MIT
Center for Space Research Chandra X-Ray Center

MEMORANDUM
April 26, 2004

To: Martin Elvis, SDS Group Leader
From: Glenn E. Allen, SDS
Subject: Applying a Time-Dependent Gain Adjustment
Revision: 1.5
URL: http://space.mit.edu/CXC/docs/docs.html#tgain_spec
File: /nfs/cxc/h2/gea/sds/docs/memos/memo_apply_tgain_1.5.tex

1 acis_process_events

1.1 Description

The continuous exposure of the ACIS CCDs to particle radiation causes a steady increase in the charge-transfer inefficiency (CTI) of the detectors. As a result, the typical pulse height recorded for an X-ray of a given energy is declining with time. This kind of change in the "gain" of the detectors and a change in the electronic gain of the ACIS-I1 CCD is calibrated (for CTI-adjusted data) and recorded in a set of "t_gain" ARD files. This document describes how the information in these files is used by acis_process_events to apply a time-dependent gain adjustment to ACIS event data. The time-dependent gain adjustment is applied after the CTI adjustment because the gain adjustment is calibrated using CTI-adjusted data.

1.2 Input

1. A Level 0, 1, 1.5, or 2 event data file (acis*evt0.fits, acis*evt1.fits, acis*evt1a.fits, or acis*evt2.fits)
2. A "t_gain" ARD file (e.g. acisD2001-05-01t_gainN0001.fits)

1.3 Output

1. An event data file

1.4 Parameters

1. tgainfile,s,h,"CALDB",,,"Name of input gain adjustment file (⟨filename⟩ — CALDB — none — NONE)"
2. apply_tgain,b,h,yes,,,"Apply time-dependent gain adjustment?"

1.5 Processing

1. Verify that the specified input files exist. If the parameter clobber = "no," then verify that the output file does not exist. If apply_tgain = "yes" and tgainfile = "none" or "NONE" (or does not exist), then write a warning message that the time-dependent gain adjustment is not being applied because a valid calibration file is not specified.

2. For each event i in the input event data file, find the row r in the t_gain ARD file that satisfies all three of the conditions

$$\text{CCD_ID}_r = \text{ccd_id}_i \tag{1}$$

$$\text{CHIPX_LO}_r \leq \text{chipx}_i \leq \text{CHIPX_HI}_r, \text{ and} \tag{2}$$

$$\text{CHIPY_LO}_r \leq \text{chipy}_i \leq \text{CHIPY_HI}_r, \tag{3}$$

   where ccd_id, chipx and chipy are the names of columns in the event data file and CCD_ID, CHIPX_LO, CHIPX_HI, CHIPY_LO and CHIPY_HI are the names of columns in the ARD file. ccd_id_i, chipx_i and chipy_i are the values of ccd_id, chipx and chipy for event i. CCD_ID_r, CHIPX_LO_r, CHIPX_HI_r, CHIPY_LO_r and CHIPY_HI_r are the values of CCD_ID, CHIPX_LO, CHIPX_HI, CHIPY_LO and CHIPY_HI for row r of the t_gain ARD file.

3. The values in the columns PHA, DELTPHA1 and DELTPHA2 for row r of the ARD file are used to compute the adjustment to the value of pha for event i. These three columns are vector columns. The number of valid elements in each column for row r is specified by NPOINTS_r, where NPOINTS is the name of a column in the ARD file. If the number of elements in the vectors PHA_r, DELTPHA1_r and DELTPHA2_r is greater than NPOINTS_r, then the ends of the vectors are padded with zeroes.

   The appropriate element n of the vector PHA_r is determined by using the condition

$$\text{PHA}_r[n] \leq \text{pha}_i < \text{PHA}_r[n+1]. \tag{4}$$

   Here, the first and last elements of the vector PHA_r are denoted $\text{PHA}_r[1]$ and $\text{PHA}_r[\text{NPOINTS}_r]$, respectively. If $\text{pha}_i < \text{PHA}_r[1]$, then $n = 1$. If $\text{pha}_i \geq \text{PHA}_r[\text{NPOINTS}_r]$, then $n = \text{NPOINTS}_r - 1$ (not NPOINTS_r).

   The value of pha_i is the pulse height of event i in the event data file. If the CTI adjustment is performed, then pha_i is the CTI-adjusted pulse height. (The CTI adjustment is performed before the time-dependent gain adjustment.) For GRADED mode observations, pha_i can be either pha_i or pha_ro_i (see Tables 1 and 2).

