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Developments at 30 GHz for Planck LFI

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Abstract. Jodrell Bank Observatory is responsible for the Front end modules (FEMs) for 30 GHz for LFI, with IAC being responsible for the hybrids and any phase switch. The University of Cantabria are responsible for the Back end modules (BEMs). Developments have been made to test prototypes both warm and cold for the FEMs. This is evolving towards flight hardware through an elegant breadboard phase EBB. Results of system performance show both white noise and 1/f characteristics.

1. Introduction

This talk describes preliminary testing of the prototype demonstrator for the 30 GHz radiometer. The measurements were designed to evolve to a system which can achieve the challenging 1/f requirements that are required for the Planck mission. To this end various temperatures and switching strategies have been tested. A Foxtrot scheme has been found to be capable of giving the required performance.

2. The Planck Radiometer with front end switch

Fig. 1 shows a schematic of a Planck radiometer with a front-end switch. The radiometer essentially divides into two halves: a 20 K front end and a 300 K back end. The front end consists of a hybrid, LNAs, two phase switches and a second hybrid. The back end consists of more gain, filters detectors, video gain low pass filters and data acquisition system. At this stage the LNAs used were based on the Pospieszalski, NRAO design for the VSA, but using Planck HRL passivated InP HEMTs The HEMT amplifiers produce 1/f noise which to a high degree

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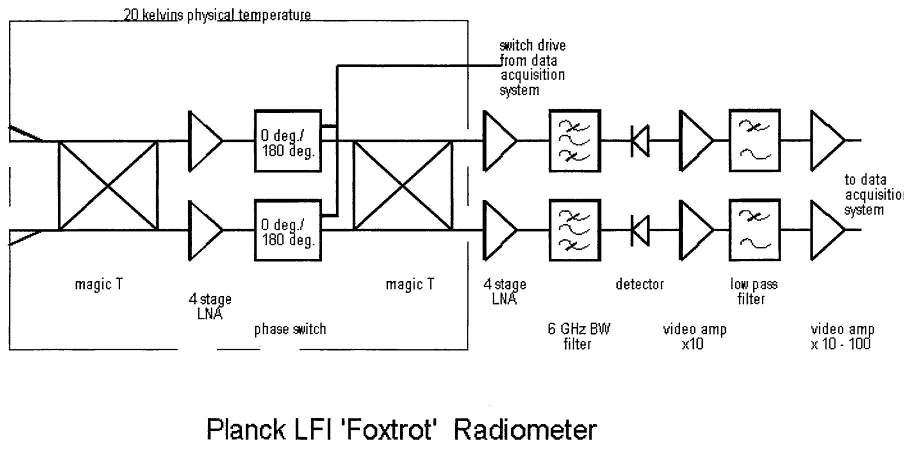

Figure 1. LFI 30 & 44 GHz Radiometer Schematic

of precision must be removed. The sky is connected to one input to the first hybrid and a reference load is connected to the other. The hybrid then causes addition and subtraction of the noise voltages. Thus both signals go through both amplifiers. The signals then are amplified and are passed through phase switches. The second hybrid returns the signals to sky and reference load exept that both have identical 1/f from both amplifers. Thus by suitable subtraction this effect can be removed.

The system requires further amplification at RF before detection and the purpose of the phase switches is to swap over the signals rapidly so that both signals pass through the same RF amplifer before its 1/f charcterisitcs vary significantly. However we now have a worry that the phase switch may have a different 1/f voltage in each state. We are using HEMT phase switches and some worries have been expressed about there 1/f voltages. Some second differencing may be required to remove this: either by differencing across the diodes or operating the switches at double speed in all four states and doing double differencing on each diode (the so called foxtrot) These measurements use the latter strategy but future measurments will investigate the former.

