RadioAstroLab
AZIENDA CERTIFICATA UNI EN ISO 9001: 2008

RADIOASTROLAB S.r.L.
Via Corvi, 96
60019 Senigallia (AN)
Tel.: 071.6608166
Fax: 071.6612768
E-mail: info@radioastrolab.it
www.radioastrolab.it – www.radioastrolab.com

11.2 GHz RAL10AP Microwave Radiometer

A simple calibration procedure for an amateur radiotelescope

Flavio Falcinelli

RadioAstroLab s.r.l. 60019 Senigallia (AN) - Italy - Via Corvi, 96
Tel: +39 071 6608166 - Fax: +39 071 6612768
info@radioastrolab.it www.radioastrolab.it www.radioastrolab.com

A very important part of the radiotelescope's operation regards the instrument's calibration. As for any measurement system, even in the case of a radioastronomic receiver, is necessary to establish a calibration procedure for obtaining consistent data with an absolute scale of antenna's temperature at the output. Because of builiding tolerances, the device's characteristics and operating parameters that are used for the reciver's construction, slightly differ from the nominal values used as a reference in the project: each instrument is unique in its reply and it is difficult to compare measurements made by several radiotelescopes or those of the same plant performed at different times. There are many factors that produce such differences, for example: variations in the temperature of the receiver's system, in the active device's characteristics and, in general, because of variations in weather conditions. Repeatedly observing a radiosource in a certain time of the year is possible to find intensity changes in the emission peak. Is important to understand if these fluctuations are caused by real changes in the source's flow or unwanted changes in the radiotelescope's replay: is therefore necessary to use an universal measuring system. The radiotelescope's calibration procedure is use for this: establish a relationship between the antenna's temperature [K] and a given amount in output from the instrument [count].

In this document we will provide some suggestions to calibrate the amateur radiotelescope's measurement scale, in a simple and practical way, observing readily "available" sources. Our experiments were made with a small radiotelescope built with the *RAL10AP* receiver and a common offset satellite dish commonly used for satellite reception in 10-12 GHz band. The procedure is approximate and generally valid, executable by anyone in a simple and free way: adequate to the small amateur radiotelescope's needs, allows to have a reliable idea on the measured values in a temperature's absolute scale.

By setting the receiver's gain so that its input-output characteristic is linear between the RF signal's power level applied and the value [count] acquired from the acquisition system's analog-digital converter (ADC), is possible to calibrate the system, measuring two different noise levels: at first it is observe a "hot" target (room temperature object), then a "cold" target (as, for example, a sky's free region from radiosources) by directly calibrating in K the antenna's temperature. Practically:

- *Cold target's measurement*: when there aren't radiosources and on a clear day, direct the antenna skyward in the local zenith. The cold sky's brightness temperature T_{sky} (of the order of 6-7 K - see Fig. 1 and 2) can be easily estimated at the 11.2 GHz frequency using the following chart, being quite undisturbed by atmosphere.

- *Hot target's measurment*: direct the antenna to the soil so that this fill its whole field of view and is sufficiently distant to consider valid the far field's radiation (at least 300 meters for an antenna with a maximum diameter to two meters). If the soil's physical temperature

RADIOASTROLAB S.r.L.
Via Corvi, 96
60019 Senigallia (AN)
Tel.: 071.6608166
Fax: 071.6612768
E-mail: info@radioastrolab.it
www.radioastrolab.it – www.radioastrolab.com

(measurable with a thermometer) is T_{soil} and its microwave emissivity is $e=0.95$ (estimated from tables found on the web), the hot target's brightness temperature is calculated using the following equation

$$T_{b\_soil} = e\, T_{soil}$$

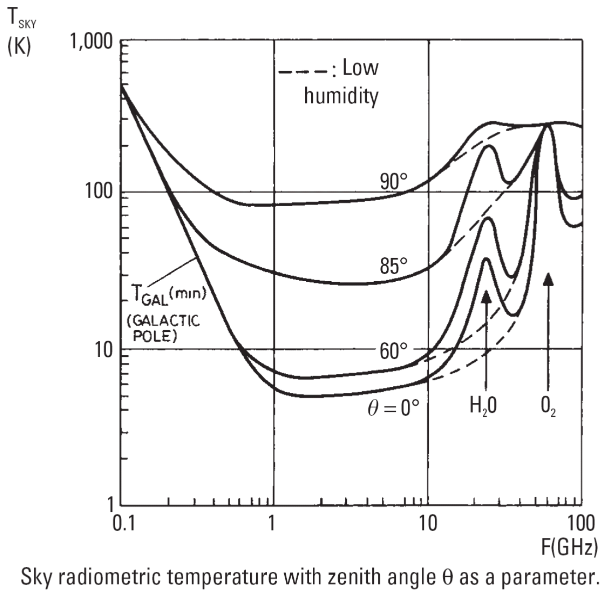

Figure 1: Sky's brightness temperature in function of frequency and angle of the antenna's elevation

