Analysis of Phase Shifted Load Curves

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Logic of using 90 phase shifted load curves:

Before taking a loadcurve the phase is set up at or near the optimum bias – in the case of the data looked at here the bias was set at ~15 mV.

As the bias is changed during any load curve the impedance of the bolometer changes. Combined with the capacitance of the cable between the JFET and the bolometer this means the phase changes with the bias causing, in turn, a change in the detected signal.

To first order the phase is given by $\theta = \tan^{-1}(2\pi f C_{cable} R_{bol})$ - (1)

To find out what the phase change is as the bias is increased we can compare the loadcurves taken at the nominal phase and at 90 degrees out of phase. Figure one shows the two sets of data taken at 130 Hz. Where the out-of-phase load curve passes through 0 we have the true 90 degree out of phase point.

One method of finding the phase change is to calculate the relative signal at each bias by dividing the out of phase signal by the in phase signal. This gives us a measure the residual signal – if we compare this to what we would expect for a-not-quite-properly-out-of-phase sine signal demodulated by a square wave then we can estimate the phase change.

There is some degeneracy here though – both the in and out of phase signals have (the same) phase error. This reduces the in-phase signal as well as increasing the out of phase signal. If we suppose that to 0^{th} order the phase error is small then the effect at the peak of the phase on the gain is also small. To test this I have calculated the phase change (using the equation above) as a function of bolometer impedance as it varies about the estimated impedance from the low bias part of the loadcurve – see figure 2. Here I have also included the effect of the cable capacitance. We can see that a) the cable capacitance can be between 40 and 60 pF with little effect of the result and b) that the maximum phase change is 15-20 degrees – at the peak phase this will amount to no more than 5-7 percent variation in the signal gain. However see later we do need to tune the value a little to make the impedances derived by this method agree with the impedance derived from the knowledge of the signal and bias voltage.

The fact that both have a phase error is then a second order effect on the final outcome – we could feed this back but I haven't done that for this first go.

O.k. so having calculated the out of phase relative signal we can compare this to the theoretical (actually numerically found!) cross correlation of a sine and square wave (figure 3) and by look up determine what the phase error is. The phase error found by this method is shown I figure 4 for the example of 130 Hz.

What we can do with our knowledge:
We now have a lot on information that we can use:

i) Using the derived phase error we can correct the low bias part of the load curve for both RC roll off and phase gain to get the low bias bolometer impedance and temperature

ii) Using equation (1) we can find the value of R_{bol} that matches the derived phase error at each part of the "in phase" load curve for a given cable capacitance

iii) We can find the current flowing through the circuit by treating the circuit as a voltage divider using V_{bias}, V_{bol} and the known load resistor values. However to do this we must correct the signal values for both the RC roll off and the phase gain <u>and</u> the applied bias for the roll off of the cables – in an admitted fudge I assume that the bias voltage roll off is the same as for the signal. Why? – as we see later: because it works!

iv) Having found R_{bol} we can use delta and R* for each detector to get the temperature and the current and corrected voltage across the bolometer to get the power. I use the bolometer impedance found from the voltage division method for this.

The impedance found from the phase method and from the voltage division method versus (corrected) bias voltage is plotted in figures 5 through 7 for frequencies 70, 130 and 190 Hz. In the case of 190 Hz the ot of phase signal went out of limits in the middle of the load curve and hence the phase derived impedances go a little wonky. The cable capacitance used in each case was 50, 40 and 40 pF respectively. The need to have a different value for the 70 Hz bias is probably because the system was not correctly phased up for this frequency.

Of course I found all this somewhat by trial and error – having found the cable capacitance value that fitted best this was fed back into the whole calculation for consistency.

Figure 9 shows the culmination of all the fiddling – the “natural” load curves in P vs T for each detector for each of the three bias frequencies. We can see that broadly speaking the 130 Hz and 190 Hz data agree with each other and the 70 Hz data don’t. The probable reason for this is shown in figure 8 where I plot the temperature of the evaporator cold tip during each load curve. The 70 Hz in phase load curve was taken at a different temperature to the others.

Figure 10 shows the close up of the P vs T curves near zero power. Also plotted here are the temperature vales derived from the linear part of the load curve. Whilst the general agreement is more or less right in detail the values differ. Also it is curious to note the that the 70 Hz data indicate a slightly higher bolometer temperature in contradiction to the evaporator temperature readout.

Strangeness remains and further discussion is called for!

