TEST OF THE SEMITRANSPARENT VANE CALIBRATION SCHEME WITH THE IRAM 30-M TELESCOPE

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Abstract

We propose to test the semitransparent (S/T) vane calibration scheme at the IRAM 30-m telescope. The proposed tests with stable loads will allow to estimate the potential accuracy of the S/T vane calibration system to a level of better than 3%. S/T vane calibration of astronomical sources will be compared with the standard dual-load calibration system used at the 30-m to cross check their accuracies. The test device, which is under construction, will allow fast switching (1 s). We plan to place the test device in two different locations along the beam path to measure the polarization effects introduced by the S/T vane and to estimate the effects on the calibration accuracy of stationary waves between the S/T vane and the receiver.

1. The S/T vane calibration test device

The S/T vane device consists of two independent rotary actuators which will be remotely controlled. The S/T vane itself will be installed in one of the actuators and an ambient load will be installed in the other one. The S/T vane test device will allow:

- Relatively fast switching (of the order of a second).
- Measurement of the temperature of the ambient load and the S/T vane with a accuracy of 0.2 K
- Stable in and out positions. Not a continuous rotating system.
- Observing simultaneously in the 3 and 1.3 mm bands.
- Calibration using the standard system at the telescope.
- Observing the cold and ambient load of the standard calibration system with the S/T vane in and out of the beam.

The S/T vane device will be installed in two locations in the beam path. Fig. 1 shows a diagram of the IRAM 30-m telescope optics with the two positions where the S/T vane calibration system will be installed.

<u>Position 1.</u> The S/T device will be located at about 1.3 m from the receivers. This location will allow to measure the polarization effects introduced by the S/T vane by observing simultaneously two orthogonal polarizations. Unfortunately, the distance of the S/T vane to the receiver is different to that proposed in the ALMA baseline, which implies a different level of standing waves between the S/T vane and the receiver.

<u>Position 2.</u> The S/T vane device will be located 10-15 cm from the receiver (i.e. a similar distance than in the ALMA baseline). This location sacrifices the high accuracy polarization measurements, but allows an estimate of the effects of the stationary waves on the calibration accuracy. An estimate of the polarization effects is still possible in this position by rotating the S/T vane by 90º.

2. Characterization of the S/T vane

Several polymer foams have been measured by B. Lazareff and M. Carter at IRAM Grenoble as possible material for S/T vanes. The polymer foams have typical attenuations of 0.05-0.1 nepers/cm at 100 GHz. We plan to use a S/T vane with a transmission coefficient of 90-95% at 100 GHz (thickness of about 1 cm).

Measurement of the transmission coefficient of the S/T vane

We plan to make the first measurements with the S/T in the two proposed locations around 100 GHz. Additional measurements will be made at other frequencies in the 3 and 1.3 mm bands.

The transmission coefficient of the vane will be measured using continuum sources as the ratio between the intensities measured with the vane-on and with the vane-off. The continuum measurements will be performed using the beam switching symmetric on-off procedure. Even for a source of 6 Jy, one can achieve an accuracy of 0.5% in the determination of the transmission coefficient with observing times of only 30 s (10 s vane-off and 16 s vane-on). To eliminate problems introduced by atmospheric fluctuations, we will alternate measurements with the vane-on for 6 s with measurements with the vane-off for 4 s. In case that a higher accuracy is needed (see next sections) we will use stronger continuum sources, such as planets. We will check the accuracy of our measurements by observing different sources under different conditions.

Polarization properties of the transmission coefficient of the S/T vane

The comparison of the transmission coefficients measured in two orthogonal polarizations with the S/T device located in position 1 will allow to estimate if the S/T introduces polarization effects at a level of 0.1 %. In this case we will measure the transmission coefficient of the S/T vane in location 1 using planets.

