5.1.5.2 WAC FM DARK CURRENT CALIBRATION RESULTS

As reported in Reference 5.1.5.2-1

Reference 5.1.5.2-1 - IOM 388-PAG-CCA97-3 " WAC FM CALIBRATION RESULTS: DARK CURRENT ", C. Avis, dated March 06, 1997

5.1.5.2.1 INTRODUCTION

The Wide-angle Flight Model thermal/vacuum testing included the acquisition of a set of images for characterization of the system dark-current. The term ‘dark-current’ describes the number of DN produced during an exposure which was not the result of incident light or bias level. This includes the contribution of lightflood-generated electrons and ambient thermal electrons.

Over 1300 images were taken in Gain State 3 in full-resolution mode. In order to measure the dark-current as a function of exposure time, the camera was commanded to take image data at each possible exposure time (with the exception of 380, 460, 680, and 1000 seconds). However, the shutter was inhibited. The detector remained cold (about -88° C), but the chamber temperatures varied widely because the data were taken mainly during temperature transitions. Data were taken with Lightflood ‘ON’ and ‘OFF’ and with Antiblooming ‘ON’ and ‘OFF’. In addition, all data were taken at a telemetry rate of 6 (365 kbits/sec).

In addition, frames were taken during System Thermal/Vacuum test which allowed the characterization of the dark-current during simultaneous camera operation. These were all taken with Lightflood=‘ON’ and Gain State 2 at a telemetry rate of 1 (60.9 kbits/sec).

5.1.5.2.2 METHOD

For this camera system, the pixel value resulting from an exposure with the shutter inhibited may be described by the following equation.

$$DN = \overline{BL} + I + DN(T)$$

where DN is the measured pixel value
$\overline{BL}$ is the mean video offset or bias level (in DN) for the image
I is the deviation from the mean bias level for an individual pixel (in DN)
T is the integration time (would be exposure time if shutter was enabled)
$DN(T)$ is the dark-current level (in DN)

In order to analyze DN(T), images may be taken at a given T:

$$DN_B = \overline{BL_B} + I + DN(T)$$

and at T=0:

$$DN_A = \overline{BL_A} + I$$

and differenced:

$$DN_B - DN_A = \overline{BL_B} - \overline{BL_A} + DN(T)$$

This gives

$$DN(T) = (DN_B - DN_A) - (\overline{BL_B} - \overline{BL_A})$$

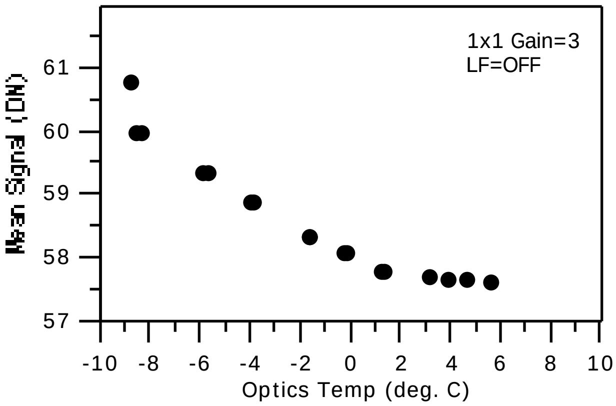
This shows that to measure the DN(T), compensation for the bias inherent in the images must be taken into account.

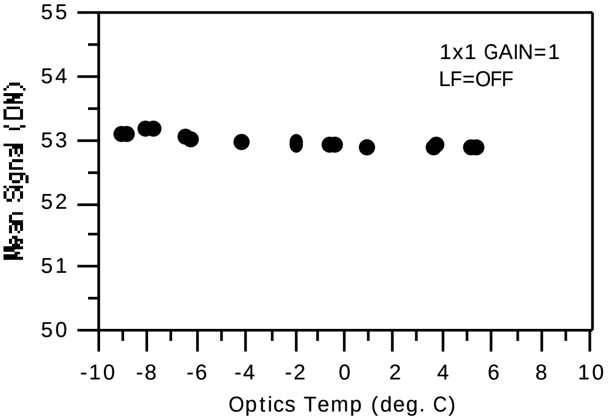
The available T=0 frames were averaged using an algorithm which checks for pathological DN values and rejects them. These frames were created for each set of images (same Antiblooming and Lightflood state) and then subtracted from each frame of the set. Mean values of the difference frames were tabulated versus T.

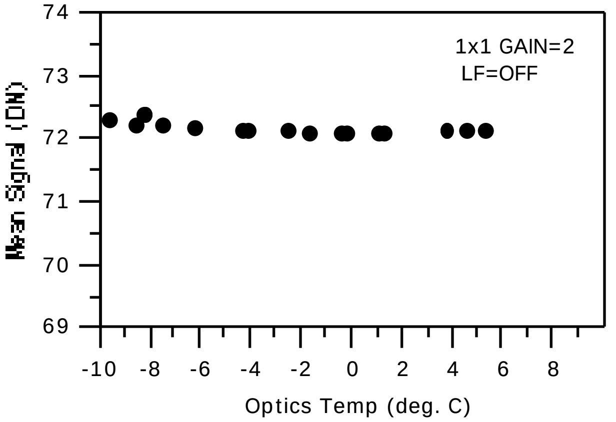
The mean bias level of each frame was calculated from the values of the overclocked pixels for each line recorded in the binary prefix of each VICAR image. The difference of these bias levels was used to adjust the values of the tabulated image differences.