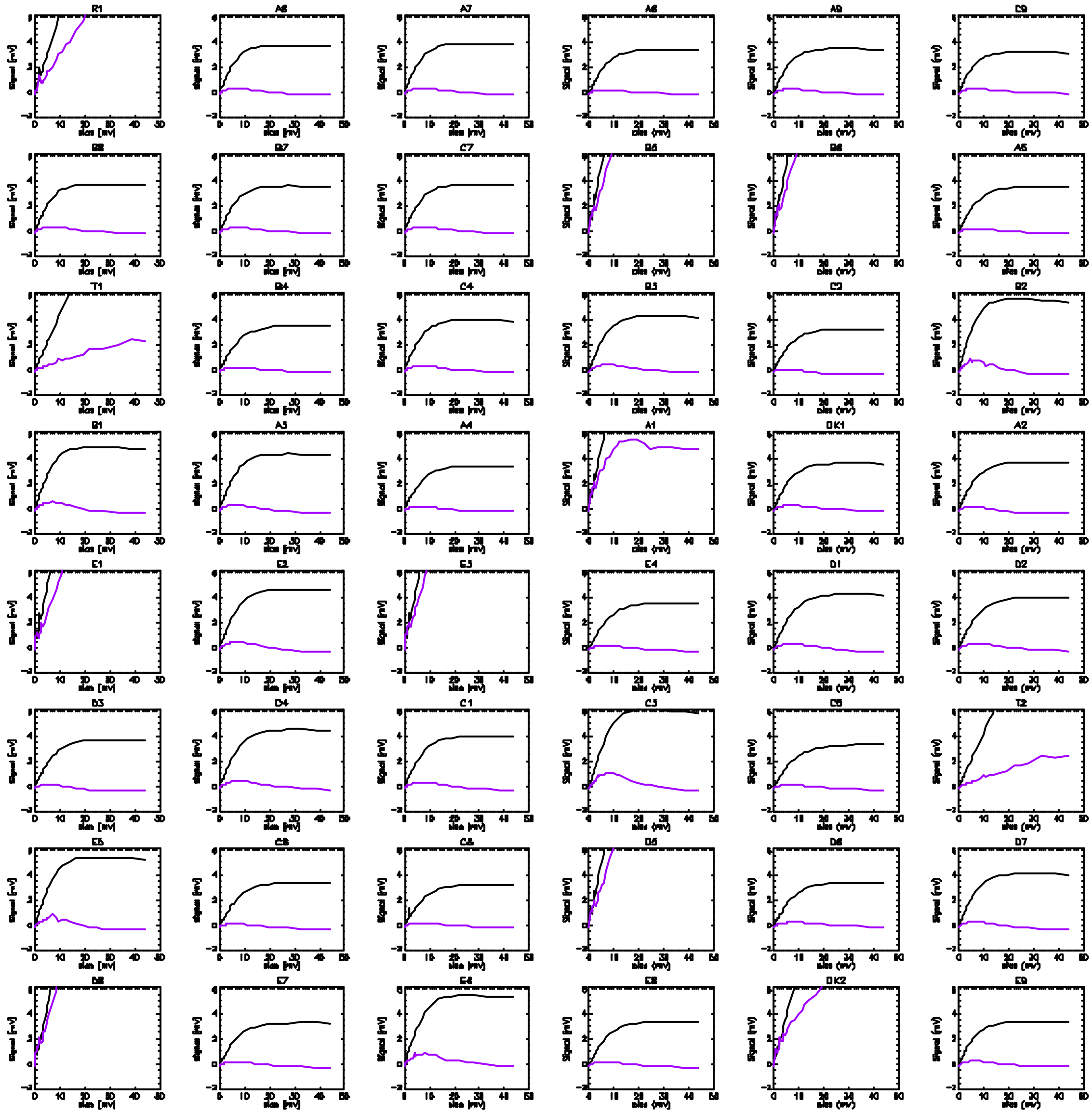

Figure 1: Comparison of dark load curves at 130 Hz with "peaked" phase (black) and 90 deg from peak (purple)

