Development of Conical Calibration Targets for ALMA

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Abstract

We present the design and test results of the hot and the ambient calibration targets for the Atacama Large Millimeter Array (ALMA). The targets have to cover a very wide frequency range from 31 to 950GHz and the hot target has to be heated up to 90°C. The required absolute radiometric accuracy of the ambient and hot targets is +/- 0.3K and +/- 0.5K (at 70°C) respectively. In order to meet these requirements different contradictory design aspects had to be considered. One of the most important parameters for a high quality blackbody calibration target is an overall emissivity close to unity. The requirement on the emissivity depends on the temperature difference between the target and its environment. Even in the worst case the ALMA requirements for the absolute accuracy of the ambient and hot targets will be met with emissivities of 0.999 and 0.998 respectively, which corresponds to a total scattering of -30dB and -27dB. In addition the coherent backscatter of the target has to be significantly smaller than these values since it can lead to standing waves between the receiver and the target and thus to a significant error on the radiometric calibration. Although not quantified explicitly in the ALMA requirements, we identified as a design goal a coherent backscatter of -56dB for the hot and -60dB for the ambient target. The second parameter which determines the absolute calibration accuracy is the temperature gradient across the target aperture or within the absorber material. Especially for the hot target there will be always a certain difference between the sensors that read the physical temperature and the effective surface temperature of the absorber.

To meet the stringent accuracy requirements the ALMA calibration targets have a folded conical geometry. The absorbing material is attached to a metal backing and consists of a multilayer composition of different absorber grades which is tuned for the most critical frequency bands of operation. We present the overall design of the calibration targets, ray-tracing simulations of the multilayer absorber cones, as well as experimental results. These include reflection measurements between 30-700GHz with a vector network analyzer, radiometric tests with a 91GHz radiometer and an assessment of the thermal gradients under different operating conditions using distributed temperature sensors and an IR camera.