# PACS Spectrometer Calibration Block: Implementation & Evaluation

**PICC-ME-GP-009**

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**Abstract**

**The spectroscopy calibration block plays a key role in the analysis and interpretation of PACS spectrometer observations. Not only provides it a clean start for the subsequent science observations, it also determines the detector response on basis of a well-defined chopped grating scan on both PACS calibration sources (CSs) at pre-defined key wavelengths. But it is also relevant for trend analysis studies over an operational day and the full mission lifetime. The calibration block might also be used to judge certain quality aspects of a subsequent science observation. Here, the content of the calibration block, the implemenation and the corresponding CUS logic, the necessary IA processing steps and final check values are described in detail.**

## Document Change Record

| | | |
|---|---|---|
| First draft | 14 May 2008 | Document setup after ICC@MPE discussions on 05-May-2008 |
| 2nd draft | 16 May 2008 | Update after comments from BV and JS |

# Contents

# 1 Purpose and Goals

The goals of this document are:

- To provide a description of the design of the calibration block, the corresponding PACS instrument configuration and the preparation phase in front of each science observation
- To give the specifications for the CUS implementation and the CUS logic and to list all relevant Cal-U tables
- To support the pipeline work, the development of various IA steps, to get started for trend analysis and quality control work ...
- To support the corresponding measurements during FS-ILT and to prepare the in-orbit validation process for the spectrometer AOT modes
- To collect all open points and various points of discussions which will influence the design of the in-orbit validation program for all spectroscopy modes.

# 2 The SPEC Calibration Block

The SPEC calibration block consists of a chopped grating up-/down scan on both PACS calibration sources (CSs, see Fig. 1) with 16 grating steps in each direction and a grating step size of roughly the size of a spectral pixel of about 420 grating units (see also Sect. 6 for open points). This guarantees that each of the 16 spectral pixels sees both CSs roughly at the same wavelengths during the grating scan. The chopping and also the grating movements are done in a similar way as in the corresponding science observations.

The SPEC calibration block will be executed in combination with all spectroscopy modes:

1. `PACS Line Spectroscopy (AOR Label PSpecL): 1st+2nd order`
   `PACS Line Spectroscopy (AOR Label PSpecL): 1st+3rd order`
    - Pointed:
      (i) Chopping/nodding (ii) Chopping/nodding (bright lines) (iii) Wavelength switching
    - Pointed with dither:
      (i) Chopping/nodding (ii) Chopping/nodding (bright lines) (iii) Wavelength switching
    - Mapping:
      (i) Chopping/nodding (ii) Chopping/nodding (bright lines) (iii) Wavelength switching
2. `PACS Range Spectroscopy (AOR Label PSpecR): Ranges in 1st+2nd order`
   `PACS Range Spectroscopy (AOR Label PSpecR): Ranges in 1st+3rd order`
   `PACS Range Spectroscopy (AOR Label PSpecR): SED in 1st+2nd order`
   `PACS Range Spectroscopy (AOR Label PSpecR): SED in 3rd order`
   `PACS Range Spectroscopy (AOR Label PSpecR): SED high in extended 2nd order`
    - Pointed (chopping/nodding)
    - Pointed with dither (chopping/nodding)
    - Mapping: (i) Mapping with off-position (ii) Chopping/nodding

## 2.1 Execution time within an AOR

Currently, the calibration block will only be executed in the beginning of each AOR, i.e., either during target acquisition while the satellite is slewing (in case of individual AORs) or right in front of an AOR (in case of 2 concatenated AORs). In cases were long satellite slews are needed to reach the science target (longer than about 60 sec), the calibration block will be executed in such a way that the end of the calibration block will coincide with the slew end. In this way the calibration block and the science block are always tied together (with only a few seconds inbetween for various instrument and satellite commands).

In addition to the standard calibration block at the beginning of an AOR, there is also the possibility to interrupt a long observations after a certain *hold time* (specified in the CalU-tables **OBCP***xx* **params** as "nhold", but currently not used) and to execute the standard calibration block again. Afterwards the science observations are resumed again.

