PROCEEDINGS OF SCIENCE

Results of the Planck 70 GHz receiver protoflight model test campaign

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1. Introduction

The Planck LFI's 70 GHz radiometers were manufactured and tested in Finland at Elektrobit Microwave Ltd. (formerly Ylinen Electronics). There are six 70GHz feedhorns at the focal plane, each divided into two orthogonal polarizations and backed by cryogenic pseudocorrelation radiometers, resulting in a total of 24 output channels.

The calibration test campaign for the six Protoflight Model Radiometer Chain Assemblies (RCA) was conducted from June 2005 to January 2006. Two RCAs were tested at a time in a large vacuum chamber (Fig.1). The chamber provides the required 20 Kelvin cryogenic environment for the Front-End Modules (FEM) and around 10K for the thermally controlled Sky and Reference targets.

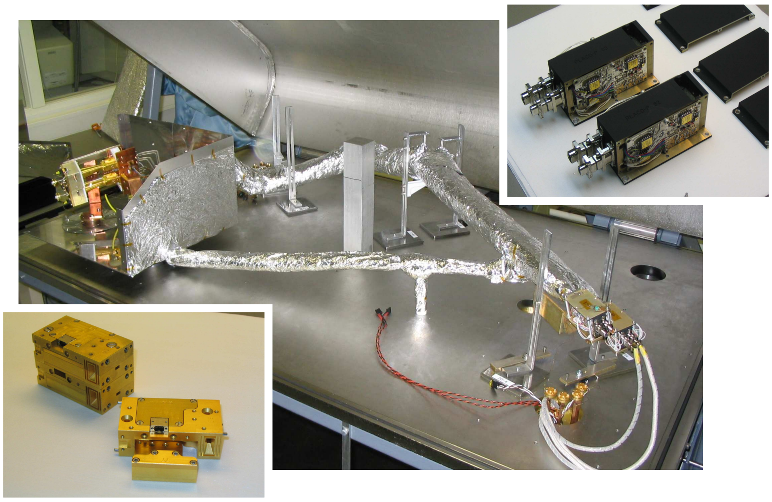

Figure 1. Vacuum chamber for RCA testing at Elektrobit Microwave. Insets show FEM (bottom left) and two BEMs (top right).

2. Performance

Several performance parameters of the radiometers were measured during the test campaign, the main ones being system noise temperature (*Tsys*), radiometric bandwidth (β), and 1/f noise knee frequency (*fk*). The requirements for these parameters were met in some, but not in all of the constructed receivers. The best achieved and the averaged values (over all 24 output channels) are shown in the table below.

Parameter	*Best*	*Average*
Tsys	27.0 K	32.3 K
Bandwidth	13.3 GHz	10.2 GHz
1/f knee	33 mHz	112 mHz
Isolation	> 20 dB	~15 dB

The system noise temperature (*Tsys*) of the RCAs, specified to be <29.2K, was determined by changing the temperature of the Sky or Reference target in controlled steps and noting the DC output voltages. From this, *Tsys* can be calculated using the Y-factor method and the measurements indicate values ranging from 27K to 37K, depending on the RCA under test. These actually represent upper limits, since accurate calibration of the horn to target matching was not possible and it was thus assumed to be perfect. Plots, such as in Fig.2, were also used for estimating linearity and Sky-Reference isolation. Linearity was found to be good down to measurement precision, while isolation ranged from 11dB to better than 20dB (spec. is >13dB).

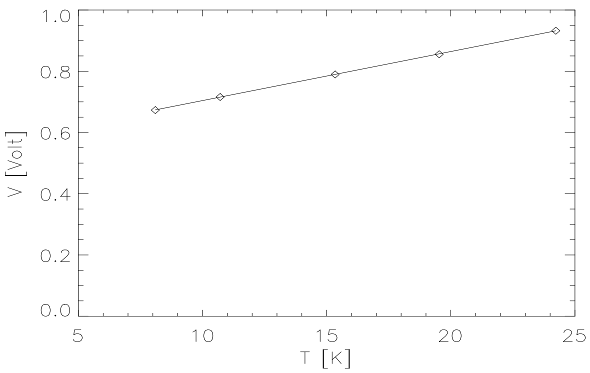

Figure 2. An output voltage vs. reference target temperature plot, used for determining Tsys, sensitivity, linearity and isolation.

