# Liquid nitrogen calibrations for RPG-HATPRO microwave radiometers in ACTRIS

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# Content

# 1. Introduction and Background

Microwave radiometers are passive instruments that measure radiances which are caused by the atmospheric emission from gases and hydrometeors. These radiances are converted to voltages.

Microwave radiometers need to be calibrated regularly to ensure good data quality. For HATPRO radiometers by Radiometer Physics GmbH, several automatic calibration methods are applied during the regular measurements, such as noise switching and calibrations using the internal blackbody (ambient load). These are all relative calibrations as they assume the noise diode to be stable between two absolute calibrations.

To ensure absolute accuracy, liquid nitrogen calibrations need to be performed every six months to compensate for instrument drifts.

Liquid nitrogen (LN2) is used as the cold reference in a so-called hot-cold calibration, and the internal load (ambient target) as warm reference temperature. With the addition of a noise diode, four calibration points are available and thus, all calibration parameters (gain, system noise temperature, noise diode temperature, non-linearity factor) can be determined for each channel individually.

LN2 has a boiling point of about 77.4 K. The boiling point depends on atmospheric pressure, which is corrected for by the in-built pressure sensor. The ambient target is usually about 10 K warmer than the surrounding air. The temperature of the ambient target is measured by two temperature sensors. As the both targets are constructed as blackbodies for microwave radiation, their physical temperature corresponds to the brightness temperature (Planck's law).

## 1.1. ACTRIS labelling

For an ACTRIS Cloud Remote Sensing station, it is required to perform at least two subsequent calibrations (with roughly six months distance) during the step 1b of the labelling process to obtain the ACTRIS label.

The necessary steps for the LN2 calibrations in ACTRIS are explained in this document. In addition to the guidelines by RPG, observations on the cold target have to be performed for a better characterization of the instrument's performance.

It is necessary to update the RPG software prior to the calibration to the version that is recommended by CCRES (currently 9.65). Measurement definition files (MDF) provided by CCRES only work with this software version.

# 2. Liquid nitrogen calibration targets

There are different targets available for RPG radiometers:

- **Classic target (90° reflector)**, produced until 2016: This target has an open surface (see Figure 1). It is not recommended to use this target anymore because of several reasons:
    - Standing waves between receiver and LN2 surface
    - Rapid evaporation of LN2
    - Mixing of oxygen from the air into LN2 which changes the boiling point temperature

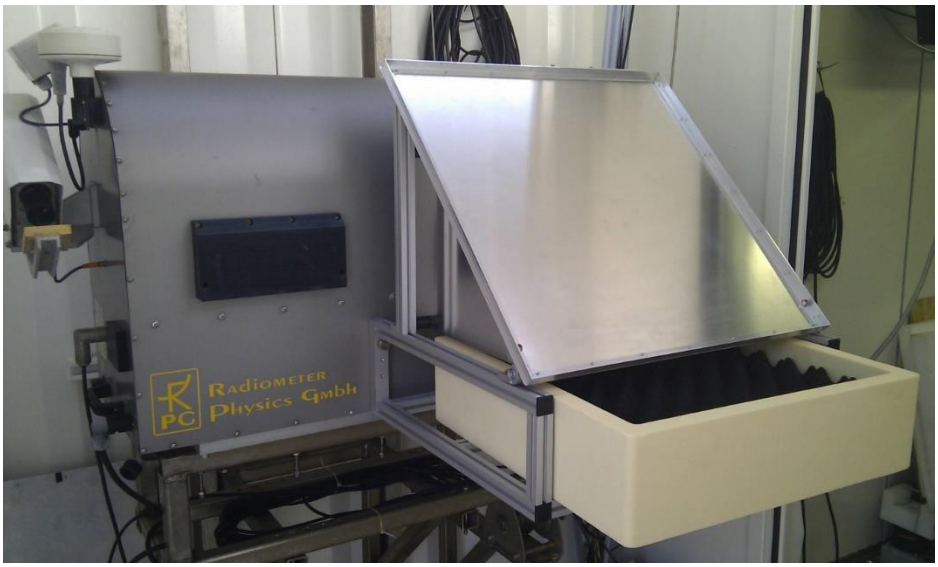



*Figure 1: Classic RPG Liquid nitrogen target (produced until 2016)*

- **PT-V1 target** (Figure 2):
    - This target was introduced in 2016 and minimizes errors compared to the classic version of the target
    - Disadvantage: During the calibration process, the target has to be turned around as it is optimized for only one polarization direction on each side of the target