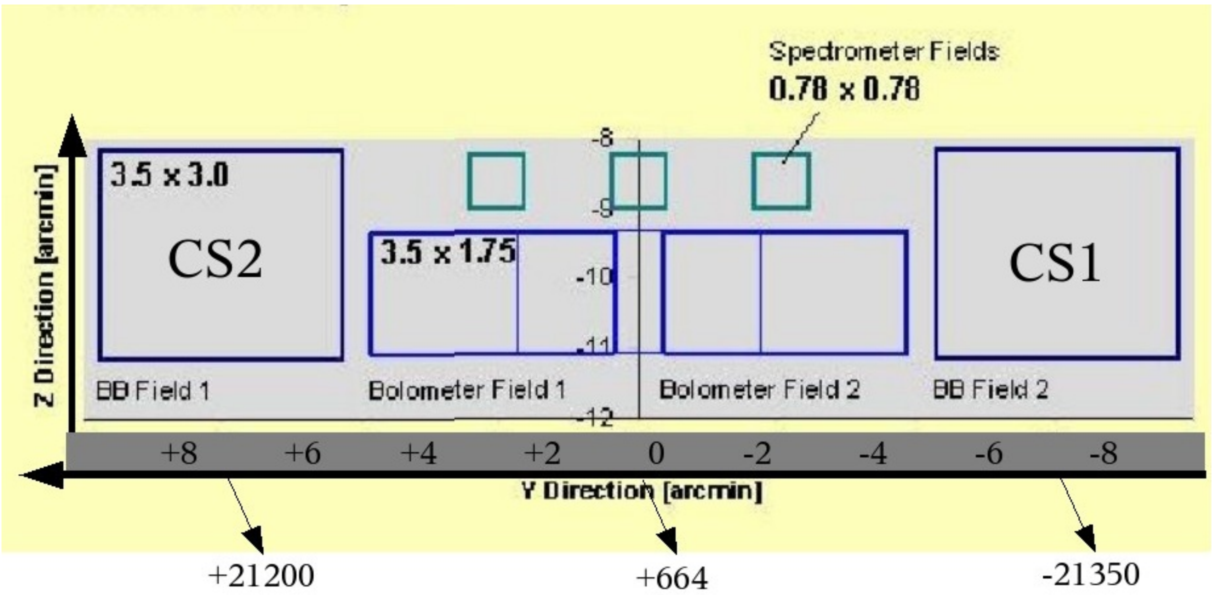

Figure 1: The PACS field-of-view in combination with the chopper positions of the optical axis and the current best positions on both PACS calibration sources (CSs). The spectrometer array with $0.78' \times 0.78'$ ($5 \times 5$ pixels with a pixel size of $9.4''$) is also shown. It is much smaller than the size of the CSs. In the calibration block chopping between both CSs is done, while the grating moves up and down around the position of a key-wavelength.

## 2.2 Instrument settings

The calibration block will be executed exactly in the same filter, capacitance and SPU setting as the requested science block. Also the ramp length will be the same as in the subsequent science observations (either 32 or 64 readouts per ramp). Several different combinations of instrument settings are therefore possible.

For the blue channel covering the grating third order (55-72 $\mu$m), the following settings for the calibration block are possible:

(a) 3rd order filter (A), capacitance 140 fF, $\lambda_{key} = 55\,\mu$m, 32 or 64 readouts per ramp

(b) 3rd order filter (A), capacitance 240 fF, $\lambda_{key} = 55\,\mu$m, 32 or 64 readouts per ramp

(c) 3rd order filter (A), capacitance 450 fF, $\lambda_{key} = 55\,\mu$m, 32 or 64 readouts per ramp

(d) 3rd order filter (A), capacitance 1150 fF, $\lambda_{key} = 55\,\mu$m, 32 or 64 readouts per ramp

For the blue channel covering the grating second order (72-98 $\mu$m):

(a) 2nd order filter (B), capacitance 140 fF, $\lambda_{key} = 74\,\mu$m, 32 or 64 readouts per ramp

(b) 2nd order filter (B), capacitance 240 fF, $\lambda_{key} = 74\,\mu$m, 32 or 64 readouts per ramp

(c) 2nd order filter (B), capacitance 450 fF, $\lambda_{key} = 74\,\mu$m, 32 or 64 readouts per ramp

(d) 2nd order filter (B), capacitance 1150 fF, $\lambda_{key} = 74\,\mu$m, 32 or 64 readouts per ramp

For the red channel, covering the grating first order (102-210 $\mu$m):

(a) 1st order, capacitance 140 fF, $\lambda_{key} = 148\,\mu$m, 32 or 64 readouts per ramp

(b) 1st order, capacitance 240 fF, $\lambda_{key} = 148\,\mu$m, 32 or 64 readouts per ramp

(c) 1st order, capacitance 450 fF, $\lambda_{key} = 148\,\mu$m, 32 or 64 readouts per ramp

(d) 1st order, capacitance 1150 fF, $\lambda_{key} = 148\,\mu$m, 32 or 64 readouts per ramp

(e) 1st order, capacitance 140 fF, $\lambda_{key} = 165\,\mu$m, 32 or 64 readouts per ramp

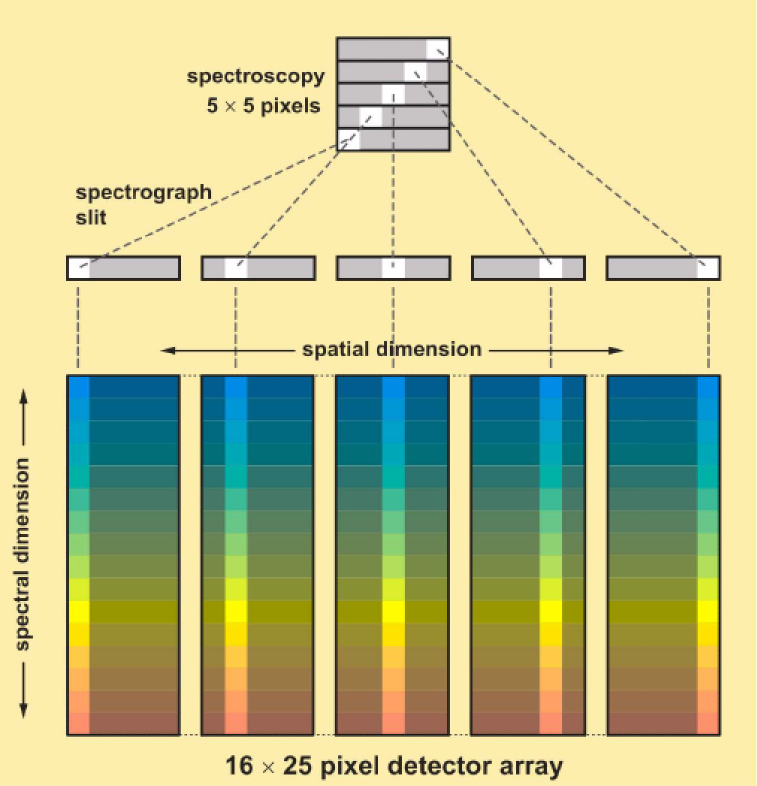

Figure 2: Projection of the focal plane onto the detector arrays in spectroscopy mode. The image slicer re-arranges the 2D field along the entrance slit of the grating spectrograph such that, for all spatial elements in the field, spectra are observed simultaneously. During the calibration block the full array is placed on CS1 and CS2 for various grating positions.