4. The adjustment to the value of pha_i at $t = \text{EPOCH1}$ is computed by performing a linear interpolation (or extrapolation) of the values in the vector DELTPHA1_r:

$$\begin{aligned}\Delta\text{pha1} &= \frac{\text{pha}_i - \text{PHA}_r[n]}{\text{PHA}_r[n+1] - \text{PHA}_r[n]}\left(\text{DELTPHA1}_r[n+1] - \text{DELTPHA1}_r[n]\right) + \\ &\quad \text{DELTPHA1}_r[n].\end{aligned} \tag{5}$$

   For GRADED mode observations, pha_i can be either pha_i or pha_ro_i (see Tables 1 and 2). EPOCH1 (and EPOCH2) are the names of keywords in the header of the t_gain file.

5. If EPOCH2 > EPOCH1 and $\text{DELTPHA2}_r[\text{NPOINTS}_r] \neq 0$, then the estimate of the adjustment to the value of pha_i at $t = \text{EPOCH2}$ is

$$\begin{aligned}\Delta\text{pha2} &= \frac{\text{pha}_i - \text{PHA}_r[n]}{\text{PHA}_r[n+1] - \text{PHA}_r[n]}\left(\text{DELTPHA2}_r[n+1] - \text{DELTPHA2}_r[n]\right) + \\ &\quad \text{DELTPHA2}_r[n].\end{aligned} \tag{6}$$

   For GRADED mode observations, pha_i can be either pha_i or pha_ro_i (see Tables 1 and 2).

   If EPOCH2 ≤ EPOCH1 or $\text{DELTPHA2}_r[\text{NPOINTS}_r] = 0$, then

$$\Delta\text{pha2} = \Delta\text{pha1 and} \tag{7}$$

$$\text{EPOCH2} = \text{EPOCH1} + 10^7 \text{ s}. \tag{8}$$

6. The pulse height adjustment at $t = \mathrm{time}_i$ is

$$\Delta\mathrm{pha} = \frac{\mathrm{time}_i - \mathrm{EPOCH1}}{\mathrm{EPOCH2} - \mathrm{EPOCH1}} (\Delta\mathrm{pha2} - \Delta\mathrm{pha1}) + \Delta\mathrm{pha1}, \tag{9}$$

   where time_i is the time associated with event i.

7. The adjusted value of the pulse height for event i is[1]

$$\mathrm{pha}'_i = \mathrm{pha}_i - \Delta\mathrm{pha} + a, \tag{10}$$

   where a is a uniform random deviate in the range $[-0.5, +0.5)$ adu. If $\mathrm{pha}'_i > 32760$, then $\mathrm{pha}'_i = 32760$.

8. Steps 2 to 7 are performed for every event in the input file.

9. The values of pha'_i (instead of pha_i) are written to the output file[1].

10. The name of the t_gain ARD file used is written to the keyword TGAINFIL and the value of the keyword TGAINCOR is set to "T" (True)[1].

[1]The content of the output file is contingent on several input conditions. See Tables 1 and 2 for the details.

Table 1. Input Conditions

Case	Parameter apply_tgain	Parameter doevtgrade	Keyword TGAINCOR	Keyword DATAMODE[a]	Column PHA_RO
1	yes	yes	F/missing	not GRADED	doesn't exist
2	yes	yes	F/missing	not GRADED	exists
3	yes	yes	F/missing	GRADED	doesn't exist
4	yes	yes	F/missing	GRADED	exists
5	yes	yes	T	not GRADED	doesn't exist
6	yes	yes	T	not GRADED	exists
7	yes	yes	T	GRADED	doesn't exist
8	yes	yes	T	GRADED	exists
9	yes	no	F/missing	not GRADED	doesn't exist
10	yes	no	F/missing	not GRADED	exists
11	yes	no	F/missing	GRADED	doesn't exist
12	yes	no	F/missing	GRADED	exists
13	yes	no	T	not GRADED	doesn't exist
14	yes	no	T	not GRADED	exists
15	yes	no	T	GRADED	doesn't exist
16	yes	no	T	GRADED	exists
17	no	yes	F/missing	not GRADED	doesn't exist
18	no	yes	F/missing	not GRADED	exists
19	no	yes	F/missing	GRADED	doesn't exist
20	no	yes	F/missing	GRADED	exists
21	no	yes	T	not GRADED	doesn't exist
22	no	yes	T	not GRADED	exists
23	no	yes	T	GRADED	doesn't exist
24	no	yes	T	GRADED	exists
25	no	no	F/missing	not GRADED	doesn't exist
26	no	no	F/missing	not GRADED	exists
27	no	no	F/missing	GRADED	doesn't exist
28	no	no	F/missing	GRADED	exists
29	no	no	T	not GRADED	doesn't exist
30	no	no	T	not GRADED	exists
31	no	no	T	GRADED	doesn't exist
32	no	no	T	GRADED	exists

