STEAMR – 340 GHz array radiometer

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Abstract-**Omnisys is responsible for the design and demonstration of the STEAMR instrument hardware. The breadboard phase was concluded in December 2010 and the Demonstration / Engineering Model phase has started in January 2011. The presentation will be on system implementation, test results and expected performance for Flight.**

I. Introduction

STEAMR is a limb sounding instrument and an array of receivers cover different altitudes without scanning, thus providing an order of magnitude performance improvement compared to a scanned single receiver implementation. STEAMR consist of 14 receivers covering 320-360 GHz with 12 GHz spectrometer bandwidth each.

The upper receiver channels will be based on the DSB principle while Sideband Separation has been considered for the lower altitudes. The pros and cons of using SSB versus DSB are considered from scientific view, based on demonstrated and estimated performance of different SSB implementations. To first order, the SSB implementation implies twice the complexity and power consumption compared to DSB and promise less confusion in the separation of line responses in the two sidebands, while the sensitivity impact is not clear today. Test results used as an input for estimation of scientific impact on different topologies will be presented.

Different subsystems have been extensively tested as well as a complete instrument.

The front-end's and back-end's have been tested in linearity, stability as well as sensitivity. For the sensitivity, both the Y-method has been used to determine T_{rec}, complemented with noise estimation in the computed spectra, enabling a determination of impact on sensitivity as a function of autocorrelation efficiency, system stability and other effects on the complete instrument. These effects increase the noise with a factor between 1.08-1.14, i.e. the effective T_{rec} would rather be about 1540 K with a T_{rec} determined by the Y-method to 1400 K.

II. Design details

The Front-End package consisting of 7-8 receivers (TBD) is under development. The optics of the instrument is the responsibility of the Prime contractor SSC, the group at the Institute of Applied Physics at the University of Bern with the assistance from Omnisys.

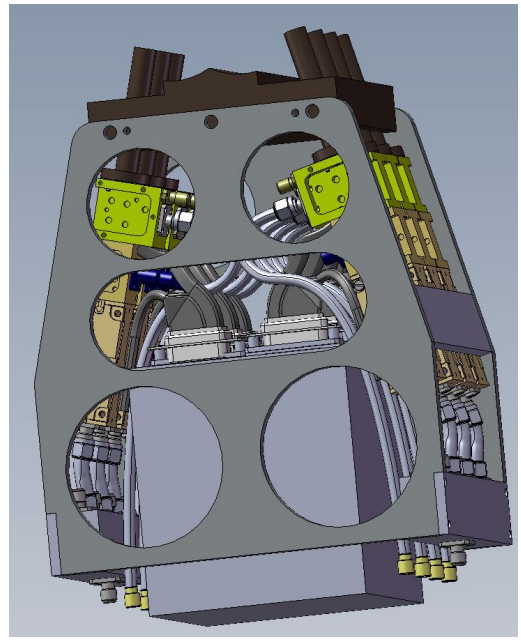

Figure 2. Front-end with 7 receivers heterodyne channels at 340 GHz.

The front-end receivers consist of one mixer with an embedded LNA, a LO schottky multiplier in combination with an x6 active multiplier, as shown below.

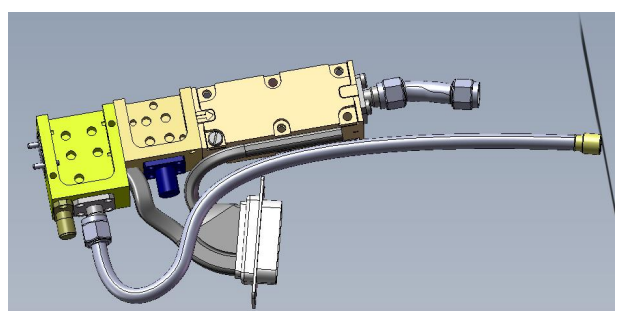

Figure 3. One receiver channel with, from the left, subharmonic schottky mixer with embedded LNA, schottky doubler and active 15 to 85 GHz multiplier.

For front-ends, this include planar diode based DSB and IQ mixers (used for SSB) with embedded custom LNA's and different types of LO generation chains. Excellent results have been achieved with both Chalmers/MC2 produced diodes as well as with VDI supplied diodes. These will be presented both for DSB as well as IQ mixer implementations.