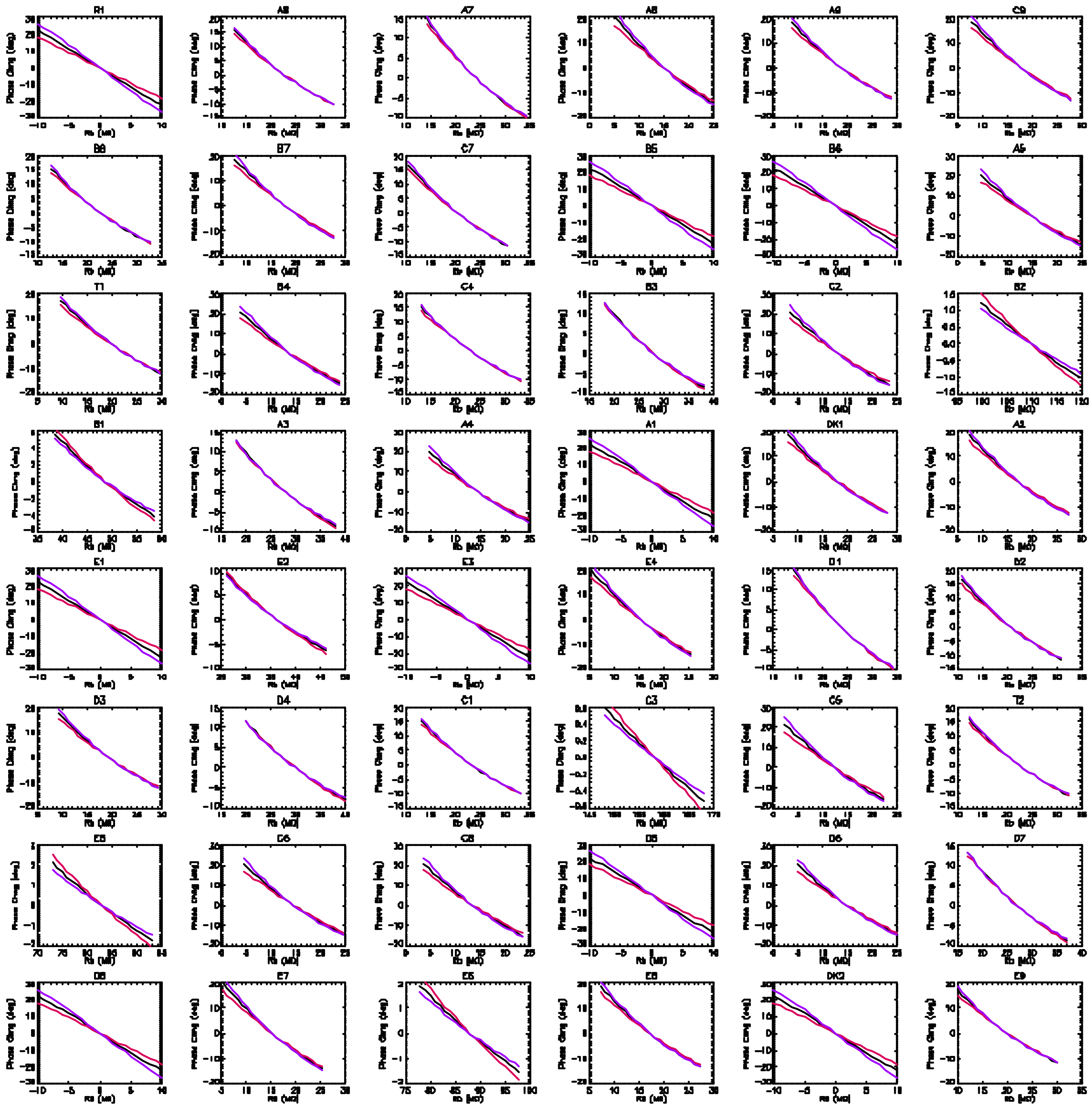

Figure 2: Change in phase as function of bolometer impedance assuming 40 (red) 50(black) and 60 (purple) pF cable capacitance.

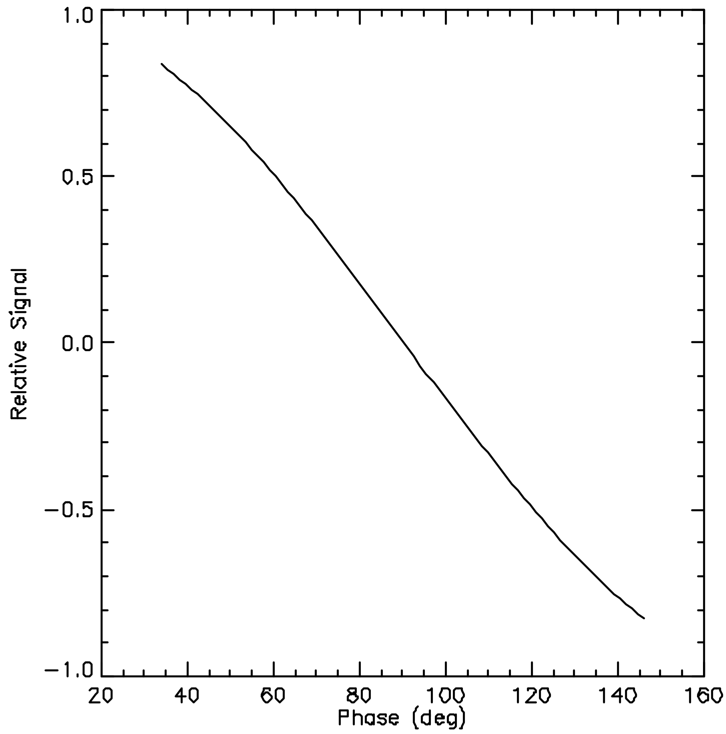

Figure 3: Relative signal as a function of phase between sine signal and square wave reference.