(f) 1st order, capacitance 240 fF, $\lambda_{key} = 165\,\mu$m, 32 or 64 readouts per ramp

(g) 1st order, capacitance 450 fF, $\lambda_{key} = 165\,\mu$m, 32 or 64 readouts per ramp

(h) 1st order, capacitance 1150 fF, $\lambda_{key} = 165\,\mu$m, 32 or 64 readouts per ramp

This assumes that the resistance settings for the PACS CSs (which determines their temperatures) and the corresponding chopper positions are always the same and that also the bias settings for the Ge:Ga detectors are not changing. Currently the two ramp-length options would also trigger different SPU settings: either slope fitting for the short ramps or sub-mean values for the longer ramps, but it is planned to homogenise the SPU mode as soon as the upgraded SPU software is available which would allow to have 8-sample subramps and to downlink the mean of these sub-ramps, independent of the ramp length.

## 2.3 Commanding aspects

The spectrometer calibration block itself is part of the **PacsSpecSlewCal**. It contains an AOT ”prologue”, then the filter is selected, and then the calibration block is executed (in the same filter, capacitance and SPU settings).

**PacsSpecSlewCal**:

- **SPEC_aot_prologue**, with the following parameters:

| | |
|---|---|
| nb_rdouts_ramp_red, nb_rdouts_ramp_blu: | ramp length |
| bias_d_red, bias_r_red, bias_d_blu, bias_r_blu: | bias values |
| capa_red, capa_blu: | capacitance settings |
| comp_mode_blu, comp_mode_red: | SPU compression/reduction mode |
| nb_rdouts_subramp_blu, nb_rdouts_subramp_red: | sub-ramp length |
| nb_raw_blu, nb_raw_red: | number of raw channels |
| glitch_det_red: | Glitch detection; 0=on; 1=off<br>(used for both channels) |
| ramp_fit_alg_red: | Ramp fit algorithm [0=LstSq;1=mean value]<br>(used for both channels) |
| filter: | filter position |
| verbose: | with/without messages |

- **OBCP_chop_grat_scan_cal** (OBCP13), with the following parameters:

| | |
|---|---|
| nb_up_dn: | Nb of up down up... cycles (P#1) |
| grat_step_coarse: | Grating coarse movement (P#2) |
| nb_grat_steps: | Seq P#3 Nb of grating steps |
| grat_step_up_fine: | Grating fine movement (P#4) |
| nb_cycles_grat: | Seq P#5 Nb cycles/grating position |
| chop_pos_CS1: | Chopper position for CS1 (P#6) |
| nb_ramps_grat_pos: | Seq P#7 Nb of ramps per grating position |
| chop_pos_CS2: | Chopper position for CS2 (P#8) |
| grat_step_dn_fine: | Grating fine movement (P#9) |
| detector: | Synchronize on this detector 1:Blue 2:Red |
| grat_start_pos: | Starting grating position |
| grat_time: | Time for grating to move to start position |
| comp_mode_blu: | ”Blue” compression |
| comp_mode_red: | ”Red” compression |
| new_grat_def_pos: | Grating default position |
| chop_def: | Chopped default position |
| grat_def_time: | Grating time to move to grat_def [msec] |
| nb_rdouts_ramp: | Number of readouts per ramp |

The correct values for the filter, the grating initial position and the SPU settings are coming from the main AOT mode which is connected to the corresponding AOR (example: **PacsLineSpec.def** or **PacsRangeSpec.def**).

For nominal spectrometer operations the SPU reduction/compression modes are defined in the Cal-U table **CONF_SPEC_params** (see A.2). It has to be noted that in the near future a sub-ramp length of 8 samples (nb_rd_sub_red=8 & nb_rd_sub_blu=8) can be used in all modes. Correspondingly, the current ramp fitting will be replaced by averages for each sub-ramp (ramp_fit_red=1 & ramp_fit_blu=1).

The definition of the spectrometer band limits, the various grating step sizes and the number of grating steps are defined in the Cal-U table **SPEC_BAND_params** (see A.3).

## 2.4 Spectrometer Key Wavelengths

The key wavelengths are defined in the Cal-U table **KEY_WAVES** (see A.4 and Fig. 3). Important criteria for the selection are:

- all pixels should see reasonable flat parts of the RSRF
- all pixels should be well outside the known filter leakage ranges
- the grating positions for the key wavelengths should produce useful, sufficiently high S/N values in both channels, the blue and the red.
- there should be only one grating position per filter setting.
- the CUS logic should be very simple
- the calibrations blocks should produce sufficient statistics during normal PACS spectrometer operational days in all 3 grating orders for trend analysis and monitoring of the detector

responses (typical 1h AOR durations would produce about 10 calibration blocks in filter A and about 10 in filter B per operational day).

- the duration of the calibration blocks are well-defined and independent of the lines specified by the observer (not dependent on the mean wavelength of all lines in an AOR)

