Pulse-shape Correction

Prepared by: Fred Lahuis (SIDT/SRON)

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1 Introduction

This note explains why and how a pulse-shape correction is applied.

What we call the pulse-shape is the after-effect of the reset-pulse applied after each reset interval. It manifests itself as an exponential curve with typical decay times of $0.25 \sim 0.5$ seconds and a typical amplitude of $20 \sim 50$ μV. The pulse-shape is an additive component added to the integrated signal of the detector.

The impact this has on the observed slope depends highly on the gain setting of the instrument. The readouts are in bits and the residual of the reset-pulse which is added to the integrated slope is in μV independent of the gain setting. The amplitude of the pulse-shape in the raw slope (i.e. the slope in bits) for the three gain settings is approximately 2, 10 and 40 bits. So it will be apparent that the highest impact will be on data taken with the highest gain setting, thus low signal data. For the highest gain it will be difficult, if not impossible to distinguish the pulse-shape on the slope.

The correction itself is in principle very simple, it is a plain subtraction of the pulse-shape. However, the difficulty here, as can be expected, is to find the right pulse-shape. It was first believed that the pulse-shape could be corrected for with a single set of pulse-shapes (one for each detector). This assumed that the the effect of the after-reset pulse was constant. Since then we have learned that this is not the case and that the pulse-shape can change from observation to observation and sometimes also changes within one observation, see section 6 on signal jumps.

So preferably we want to correct for the pulse-shape on an observation to observation basis and in some cases also on individual parts within one observations. This means we cannot rely on a fixed type of calibration but that we have to use the data itself to do the calibration.

2 Pulse-shape correction

There are a few different ways in which it is possible to do the pulse-shape correction. What each of these have in common is that the data itself is used to derive the pulse-shapes.

- Single pulse-shape: one correction for all resets
- Multiple pulse-shapes: independently correct section of the ERD
- Running average pulse-shape: individual correction for each slope

The basic procedure to determine the pulse-shape is the same for all three cases. The resets which fulfill a certain selection criterion are selected, in the case of a single correction e.g. all dark current data with the highest gain, in the case of multiple pulse-shapes all data with the highest gain in a section and in the last case all resets. What we have in each reset is the integrated slope of the signal with added on top of that the exponential pulse-shape. These can be separated by fitting a first order slope with an exponential. In the first two cases a medium shape will be applied to all the resets in the ERD or the appropriate section of the ERD. In the last case the fitted exponential will be subtracted, possibly averaged with the pulse-shapes of its neighbors to improve the stability.

When applying the pulse-shape correction it is assumed that a correct midbit and AC-correction has been applied. This is the subject of a separate, but certainly not independent study. In the case when an incorrect AC-correction has been applied especially the last type of correction, the running average pulse-shape correction, suffers. The slope will then consist of the integrated signal, the pulse-shape, and remaining curvature due to the incorrect AC-correction. This will most likely increase the scatter in the fits and thus the scatter in the calculated slopes in the SPD. This is no problem where we apply a median pulse-shape, there it may only affect the overall value of the standard deviation of the slopes, not the scatter of the slopes.

3 Correction tools

In IA there are a number of possible ways to do a pulse-shape correction.

- DERIVE_PULSE_SHAPE: derives a median pulse-shape (as a CAL02B) which can be applied via DSPD
- PULSE_SELFCAL: command line tool which works on a midbit and AC calibrated ERD and returns a pulse-shape corrected ERD
- PULSE_FIT: idem, but then makes use of a widget inteface and allows the user to apply different pulse-shapes for different section of the ERD, see section 6 on signal jumps

See section 2 on how the pulse-shapes are derived.

4 Impact on slope values

The value of the slope calculated over a small part of an uncorrected reset changes significantly, see figure 1. This can have an impact on the slope value calculated for a reset which is split into a number

