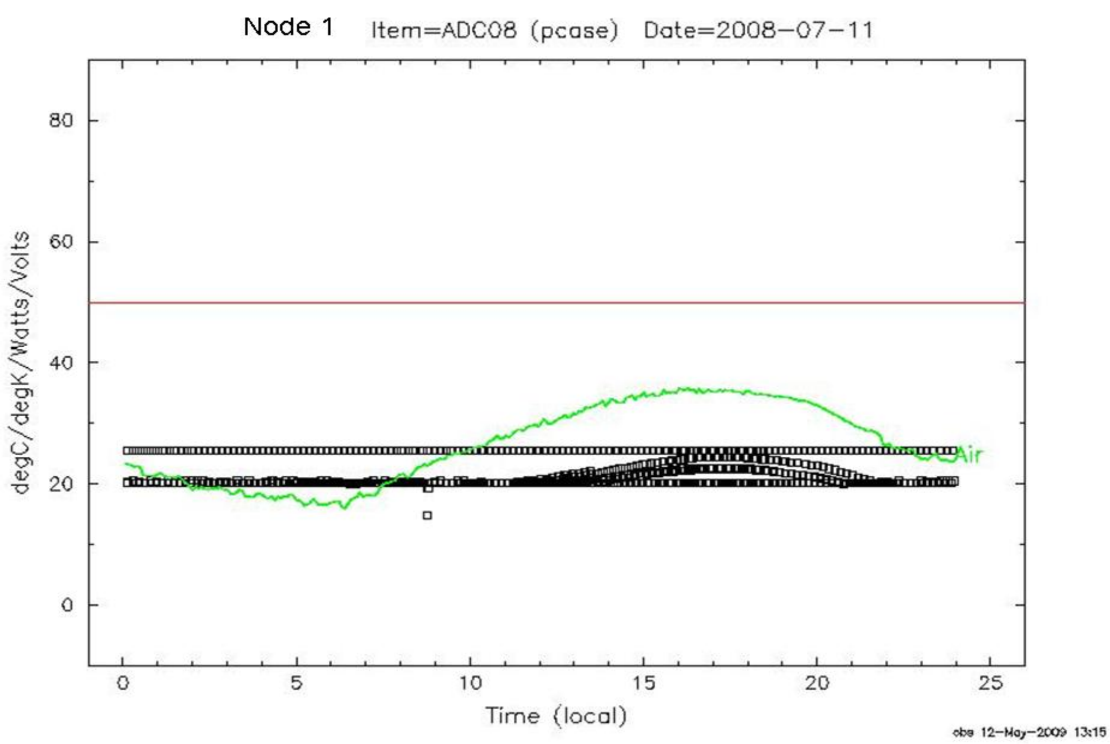

Fig 3. Temperatures of the different antenna Pax Boxes in node 1 during the day. The green line is the outside air temperature. The red line at 50C is the specified maximum operating temperature for most ATA electronics.