If the radiometer's outputs (expressed in measurement units count ADC) when "see" the target with different brightness temperatures T_{b_soil} and T_{sky} are, respectively

$count_{soil}$	when the instrument "see" T_{b_soil} (*hot target*)
$count_{sky}$	when the instrument "see" T_{sky} (*cold target*)

is possible to express the antenna's generic temperature T_a as a function of the corresponding reply *count* as:

$$T_a = T_{bsoil} + \frac{count - count_{soil}}{count_{soil} - count_{sky}} \cdot (T_{bsoil} - T_{sky}) \qquad [K]$$

The radiotelescope's calibration, of course, has to be repeated possibly before and after each observation, and every time is necessary to change a strumental parameter (gain, baseline's livel , etc.). The formula just found allows to express in a brightness temperature's absolute scale, the radiometric measurements expressed in ADC acquisition's arbitrary units (count), and then to obtain the instrument's calibration characteristic (Fig. 3).

RadioAstroLab

AZIENDA CERTIFICATA UNI EN ISO 9001: 2008

RADIOASTROLAB S.r.L.
Via Corvi, 96
60019 Senigallia (AN)
Tel.: 071.6608166
Fax: 071.6612768
E-mail: info@radioastrolab.it
www.radioastrolab.it – www.radioastrolab.com

