Water Vapor Radiometer for ALMA

Dr. A. Emrich, S. Andersson, M. Wannerbratt, P. Sobis, Serguei Cherednichenko, D. Runesson, T. Ekebrand, M. Krus, C. Tegnader, U. Krus.

Omnisys Instruments AB
Gruvgatan 8 SE-42136 V.Frolunda
Sweden
Email: ae@omnisys.se

***Abstract*—Omnisys Instrument AB has developed a Water Vapor Radiometer for the ALMA project from scratch in 18 months and will deliver 50 units within the next 18 months. The radiometer includes an Optical Relay, Mounting Frame as well as the Radiometer core module. The radiometer core include optics and calibration system as well as a schottky mixer based front-end and a filterbank back-end. These subsystems are supported by a thermal management subsystem, control and communication subsystem as well as a power subsystem. The system and subsystems will be described in the paper.**

***Index Terms*—Radiometer**

I. INTRODUCTION

Omnisys Instrument AB has developed a Water Vapor Radiometer for the ALMA project from scratch in 18 months and will deliver 50 units within the next 18 months. The radiometer includes an Optical Relay, Mounting Frame as well as the Radiometer core module.

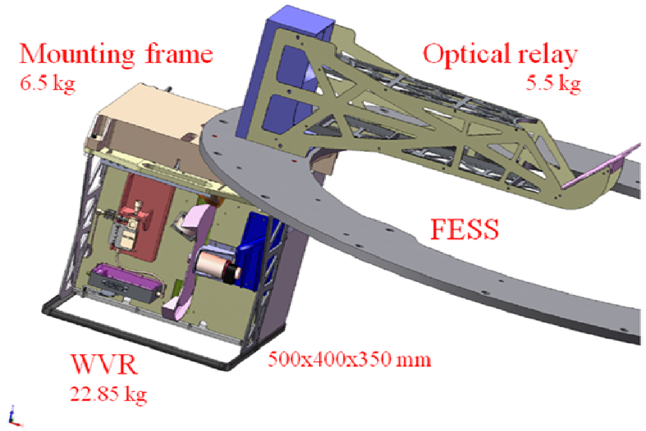

Fig 1. The Water Vapor Radiometer including Mounting Frame and Optical Relay, mounted on the FESS on an ALMA antenna.

The size and mass of the system is about a factor three lower than allocated and facilitates manual handing by one man.

The radiometer core include optics and calibration system as well as a schottky mixer based front-end and a filterbank back-end. These subsystems are supported by a thermal management subsystem, control and communication subsystem as well as a power subsystem.

II. RADIOMETER CORE

The optics in the radiometer core is shown below. The beam enters through a window (implemented in a tilted PPA30 sheet) and is reflected at two active mirrors (M2&M3) before the receiver horn and mixer. In between a chopper wheel is operated deflecting the beam on either the cold load or the hot load with the cycle: SKY-COLD LOAD-SKY-HOT LOAD.

Fig 2. Optics in the radiometer core.

In the RF chain, the signal is received by a corrugated horn, followed by a subharmonic schottky mixer and an LNA. The mixer is provided by Radiometer Physics Gmbh and the LNA is provided by Miteq (custom implementation).

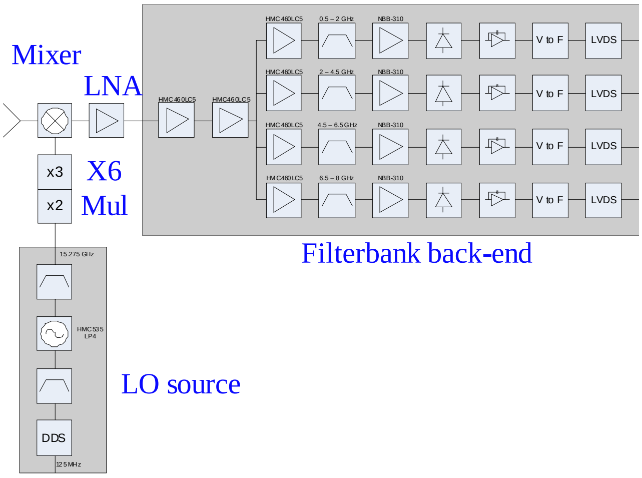

Fig 3. RF chain block diagram.

The LNA is followed by a filterbank. The local oscillator (LO) for the mixer is created by a 15.275 GHz synthesizer followed by an active x6 multiplier, both designed and produced by Omnisys. The active multiplier includes a high precision power output control function, enabling accurate LO power setting for each individual schottky mixer. The optimum power level varies with about a 2-3 dB.

