ALMA WVR final report

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***Abstract*- Omnisys Instruments has designed and produced of 58 Water Vapor Radiometers for the ALMA telescope in Chile. The design phase was 24 months including the first installation followed by a production phase of 18 months.**

The ALMA design and performance verification will briefly be presented but the focus on the presentation will be on production and test aspects, including optical and radiometric performance. As of December 2010, all 58 radiometers have been shipped to the ALMA site and passed on site acceptance tests.

The radiometers are tested for optical performance as well as radiometric performance in frequency response, stability, sensitivity, linearity and accuracy. The production verification data will be presented and conclusions drawn. This should give good insight for future THz radiometer design, including many aspects such as optical design, calibration system aspects etc.

I. Introduction

The ALMA WVR is a complete instrument with optical coupling to the reflector antenna in one end and power and CAN bus interface in the other end.

The ALMA WVR consist of a schottky mixer based front-end connected to a filterband back-end. The sensitivity is state of the art with Trec < 1000 K, but the most important aspects are the absolute accuracy and the stability of the instrument. Other constraints are the design lifetime of > 20 years without maintenance, a modular design with simple changes with spare parts and a design compatible with cost effective production and testing.

The production tests include stringent optical performance, sensitivity, absolute stability, frequency response of the complete instrument, out of band rejection and many other parameters. Test results from 58 units will be presented and analysed.

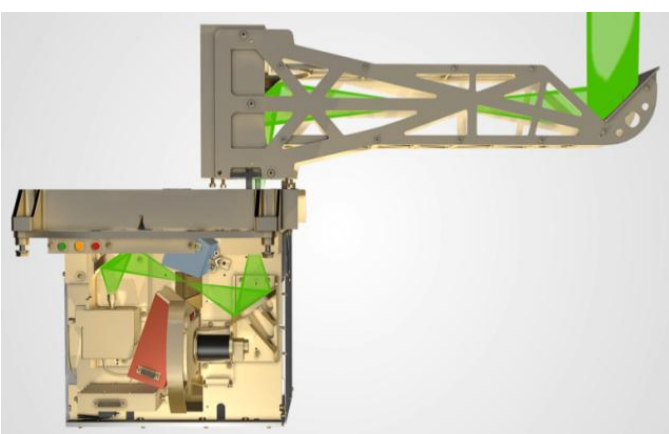

Figure 1 ALMA WVR unit.

Figure 3 WVRs in the ALMA warehouse. Courtesy of Ferdinand Patt, ESO

II. Status

All radiometers have been delivered and tested on site. Most of them are currently stored in the ALMA warehouse waiting for installation in the antennas. Ten WVR's are installed and fully operating and about ten more are being integrated.

III. Key performance

A. *Sensitivity*

To achieve good sensitivity, the receiver temperature was minimized by adjusting the LO chain bias, while measuring Trec live. The receiver temperature and standard deviation are shown in the plots below. The average standard deviations for the four channels respectively were 0.081 K, 0.063 K, 0.066 K, and 0.078 K.

