Improving long time stability of a radio astronomy receiver

Christian Monstein

Astronomical radio receivers which are used to observe weak radio sources often suffer from instabilities in the output signal due to changes of the ambient temperature which make it impossible to detect even strong celestial sources. Here, I report about a cheap and successful solution, based on a wine cooler to keep operating temperature stable within +/- 0.1°C.

Keywords: Callisto, temperature, Allan-time

Recent experiments with our radio telescope showed that it was almost impossible to detect celestial radio sources like Cygnus A due to the fact that the ambient temperature of the receiver and spectrometer changed in temperature in the order of +/-1°C. The light-curves of previous observations had fluctuations in intensity three times higher than the amplitude of Cygnus A. This was given by changes of amplifier gain and detector sensitivity which are anti-correlated with temperature. We found out, that the higher the temperature, the lower the signal amplitude. Theoretically it would be possible to compensate light-curves with a simple mathematical model, based on the measured ambient temperature.

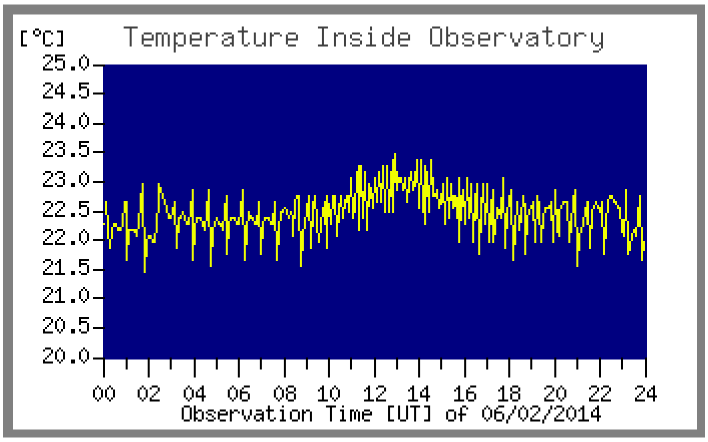

Figure 1: Example of a typical temperature plot of the observatory, hosting the spectrometer. Temperature changes in the order of +/- 1°C directly affect the output of the detector circuit AD8307 in the spectrometer leading to an unacceptable low value of the Allan-time, see figure 2.

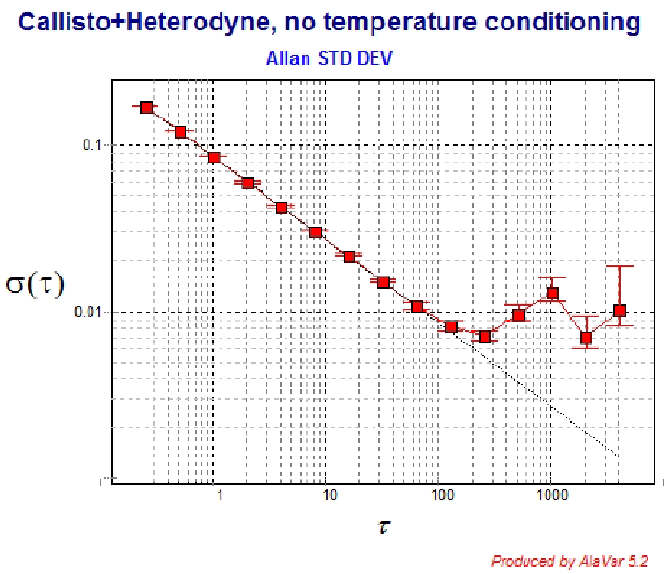

Figure 2~ Allan time **[SARA (2012)]** variance while observing the sky at 1 GHz. Receiver and spectrometer were exposed to changing ambient temperature. X-axis shows integration time expressed in seconds, y-axis denotes to standard-deviation of the intensity signal, expressed in digits of the ADC. Best sensitivity in this example is given with an integration time of roughly 150 s (minimum of red plot). The straight line with a slope of -0.5 is a theoretical model based on purely Gaus'schen noise distribution. After this time a re-calibration has to be applied to the whole system.

Figure 3~ This commercial wine cooler contains from bottom to top: Power distribution 230 Vac, heterodyne receiver 960 MHz … 1260 MHz down to UHF-range 750 MHz … 450 MHz, Callisto spectrometer **[Benz (2004)]** and a separate temperature-humidity sensor. This wine cooler is based on a Peltier-cooling system in the backplane and a control panel embedded in the front door. Temperature range can be set digitally between 12°C and 18°C. All coaxial- and control (RS-232) cables are fed through a hole in the backplane which was closed after installation by Urethane foam.