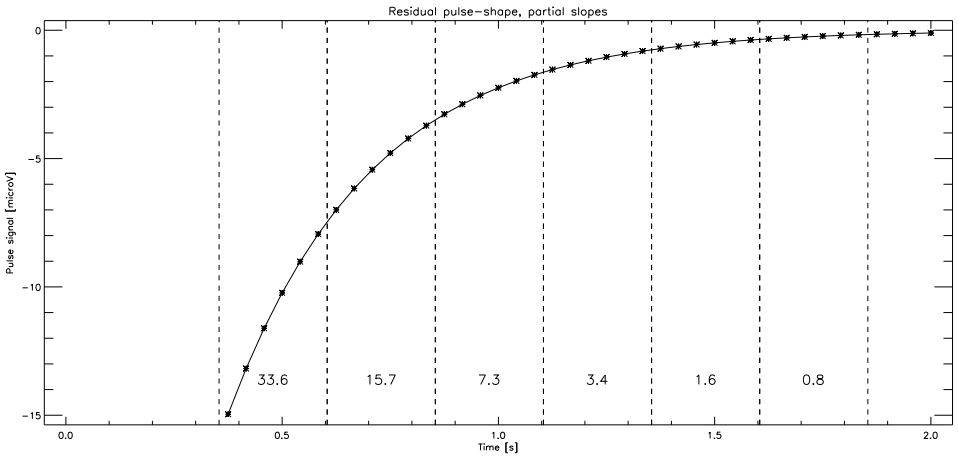

Figure 1: A typical example of a pulse-shape for a reset interval of two second. On the bottom of the plot the partial-slopes are written in μV/s. So a calculated slope which is derived from partial slopes, e.g. when there is a glitch, can be affected if no pulse-shape correction is applied.

of partial slopes because of the presence of glitches. In this case always a small part of the slope is not used, e.g. the points around the glitch. If no pulse-shape correction has been applied this can result in an erroneous slope value, because compared to a complete reset (a non-affected slope) a different part of the reset-pulse has been included, thus a different pulse-slope added. When the pulse-shape has been corrected for correctly this will not be the case.

5 Glitch detection

There are two ways in which the pulse-shape correction helps in the detection and correction of glitches. The first obvious one is the linearization of the slopes. The straighter a slope the more easy it is to detect and correct a slope. The partial slope before and after the glitch are, in principle, the same so the samples which are thrown away do not affect the value of the calculated slope (see section 4.

The second method for detecting glitches is by looking at the standard deviation of the calculated slope. In the case we have a glitch, small or large, it will not only affect the calculated slope, but also the calculated standard deviation of the slope. This can be used to do another glitch-removal by removing all resets with a large standard-deviation. If we do not apply the pulse-shape correction these small glitches would not be seen in the standard-deviation because the larger scatter introduced in standard deviations as a result of the curvature of the slopes.

6 Signal jumps

One of the artifacts seen in SWS data are sudden changes in the signal of a single detector. This effect has been described by Ana Heras in the note "Single Detector Signal Jumps" of 9 June 1997, a

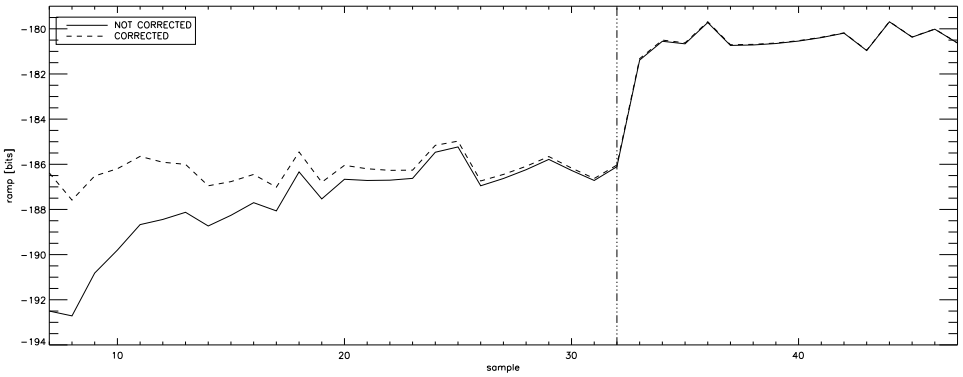

Figure 2: Example of a reset affected by a glitch. Not only will it be more easy to detect such a glitch in the corrected slope. In case the glitch is not detected it will directly be distinguishable from a non-affected slope via its standard deviation. This would be more difficult if no correction is applied because due to the curvature the standard deviation is already high, just a wrong slope would be calculated.

summary of which is included in the SWS IDUM.

One of the ideas for a possible cause of these jumps is the pulse-shape. It might be possible, that for some reason the pulse-shape suddenly changes. A change in the pulse-shape will reflect itself in the data as a jump because the pulse-shape is additive. So if we do no pulse-shape correction or if we do a single pulse-shape correction, the difference in the average slopes of the pulse-shapes will be the amplitude of the jump.

With the IA^3 module PULSE_FIT it is possible to interactively correct the pulse-shape for different parts of the observation. It appears that indeed some of the jumps are a result of a change in the pulse-shape. Correcting for a different pulse-shape before and after a jump virtually removes the jump, see figure 3, but there are also jumps which cannot be removed with a pulse-shape correction although the pulse-shape does appear to change, see figure 4.

Another way of correction for this jump is by correcting with a running average pulse-shape using PUSLE_SELFCAL or PULSE_FIT (which uses PULSE_SELFCAL for the derivation and application of the pulse-shape). The limitation of this method is the actual derivation of the exponential pulse-shape for each individual reset interval. This is limited by the noise on the sample data. This can sometimes be overcome by applying the average over a few reset intervals.