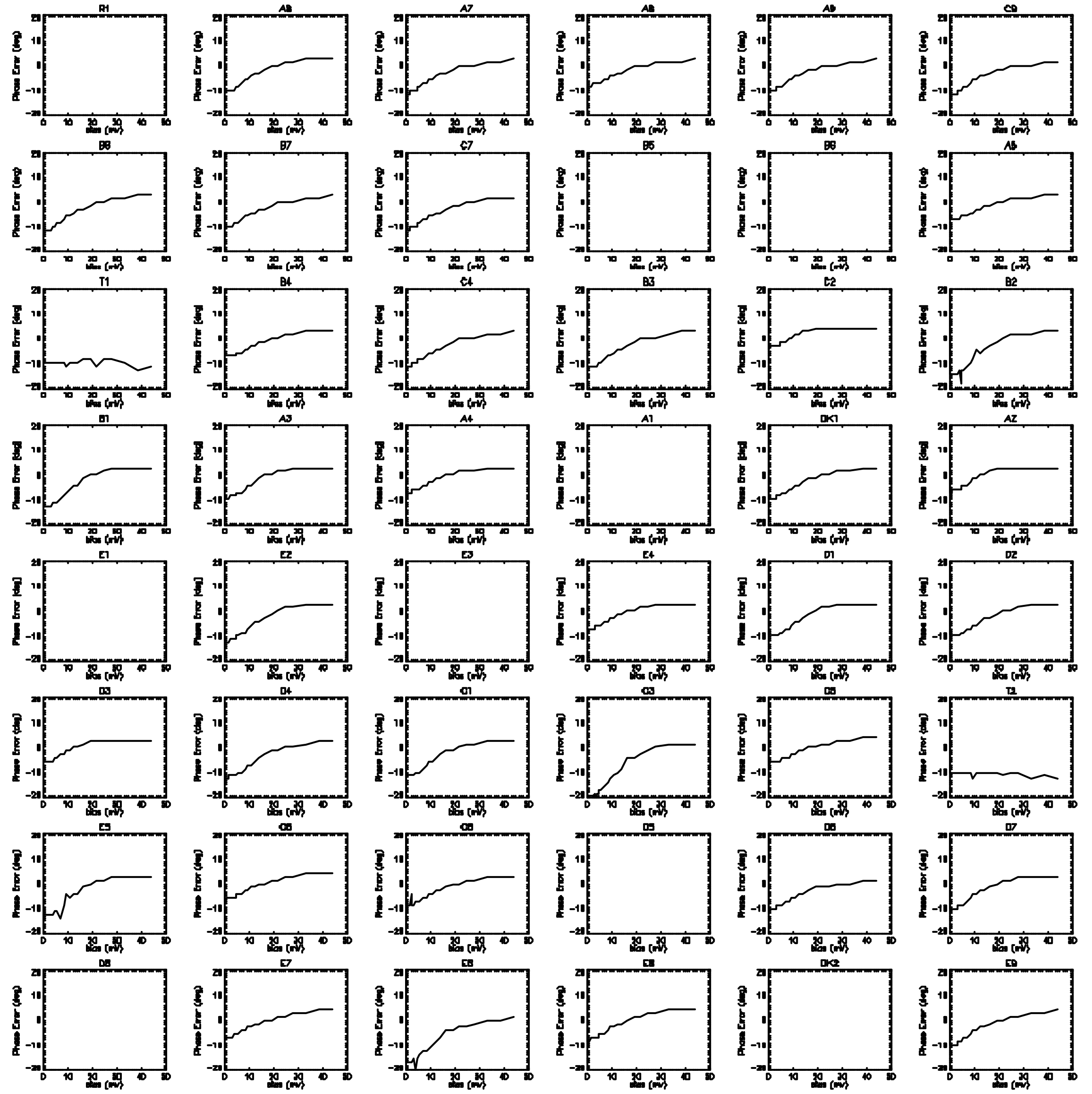

Figure 4: Phase change determined from comparison of load curves and cross correlation of square and sine wave.