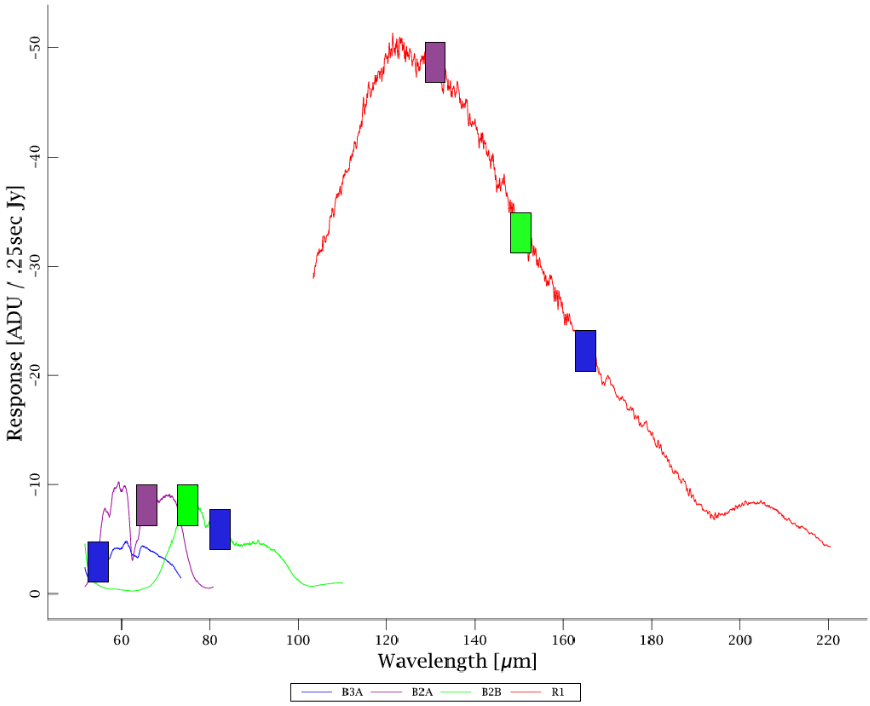

Figure 3: The key-wavelengths in combination with the RSRF curves as it was proposed in early 2008.

In the new CUS-implementation, as of mid-May 2008, the following rules and guidelines have been applied for the selection of the key wavelengths in the various spectrometer modes:

1. Filter A is selected (grating 1st and 3rd order):
    a) `Line spectroscopy [55-73] and [103-210] microns (3rd + 1st orders)`
    b) `Range spectroscopy [55-73] and [102-210] microns (3rd + 1st orders)`
    c) `SED Blue [55-73] microns (3rd order and a small part in 1st order)`
    d) `SED Blue high sensitivity [60-73] microns (extended 2nd order)`
    → filter A is selected
    → calibration block will be executed at grating position 623 311 (tbc), this will give useful data in 1st order at around 165 μm and in 3rd order at around 55 μm
2. Filter B is selected (grating 1st and 2nd order):
    a) `Line spectroscopy [73-98] and [103-210] microns (2nd + 1st orders)`
    b) `Range spectroscopy [71-98] and [102-210] microns (2nd + 1st orders)`
    c) `SED Red [71-210] microns (2nd + 1st orders)`
    → filter B is selected
    → calibration block will be executed at grating position 753 613 (tbc.), this will give useful data in 1st order at around 148 μm and in 2nd order at around 74 μm

It should be noted here that it is planned to observe all celestial flux calibrators also at the specified key wavelengths. Two concatenated range-scan AORs (high sampling density) will be executed on each target:

1. The first AOR contains range scans in first, third order and off-band second order (filter A): short ranges around 165/55 $\mu$m and around 130/65 $\mu$m (grating step size optimised for the 55 $\mu$m wavelength, i.e., a grating step size of 168 units).
2. The second AOR contains range scans in first and second order (filter B): short ranges around 148/74 $\mu$m and around 165/82 $\mu$m (grating step size optimised for the 74 $\mu$m wavelength, i.e., a grating step size of 188 units).

Each of the AORs will be started with a standard calibrations block, with the first AOR containing a calibration block at the 165/55 $\mu$m key wavelengths and the second AOR containing a calibration block at the 148/74 $\mu$m key wavelengths.

The transition between celestial point-sources and the extended PACS CSs will be done via the standard flat-fielding (tbc.).

## 2.5 Duration of the calibration block

The calibration block is executed via OBCP 13 "OBCP_chop_grat_scan_cal" which is driven by the CalU-table **OBCP13params** (see A.5). The additional time parameters to calculate the duration of the calibration block duration are given in the CalU-table **PACSparams** (see A.1).

There will be in total 16 grating steps up and down. On each grating position there will be one full full chopper cycle (chopping between CS1 and CS2) which chopper plateau lengths of 1(+1) ramps (either 32 or 64 readouts per ramp). The total duration of the complete DMC sequence is (PACS-ME-LI-005, section 4.2.8): 2 + 1 * (1 + 2*16*(1+2*1*(1+1))) ramps = 163 ramps
= 40 750 msec (in case of 250 msec ramps)
= 20 375 msec (in case of 125 msec ramps)

In addition to the DMC sequence time of 40 750 or 20 375 msec, the following overheads have to be taken into account (from Cal-U table **PACSparams**):

- 2 600 msec (13×200 msec) for the execution of the 13 OBCP commands
- 2 500 msec DMC margin
- 1 000 msec OBCP margin
- up to max. 10 000 msec time to move the grating from its initial position to the start position for the key wavelength scan (see Fig. 4 for typical durations of grating movements).
- up to max. 10 000 msec time to move the grating after the end of the key wavelength scan to the start position for the first science line scan.

The total time for a SPEC calibration block will therefore be between about 50 and 70 sec (1/4 sec ramps) and between about 30 and 50 sec (1/8 sec ramps).