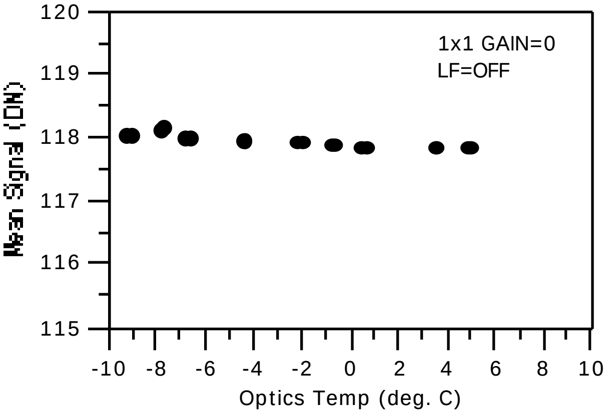
5.1.5.2.3 TEMPERATURE SENSITIVITY

The dark-current tests were taken during times of temperature transition. Plots of Mean DN(T) (without any corrections) vs. Optics Temperature in each Gain State are shown below. All data plotted came from frames with exposure times of 0 or 100 milliseconds. Gain 3 shows a large temperature sensitivity while the others show almost none.

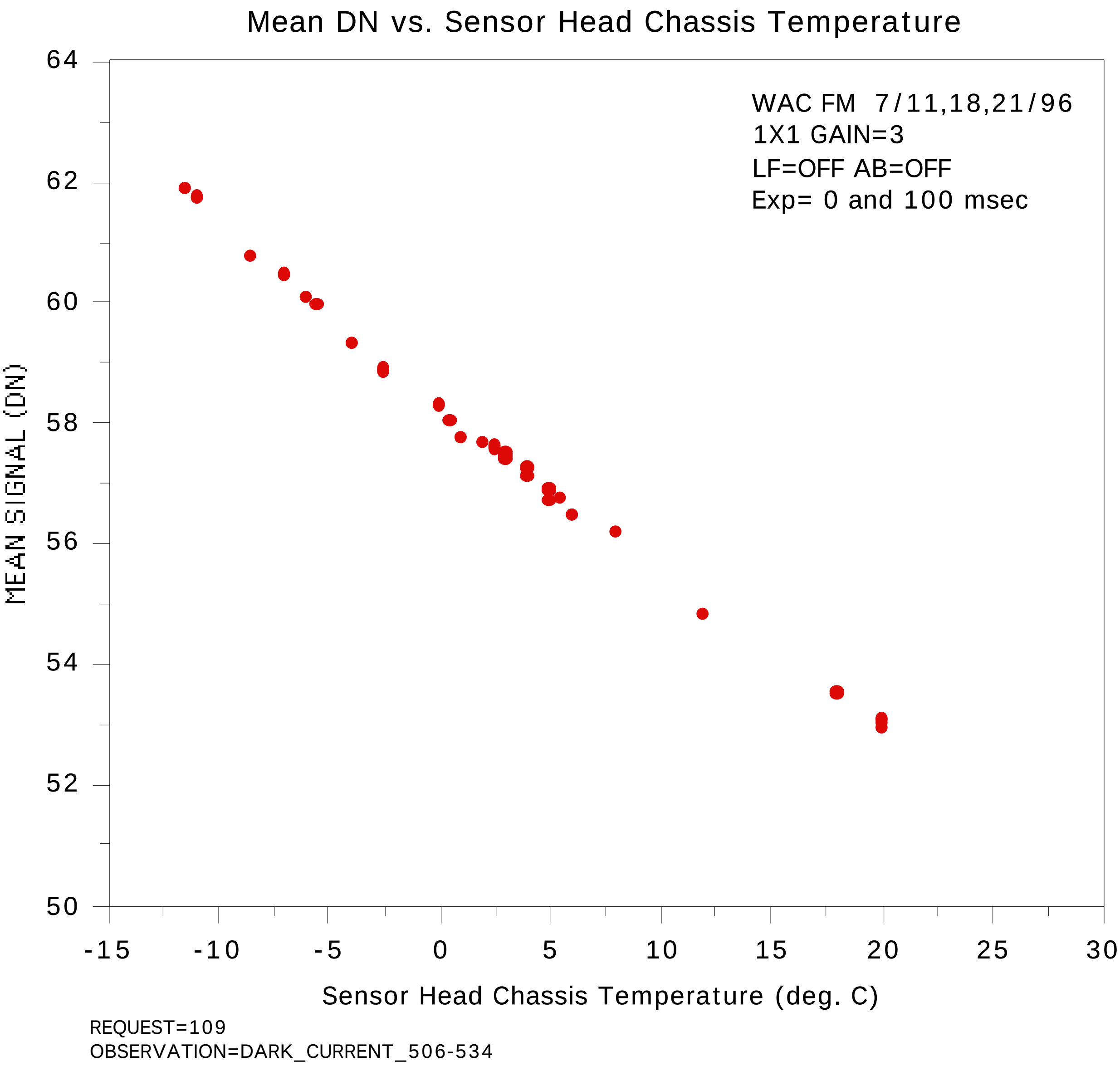






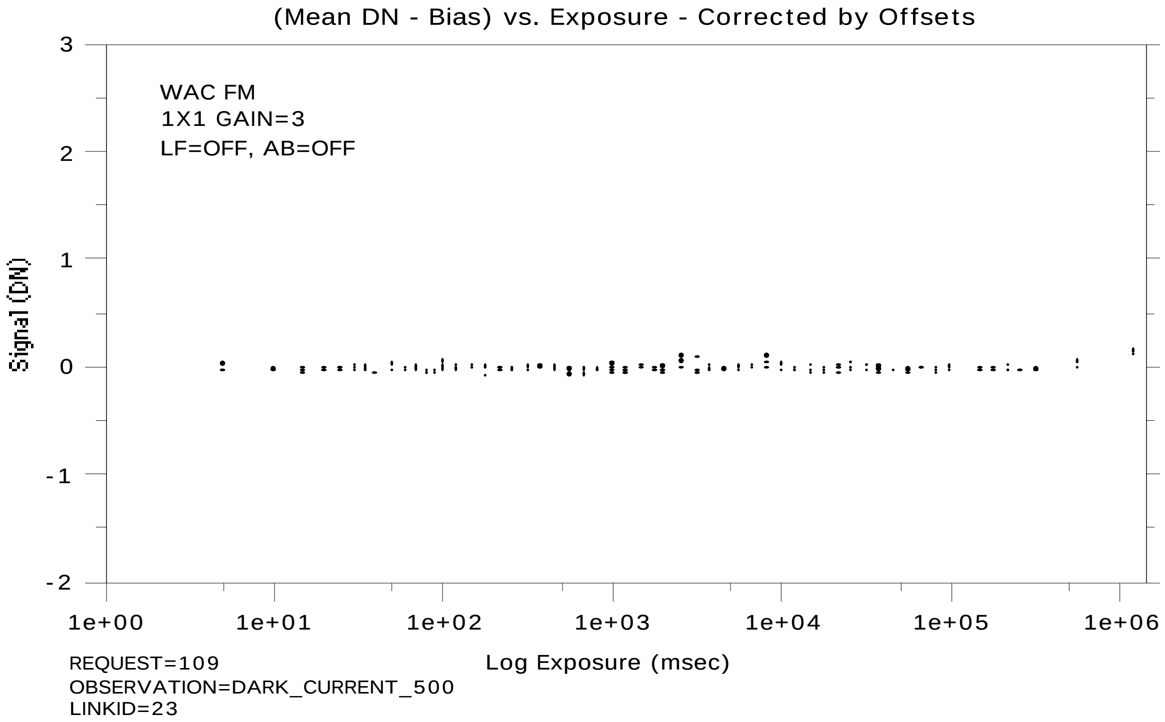


To better characterize this result, the Gain 3 Mean DN(T) (without any corrections) are plotted versus Sensor Head Chassis temperature and extended to higher temperatures. Apparently, this Chassis temperature directly affects the bias level, while the Optics temperature is a less reliable indicator.