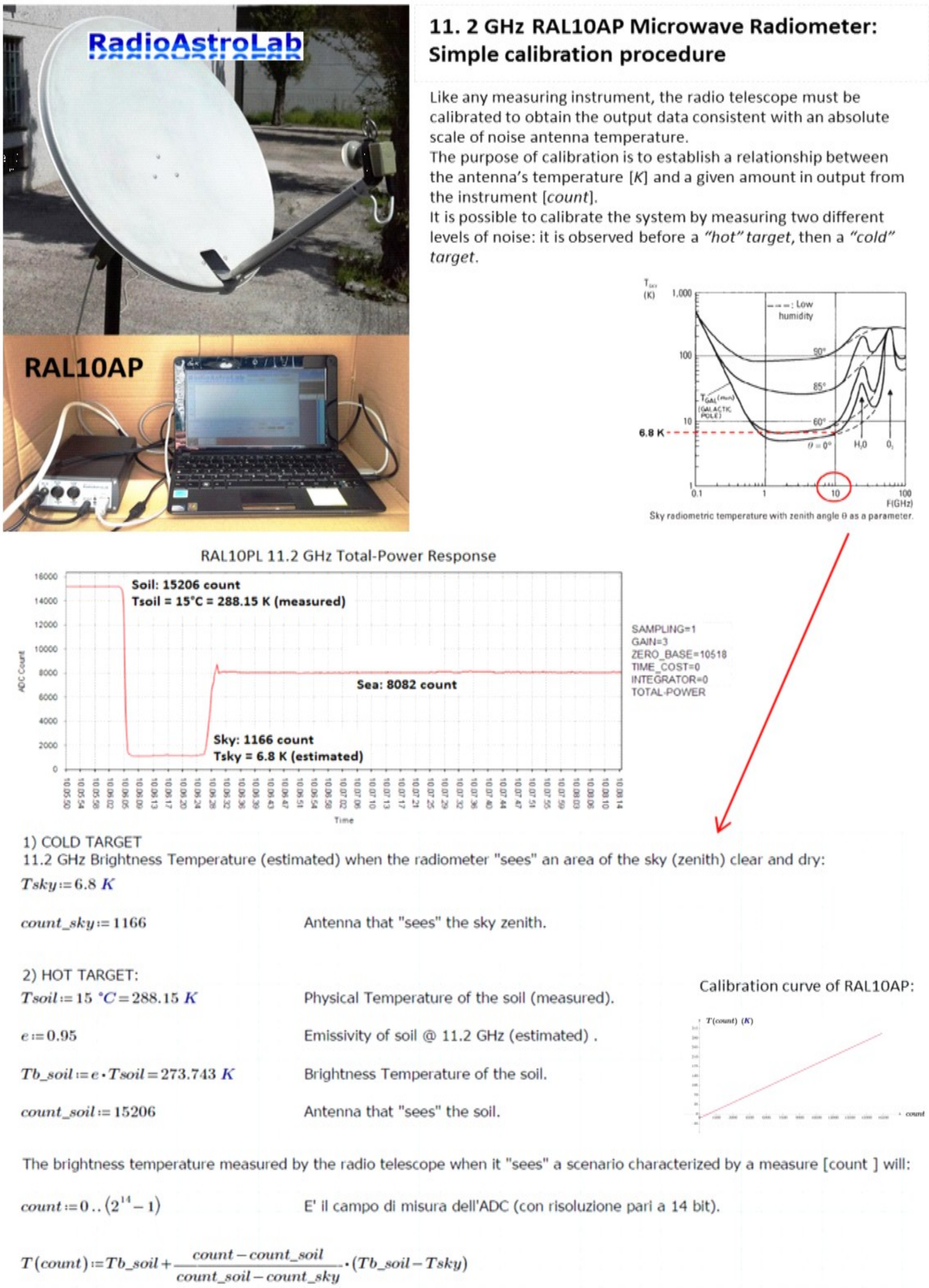

Figure 2: Amateur radiotelescope's calibration procedure.

The figure 2 summarize this simple procedure, that even in its approximation, provides a reliable idea about the measurig scale's dynamics in instrument's K grades. The experiment, valid for a radiotelescope based on the *RAL10AP* receiver connected to a common antenna with a parabolic reflector (offset) for TV-SAT 10-12 GHz receiving, is proposable for any amateur installation. Use the instrumental reply's recordings when the antenna is facing the soil (it was chosen a large plot of uniform land freshly plowed for which we assumed an *emissivity* of about 0.95) and when the antenna "sees" the cloudless sky at the zenith. After measuring the soil's physical temperature, we have used the radiometre's answers to [count] to the two hot and cold targets to calculate the instrument's calibration curve.

As repeatedly stressed, the described procedure is simplified and approximate, however is adequate to the amateur radioastronomy's needs. Its accuracy depends on many factors, instrumental and environmental: weigh heavily the sky's brightness temperature estimates and the soil's emissivity, the radiometer's parameters constancy (stability, especially with temperature) and the linearity of its characteristic RF power applied - voltage at the output of the detector.

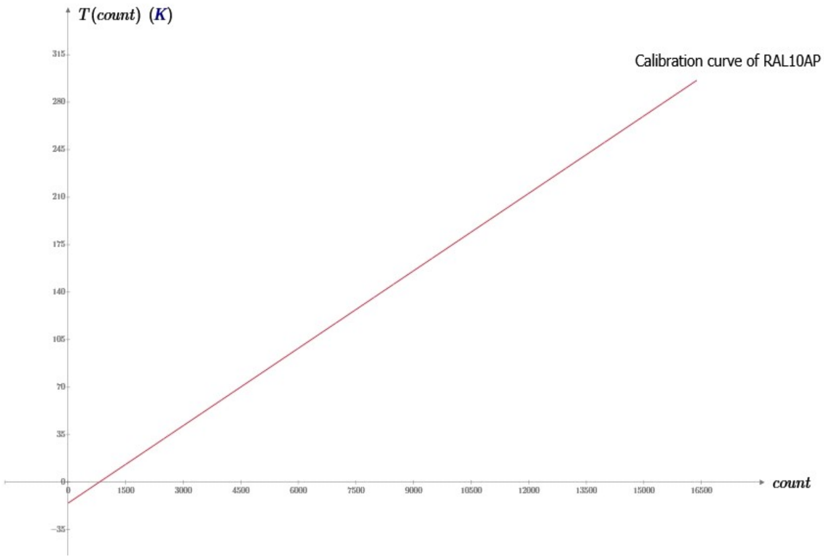

Figure 3: Amateur radiotelescope's adjustment characteristics built with the RAL10AP receiver.

Doc. Vers. 1.0 del 20.07.2015

RadioAstroLab s.r.l., Via Corvi, 96 – 60019 Senigallia (AN)
Tel. +39 071 6608166 Fax: +39 071 6612768
Web: www.radioastrolab.it www.radioastrolab.com Email: info@radioastrolab.it