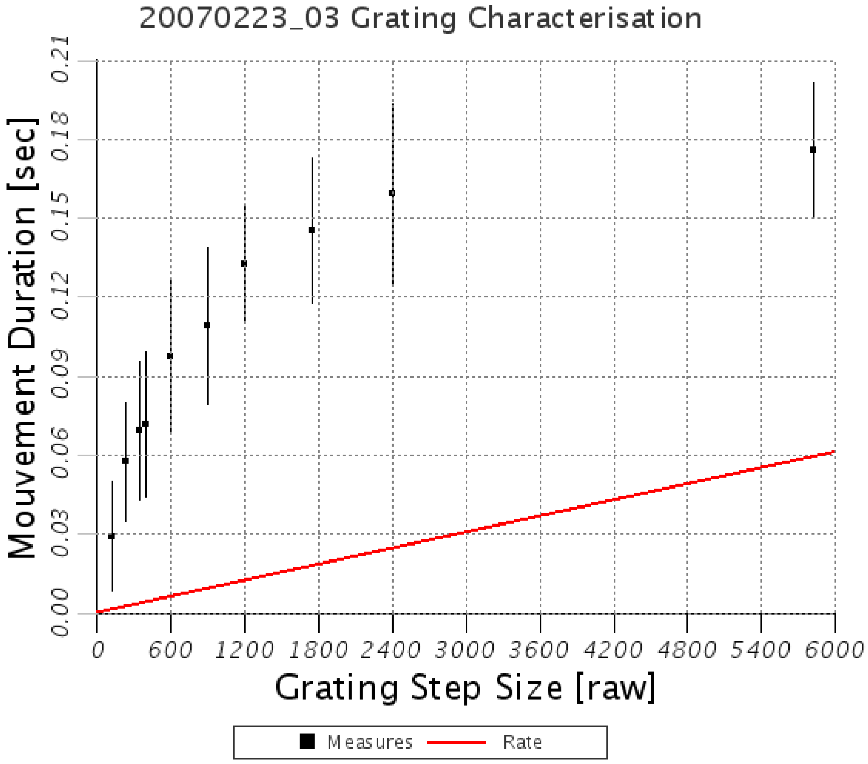

Figure 4: The grating stabilisation times for typical grating step sizes. In the calibration block the grating moves with step sizes of about 420 units.

# 3 Data analysis and pipeline steps

## 3.1 General Pipeline processing from level 0 to level 0.5

The following steps assume that all relevant data are downlinked in 8-sample sub-ramps with the mean readout value for each subramp. The ramp length can either be 1/4 sec or 1/8 sec. The signal derivation takes place on ground.

- **specFlagBadPixelsRamps**: Pixel selected out by the Detector Selection Table are flagged with the BLINDPIXEL mask already during Level 0 data generation, but the additional bad or damaged pixels are flagged out during this step in the BADPIXEL mask.

- **cleanPlateauRamps**: Flags unreliable ramp readouts during the chopper transition phases. This task first searches for chopper plateaus and flags chopper readouts deviating more than the specificated thresholds from the median plateau position. Note: typical chopper transition times are about 30 msec while one sub-ramp with 8 readouts lasts 31.25 msec. Typically, 1 subramp might be affected each time the chopper moves.

- **flagGratMoveRamps**: Flags unreliable ramp readouts during grating transition phases. This task first searches for grating plateaus and flags readouts deviating more than the specificated thresholds from the setpoints. Note: typical grating transition times for grating step sizes between 400 and 500 units are about 70-80 msec (see Fig. 4) while one sub-ramp with 8 readouts lasts 31.25 msec each). Typically, 2-3 sub-ramps might be affected each time the grating moves.

- **specFlagSaturationRamps**: Detects ramp readout values above the saturation limit and sets the corresponding SATURATION flag (mask) for those readouts. Red and blue array is distinguished. Reads saturation voltage from cal file.

- **flagDeviatingOpenDummyRamps**: flags data of a complete 16-pixel module in case of FEE problems, glitches, saturation, ... (statistical analysis of the open and dummy channels for each module).

- **subtractOpenRamps**:subtract ramps of open channel from ramps of detector channels for each module, keep as dummy until test results confirm improvement of S/N (during CQM-ILT it was needed, but in FM-ILT no improvement).
- **specFlagGlitchRamps**: will it be possible to detect glitches based on 8-sample subramps? If yes, then this will flag ramps which are affected by glitches.
- **specConvDigit2VoltsRamps**: Converts the digital readouts in the Ramps dataset to Volts.
- **addUTC**: Convert from spacecraft on-board time (OBT) to coordinated universal time (UTC) using the time correlation table (UTC, correlation gradient, correlation offset). Fill the UTC field in the Frames dataset.
- **convertChopper2Angle**: Calculates the chopper position angle with respect to the FPU and the angle on sky by reading the status DEC/MEC parameter "CPR" in position readouts and then populating new status words in the returned frames.
- **fitRamps**: Fits the slope of the integration ramp to convert to signal [V/sec]. Stores these signals and the fit uncertainties in a Frames dataset. Propagates/rebins masks per ramp readout to a flag per reset interval. Propagetes/rebins status words to a status word at the reset interval frequency.
  or alternatively: **pairDiffSigClip**: Calculates the signal by using sigma clipped pairwise differences [V/s]. Stores these signals and the fit uncertainties in a Frames dataset. Propagates/rebins masks per ramp readout to a flag per reset interval. Propagetes/rebins status words to a status word at the reset interval frequency (deglitching on signal level).
  or alternatively: **pairDiffHodLehEst**: Calculates the signal by applying the Hodges-Lehmann estimator on pairwise differences of each ramp. The H.-L. estimator is defined as the median of the mean of pairs of a pairwise differences array, that means it calculates a stable mean.

The frames are created at this level. They contain one signal value (unit V/s) for each pixel and each ramp (either 1/4 sec or 1/8 sec ramp). A few additional steps, like **decodeLabel** (convert Label entry into verbose form and put it into Frames Status), **completeStatus** (convert Label entry into verbose form and put it into Frames Status), **findBlocks** (to allow the next steps to find the applicable calibration source measurement, the nod scans to differentiate, etc... a summary of major 'blocks' in the observation is constructed. In a first version this is done based on the LBL status word, the raster point counter and the status information) and **addOBCP2Frames** (add the OBCP numbers to the Meta data of a Frames class), might still be useful to complete the information inside the frames class.

## 3.2 Absolute signals of CS1 and CS2 separately

The following analysis steps would then be useful:

- Plot the individual signals per pixel for the CS1 and CS2 separately as a function of time: are there still systematic outliers due to chopper or grating movements? Are there glitches visible? If yes, flag the affected signals. Is there an overall trend with time?
- Plot the individual signals per pixel for the CS1 and CS2 separately as a function of wavelength: is the signal of CS1 (CS2) constant during the grating up- and down-scan? Or is there a transient or memory effect?
- average the signals per chopper plateau (typically 2-3 signal entries per chopper plateau) for each pixel separately
- average the signals of the grating up- and down-scan for each pixel and chopper position separately
- store the resulting short spectra for each pixel and each chopper position
- compare the individual pixel spectra for all pixels of a module and all pixels in the full array for both CSs.
- calulate the mean/median signal for each pixel: this should be representative for the absolute pixel response (as based either on the CS1 flux or the CS2 flux).

