

Water Vapor Radiometer for ALMA: optical design and verification

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Abstract

Atacama Large Millimeter wave Array (ALMA) is being built at a high altitude Atacama Desert in Chile. It will consist of 50 12m telescopes with heterodyne instruments to cover a large frequency range from about 30GHz to nearly 1THz. In order to facilitate the interferometer mode of operation all receivers have to be phase synchronized. It will be accomplished by phase locking of all local oscillators from a single reference source. However, a noticeable part of the phase error is caused as the signal propagates through the Earth atmosphere. Since this effect originates from the fluctuations of water vapors, it can be accounted for by carefully measuring the spectral width of one of water vapor resonance absorption lines. This will be done with a submillimeter heterodyne radiometer, Water Vapor Radiometer (WVR) [1]. WVR will measure the sky brightness temperature in the beam path of every telescope across the 183GHz water line with a spectral resolution of about 1GHz.

Accuracy of the calculated optical delay is determined by the combination of the radiometric accuracy of the WVR and of the errors originated in the WVR illumination of the telescope. We will describe major challenges in the design of the WVR to comply with the stringent requirements set to the WVR. Several approaches to simulate the quasioptical waveguide which brings the signal from the telescope's subreflector to the mixer horn, were used: fundamental mode Gaussian beam propagation, combined ray tracing with diffraction effects (using package ZEMAX), and a full vector electromagnetic simulations (using GRASP). The computational time increases rapidly from the first method to the last one. We have found that ZEMAX results are quite close to the one from GRASP, however obtained with nearly instant computation, which allows multiple iterations during system optimization. The beam pattern of the WVR and of WVR with the optical Relay (used to bring the signal from the telescope's main axis to the WVR input window) was measured by a scalar beam scan at four planes in the far field. The experimental results correspond to the simulated ones with a high accuracy. The WVR illuminates the telescope subreflector with a spillover of less than 1.5% while maintaining high aperture efficiency. We developed an approach to calculate the beam center position at the subreflector (with is at 6m from the WVR) from our test data (at maximum 2m from the WVR) in order confirm the maximum beam deviation does not exceed 20mm, i.e. 1/15 of the beam width.

REFERENCES (OPTIONAL)

- [1] A. Emrich, S. Andersson, M. Wannerbratt, P. Sobis, S. Cherednichenko, D. Runesson, T. Ekebrand, M. Krus, C. Tegnader, U. Krus, "Water Vapor Radiometer for ALMA", in Proc. of 20th International Symposium on Space Terahertz Technology, April 2009, Charlottesville, USA, p. W3B.