2 **Estimate of the potential accuracy of the S/T vane calibration system**

Testing the main hypothesis of the S/T vane calibration scheme

The basic assumption of the S/T calibration scheme (see ALMA Memos 318, 321, 371, 372 and 423) is that all losses produced in the vane are basically due to absorption. Under this assumption the emissivity of the semitransparent vane can be characterized by just the transmission coefficient which is relatively easy to measure with high precision as described above. However, if a fraction of the losses are due to reflections on the S/T vane, its emissivity cannot be described by just the transmission coefficient.

To check the level to which the S/T assumption is fulfilled we will use a load at liquid Nitrogen temperature (hereafter N2 load) and an ambient load. We will measure the temperature of the N2 load with the vane-on, T_{vane}, using the N2 load and the ambient load as calibrators. The measured T_{vane} will be compared with the expected temperature under the assumption that all losses in the vane are due to absorption. The discrepancies between the expected and the measured temperature will provide an estimate of the level to which the S/T assumption is fulfilled.

Since we can measure the temperature of the ambient load and that of the S/T vane with a precision of better than 0.5 K, the main sources of error are expected to be a possible non-uniform temperature of the N2 load, the possible saturation effects on the ambient load and the accuracy of our measurement of the S/T vane transmission coefficient. An error of 1 K in the N2 load will introduce an error of 1.2% in our measurements. For a S/T vane with a transmission coefficient of 0.9, the error introduced by 10% saturation on the ambient load (saturation temperature of only 3000 K) would be of 1.5% . An error of 0.5% in the S/T vane transmission coefficient will introduce an of 1.8% in our estimate of T_{vane}. As a consequence, it might be possible to check the hypothesis of the S/T vane calibration scheme at a level of better than 3%.

Polarizations effects

Like for the transmission coefficient , the comparison of the measurements in two orthogonal polarizations with the S/T device located in position 1 will allow to estimate if the S/T introduces polarization effects.

Effects of standing waves on the calibration accuracy

Because of reflections, standing waves between the S/T vane and the receiver could influence the calibration accuracy. One can estimate the effects of the standing waves on the calibration accuracy by tilting the S/T vane in the test device located in position 2. We will make an estimation of the effects of the standing waves by calibrating the stable ambient load as a function of the tilt angle of the S/T vane using the S/T vane device with the N2 load as the reference. The scatter of the measured temperature of the ambient load will give an estimate of the influence of the standing waves. The trends, if observed, will help to study solutions to minimize this effects. Since this is a relative measurement it might be possible to achieve an accuracy of better than 3% depending on the stability of the N2 load.

IN CASE THAT THE MAIN ASUMPTION OF THE S/T VANE CALIBRATION SCHEME is fulfilled to an accuracy of 3% we will proceed with tests on the sky.

3. Comparison of the accuracy of the S/T vane calibration relative to the dual-load and chopper wheel calibration systems

For this, we will measure the intensities of astronomical sources calibrated with the two schemes as a function of elevation and different atmospheric conditions. This will allow to estimate the relative accuracy of both schemes to correct the observed intensities for elevation effects.

In the dual-load calibration system the atmospheric opacity is derived by fitting the measured “atmospheric” emission using the ATM model.

For the S/T vane scheme the second order calibration term we will derived using the “atmospheric” emission derived from the ATM model constrained by the precipitable atmospheric water vapour (to mimic the ALMA situation) and the ground parameters (pressure, temperature and relative humidity).

We will also compare with the calibration made with the chopper wheel method (sky and ambient load) corrected for saturation effects if necessary.

4. People involved and responsibilities

Design and construction of the device: S. Navarro, M. Carter
Implementation in the 30-m telescope : W. Brunswig and A. Sievers
Tests: J. Martín-Pintado, J. Cernicharo, A. Rodríguez J.R. Pardo, S. Martin

5. Schedule

Construction of the device: end of December 2003
Installation and implementation: Beginning January 2003
Test: Two periods: February and March 2003
Final report: March 2003

Fig. 1. Schematics optics of the 30-m telescope showing the two location where the semitransparent vane will be installed.