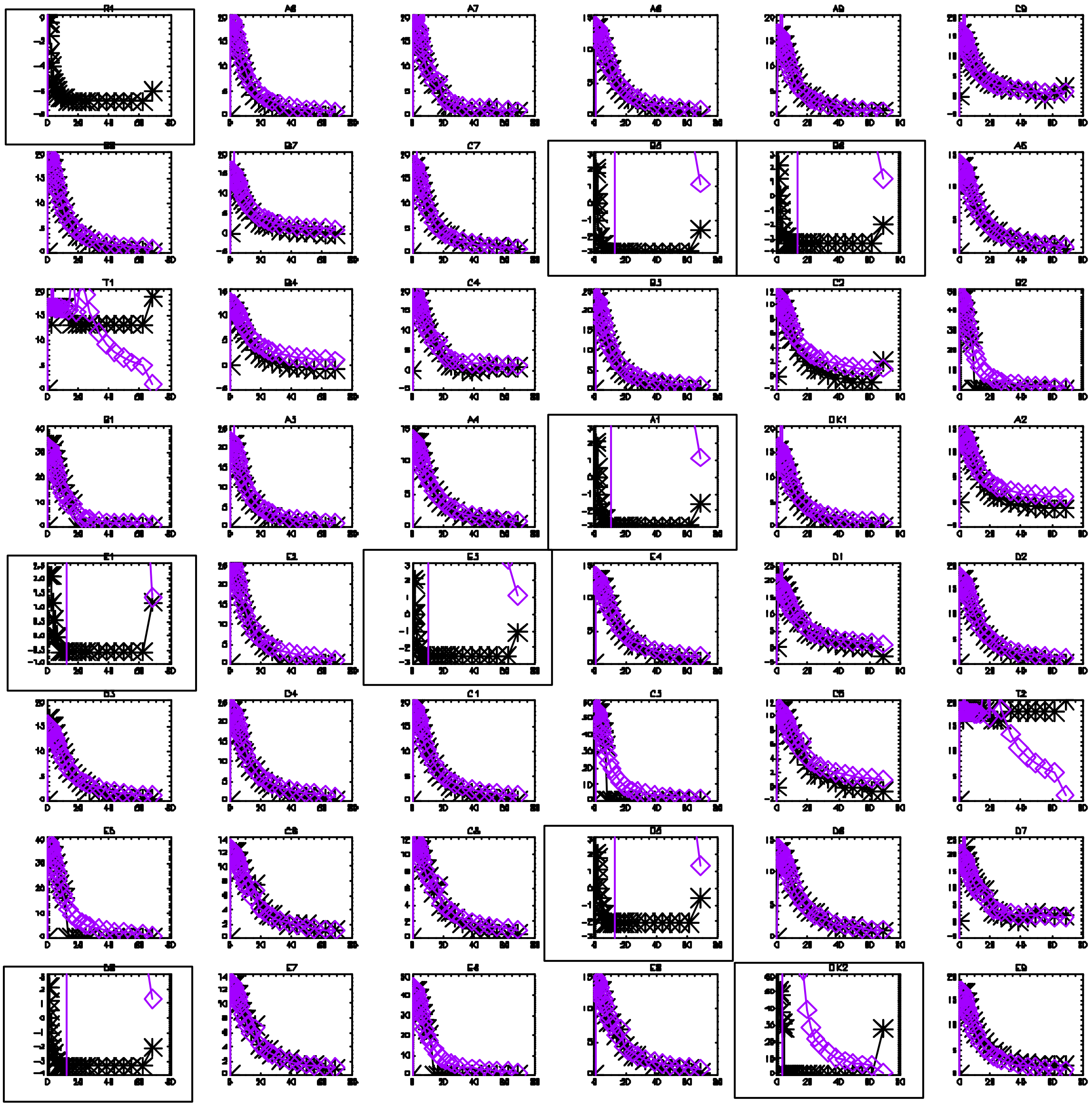

Figure 5: Derived R_{bol} as a function of bias voltage derived from phase change (black stars) and from the derived bias current and voltage across the bolometer (purple squares). This is for 70 Hz bias.

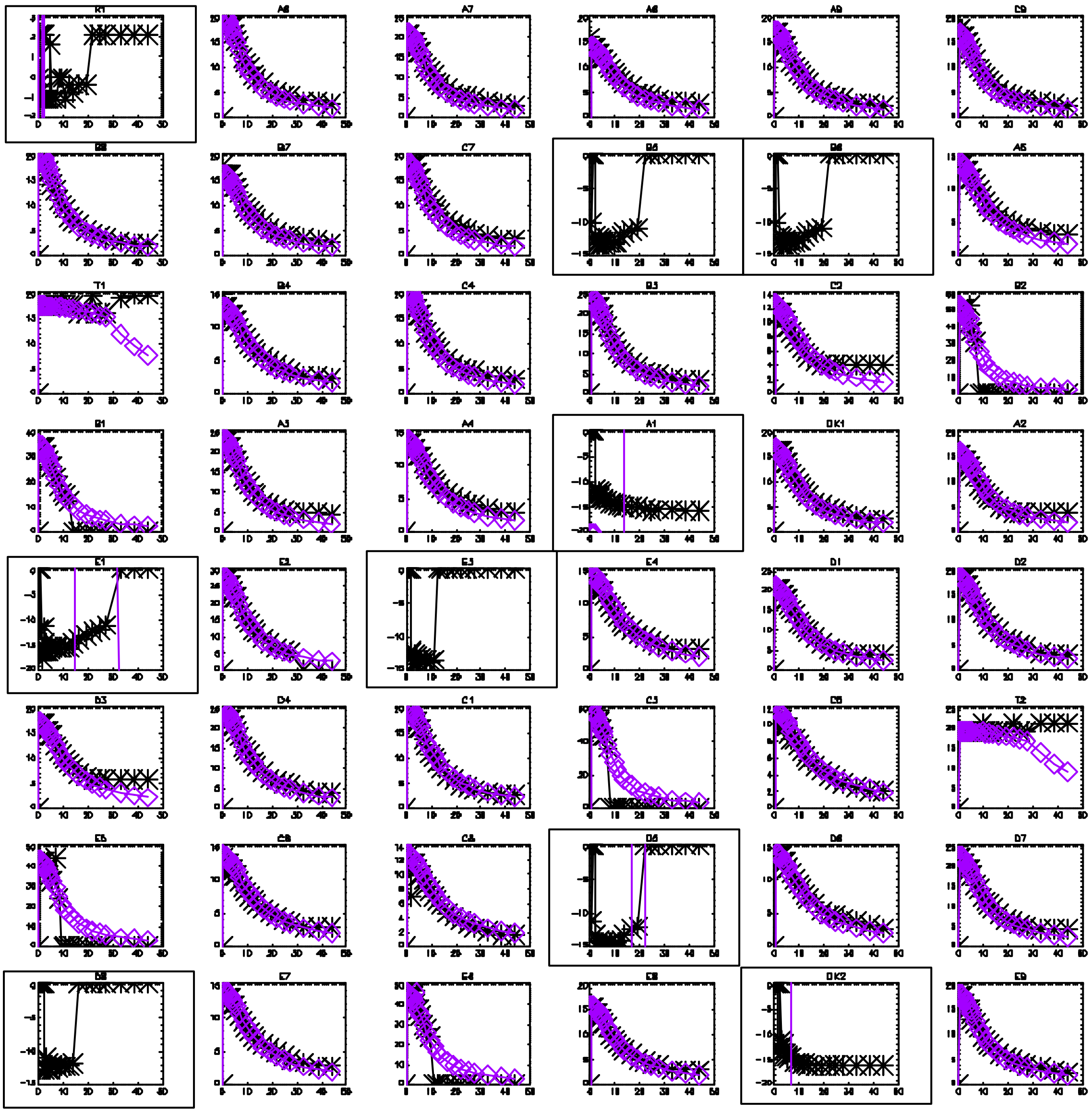

Figure 6: Derived R_{bol} as a function of bias voltage derived from phase change (black stars) and from the derived bias current and voltage across the bolometer (purple squares). This is for 130 Hz bias.