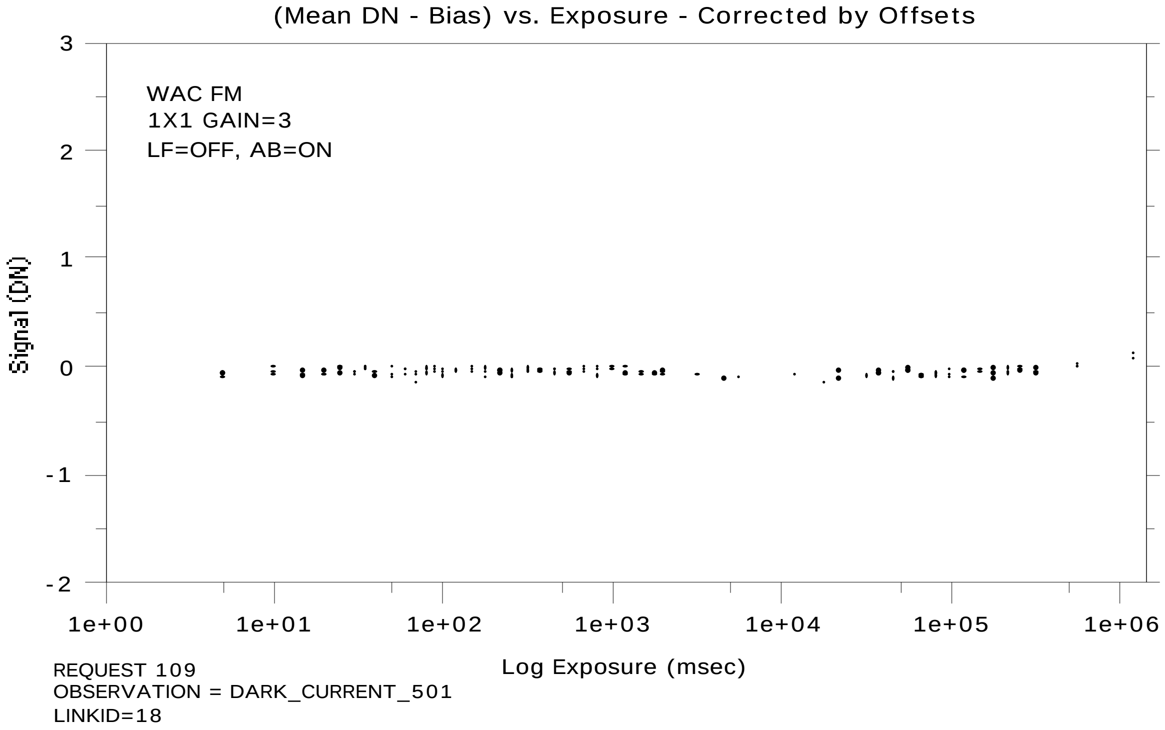


5.1.5.2.4 EXPOSURE TIME SENSITIVITY

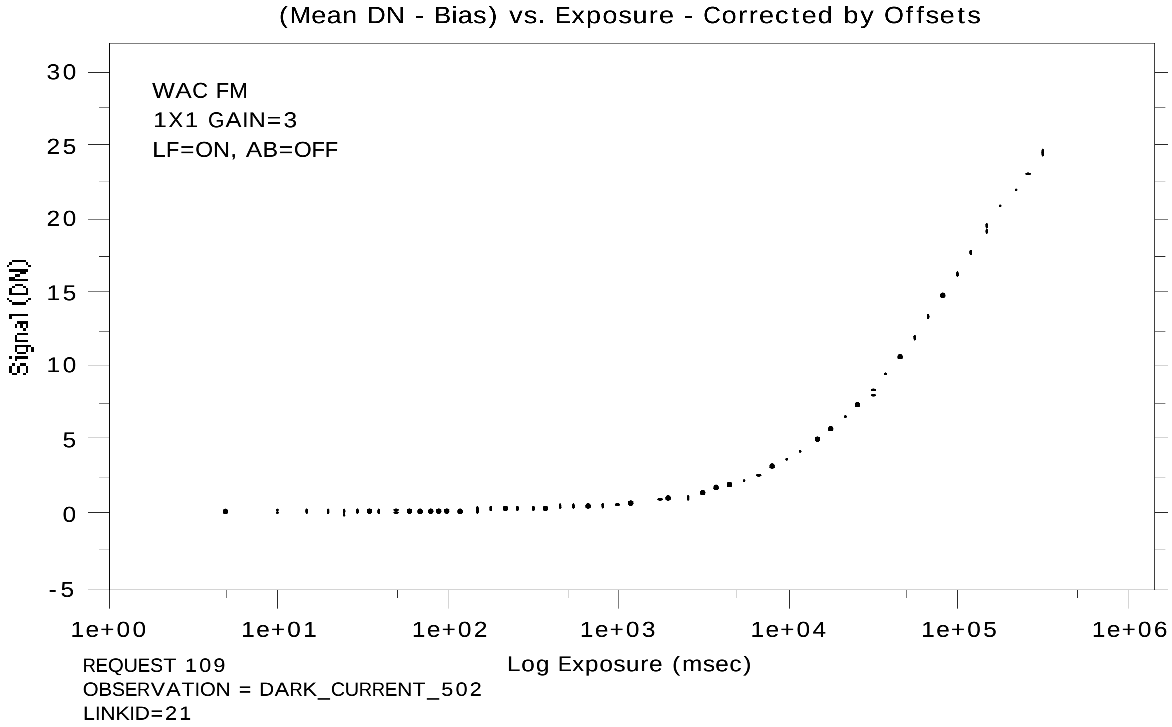
The following plots characterize the DN(T) component of the dark-current signal in Gain State 3 in all Lightflood and Antiblooming modes. All the dark-current results below were generated by taking into account the bias levels, as in the equations above.

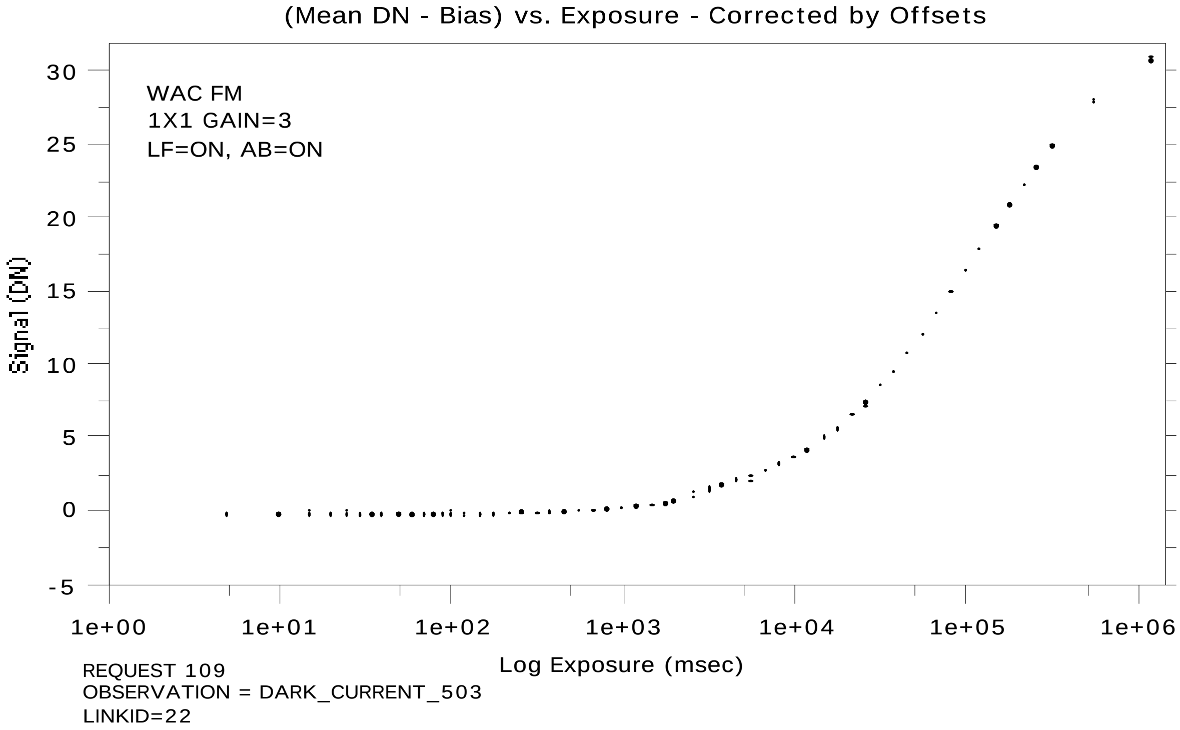


REQUEST=109
OBSERVATION=DARK_CURRENT_500
LINKID=23



REQUEST 109
OBSERVATION = DARK_CURRENT_501
LINKID=18


(Mean DN - Bias) vs. Exposure - Corrected by Offsets
WAC FM
1X1 GAIN=3
LF=ON, AB=OFF
Signal (DN)
30
25
20
15
10
5
0
-5
1e+00
1e+01
1e+02
1e+03
1e+04
1e+05
1e+06
Log Exposure (msec)
REQUEST 109
OBSERVATION = DARK_CURRENT_502
LINKID=21


(Mean DN - Bias) vs. Exposure - Corrected by Offsets
WAC FM
1X1 GAIN=3
LF=ON, AB=ON
Signal (DN)
30
25
20
15
10
5
0
-5
1e+00
1e+01
1e+02
1e+03
1e+04
1e+05
1e+06
Log Exposure (msec)
REQUEST 109
OBSERVATION = DARK_CURRENT_503
LINKID=22