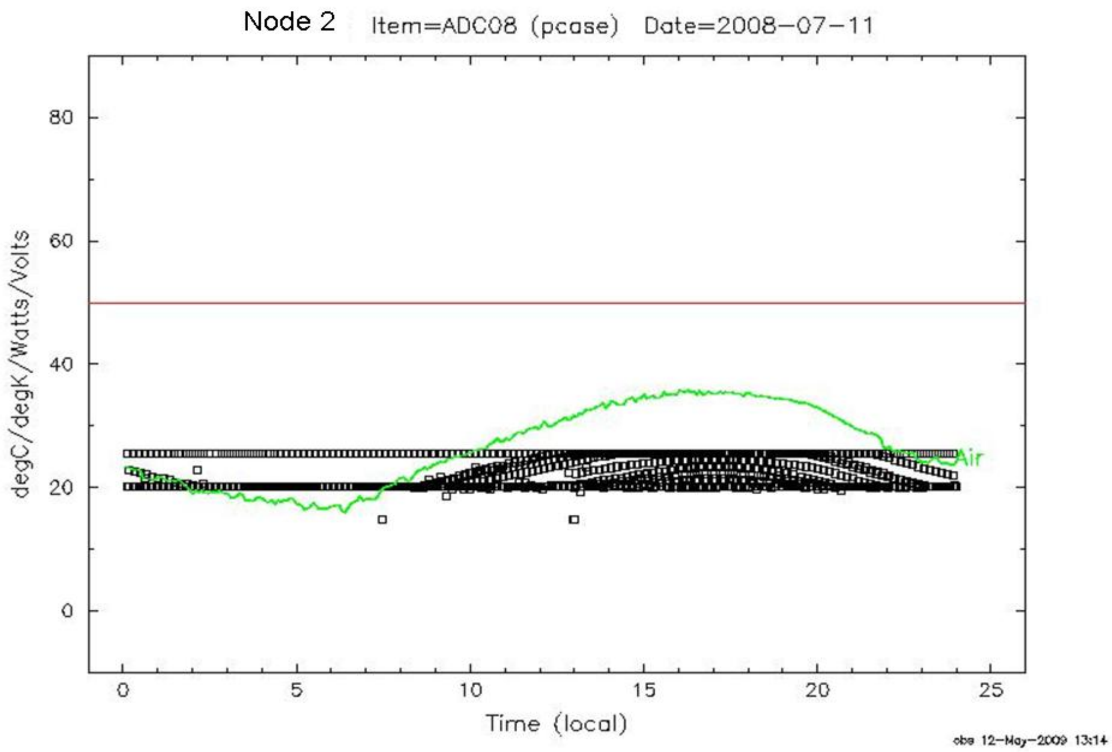

Fig 4. Node 2 Pax Box temperatures. A few with long underground cooling pipes remained in regulation. Bad or saturated sensors appear as flat lines at 25.5C (5v on ADC) and 15.7C (0v). Well regulated sensors are flat lines at 20.1C (2.5v).

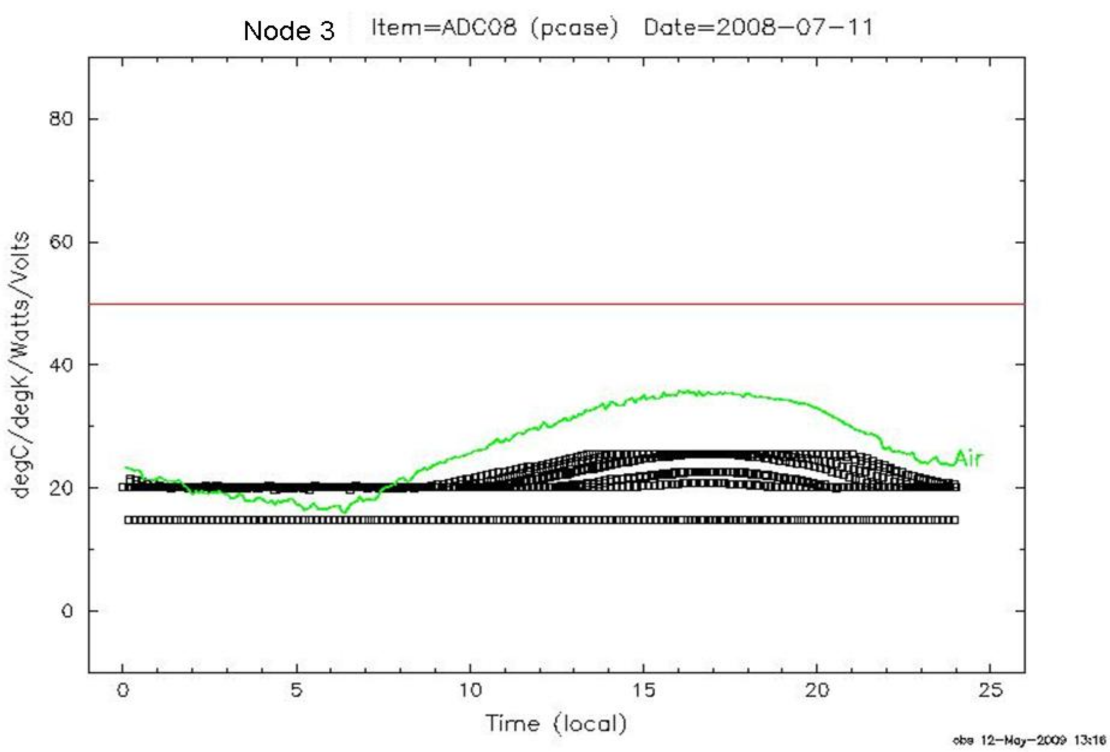

Fig 5: Node 3 Pax Box temperatures. None remained in regulation.

During the warmest season, the ground becomes very dry, and the underground temperature cooling system fails. Only one or two of the very long runs of pipe in nodes 1 and 2 show a regulated temperature for the PAX box. Other experiments show that if the ground is watered during the warm season the cooling system works, bringing the temperature of the air in the pipes throughout the day to the average of the day and night temperatures as expected (Welch ATA memo # 68, 2005). Further experiments are underway to determine exactly how much watering is required to maintain the system in operation throughout the year.