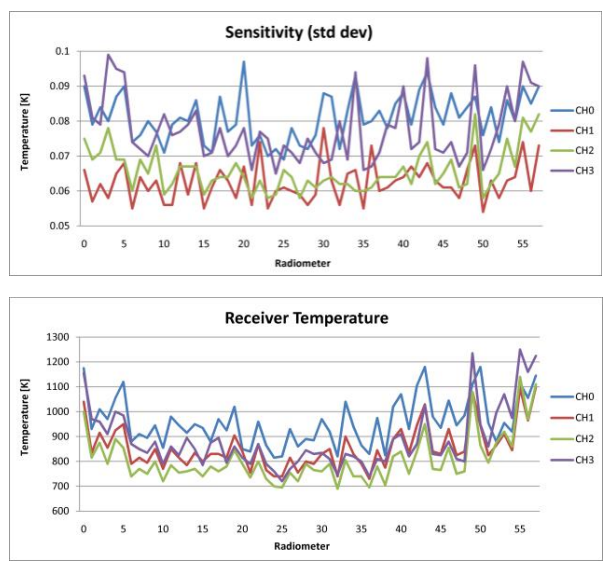

Figure 2 Key performance of each system

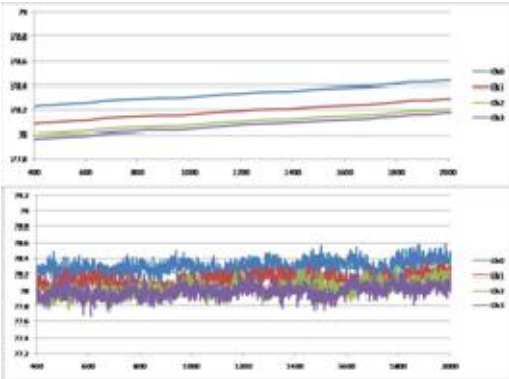

Figure 4 Stability measured with a LN2 load

B. *Stability*

The stability of the radiometer is excellent thanks to thermal regulation of all internal subsystems.

C. *Quasi optics*

The alignment specification is ±28mm on 6m distance. This was very well achieved as can be seen in the plot at the bottom of this page.

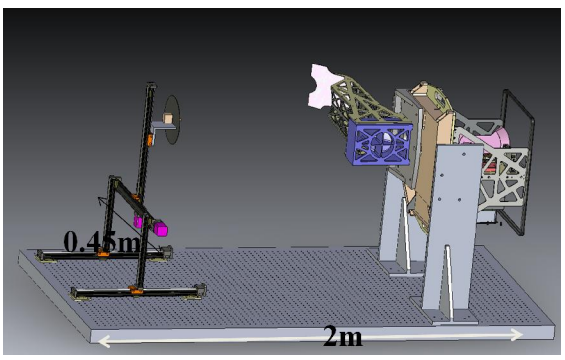

Figure 5 Optical test set-up

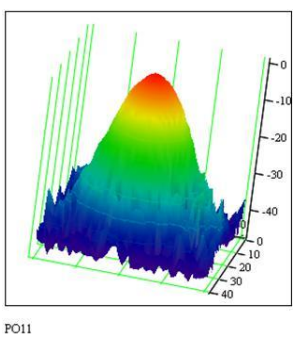

Figure 6 Optical performance measured with 55 dB dynamic range

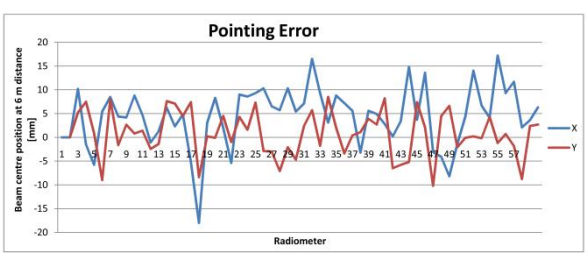

Figure 7 Pointing errors on each system

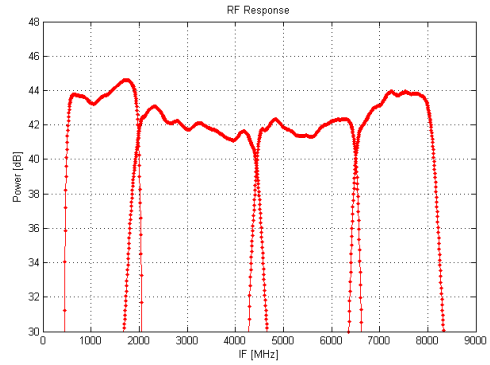

Figure 8 Typical RF characteristics

E. *RF response*

Many of the radiometers passed the bandwidth and centre frequency criteria on first try, but some of them had to be tuned using an equalizer. Above is a typical radio frequency response.

IV. Lessons Learned

Quasi Optics

The quasi optics proved to be far better than expected. Lower precision could have cut costs. Only one system was initially tested out of spec. Automated optics scan at four distances worked very well. Test started when going home, test results in the morning.

Test automation

Use more DAC for automatic tuning. Internal power levels on RF signals was tuned manually by setting resistor values. By using DACs and automated tuning days could have been saved for each system.

Testing at LN2 temperature consumes a lot of time for cooling down loads and keeping load stable. A good reference load with a cryo cooler system would have improved quality of tests and the calibration of the radiometers.

Prototype production

The WVR contract did not contain prototypes or functional models. If this would have been developed, a natural production adjustment would have been made and the customer would have had time to evaluate the product and if needed update their requirements before serial production. This could potentially save costs and schedule.

Over production

The delta cost for producing a few extra parts of each sort is small compared to the cost for starting a new batch. This worked well except for a few cases. In these cases there was both an extra cost and lead time.