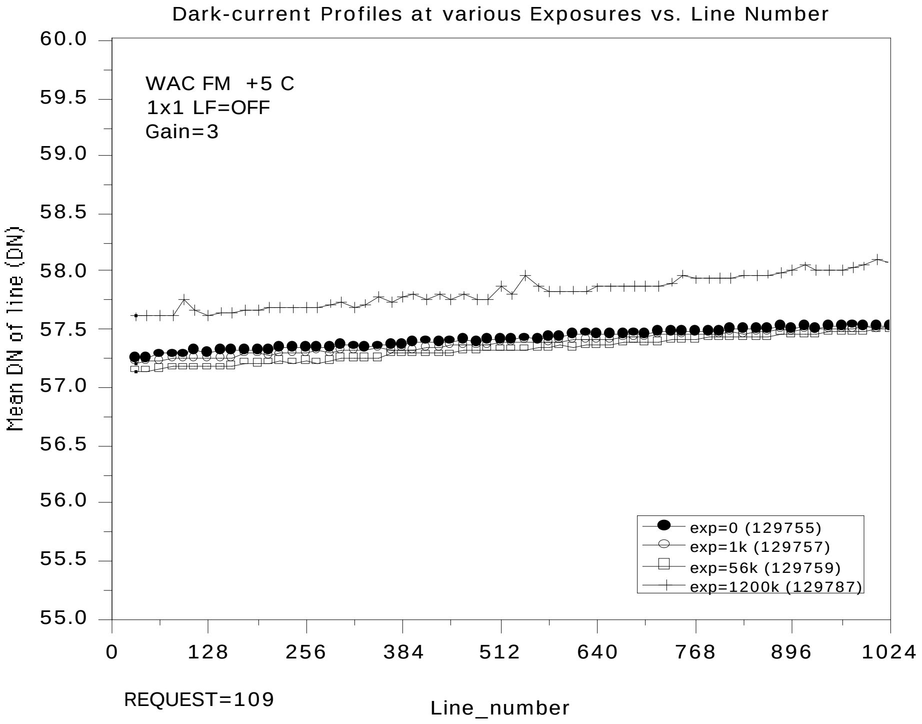
The following tabular results show the mean DN(T) component for Gain=3 derived from all Lightflood='ON' cases after compensation for the temperature-dependent bias levels. Note the residual level of about -0.1 DN.

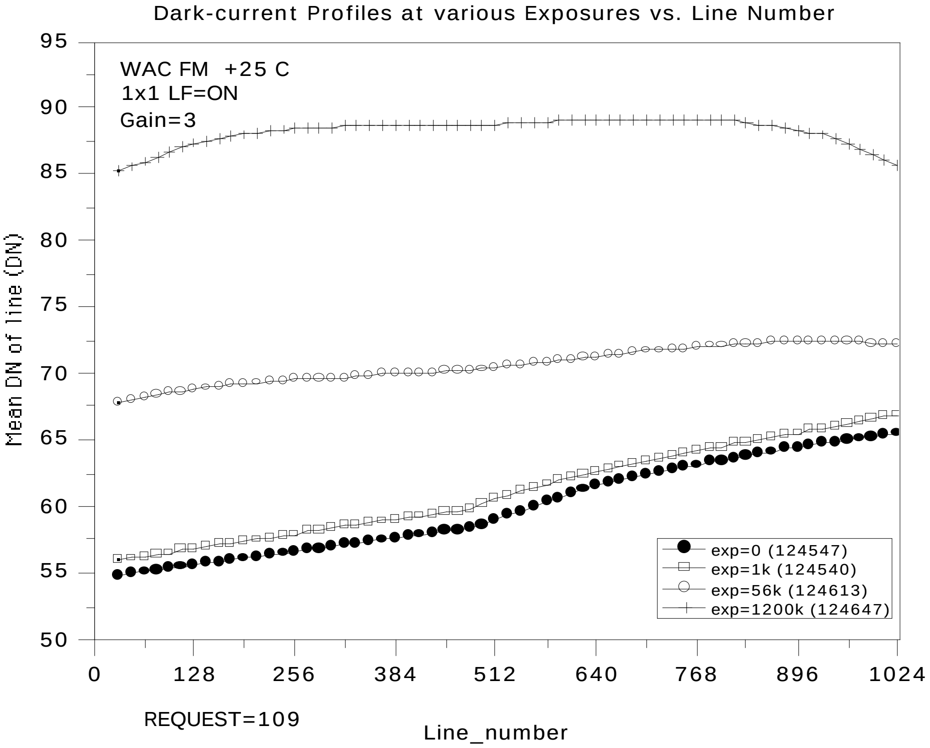
Exposure (msec)	DN(T)
0	-0.11
5	-0.15
10	-0.15
15	-0.03
20	-0.08
25	-0.05
30	-0.10
35	-0.08
40	-0.09
50	-0.07
60	-0.10
70	-0.09
80	-0.09
90	-0.06
100	-0.02
120	-0.09
150	-0.01
180	0.04
220	0.03
260	0.04
320	0.06
380	0.07
460	0.17
560	0.22
680	0.17
820	0.24
1000	0.30
1200	0.49
1500	0.61
1800	0.65
2000	0.81

Exposure (msec)	DN(T)
2600	1.04
3200	1.39
3800	1.65
4600	1.92
5600	2.18
6800	2.65
8200	3.09
10000	3.62
12000	4.16
15000	4.91
18000	5.59
22000	6.47
26000	7.26
32000	8.39
38000	9.38
46000	10.60
56000	11.91
68000	13.37
82000	14.80
100000	16.25
120000	17.73
150000	19.36
180000	20.80
220000	22.08
260000	23.21
320000	24.68
380000	N/A
460000	N/A
560000	27.88
680000	N/A
1000000	N/A
1200000	30.73

