Optimum Fowler Sampling (6/17/99)

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The use of Fowler sampling is a trade-off between decreased effective read noise and loss of signal due to the extra overhead required for the multiple reads. This memo recomputes the best Fowler Number to use for a given integration time based on an updated IRAC noise model. It is an update to IRAC/TM97-3002.

The noise was modeled using

$$N_T = ((22.2/\sqrt{FN})^2 + (1.56Logt_I)^2 + 4 + B \cdot t_I)^{(1/2)} \tag{1}$$

for t>1 second, where N_T is the total noise, FN is the Fowler Number, B is the background rate, and t_I is the effective integration time. For t<1 second the second (log) noise term was set to zero. This equation was used for the InSb array — for the SiAs array the first three terms above were multiplied by 0.6. t_I is related to the total commanded time available for the observation via

$$t_I = t - FN \cdot t_R \tag{2}$$

where t_R is the time for a single read of the array (there is only one factor of FN because the beginning and end of integration sets of reads occur at an averaged time 0.5 FN t_R from the start and stop of the shutter-open integration). For a given integration time t we wish to find the FN that maximizes t_I/N_T, thereby yielding the maximum S/N. A read time t_R of 0.2 seconds was assumed. The background rate B at 3.6, 4.5, 5.8, and 8μm was assumed to be 1.9, 7.6, 25, and 167 e^{-1}/sec at the ecliptic pole, and four times higher in the plane. The problem was solved numerically in the IGOR data anlysis package by computing the ratio t_I/N_T for all 7 Fowler Numbers and all integration times between 0.1 and 200 seconds. The same code can be reused later simply by plugging in a different noise model.

Results are tabulated in Tables 1 & 2. The tables give the exposure time t (in seconds) above which a given Fowler Number should be used. Overall characteristics are apparent. In background-limited cases, high Fowler sampling cannot noticeably improve S/N, since read noise contributes little. Similarly, with low background rates it is worth sacrificing some exposure time by using a large number of samples in order to decrease the read noise. The difference between these results and those of TM97-3002 is primarily due to the relatively lower read noise. For FN=1 and zero exposure time the read noise is approximately half that used previously. It appears that FN=8 is the best compromise value. For exposures greater than a few seconds it outperforms lower Fowler numbers. While higher Fowler numbers may be better under low noise conditions, in general the gain seems to be relatively modest. In the most extreme case illustrated, with a 200 sec exposure at 3.6μm using the polar background rate, FN=32 is only ≈5% better than FN=8. It is also worth noting that for long exposure times with high background it is pretty much irrelevant which FN is chosen (i.e. little penalty is incurred), while in the low background case it is important to select a high FN as long as it is above 8 . For short exposures, a low FN should always be used (lest the actual integration time tend towards zero!).

Table 1. Optimum FN near Ecliptic Pole

FN	3.6μm	4.5μm	5.8μm	8.0μm
2	0.9	0.9	1.0	1.3
4	1.8	1.9	2.2	...
8	3.7	4.0	27.5	...
16	8.2	11.1	...	...
32	25.1	...	...	...
64	...	...	...	...

Data are the time in seconds above which a given FN should be used. For example, at 3.6μm, FN=8 should be used for observations between 3.7 and 8.2 seconds long.

Table 2. Optimum FN near Ecliptic Plane

FN	3.6μm	4.5μm	5.8μm	8.0μm
2	0.9	1.0	1.1	...
4	1.9	2.0	13.2	...
8	4.0	5.3	...	...
16	11.1	...	...	...
32	...	...	...	...
64	...	...	...	...

Ecliptic plane uses $B=4\times B_{polar}$