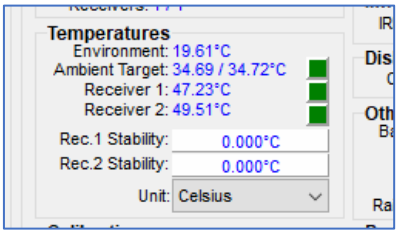

*Figure 2: PT-V1 calibration target*

- **PT-V2 target (since 2021):**
    - From the outside this target looks similar to the PT-V1, but has only one window.
    - Therefore, it doesn't need to be turned around during the calibration anymore which facilitates and accelerates the whole process
    - Furthermore, it needs less LN2 than PT-V1 target (~25 vs. ~40 litres)

# 3. Preparing a LN2 calibration

## 3.1. Planning and preparation

- Check weather forecast for calibration day.
  - Do not perform any calibration during rain as raindrops can deposit on the target
  - Avoid high relative humidity (ideally below 70%), as water vapor might condensate on the outside of the target. Scheduling calibrations in the afternoon is usually better than early morning.
- **Do not perform a calibration immediately after powering up the radiometer**. The instrument has to run at least for 1 hour until the receiver temperatures have reached an equilibrium. This can be checked on the "Status and Conf." tab of the software. If all boxes next to the temperature values of Receiver 1 and Receiver 2 are green, a calibration can be performed (see below).




## 3.2. Items needed

- Container that serves as LN2 target including table (provided by RPG with the instrument)
- Sufficient liquid nitrogen (at least 40 litres in case of PT-V1 target, and 25 litres for PT-V2).
- Protective clothes, glasses and gloves for LN2 handling
- 2 people for performing the calibration

## 3.3. Overview of the steps to be performed

- Before performing the LN2 calibration, observe the brightness temperatures on the cold load for 2 minutes on each side of the target (MDF file provided). If using PT-V1 target, remember to first use R1 and R2.
- Perform the LN2 calibration using the HATPRO software with an integration time of 100 seconds
- Repeat observations of the cold load on both sides as stated above
- Save the calibration results
- A detailed description of all steps follows in Section 4.

*Figure 3: Equipment for LN2 calibration*

# 4. Step-by-step instructions to perform LN2 calibration

## 4.1. Fill and install liquid nitrogen target to radiometer

- Mount the support that holds the LN2 target to the radiometer (steps are described in detail in the “RPG MWR installation and maintenance manual”)
- Fill the target with liquid nitrogen
- Lift the target up on the table

## 4.2. Stop running measurements

After stopping the routine measurements, the message “Measurement finished” will appear (blue box on top). The bottom line should say: “Rad.-Status: STANDBY”