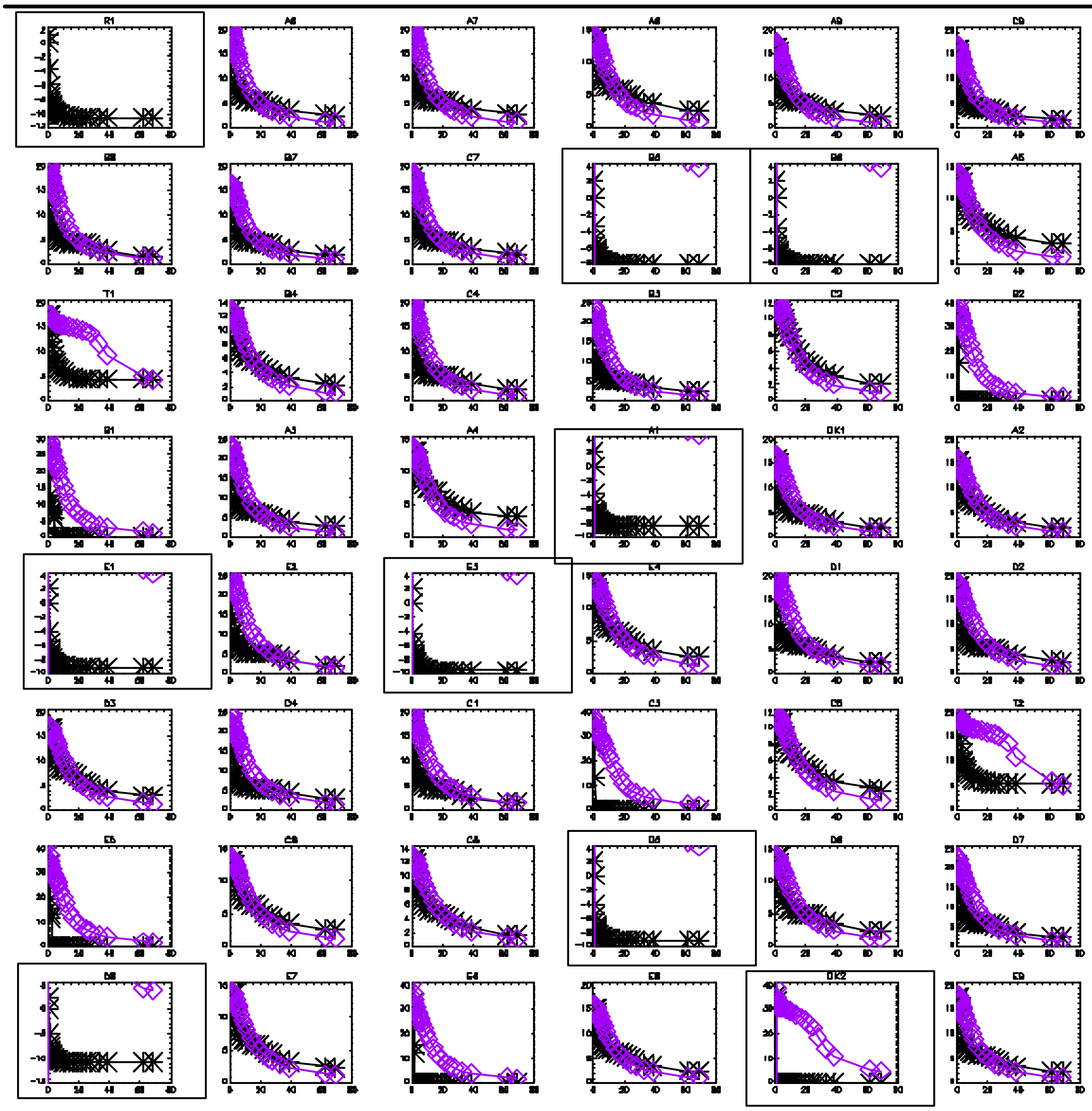

Figure 7: Derived R_{bol} as a function of bias voltage derived from phase change (black stars) and from the derived bias current and voltage across the bolometer (purple squares). This is for 190 Hz bias.

