is given. For a constant voltage biased transition edge sensor (TES), as used in EBEX, the current responsivity is given by:

$$S_I = \frac{\Delta I}{\Delta P_{op}} = \frac{-1}{V_b} \cdot \frac{\mathcal{L}}{\mathcal{L}+1} \tag{7.1}$$

where V_b is the voltage bias of the TES and $\mathcal{L}$ is the TES electro-thermal feedback loop-gain. The loop-gain characterizes the strength of the electro-thermal feedback and is given by[1] :

$$\mathcal{L} = \frac{P_e \alpha}{GT} \tag{7.2}$$

Where P_e is the electrical power biasing the detector, T is the temperature of the detector, G is the average thermal conductance of the detector's weak link to the bath and $\alpha \equiv \frac{d(log(R))}{d(log(T))}$. The responsivity of a few EBEX detectors was measured before the test flight to range from $10^5 - 10^6 \frac{Amp}{W}$[60].

7.2.1 Bath Temperature Dependence

The dependence of responsivity on bath temperature (T_0) is found by:

$$\frac{dS_I}{dT_0} = \frac{dS_I}{d\mathcal{L}} \frac{d\mathcal{L}}{dP_{el}} \frac{dP_{el}}{dT_0} = \frac{1}{V_b} \frac{1}{(\mathcal{L}+1)^2} \frac{\kappa(T_0)}{\kappa(T)} \cdot \frac{1}{T} \cdot \alpha \tag{7.3}$$

where κ is the thermal conductivity of the bolometer's weak link to the bath. To find the relative change in the responsivity we look at:

$$\frac{\Delta S}{S} = \frac{\frac{dS}{dT_0} \cdot \Delta T_0}{S} = \frac{1}{\mathcal{L}(\mathcal{L}+1)} \frac{\kappa(T_0)}{\kappa(T)} \cdot \alpha \frac{\Delta T_0}{T} \tag{7.4}$$

The values of V_b, $\mathcal{L}$ and α are challenging to measure and may vary between detectors. To get an order of magnitude estimate for how responsivity will be affected by a change in bath temperature we use the assumption that $\kappa(T) = \kappa_0 \cdot T^n$, with n=2. Figure 7.2 shows resistance vs. temperature data from a TES bolometer in a test cryostat measured by Kate Raach. From the plot we measure $\alpha \approx 2800$. The voltage bias for this detector was $\sim V_b = 3\mu$V. Taking an approximate value for G=60 pW/K, we calculate from equation 7.2 $\mathcal{L} \approx 1000$ ($T=T_c$=413.5 mK, T_0=320 mK, R=1.2 Ω).

[1] This is the zero frequency loop-gain

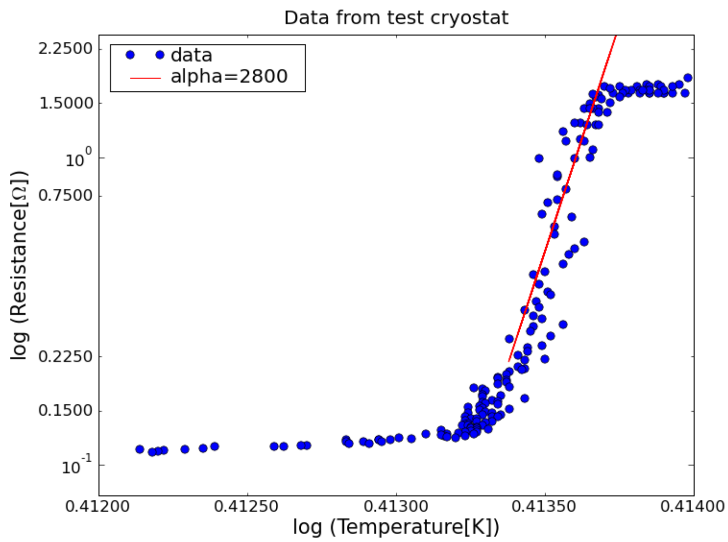

Figure 7.2: Resistance vs. temperature data of a TES bolometer

This gives:

$$\frac{\Delta S}{S} = 3 \cdot 10^{-3} \cdot \frac{\Delta T_0}{T} \tag{7.5}$$

So for every change of 1% in the bath temperature the responsivity will change by 0.003%. Even if we take a factor of ten safety margin for the approximation done here, there is still a ratio of 1 to 30 in the affect bath temperature has on the bolometer responsivity. The change in responsivity is suppressed by the loop-gain squared but is enhanced by α.

Actual temperature drift

During the test flight a ruthenium dioxide temperature sensor was mounted on each of the wafers. Figure 7.3 shows the data from these sensors between 19:30 UTC and the end of the flight. Once the focal plane's temperature stabilized after being warmed during the bolometer system tune-up, the temperature remained stable to within 2 mK for the remainder of the flight. This temperature variation is less than 0.8% of the wafer temperature. This variation in temperature causes a variation of less than 0.01%