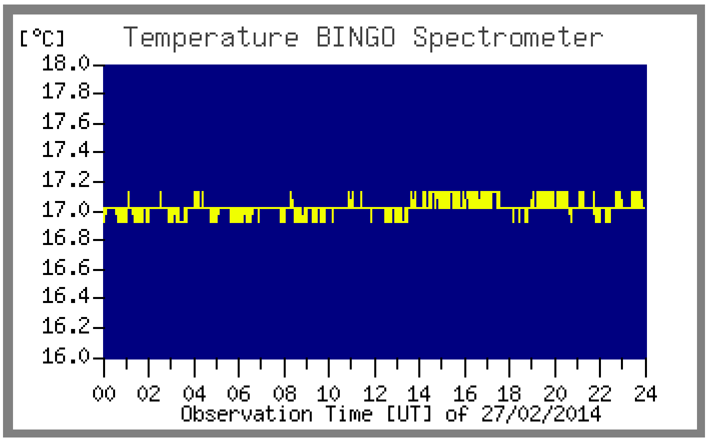

Figure 4~ Recent example of a typical temperature plot of the receiver combined with the spectrometer inside the wine cooler. Temperature stability is in the order of +/- 0.1°C leading to improved Allan-time of the spectrometer system. Further improvements are possible but cost would increase exponentially with stability requirements.

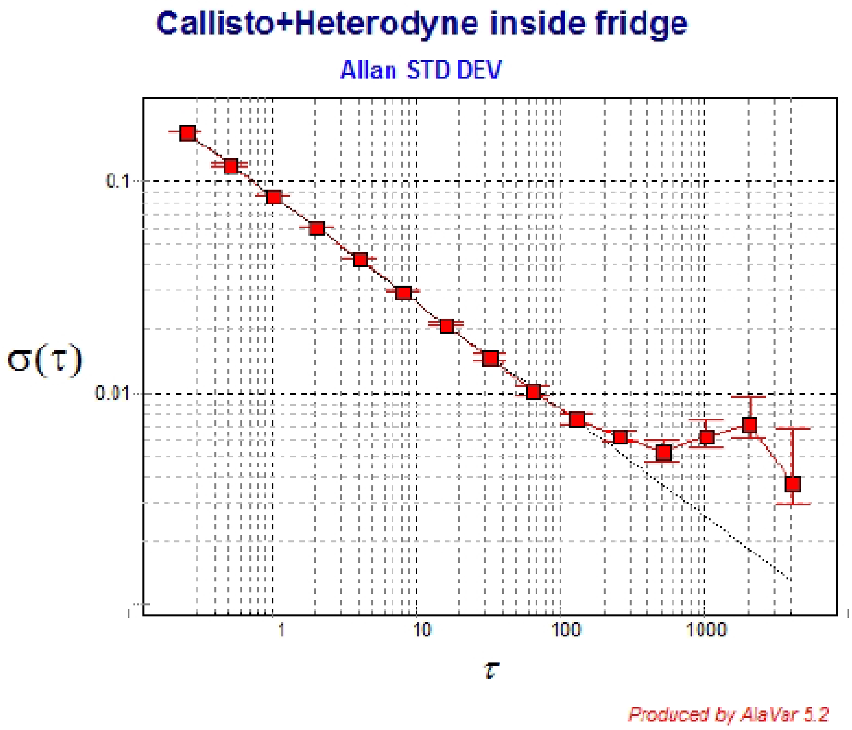

Figure 5~ Allan time variance while observing the sky at 1 GHz. Receiver and spectrometer are here mounted in a temperature stable wine cooler at 16.9°C +/- 0.1°C. Best sensitivity in this improved example is given with a larger integration time of roughly 500 s (minimum sigma value of the red plot). The straight line with a slope of -0.5 is a theoretical model based on purely Gaus'schen noise distribution given by the so-called radiometer equation.

Conclusion

Radio astronomical observations of weak celestial sources require high stability of temperature of the whole instrument (pre-amplifier, receiver, spectrometer and consequently even cables and connectors). Otherwise re-calibration of the whole chain is needed every two minute or so. Each calibration task is synonymous to data loss and finally leading to waste of observation time. Modern, cheap wine coolers allow keeping instrument stable within temperature ranges down to +/-1°C. Next step in our improvement plan is to stabilize temperature of the low noise pre-amplifier in the frontend of the telescope. It would even allow cooling the pre-amplifier a few Kelvin below ambient temperature to reduce noise figure of the frontend. On the other hand this is also a risk to produce humidity and further on water in the amplifier due to temperature gradient to the outside temperature.

Links:

Callisto general information: http://www.e-callisto.org/

References and further reading

[SARA (2012)] Christian Monstein, Allan Time, SARA journal May – June 2012
[Benz (2004)] Arnold O. Benz, Christian Monstein and Hansueli Meyer, CALLISTO, A New Concept for Solar Radio Spectrometers, Kluwer Academic Publishers, The Netherlands, 2004