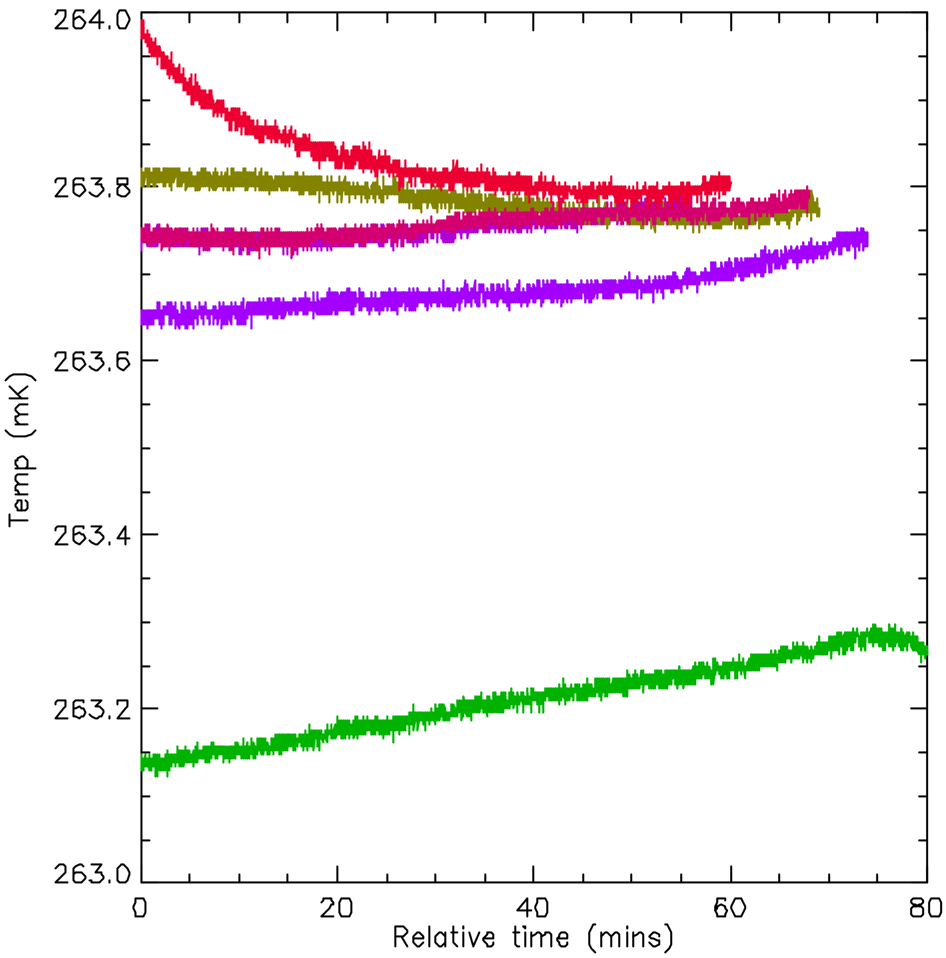

Figure 8: Evaporator temperature during the six loadcurves. Green(ish) is 70 Hz; Red(ish) 130 Hz and Purple (ish) 190 Hz. The brighter colour in each case is the in phase curve. The bottom green curve is for the 70 Hz in phase case.