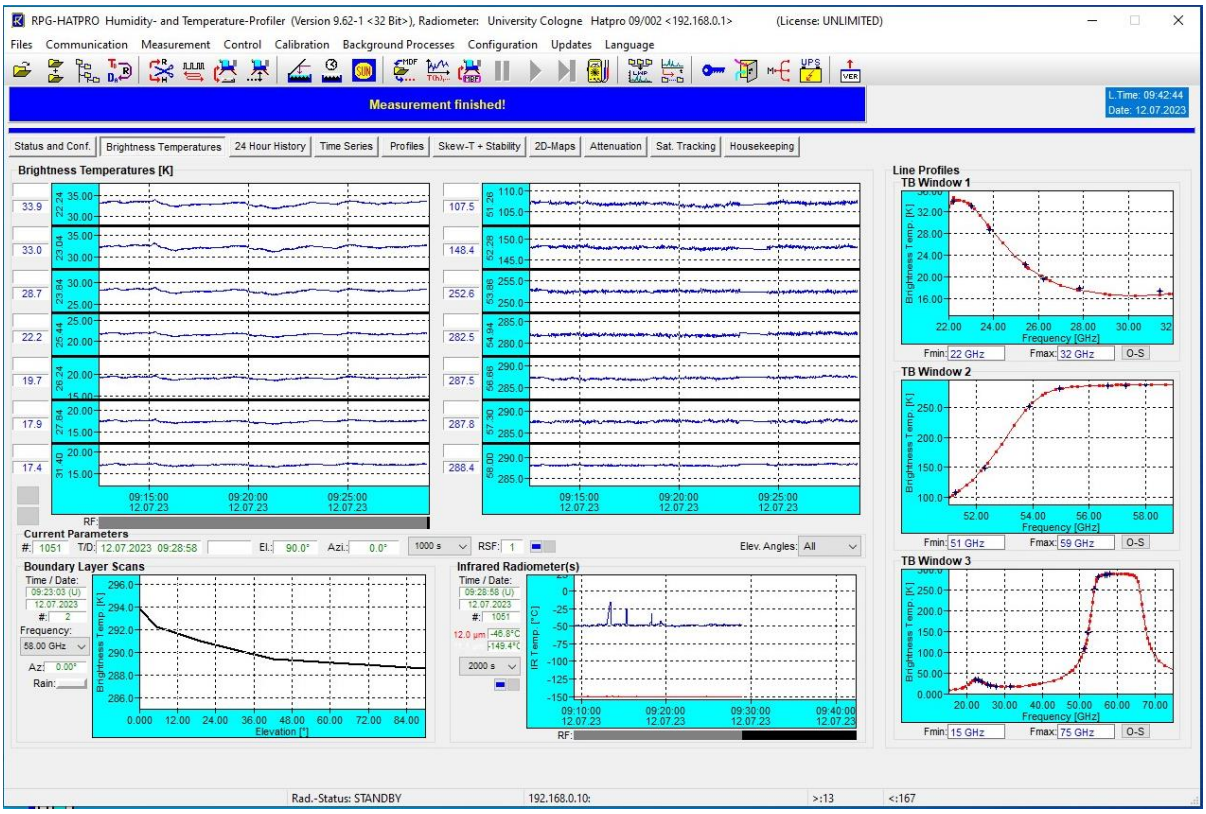



*Figure 4: Finish current measurements*

## 4.3. Observation on LN2 target

This step is done to assess the drifts since the last calibration. In future this shall be done by the software automatically, for now an own MDF file has to be created (will be also provided by CCRES).

The measurement is performed with an observation angle of 0° (horizontal) and a duration of 300 seconds in limited mode. Observe only brightness temperatures, meteorological sensors and housekeeping data, each of them with temporal resolution of 1 second.

If you are using PT-1 target, make sure to repeat this measurement by turning the target