[a] The DATAMODEs "GRADED," "GRADED_HISTO," "CC_GRADED," and "CC33_GRADED" are collectively refered to as GRADED.

Table 2. Output

Case	Column PHA	Column PHA_RO	Keyword TGAINCOR	Keyword TGAINFIL	Notes
1	Adjusted PHA[a]	Computed from PHAS[b]	T	⟨t_gain⟩	A typical pipeline case
2	Adjusted PHA[a]	Computed from PHAS[b]	T	⟨t_gain⟩	Compute PHA
3	Adjusted PHA[c]	Input PHA	T	⟨t_gain⟩	A typical pipeline case
4	Adjusted PHA[e]	Input PHA_RO	T	⟨t_gain⟩	Recompute PHA
5	Adjusted PHA[a]	Computed from PHAS[b]	T	⟨t_gain⟩	Recompute PHA
6	Adjusted PHA[a]	Computed from PHAS[b]	T	⟨t_gain⟩	Recompute PHA
7	Input PHA	Zero	T	Copy[d]	Error in input file
8	Adjusted PHA[e]	Input PHA_RO	T	⟨t_gain⟩	Recompute PHA
9	Input PHA	Zero	F	Copy[d]	Error: doevtgrade=no
10	Input PHA	Input PHA_RO	F	Copy[d]	Error: doevtgrade=no
11	Adjusted PHA[c]	Input PHA	T	⟨t_gain⟩	Compute tgain
12	Adjusted PHA[e]	Input PHA_RO	T	⟨t_gain⟩	Recompute tgain
13	Input PHA	Zero	T	Copy[d]	Error: doevtgrade=no
14	Input PHA	Input PHA_RO	T	Copy[d]	Error: doevtgrade=no
15	Input PHA	Zero	T	Copy[d]	Error in input file
16	Adjusted PHA[e]	Input PHA_RO	T	⟨t_gain⟩	Recompute tgain
17	Summed PHAS[f]	Computed from PHAS[b]	F	NONE	Recompute PHA
18	Summed PHAS[f]	Computed from PHAS[b]	F	NONE	Recompute PHA
19	Input PHA	Input PHA	F	NONE	Calculation disabled
20	Input PHA_RO	Input PHA_RO	F	NONE	Calculation disabled
21	Summed PHAS[f]	Computed from PHAS[b]	F	NONE	Recompute PHA
22	Summed PHAS[f]	Computed from PHAS[b]	F	NONE	Recompute PHA
23	Input PHA	Zero	T	Copy[d]	Error in input file
24	Input PHA_RO	Input PHA_RO	F	NONE	Recompute PHA
25	Input PHA	Zero	F	NONE	Calculation disabled
26	Input PHA	Input PHA_RO	F	Copy[d]	Error: doevtgrade=no
27	Input PHA	Input PHA	F	NONE	Calculation disabled
28	Input PHA_RO	Input PHA_RO	F	NONE	Recompute PHA
29	Input PHA	Zero	T	Copy[d]	Error: doevtgrade=no
30	Input PHA	Input PHA_RO	T	Copy[d]	Error: doevtgrade=no
31	Input PHA	Zero	T	Copy[d]	Error in input file
32	Input PHA_RO	Input PHA_RO	F	NONE	Recompute PHA

[a] The value of PHA is the CTI (if apply_cti=yes) and time-dependent–gain adjusted value of the summed PHAS.

[b] The value of PHA_RO does not include the CTI and time-dependent gain adjustments.

[c] The value of PHA is the time-dependent–gain adjusted value of the input PHA.

[d] The keyword TGAINFIL is copied only if it exists. If it does not exist, then it is not created.

[e] The value of PHA is the time-dependent–gain adjusted value of the input PHA_RO.

[f] The value of PHA includes the CTI adjustment (if apply_cti=yes), but not the time-dependent–gain adjustment.