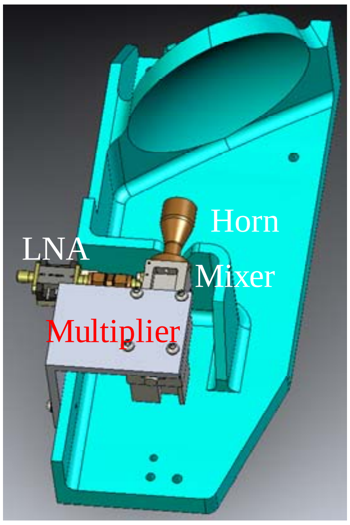

Fig 4. The M3 mirror with the front-end electronics.

III. Calibration Loads

The Cold Load use a Peltier cooler and the Hot load use resistive heaters for accurate temperature control. The nominal operating temperatures are 283 and 353 K respectively and the dew point at the ALMA site is avoided.

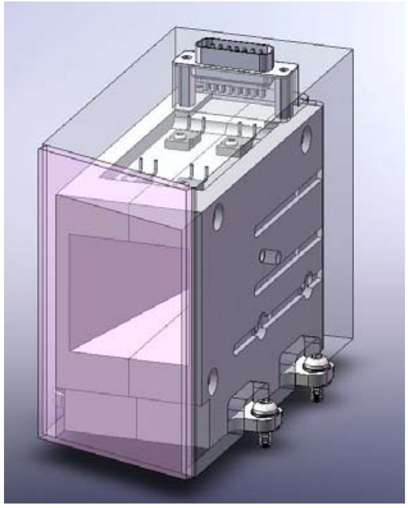

Fig 5. The Hot Load with isolation.

The Cold Load is 3 reflection design, while the Hot Load is a 7 reflection design, both implemented in aluminium coated with 1.2 mm CR-110 Eccosorb. The SWR and back scatter has been measured both on lab bench and in the system.

Both loads has been simulated in 3D in Solidworks simulation module CosmosWorks, as shown below. The internal thermal differences are within 50 mK.

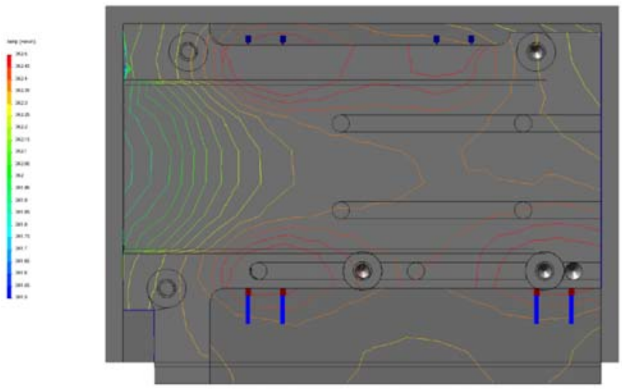

Fig 6. The Hot Load thermal simulation in CosmosWorks.

Several temperature sensors were used in the evaluation of the loads and two are used in each in the production model, to allow for a independent safety temperature monitoring function. A typical temperature variation is shown below and the variation is well below 10 mK.

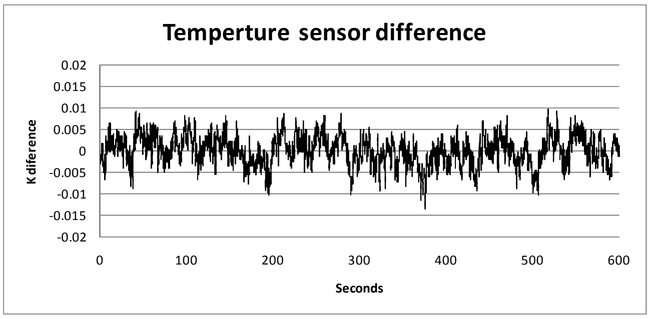

Fig 6. Thermal stability of the Hot Load.

IV. FILTERBANK

The back-end consist of a four channel filterbank covering 0.5-8 GHz. It is implemented in one box but in two compartments. One is used for bias electronics and thermal regulation and one, as shown below, for the microwave electronics.

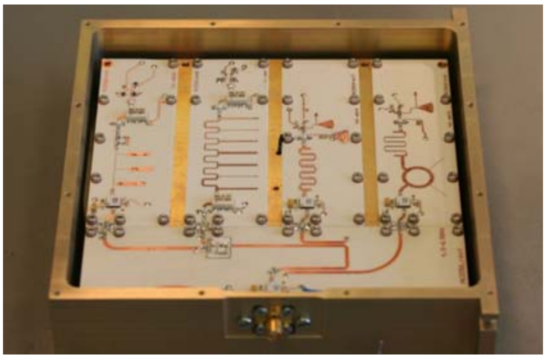

Fig 7. Microwave compartement of the Filterbank back-end.