A detailed study is still required to assess the real impact of this. It has to be tested how many of the observed jumps can be corrected this way, if these coincide with glitches and if the jump is reflected in the signals of the neighboring detectors. Also a comparison between correcting with a few single pulse-shapes or with a running average pulse-shape has to be tested. An overview of the difference between these two methods in the term of the resulting noise in the derived SPD would be very useful to make recommendations for an automated correction procedure.

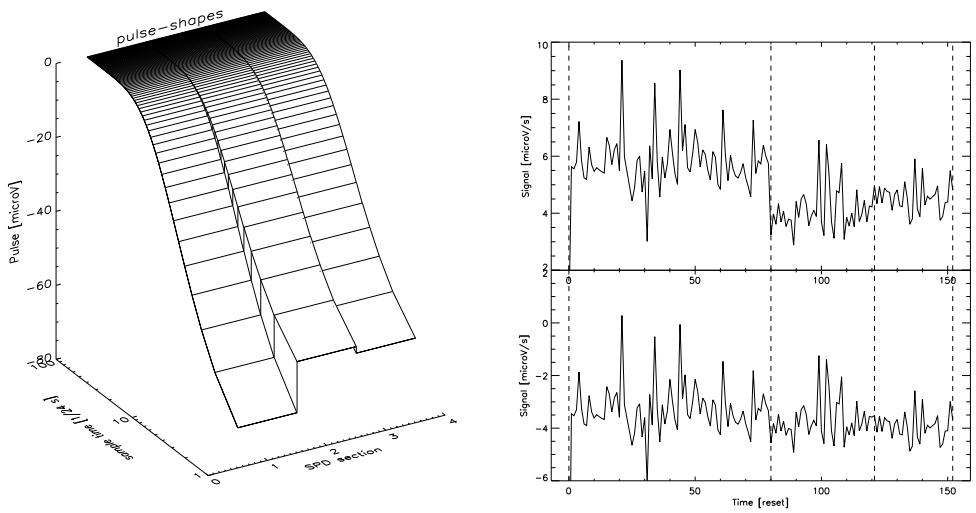

Figure 3: Shown here is a stretch of dark current data, which appears to have a signal jump at app. reset 80 and possibly a small jump at reset 120. Using PULSE_FIT these break-points are identified and a different exponential pulse-shape correction is applied to the three sections. The left plot shows the three pulse-shapes for the three sections and the right plot the data before and after correction.

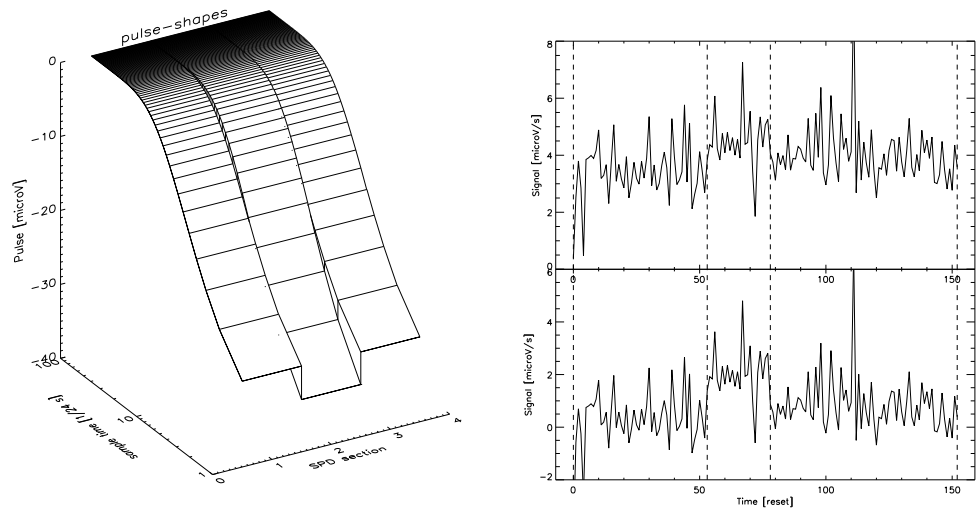

Figure 4: Same observation as shown in figure 3 but a different detector. Again apparent signal jumps, but now after correction the jump does not disappear although the pulse-shapes do change. This is still an open problem and an inventory has to be made to try and characterize the different type of signal jumps.

7 Conclusion

The pulse-shape correction is, especially for low signal sources, a very important step. It helps in correcting and identifying glitches and the improved standard deviations are very important in the analysis of the data.

Within IA there are a number of tools available for the pulse-shape correction, both simple and versatile. These tools are useful in the standard data analysis of low signal sources and are necessary tools to further analyze the data and instrumental artifacts that may happen on ERD level.