- calculate the corresponding r.m.s. values
- other aspects?

## 3.3 Differential signals of the calibration sources

It would also be possible to work on the differential signal level:

- average the signals per chopper plateau (typically 2-3 signal entries per chopper plateau) for each pixel separately and calculate the differential signal for each chopper cycle. **Alternatively:** calculate the differential signal pairwise, i.e., subtract the signals of corresponding ramps on the CS1 and CS2. This method might be more robust in case of glitches and it might also allow to better characterise the influence of chopper and grating movements. Transients will also play a big role in all spectroscopy observations and especially with short chopper plateaus of less than 1 sec one might never reach a stable signal (see also report on "Chopper synchronous operation with Ge:Ga detectors", PICC-MA-TR-41). It is therefore very important to have very similar chopper and grating patterns in the calibration block and in the science block. With the pairwise differential signals the signal statistics would clearly improve and might allow a better characterisation of all kind of detector/mechanism effects.
- Plot the differential signals per pixel as a function of time: are there still systematic outliers due to chopper or grating movements? Are there glitches visible? If yes, flag the affected signals. Is there an overall trend with time?
- Plot the differential signals per pixel as a function of wavelength: is the CS1-CS2 signal constant during the grating up- and down-scan? Or is there a transient or memory effect?
- average the differential signals of the grating up- and down-scan for each pixel
- apply the RSRF to obtain flat spectra for better sigma-clipping
- store the resulting short differential spectra for each pixel
- compare the differential pixel spectra for all pixels of a module and all pixels in the full array
- calulate the mean/median differential signal for each pixel: this should be representative for the absolute pixel response (as based on the CS1-CS2 flux), either with or without a filter-function (similar to the SWS-procedure) to give less weight to the outer parts of the short spectra. Calculate the corresponding r.m.s. values indicating the typical pixel-to-pixel variations.
- calculate the calculate the mean/median response value for all pixels in one module (and in the full array) and the corresponding r.m.s. values, indicative for the stability and reliability of the response drifts over the length of an operational day.
- The differential signals allow to connect the PACS CSs to the celestial calibrators. On the sky the differential signals are directly connected to Jy via the calibrator flux models.

**Note:**

Short-term responsivity variations on pixel level can be monitored via the telescope flux in the off-source position for the times between 2 consecutive calibration blocks.

## 3.4 Noise properties

- the pixel-to-pixel response variations, as well as the mean/median module/array response, as derived from the spectrometer calibration blocks (within a module and within the full array) might be indicative for the quality of the sub-sequent science block, but this can only be judged based on in-orbit data

# 4 Trend analysis steps

## 4.1 Additional relevant parameters

Other relevant paramters for the analysis of the calibration blocks are:

- the temperatures of the PACS CSs: commanded via the CalU table **CSparams** (tbd.); current values: $48.0\,\Omega$ for CS1 and $58.0\,\Omega$ for CS2; HK entries in the downlink: DM_CS1_RES_VAL and DM_CS2_RES_VAL;

- the chopper positions on the PACS CSs: commanded via the CalU table **CHOPPERCSparams**; current values: +21200 for the chopper position on CS1 and -21350 for the chopper position on CS2; HK entries in the downlink: DM_CHOP_CUR_POS;

- the applied bias values: commanded via the CalU table **CONF_SPEC_params**; all biases values are also available in the corresponding downlinked HK packets; current default values are 30 mV for the red detector and 80 mV for the blue detector

- the temperature of the detectors are given in:

| | | |
|---|---|---|
| DM_DECR_TS_1_1 | at FEE, group 1, high stressed | ∼4.0-5.5 |
| DM_DECR_TS_2_1 | at structure, group 1, high stressed | ∼1.8, higher during curing (heating) |
| DM_DECR_TS_1_2 | at FEE, group 2, high stressed | ∼4.0-5.5 |
| DM_DECR_TS_2_2 | at structure, group 2, high stressed | ∼1.8, higher during curing (heating) |
| DM_DECB_TS_1_3 | at FEE, group 3, low stressed | ∼4.0-5.5 |
| DM_DECB_TS_2_3 | at structure, group 3, low stressed | <2 (∼2.5 when heated) |
| DM_DECB_TS_1_4 | at FEE, group 4, low stressed | ∼4.0-5.5 |
| DM_DECB_TS_2_4 | at structure, group 4, low stressed | <2 (∼2.5 when heated) |

- the blue detector heater current DM_DECB_HEAT_C (current default value 0.78 mA)

- The telescope mirror temperatures of M1 and M2; HK entries for M1: PT1000_T331, PT1000_T332, PT1000_T333, PT1000_T334, PT1000_T335, PT1000_T336, PT1000_T337, PT1000_T340; HK entries for M2: PT1000_T339, PT1000_T341, PT1000_T342

- Various baffle temperatures might also play a role (tbc).

- The cryostat L0/L1 level temperatures, as well as the vent line temperatures close to PACS (especially the L0 sensors close to DECR and DECB) should also be monitored in combination with the calibration block results.

## 4.2 Trends to be investigated

- Do the mean/median and r.m.s. values show trends with the detector temperatures?

- Do the mean/median and r.m.s. values show trends with the temperatures of the PACS CSs? (DM_CS1_RES_VAL and DM_CS2_RES_VAL)

- Do the mean and r.m.s. values show trends with time after the last curing (or the time after the last biasing of the Ge:Ga detectors)?