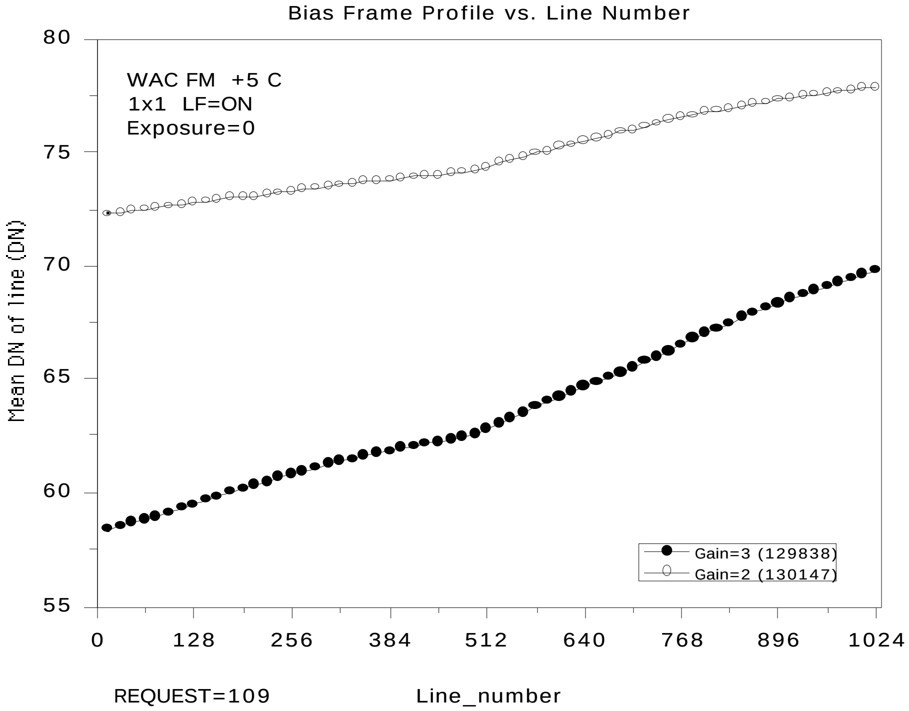
5.1.5.2.5 LINE NUMBER SENSITIVITY

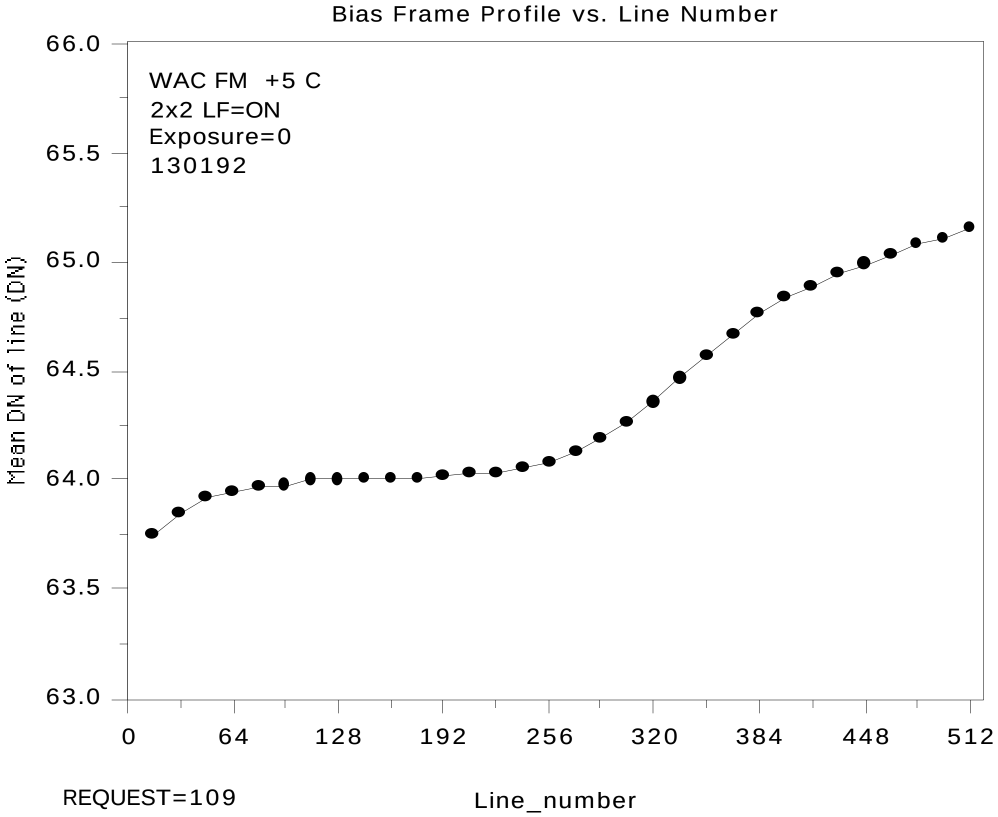
The following plots show the typical dark-current as a function of line number in various camera modes and exposure times.