3. Room temperature measurements

Fig. 2 shows a room temperature radiometer. On the left is seen a magicT hybrid. Its two inputs are a waveguide termination and an input from the VNA or other source. The outputs go to two LNAs and then by waveguide to SMA transition to two commercial room temperature phase switches and thence to the second hybrid. This initial setup allowed the problems of amplitude and phase matching to be investigated while all of the equipment was readily accessible. The back end and data aquisition system were also further developed at this stage. Fig. 3 shows the front end mounted in a 20 K cryostat. The top of the

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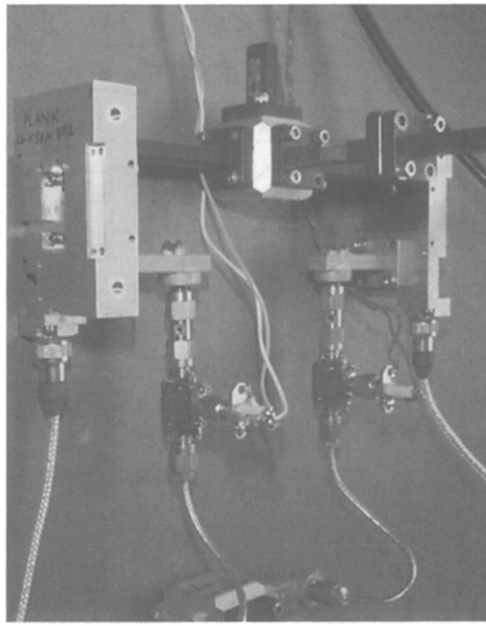

Figure 2. 30 GHz room temperature radiometer

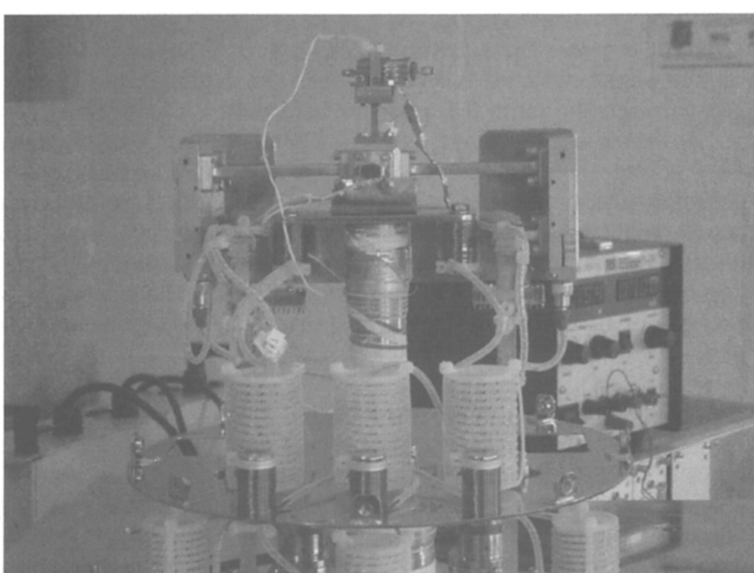

Figure 3. 30 GHz radiometer front end mounted in cryostat

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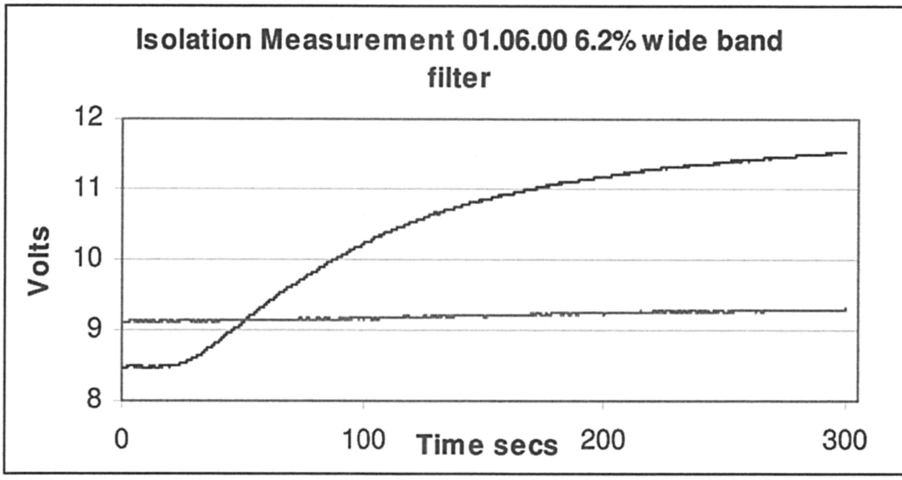

Figure 4. Isolation plot for the cold 30 GHz radiometer

photograph shows a heated waveguide load mounted on a magicT hybrid the outputs of which are connected to the two LNAs. The coils of wire are to reduce the thermal conduction along the electrical connections to the amplifiers. The flat plate is the 80 K station which in operation has a radiation screen attached to it.