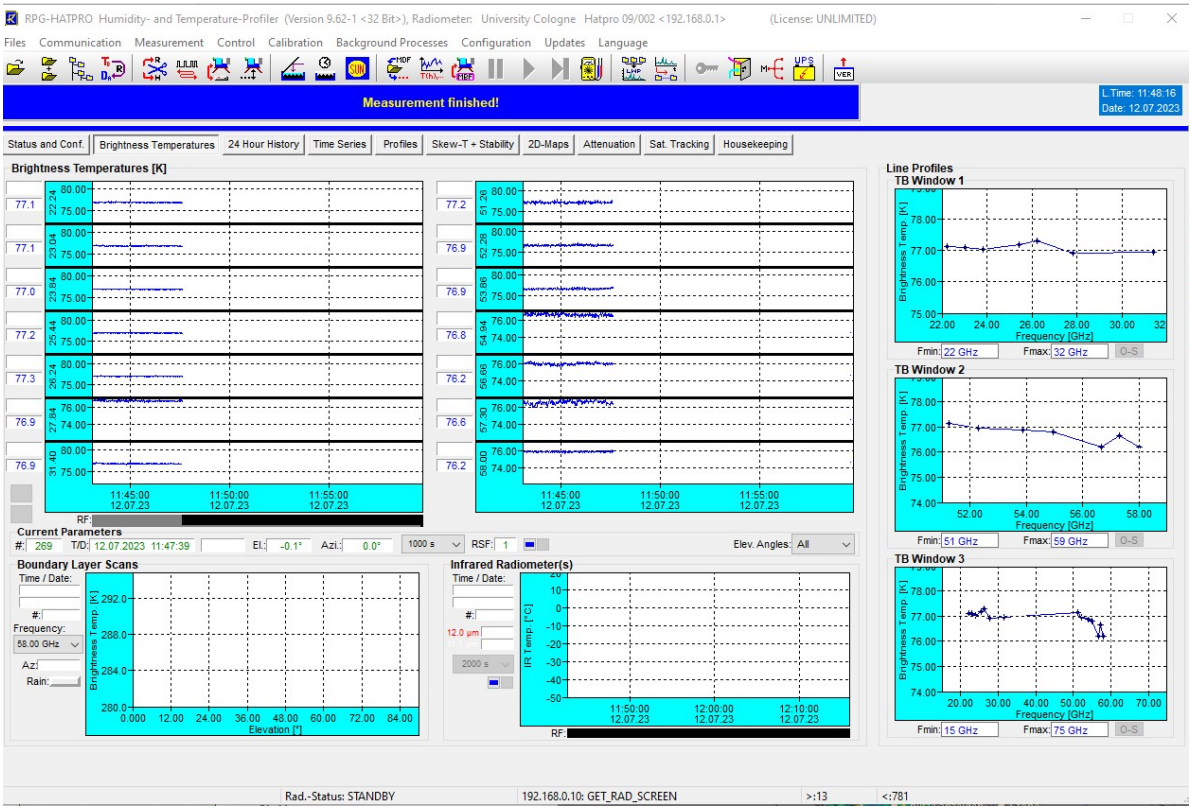



*Figure 5: Measurement of LN2 observations finished. Note that all TBs should lie around the boiling point of liquid nitrogen (~77 K).*

## 4.4. Perform Liquid nitrogen calibration

Make sure that the target is installed, then click on “Calibration – Absolute calibration”

Follow the steps of the calibration menu to prepare calibration (see Figure 6):

1. Choose Target type. If you cannot choose PT-V2 in your software version (before 9.47), choose PT-V1. Follow all steps except turning the target.
2. Make sure that both receivers are selected (Humidity profiler and Temperature profiler)
3. Make sure that pressure correction is on “automatic”. If no weather station is attached to the radiometer you can manually enter the current local air pressure value (not recommended!)
4. Choose 100 second integration time
5. When all settings are correct, click on “Start calibration”

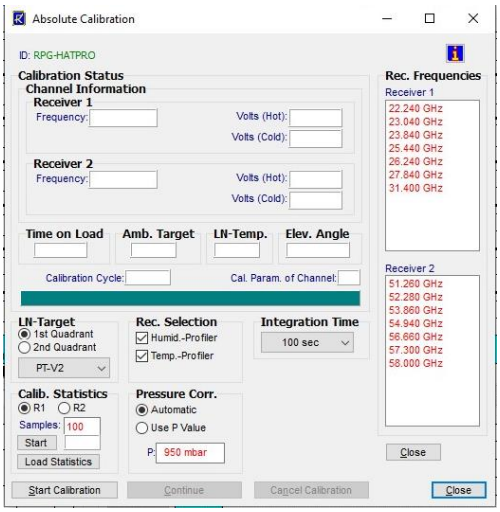



*Figure 6: Software preparation for Liquid nitrogen calibration*

6. Wait about 1 minute to make sure that target surface is dry, click “yes” if you are sure that surface is dry (see Figure 7)
7. Follow the instructions given by the software.
8. In case of PT-V1 calibration target, it has to be turned during the process. A pop-up window will appear when it is time to turn the target.