Several versions of the DSB mixer with an embedded LNA have been tested with different schottky diodes and LNA's. Examples are shown below.

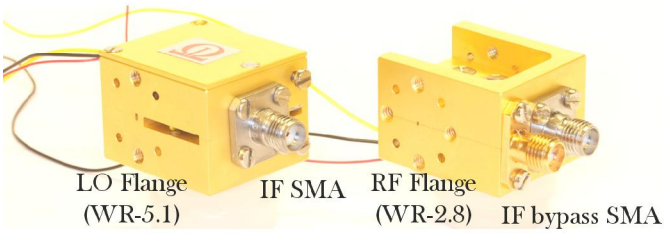

Figure 4. Two 320-360 GHz DSB mixers with embedded LNA's.

The mixers show excellent performance over the wide bandwidth that is required for the instrument, as shown below.

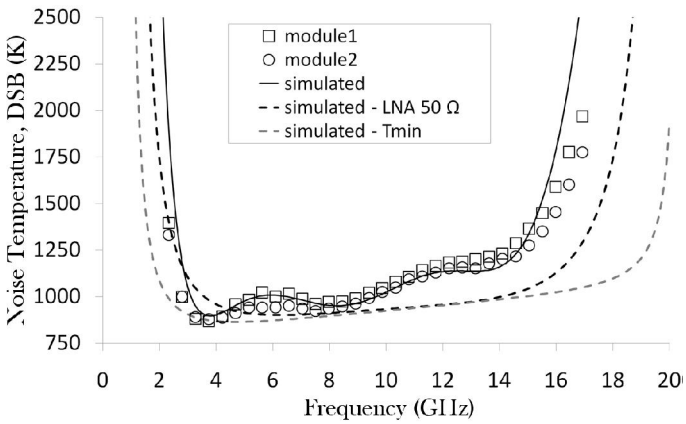

Figure 5. Two 320-360 GHz DSB mixer test results. Note that this is receiver temperature, not mixer temperature.

For back-ends, this will include the first presentation of a spectrometer covering 6 GHz bandwidth based on a single chip autocorrelator with integrated ADC's. Two has been operated in parallel to meet the 12 GHz specified STEAMR bandwidth. With 14 receivers operating in the array, 168 GHz spectrometer bandwidth will be covered and we are now entering into the THz domain in bandwidth, not only operating frequency. Omnisys has currently >200 ASIC's in storage and about 40-50 is needed for the complete project, including spares.

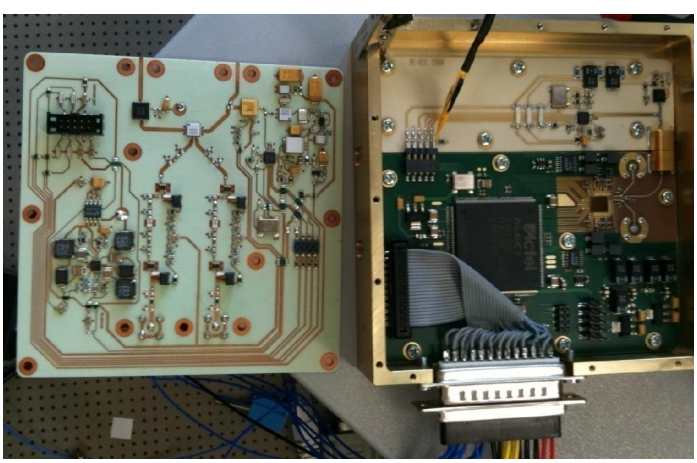

Figure 6. Spectrometer breadboard top and bottom.

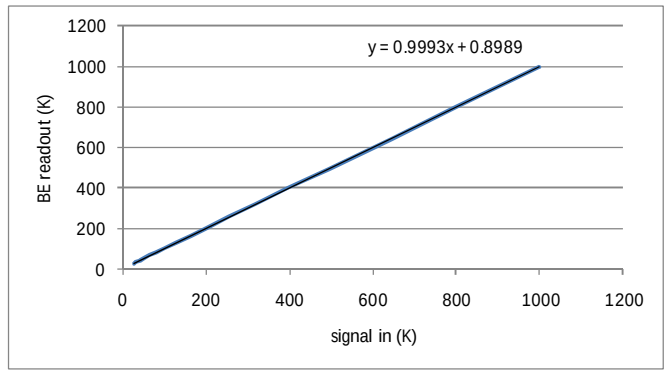

Figure 7. Back-end linarity.