- Do the mean and r.m.s. values show trends with the temperature of the telescope mirrors M1 and M2? (M1: PT1000_T331, PT1000_T332, PT1000_T333, PT1000_T334, PT1000_T335, PT1000_T336, PT1000_T337, PT1000_T340; M2: PT1000_T339, PT1000_T341, PT1000_T342)

# 5 Results from FM-ILT Data

## 5.1 SPEC Calibration Blocks during FM-ILT

```
FM-ILT part I:
  FILT_CalBlock_20061129_01.tm
  FILT_SpecCalBlock_20061129_02.tm
  FILT_SpecCalBlock_20061129_03.tm

FM-ILT part II:
  FILT_SpecCalBlock_20070315_01.tm ... FILT_SpecCalBlock_20070315_11.tm
  FILT_SpecCalBlock_20070316_01.tm ... FILT_SpecCalBlock_20070316_08.tm
  FILT_SpecCalBlock_20070317_01.tm ... FILT_SpecCalBlock_20070317_06.tm
  FILT_SpecCalBlock_20070326_01.tm ... FILT_SpecCalBlock_20070326_11.tm
  FILT_SpecCalBlock_20070328_01.tm ... FILT_SpecCalBlock_20070328_12.tm

  AOT-code which contains also a calibration block:

  FILT_SpecAOTRange3rdOrder_20070326_01.tm
  FILT_SpecAOTRange3rdOrder_20070326_02.tm
  FILT_SpecAOTRange2ndOrder_20070326_01.tm
  FILT_SpecAOTRange1stOrder_20070326_01.tm
  FILT_AOT_LINE_WATER_20070328_01.tm
  FILT_AOT_LINE_WATER_20070328_02.tm
  FILT_AOT_LINE_WATER_20070328_03.tm
  FILT_AOT_LINE_WATER_20070328_04.tm
  FILT_AOT_LINE_WATER_20070328_05.tm

FM-ILT part III: ---
```

## 5.2 Results

TBD.

# 6 Open points and points of discussion

- The calibration block should sample the spectral resolution of the PACS instrument. Therefore, it might be necessary to decrease the grating step sizes (and increase the number of grating steps) so that the instrumental spectral resultion is Nyquist sampled also at the shortest key wavelengths at 55 $\mu$m where the FWHM of an unresolved line is about 1.26 spectral pixels. The step size should therefore be at around 180 grating units, corresponding to about 0.4 spectral pixels at 55 $\mu$m. The number of grating steps could either be increased or kept at 16 for each scan direction.

- Instead of rotating raw channels it would be advantageous to have raw data (in addition to the nominal SPU processed data) of the most important pixels: in line and range spectroscopy on point-like sources these pixels are the pixels 7, 8, 9 of the central module 12. But this would require some modifications in the SPU OBSW (this topic in on the tbd-list of Roland Ottensamer, E-mail 2008/Mai/14).

- the procedure to connect the differential signals from the point-like flux calibrators on the sky to the extended PACS CSs as seen in the calibration blocks is not yet clear and requires a more detailed description.

- ...

# A Cal-U Tables connected to the SPEC Calibration Block

## A.1 PACSparams

```
# Purpose   : Useful PACS parameter "database" containing data needed
#             to compute several bolo and spectro time related parameters
#             (ramp duration, bolo integration, etc). Also duration of
#             "internal" DEC/MEC commands. Most entries here are supposed
#             not to change over the mission but one never knows ...
# CVS file  : PACSparams
# Comments  : Entries here are mostly used by CUS to perform
#             time related computations
# Successive rows are, respectively:
#  1- Bolometer sampling frequency
#  2- GeGa detectors sampling frequency
#  3- Duration of a TC issued internally by any OBCP
#  4- DEC/MEC sequence duration margin
#  5- OBCP  communication "jitter"
#  6- PHOT/SPEC filter wheel move time
#  7- GRATing move time to default position
#  8- GRAT speed steps/msec
#  9- GRAT setlingtime in msec
#
string       double    string
parameter    freq_time   unit
bolo_sample      40.0    Hz
spec_sample     256.0    Hz
int_cmd         200.0    msec
dmc_margin     2500.0    msec
obcp_margin    1000.0    msec
fltw_time     15000.0    msec
grat_time     10000.0    msec
grat_speed       92.0    steps/msec
grat_settle     200.0    msec
```

## A.2 CONF_SPEC_params

```
# CVSfile       : CONF_SPEC_params (FM-AOT code)
# Purpose   : Lists values for the confSPEC internal tuple array
# Successive rows are (first for red and then same for blu)
#  - capacitor
#  - nb_rdouts_ramp
#  - nb_rdouts_subramp
#  - compression mode
#  - glitch detection algorithm
#  - ramp fitting algorithm
#  - number of raw pixels
#  - bias "r" [mV]
#  - bias "d" [mV]
#
# Compression modes from SPW User's Manual
# CMM  Photometry                   Spectroscopy
# 0x00 BOL0: Default                None
# 0x01 BOL1: Double Compression     None
# 0x02 BOL2: Half Compression       None
# 0x04 BOL4: Lossless Compression   None
# 0x07 BOL7: Transparent            None
# 0x09 BOL9: Buffer Transmission    None
# 0x10 None                         SPEC0: Default
# 0x11 None                         SPEC1: Default  (same as SPEC0)
# 0x14 None                         SPEC4: Lossless Compression
```

```
# 0x17 None                         SPEC7: Transparent
# 0x18 None                         SPEC8: Compression for 4 second reset
# 0x19 None                         SPEC9: Buffer Transmission
#
string        int         int     int
parameter     Normal0     Fast0   FastOLD
capa_red         12        12        12
nb_rdouts_red    64        64        32
nb_rd_sub_red    16        16        32
comp_mode_red    16        16        16
glitch_det_red    1         1         1
ramp_fit_red      1         1         0
nb_raw_red        3         3         3
bias_r_red       10        10        10
bias_d_red       69        69        69
capa_blu          0         0         0
nb_rdouts_blu    64        64        32
nb_rd_sub_blu    16        16        32
comp_mode_blu    16        16        16
glitch_det_blu    1         1         1
ramp_fit_blu      1         1         0
nb_raw_blu        3         3         3
bias_r_blu       10        10        10
bias_d_blu      198       198        98
```