4. Cryogenic testing

F. Winder has developed our own HEMT phase switches which were installed in the cryostat. After balancing the radiometer front end in the cryostat with phase adjusters outside the cryostat it was time to measure the isolation. If the radiometer is well balanced then after the second hybrid the signals should be unravelled and be returned to sky and load (in this case two separate loads). In practice this is never perfect and some of one of the signals leaks onto the other.

Fig. 4 shows the two outputs of the system as heat is applied to one of the waveguide loads. The figure shows the steady heating of the load but also a small leakage into the other channel measured as 6.2%.

5. Cryogenic 1/f measurements of the radiometer with different switching strategies

The 1/f requirement for Planck LFI is better than 50 mHz. We have made these initial measurements of the the 1/f spectrum. The loads and input hybrid and LNA's are in the cryostat with the rest of the radiometer warm. For each switching strategy the load temperatures have been imbalanced to bring the 1/f conditions to that of Planck using the formula derived by M Seiffert. In these early measurements the switching rates were limited to 10 Hz due to data

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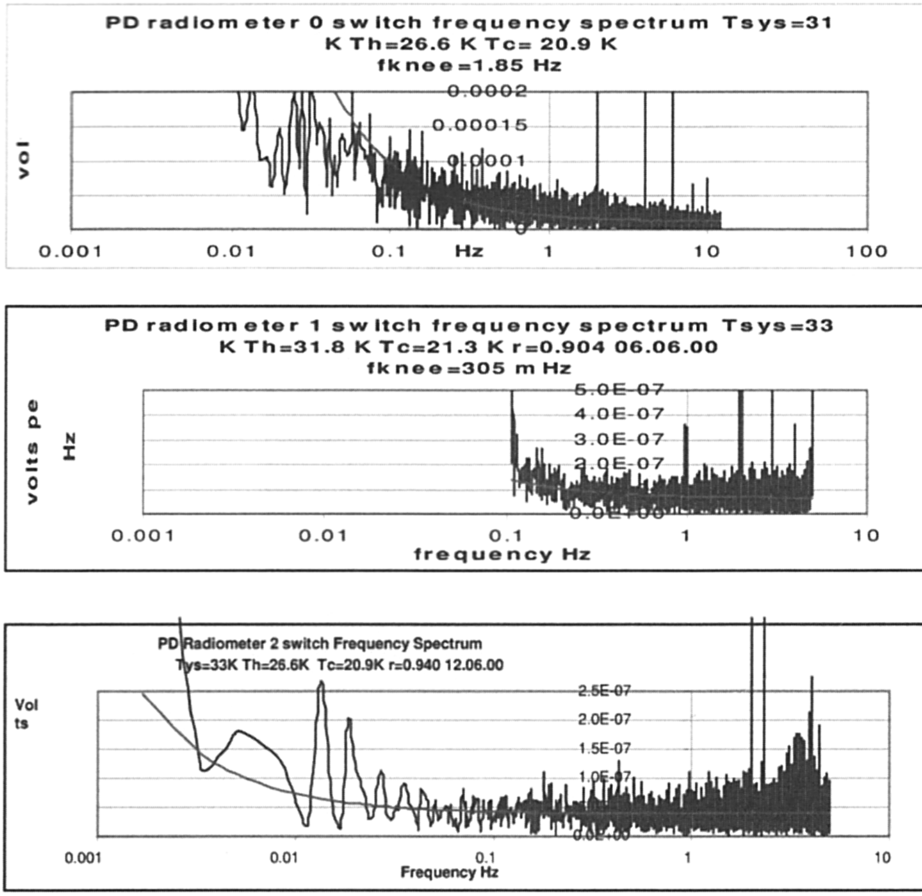

Figure 5. Measured 1/f noise spectra for no switching, one phase switch and two phase switching (Foxtrot)

acquisition hardware. Figure 5 shows the results for no switching of 2 Hz 1/f knee, of 300 mHz with one switch and 22 mHz for both switches (foxtrot). These were early measurements and to date much more has been done with faster switching hardware and even cold phase switches and differencing across the diodes rather than the foxtrot. The detailed results of all of this will be written up elsewhere.

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