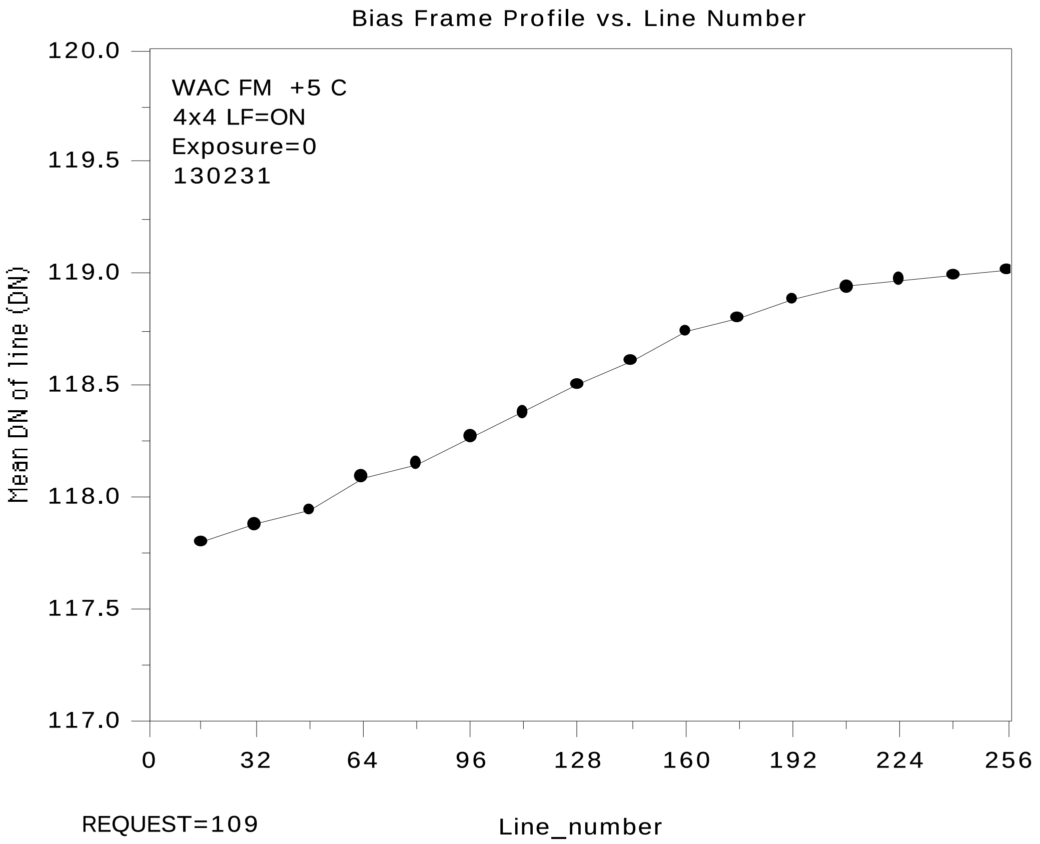




The following plots show the typical dark-current for exposure=0 frames as a function of line number in various camera modes.

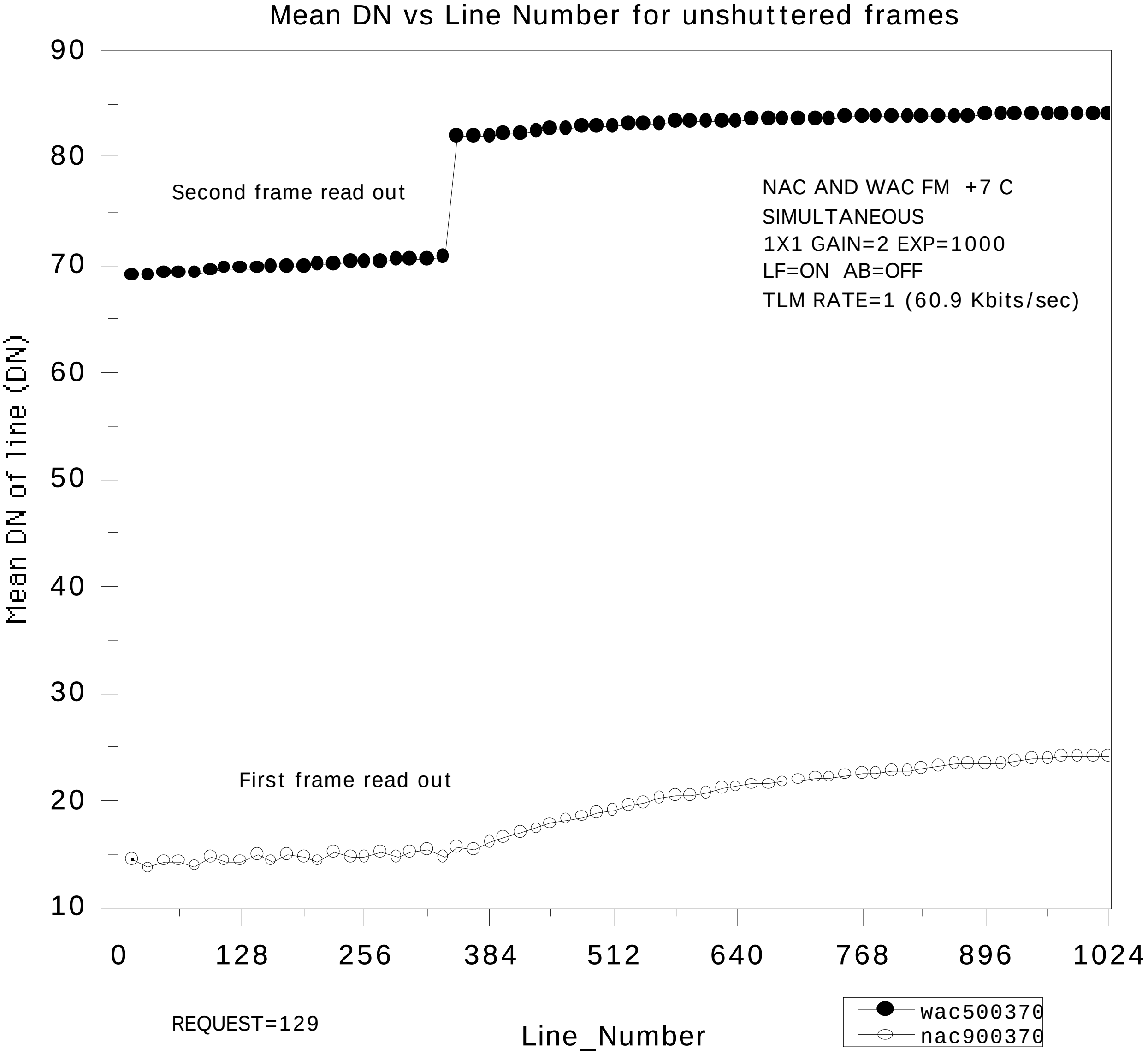





Bias Frame Profile vs. Line Number
WAC FM +5 C
4x4 LF=ON
Exposure=0
130231
Mean DN of line (DN)
120.0
119.5
119.0
118.5
118.0
117.5
117.0
0
32
64
96
128
160
192
224
256
REQUEST=109
Line_number