Several types of microstrip, lumped and commercial filters are used in different configurations in the four channels to allow for sharp response as well as out of band rejection. Differential schottky diode detectors are use with voltage to frequency converters for the final detection. A typical frequency response is shown below for both sidebands.

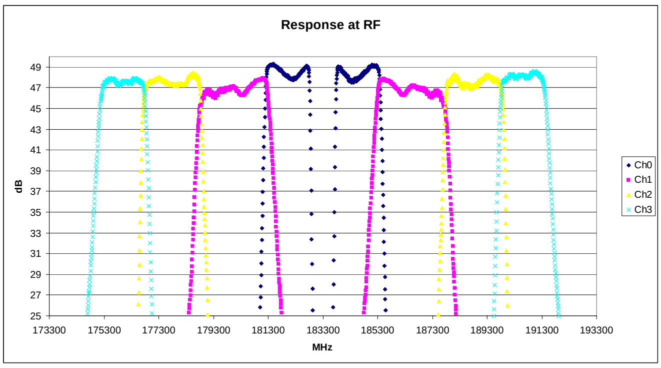

Fig 8. Frequency response of complete WVR.

V. THERMAL REGULATION

There has been extensive work in the design, test and optimization of the thermal control and regulation system. The Central Base plate in the radiometer core is regulated by the fan speed control in the cooling channel, while the calibration loads and the back-end have separate thermal regulation systems.

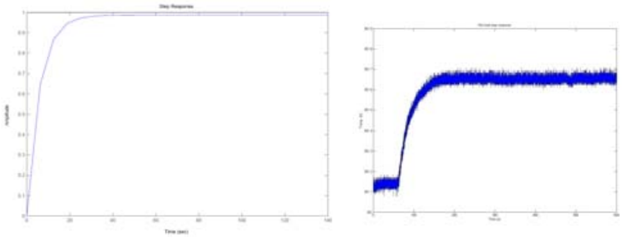

Fig 9. Simulated and tested step response of a thermal regulation function.

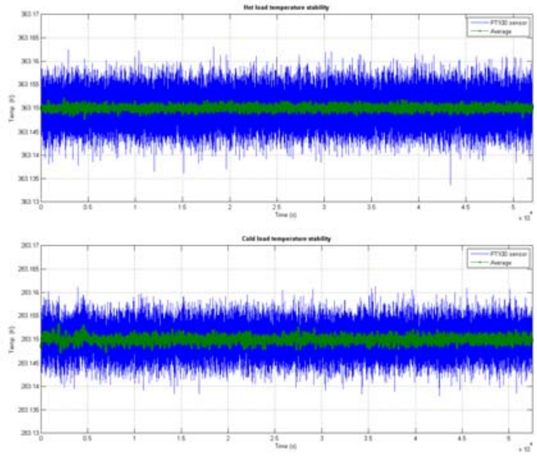

Fig 10. Long term (14 h) thermal stability of the Hot and Cold load.

Typical regulation accuracies are well below 10 mK and the system is compliant to operating between 16-21 C ambient temperature at 5000 m elevation. Start up from cold is also within specification.

Fig 11. The radiometer installed on an ALMA antenna.

VI. System Tests

The first WVR has been tested at the site at 3000 m elevation and test data is shown below. Typical mounting and dismounting of the WVR at the antenna is below 30 minutes, due to a clever arrangement of mechanical/optical interface.

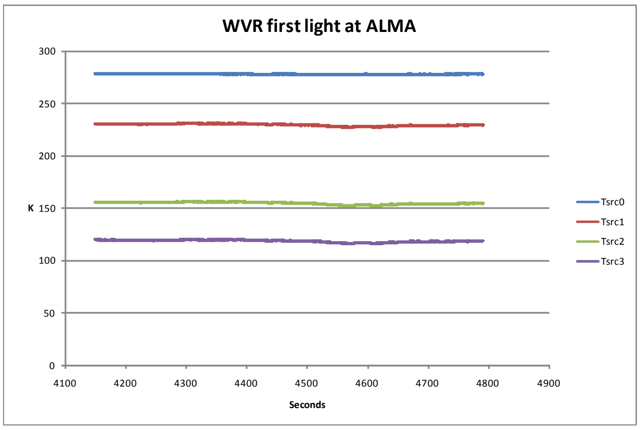

Fig 11. First light data from WVR #102 at the ALMA site.

VII. Conclusion

A new Water Vapor Radiometer has been developed by Omnisys Instruments for the ALMA project in 18 months. It is compliant to all requirements and adapted for long lifetime operations, limited and simple maintance and reasonable per unit cost. More than 50 units will be produced over the next 18 months.