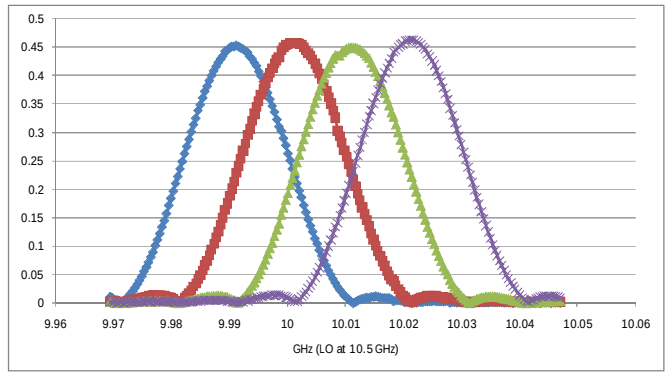

Figure 7. Back-end frequency response.

The front-end's and back-end's have been tested in linearity, stability as well as sensitivity.

For the sensitivity, both the Y-method has been used to determine T_{rec}, complemented with noise estimation in the computed spectra, enabling a determination of impact on sensitivity as a function of autocorrelation efficiency, system stability and other effects on the complete instrument. These effects increase the noise with a factor between 1.08-1.14, i.e. the effective T_{rec} would rather be about 1140 K with a T_{rec} determined by the Y-method to 1000 K.

The spectrometer show excellent results in terms of linearity as well as in frequency response, as can be seen above.

Tests in terms of stability has been performed bot in stable operation of the instrument and with applied temperature gradients on the front-end and/or the back-end. The results show compliance to the preliminary instrument requirements.

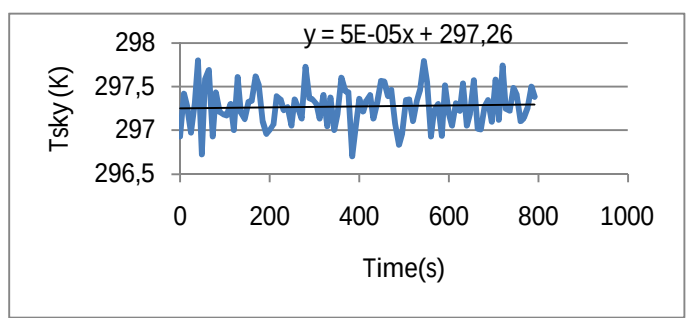

Figure 6. Radiometer stability at 340 GHz.

III. Power budget

For the complete STEAMR system, we have four Front-End Quad's, four Back-End Quad's, four power subsystems and a common redundant controller.

Radiometer	Per unit	#Units	Sum	Cont.(20%)	Total (mW)
FE quad	12137.5	4	48550	9710	58260
BE quad	28380	4	113520	22704	136224
CNT	4000	1	4000	800	4800
PWR (90%)	6451.75	4	25807	5161.4	30968.4
SUM			**166070**		**199284**

Translated into standard radiometer terms, we have 14 complete front-ends and 14 extremely broad back-end spectrometers with 168 GHz analyzed bandwidth.

The complete radiometer power consumption is estimated to be 199.3 W, including 20% contingency.

As a comparison, the autocorrelation spectrometers used in the HIFI instrument on Herschel process 4 GHz of bandwidth with over 250 W power consumption by themselves.

IV. Conclusion

The STEAMR development is on-going and show very promising results on breadboard and prototype level in compliance to the preliminary instrument specifications.

The results define a new level of state of the art in terms of schottky front-end performance of $T_{rec} < 1000$ K at 340 GHz, spectrometers bandwidth as well as system design and integration level. The power consumption per complete receiver is about 14 W, including LO system, a 12 GHz and 512 channels spectrometer back-end and power and control functions.