5.1.5.2.6 EFFECTS OF SIMULTANEOUS EXPOSURE

Commanding the cameras to take simultaneous exposures also affects the dark-current, but only for one of the two frames. The frame which is read out first is treated like a non-simultaneous frame by the camera and is therefore not affected by this mode. The second frame read out has a pause in its process of transferring data into memory while the first frame reads out. This pause causes a longer dark-current buildup time for part of the frame. The following plot shows the effect of simultaneous operation on the two frames' DN profile. Compare the line number where the change in slope occurs to that of the earlier plots which used telemetry rate of 6.



5.1.5.2.7 CONCLUSIONS

1. The bias level of Gain 3 is highly sensitive to the temperature of the Sensor Head. This temperature is reported as the Sensor Head Chassis temperature via spacecraft telemetry (not in ISS telemetry data).
2. Such sensitivity is not a problem if the reported bias levels are used to compensate. However, it appears that this compensation may be subtracting about 0.1 DN too much.
3. Antiblooming has no significant effect on the dark-current.
4. For Lightflood='OFF', the Mean DN doesn't rise out of the noise except for the 1000 and 1200 second exposures, and then it is only fractions of a DN. For Gain 3, the profile vs. line number shows no slope change and no difference in behavior is seen between the top and bottom of the frame.
5. For Lightflood='ON' Gain 3, the Mean DN doesn't rise past 0.5 DN until an exposure time of 1.2 seconds. There is a slope change in the profile vs. line number around line 490. This is due to the change in transfer rate from detector to memory at the point where the memory fills up. This change gets gradually dominated by Lightflood effects at exposures longer than 1 second. At extreme exposure times, the Lightflood profile is all that is seen. This change from one profile to another causes the top and bottom of the frame to behave differently as a function of exposure time.
6. For Gain 2 (LF=ON, exposure=0), the slope change is also seen in the profile vs. line number.
7. For Gain 1 (LF=ON, exposure=0, 2x2 summation), the profile slope is variable from top to bottom.
8. For Gain 0 (LF=ON, exposure=0, 4x4 summation), the profile slope is constant until about line 160 where it begins to decrease.
9. Simultaneous imaging causes a dramatic change in the DN profile vs. line number for modes which can't fit all the pixel data immediately into memory (1x1 12-bit uncompressed and possibly 1x1 8-bit and 1x1 Lossless compressed).
10. The telemetry rate also affects the shape of the profile for modes which can't fit all the pixel data immediately into memory. The effect was noticeable between rates 1 and 6, but no other data was taken.

5.1.5.2.8 MATCHING DARK-CURRENT FRAMES TO EXPOSED FRAMES

The following are some of the considerations to keep in mind when matching dark-current frames to image frames.

1. Telemetry Rate, Simultaneous Imaging and Data Compression may matter only for frames which don't immediately fit into memory.
2. Uncompressed frames which don't fit into memory must be matched by dark-current frames with the same Telemetry Rate and Simultaneous Imaging Mode.
3. Compressed frames which don't fit into memory when compressed will have an unpredictable dark-current behavior because the rate of memory 'fillup' is scene-dependent.
4. All Lightflood='ON' frames must be matched by dark-current frames with the same exposure time.
5. The Temperature of the Sensor Head greatly affects Gain State 3, but all effects seem to be tracked by the bias level. This is reported for each frame.

Once a dark-current frame has been matched to an exposed frame, the following considerations apply.

1. Before subtracting a dark-current frame, both the dark-current frame and the exposed frame must have their own bias level subtracted out. This will correct for differences in temperature.

$$S = DN - \overline{BL} - \left(dn - \overline{bl}\right)$$

where S is the signal
DN is the measured DN of the image
$\overline{BL}$ is the mean bias level of the image
dn is the measured DN of the dark-current frame
$\overline{bl}$ is the mean bias level of the dark-current frame

The bias level is recorded in the VICAR label in the OFFSET keyword. This mean value is derived from the over-clocked pixel values recorded in the binary prefix of each line. These values reside in word 12 of the prefix. For 8-bit data, two over-clocked pixel values reside in the two bytes of word 12.

2. It may be necessary to compensate for the -0.1 DN residual determined empirically above.
3. All these calculations will be best if done in floating point and when it isn't necessary to truncate back to integer.

5.1.5.2.9 SUMMARY

Inflight collection of unshuttered frames will be absolutely necessary for proper radiometric analysis. The camera modes used for the actual image data need to be used for the unshuttered frames as well. The following list outlines our current knowledge of parameters which seem to affect the dark-current (whether the bias or the exposure-dependent components) for at least some images.

Parameter	Affects Dark Current in this images
Camera	All
Gain	All
Summation Mode	All
Temperature of CCD	All
Telemetry Rate	All that don't fit into memory
Lossless Data Compression	All that don't fit into memory
Lossy Data Compression	All
Exposure Time	All that use Lightflood
Lightflood	All
Temperature of Sensor Head	Gain state 3
Simultaneous Imaging	All that don't fit into memory

The image types which do not fit into memory are:

1. 1x1 12-bit uncompressed
2. 1x1 12-bit Lossless compression
3. 1x1 8-bit uncompressed