## A.3 SPEC_BAND_params

```
# CVS file   : SPEC_BAND_params
# Purpose    : Define band limits for spectroscopy; associated
#              U-CAL file (grating position, RSRF, etc.), and
#              lo, med, and hi resolution grating steps
# Description: Holds PACS wavelength band limits for use
#              by spectroscopy AOTs, step sizes, pointer to grating
#              position vs. wavelength calibration table
# Successive columns indicate:
# ORDER      : order Plain numbers used with RANGE;
#              L numbers with LINE
#              K numbers for key wavelengths
# BLU RED    : blue and red edges [microns]
# LOW MED HI : step size for low, medium, high resolution (Range and Line Scan)
# NSTEPS     : number of steps for LineScan
# GRAT_WDTH  : number of steps to go from pix 1 to pix 16
# CAL_FILE   : Grating pos vs. wave U-calibration table
# NOTES      : - #4, #5 and #6 pertain to sed2, sed3, and sed4
#              - order 23 describes "short" 2nd order within order 3 range
#              - Entry CROS gives 1st order wavelengths for grating positions
#                that will fall in bandpass of filter at POS A and POS B (see
#                module PacsSpecRMS)
#              - CROS is no longer used (removed from table)
#              - NSTEPS is irrelevant for Range; but since used for LINE it
#                must be kept for table structure
#              - Introduced rows K1, K2, K3 to be used for key wavelengths
#                Only HI, NSTEPS and CAL_FILE columns are relevant for Kn rows
#
string   double   double   int   int   int   int   int   int   string
ORDER  BLU     RED    LOW    MED     HI NSTEPS FASTSTEP GRAT_WDTH   CAL_FILE
1    102.0   210.0   2500    360    240     48       16      6700   SPEC_RSRF_Red
2     71.0    98.0   2500    282    188     48       16      6800   SPEC_RSRF_Blue_LW
3     55.0    73.0   2400    252    168     48       16      6900   SPEC_RSRF_Blue_SW
4    102.0   210.0   3600   2500   1200      0        0      6700   SPEC_SED_params
5     55.0    73.0   3750   2400   1250      0        0      6800   SPEC_SED_params
```

```
6     60.0    73.0   3600   2500   1200      0         0       6700   SPEC_SED_params
23    60.0    73.0   2400    252    168     48        16       6900   SPEC_RSRF_Blue_SW
L1   103.0   210.0   2500    360    240     43        16       6700   SPEC_RSRF_Red
L2    73.0    98.0   2500    282    188     46        16       6800   SPEC_RSRF_Blue_LW
L3    55.0    73.0   2400    252    168     48        16       6900   SPEC_RSRF_Blue_SW
K1   103.0   210.0   2500    360    419     16        16       6700   SPEC_RSRF_Red
K2    73.0    98.0   2500    282    425     16        16       6800   SPEC_RSRF_Blue_LW
K3    55.0    73.0   2400    252    431     16        16       6900   SPEC_RSRF_Blue_SW
```

## A.4 KEY_WAVES

```
# Missionphase  : Operations
# Purpose       : List KeyWavelengths to be used with a given order
# Description   : This Table is used to generate a list of KeyWaves from a
#                 list of UserWaves
# Comments      : Acces key is grating order. Each row contains nWAVE KeyWave
#                 values (unused COLs are 0.0 filled)
#
string  int    double    double    double    double    double    double
order   nWAVE  KeyWave1  KeyWave2  KeyWave3  KeyWave4  KeyWave5  KeyWave6
3        1      58.86      0.0       0.0       0.0       0.0       0.0
2        1      88.28      0.0       0.0       0.0       0.0       0.0
1        2     143.55    176.57      0.0       0.0       0.0       0.0
```

## A.5 OBCP13params

```
# Missionphase  : Operations
# Purpose       : Predetermined values for confOBCP data structure
# Comments      : Follows (almost) column by column contents of confOBCP13
# The table is accessed by the grating order
#
int     int         int         int               int
order   nb_up_down  nb_SRC_OFF  nb_ramps_plateau  nb_CS1_CS2
1       1           0           1                 1
2       1           0           1                 1
3       1           0           1                 1
```

## A.6 CHOPPERparams

```
# CVS file      : CHOPPERCSparams
# Purpose       : Gives chopper positions to "see" the internal CSs
# Author        : Diego A. Cesarsky
# Description   : Plain ASCII table. Gives the chopper angular displacement
#                [ENG] to see CS1 and CS2; values for SPEC and PHOT
# Comments      :
# Version : 0.1  11-may-2006 DAC
#           0.2  26-mar-2007 FM values for CSn/chopper
# Start of Table:
string   int   int
SubSystem   pos_CS1   pos_CS2
SPEC   21200   -21350
PHOT   21200   -21350
```

## A.7 SPEC_CHOP_params

```
# CVS name     : SPEC_CHOP_params
# Missionphase : Operations
# Type         : CAL-U table
```

```
# Purpose      : Gives chopper SRC, REF1, and REF2 based on HSPOT choice
# Description  : Chopper throw parameters indexed by HSPOT's
# string throw = "large" in ["large", "medium", "small"]
#
string     double   double   double
throw         SRC     REF1     REF2
small       -30.0     30.0     30.0
medium      -90.0     90.0     90.0
large      -180.0    180.0    180.0
offraster     0.0      0.0      0.0
```