Readout of a 160 Pixel FDM System for SAFARI TES Arrays

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SAFARI is one of the focal-plane instruments for the Japanese/European far-IR SPICA mission proposed for the ESA M5 selection. It is based on three arrays with in total 3550 TES-based bolometers with noise-equivalent powers (NEP) in the range of 2 E-19 W/√Hz. The arrays are operated in three wavelength bands: S-band for 30-60 µm, M-band for 60-110 µm and L-band for 110-210 µm, and have background-limited sensitivity and high efficiency. At SRON we are developing Frequency Domain Multiplexing (FDM) for read out of large AC biased TES arrays for both the SAFARI instrument, for the far-IR SPICA mission, and XIFU instrument, for the X-ray Athena mission. In this paper we focus on the development of a FDM demonstration model for the SAFARI instrument. In FDM the TES bolometers are AC biased and readout using in 24 channels. Each channel contains 160 pixels of which the resonance frequencies are defined by in house developed cryogenic lithographic LC filters. To overcome the dynamic range limitations of the SQUID pre-amplifier, a special technique, baseband feedback (BBFB), is applied.FDM is based on the amplitude modulation of a carrier signal, which also provides the AC voltage bias, with the signal detected by the TES. BBFB attempts to cancel the error signal in the sum-point (located at the input coil of the SQUID), by feeding back a remodulated signal to the sum-point, and therefore improving the dynamic range of the SQUID pre-amplifier.

After reporting on the successful low-noise read-out of 38 bolometer TES pixels with an NEP level of 1 - 2E-18 W/√Hz we reported on a detailed study on the effects of electrical crosstalk using out first iteration of a prototype of a full 160 pixel FDM experiment. Using the obtained knowledge a second generation prototype of a full 176 pixel FDM experiment is developed in which the crosstalk elements of carrier leakage, mutual inductance and common impedance are minimized. The cold part of the experiment consists of a detector chip with 176 pixels with a design NEP of 7E-19 W/√Hz and two matching LC filter chips, each of which contains 88 carefully placed high-Q resonators, with in total 176 different resonance frequencies, and a single-stage SQUID. The warm electronics consist of a low-noise amplifier (LNA) and a digital board on which the generation of the bias carriers, the demodulation of the signal and remodulation of the feedback signal are performed. The effect of carrier leakage has been reduced by a factor two and the effects of mutual inductance have been removed. The common impedance has been reduced by design to 4nH, of which 3nH is from the input coil of the SQUID. It has successfully been further reduced to below 1nH by implementing screening of the input coil. The pixels have been connected in stages, a quarter, half and the full array, to be able to detect and solve any issues coming up. In this paper we will report on the results obtain with this 176 pixel FDM experiment.