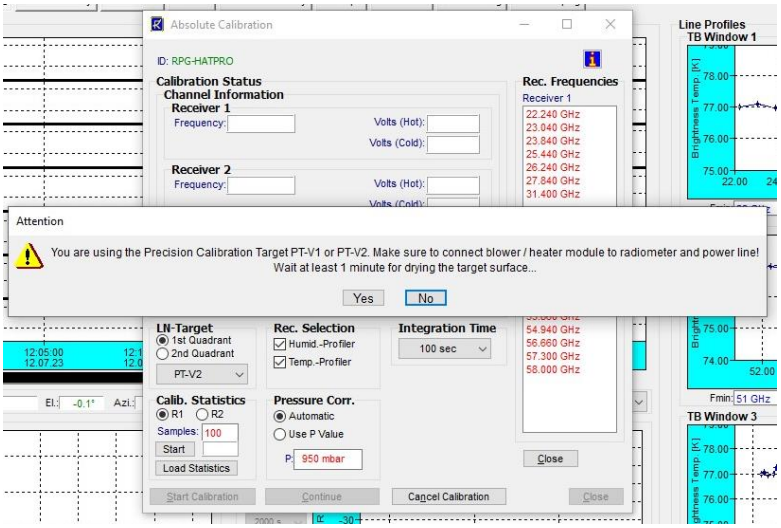



*Figure 7: Pop-up window at absolute calibration to make sure that target surface is dry*

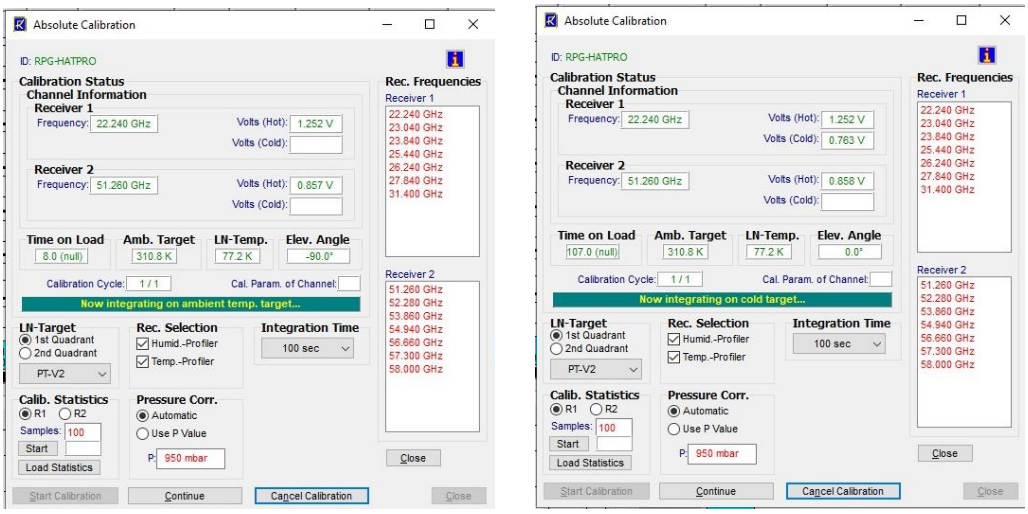



*Figure 8: Absolute calibration window during LN2 calibration*

9. At the end of the automatic process, the newly determined calibration parameters will appear. Click on them to make them disappear.