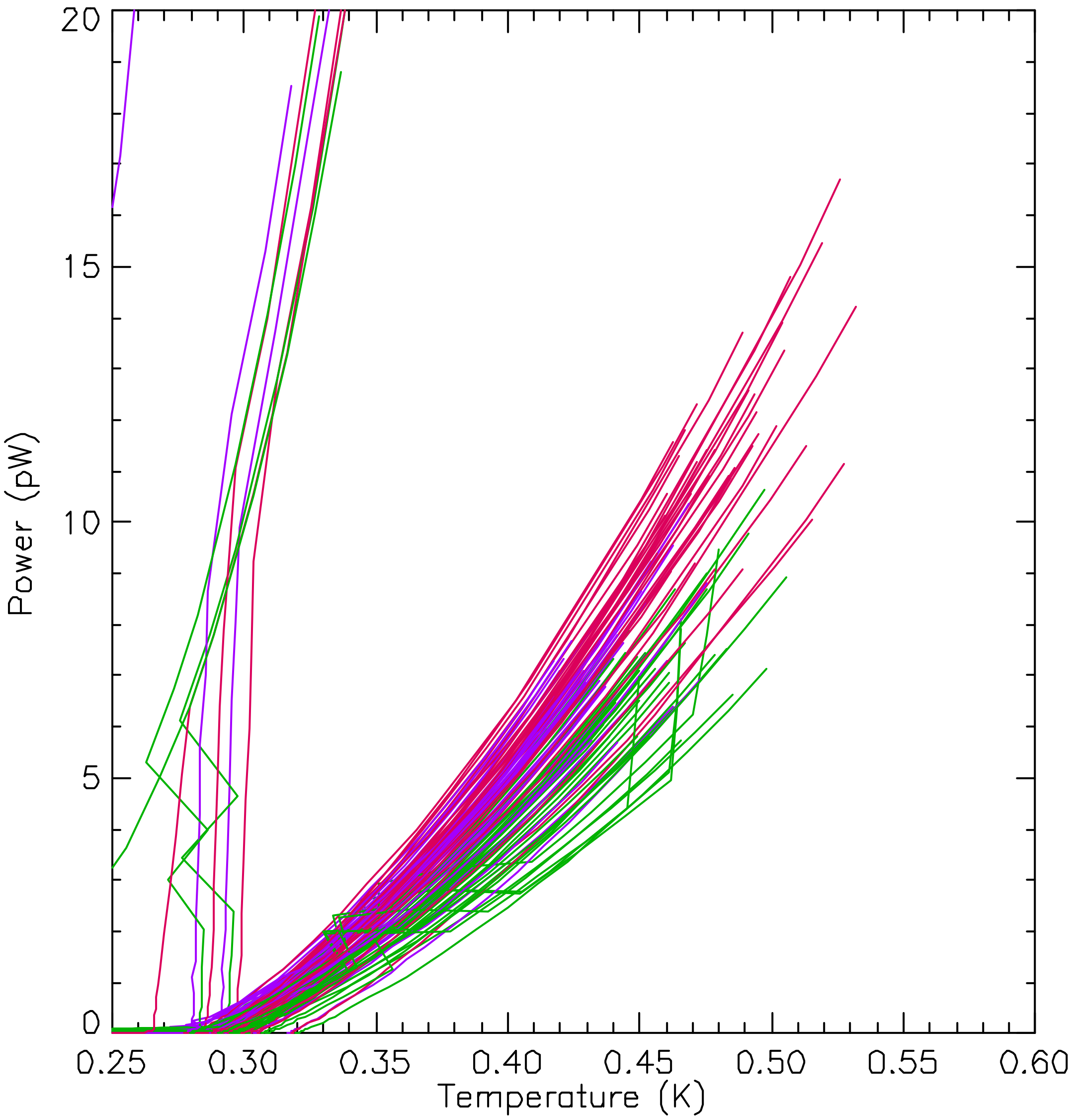

Figure 9: Corrected load curves for 70 (green); 130 (purple) and 190 (red) Hz plotted as Power versus temperature. Dead channels have been excluded – the vertical lines are for the resistor and thermistor channels. The strange lines in the 70 Hz data are where the offsets were mis-associated in the data.

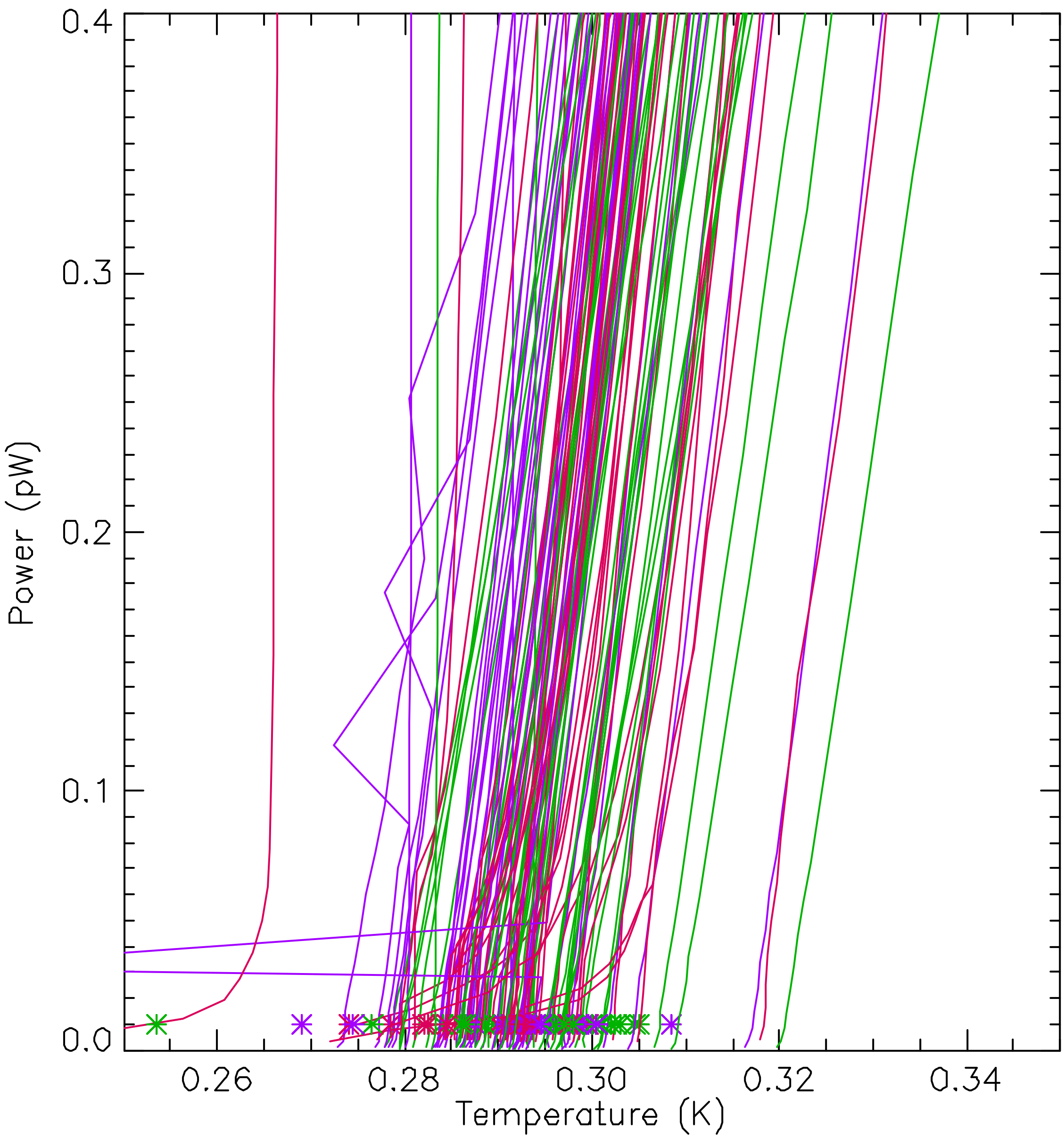

Figure 10: As figure 9 but close up of low power part of curve. Also plotted are temperatures found from the low bias part of the load curve a la Jamie. There is reasonable but not detailed agreement between the values. Also note that some of the 190 Hz curves have not been fully corrected by this method – the reason for this is not clear but probably associated with those channels where the out of phase data went negative.