Flux calibration of a small X-/Ku-band radio telescope, based on a satellite dish and wide band LNB

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Abstract

For flux calibration and temperature compensation of gain fluctuations we describe a process on how to perform such a calibration, This, based on a small satellite dish together with a wide band LNB mounted on a tracking system. Such an instrument can be used to demonstrate drop of flux during an eclipse or to measure average moon disc temperature.

Index: CALLISTO, Solar flux, sky temperature, calibration

Contents

1 Introduction

The aim of this document is to describe a possible process to calibrate the readings of the telescope either in equivalent antenna temperature or in solar flux units (sfu). It also helps to compensate for gain variations due to temperature changes of the LNB and spectrometer.

2 Calibration process

For any calibration process we need at least two independent observations, usually denoted to as Tcold and Thot. In our case with the small satellite dish and wide-band LNB we use a position on the sky with no strong radio source. This provides a calibration temperature Tcold as shown in figure 2. The telescope interrupts its regular observations of the sun and moves to this cold position for one minute of time. Then we move the telescope to the hot position, in this case to the grass in the garden with a well known hot temperature of 295.45 kelvin. Once the observation is finished we copy the light-curve file to a Python script for processing. First process is to read the data and to convert voltage from the logarithmic detector into dB as given in equation 1. Constant value 25.4 mV/dB is given by the specification of the logarithmic detector AD8307 inside the CALLISTO spectrometer.

$$I_{dB} = \frac{I_{mV}}{25.4\ mV/dB} \tag{1}$$

Next step is to convert light-curve, converted and expressed in dB into linear scale as shown in equation 2

$$I = 10^{\frac{I_{dB}}{10\ dB}} \tag{2}$$

Then, for easier analysis and visualization we transform the linear light-curve into normalized range 0...1, see equation 3.

$$In = \frac{I - min(I)}{max(I) - min(I)} \tag{3}$$

Variable In has to be applied to all intensities, namely Ihot, Icold as well as to Isun.

3 Temperature calibration

Basic equation for calibration in equation 4 is based on two measurements with two known temperatures. In the present case we perform calculations on a cold temperature from a cold position on the sky (Tcold) with cold temperature of about 12 kelvin. And a hot position while the telescope

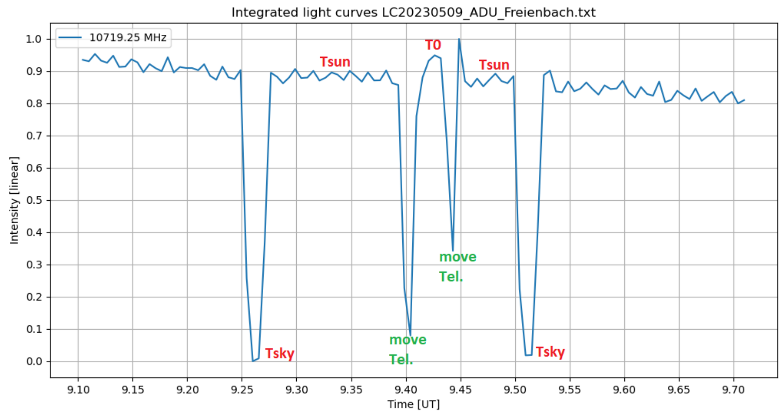

Figure 1: Part of a daily light-curve at 10.71925 GHz, including a move of the telescope to a position of cold sky (Tsky = Tcold) as well as to a position on the horizon pointing into the grass to feed in reference temperature T0 = Thot.

is pointing to the ground (Thot). In the present case the observed reference temperature of ground: 273.15 K + 22.3°C = 295.45 kelvin. Linear intensities are taken from the light-curve, shown in figure 1

Linear intensity cold sky: 0.09 (averaged over several observations)

Linear intensity hot ref.: 0.9488

Linear sun intensity: 0.8933

$$Tsun = \frac{Thot - Tcold}{Ihot - Icold}\,(Isun - Icold) + Tcold \approx 278\ K \tag{4}$$

4 Flux calibration

To get flux from given antenna temperature we need additional information such as wavelength λ of the signal and gain G of the antenna. Estimation of gain G = 35 dB has been determined in a previous report, based on a solar transit observation.

$$Ssun = \frac{8k\pi\ Tsun}{\lambda^2\ G} \approx 390\ sfu \tag{5}$$

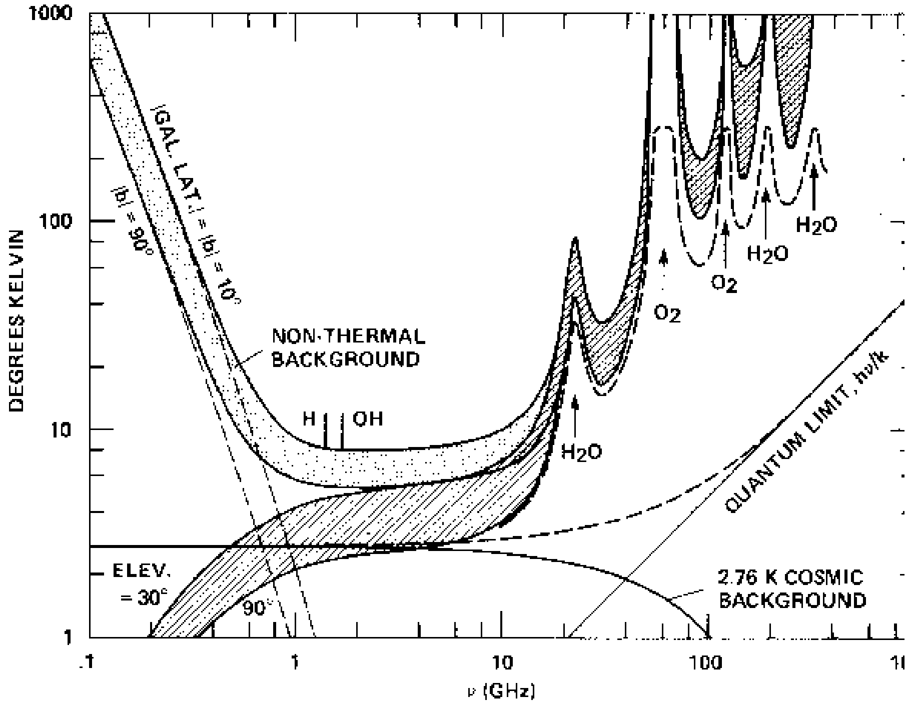

Figure 2. Terrestrial microwave window.

Figure 2: Sky temperature as cold reference, taken from Kraus.

5 Conclusions

In case the telescope can observe sky, sun and horizon, a quite simple calibration procure can be applied. A dedicated control software for the tracking system is required to automatically move to the different positions in a periodic way. Such a process helps to get a 'nicer' light curve or even a calibrated spectrum and to better see any drops due to the eclipse. For reference we can get solar flux data from SWS.bom.au which provide values for 8.8 GHz with 191 sfu and for 15.4 GHz with 431 sfu on that specific day of observation, on Tuesday, May 9 2023. Thus, our rough estimation of 390 sfu doesn't look too bad as it is in between officially calibrated values.