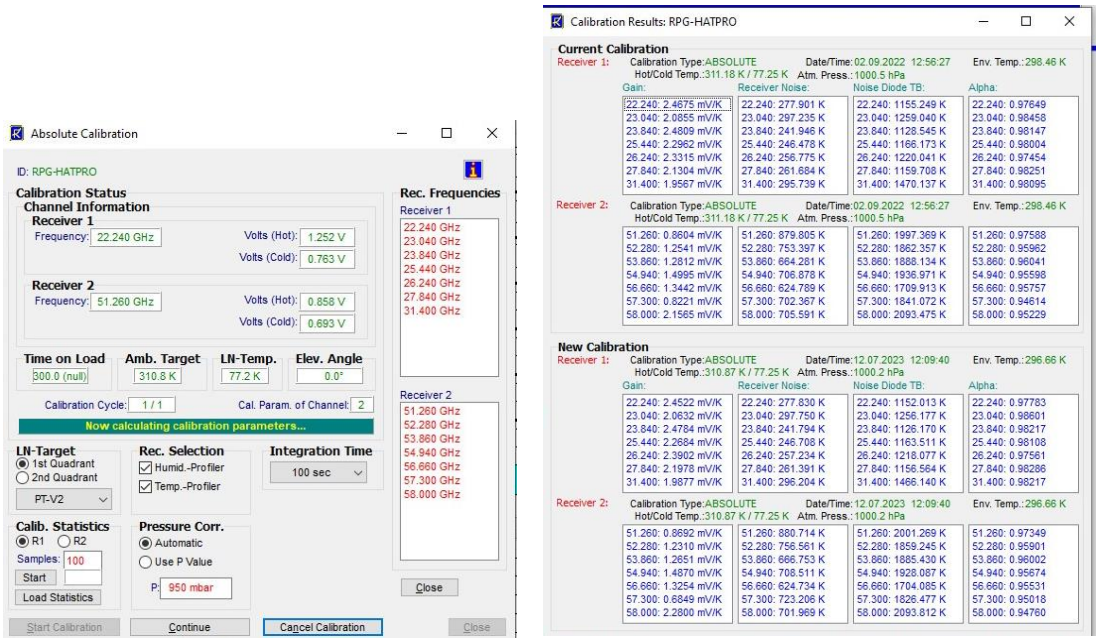



*Figure 9a/b: Calculation and display of calibration parameters*

10. **Click on "Continue"** when status message says "Calibration successful! Save? (Continue/Cancel)", see Figure 10. **If you fail to do so, the calibration will not be saved**!

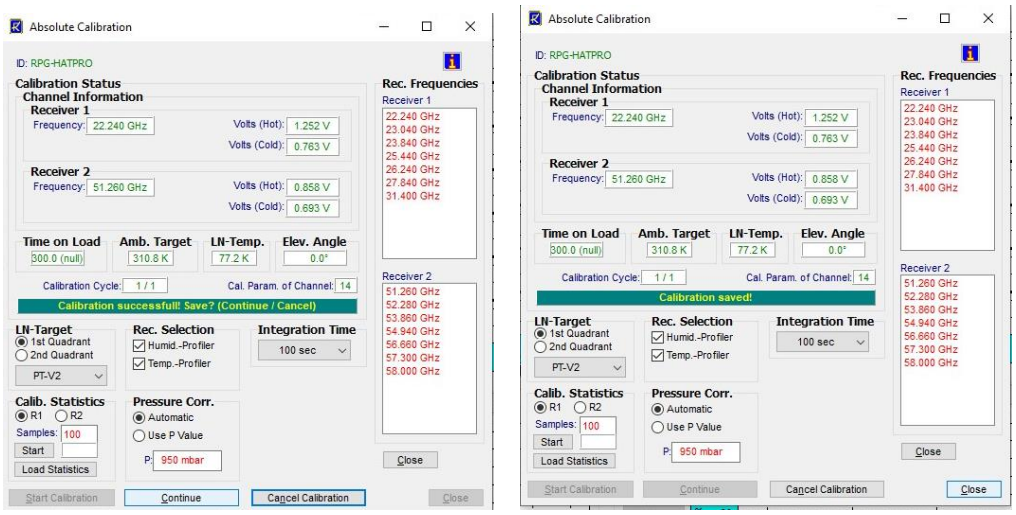



*Figure 10: Calibration successful - click "Continue". Message "Calibration saved!" will appear.*

## 4.5. Repeat observation on LN2 target

This step is identical to the LN2 observation before the calibration and is performed to check the quality of the calibration. Follow the instructions of section 4.3.

## 4.6. After the calibration

- Do not forget to restart routine measurements

Send the following files to CCRES by e-mail: actris-ccres-mwr@uni-koeln.de
(in future these files will be uploaded to the CCRES calibration database)

- BRT, MET, HKD files from observations on target before and after LN2 calibration
- ABSCAL_YYYYMMDD_HHMMSS.LOG"
- CovMatrix_LN2_YYMMDD_HHMMSS.LOG"
- CovMatrix_AMB_YYMMDD_HHMMSS.LOG"

The latter three files can be found in the "LOG/ABSCAL" and "LOG/Covariance" subfolders under the folder where the RPG-HATPRO software is installed.