The bandwidth of the RCAs is specified as 14GHz based on the predetection bandwidth (frequency response), and measurements fall into the range 13-18GHz. The bandwidth can also be calculated from the radiometer sensitivity equation (white noise) which gives somewhat lower values of 8 to 13GHz. This is interpreted as coming from post-detection noise in the BEM audio amplifiers; the blanking of the signal during phase switch transitions; and from the frequency response of the combined feedhorn/OMT which are not included in the lower level test (Fig. 3).

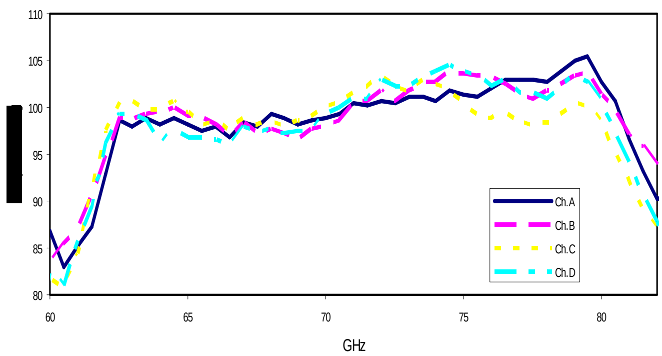

Figure 3. Frequency responses measured at FEM+BEM level test (not incl. the feedhorn and OMT).

The specification for 1/f knee is *fk*<50mHz, at which level it is still possible to remove the effects of 1/f noise in the data processing. The reliable measurement of the knee frequency was diffcult with the test setup – for each RCA values as low as 40-60mHz and as high as 200-300mHz were recorded.

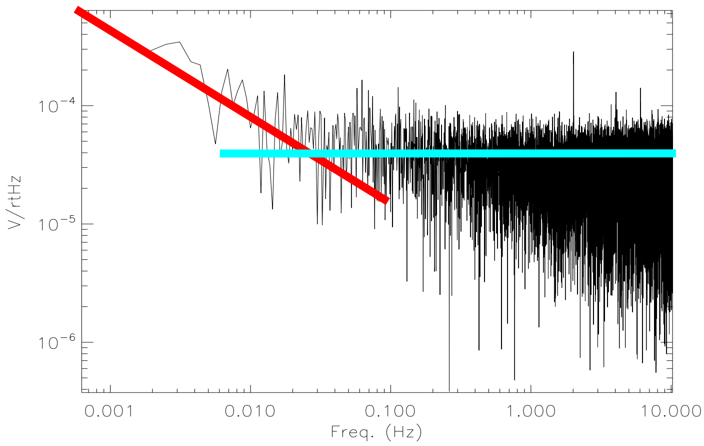

Figure 4. 1/f spectrum showing fk=43mHz, calculated from exponential curve fit and white noise average.

In addition to performance testing, the FEMs and BEMs were also subjected to environmental tests including vibration, EMC and thermal vacuum cycling. Vibration levels were up to 50g along some axes at certain frequencies; thermal vacuum cycling for the BEMs included four cycles between -30 and +60°C. The FEMs were, in the course of routine testing, cycled between ambient temperature and 20K more than ten times, without suffering harm. EMC testing was carried out on the BEMs (to measure their susceptibility to external interference). The sensitivity of both the BEM and the FEM to small temperature fluctuations were measured.

References

This poster is based on a paper of the same name, published in the Proceedings of the 4th ESA Workshop on Millimeter-Wave Technology and Applications, Finland 2006, pp.475-479. Some figures have been updated.