SUBJECT: SPIRE Peak-up Mode Requirements

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1. INTRODUCTION

1.1 Scope

The feasibility and implementation of a peak up mode for SPIRE has been discussed in RD01. This document describes the operational implementation of such a mode in terms of the instrument commanding and on-board processing required.

1.2 Documents

1.2.1 Applicable Documents

AD01 IID Part A (SCI-PT-IIDA-04624), Issue 3.3
AD02 SPIRE Data ICD (SPIRE-RAL-PRJ-001078), Issue 2.0

1.2.2 Reference Documents

RD01 Peakup mode implementation and simulation (SPIRE-RAL-NOT-001968), Issue 1.0, 22nd March 2004

2. PEAK-UP PROCEDURE

RD01 proposes that the position of the peak of a source may be found by obtaining samples of the source signal in positions forming a cross in the CHOP and JIGGLE directions. In order to determine the source signal the BSM will be chopped at each position and detector data taken at both on and off source positions. The OBS has the task of taking the data generated and calculating the offset from the current pointing position to the position of maximum signal. This offset is then used either to issue an event to trigger an update of the telescope pointing or to set an offset for the BSM centre position (the former is the current nominal action).

Note: RD01 assumes that he source is 'well behaved' – i.e. the source is significantly larger than any change in background signal across the scanned area and that there are no significant instrument changes (e.g thermal drifts) that affect the sensitivity of the central pixel during the observation. If this is not the case then a revised algorithm may be necessary.

As a general rule the OBS does not look into the science data that it receives from the DRCU and just formats and packages it into telemetry packets to be sent to the ground. In this case, however, it is necessary for the OBS to deal with the science data contents. To do this the OBS must be in control of the data collection so that it is aware of what data is taken and when the data will arrive in the data stream from the DRCU. This will be done by implementing the peak-up operation as a single PERFORM_PEAKUP command executed by the OBS, and passing the necessary information as arguments of the command (these arguments cannot be defined a priori as they may depend on the source).

PKP-PRO-010: The OBS shall provide a single PERFORM_PEAKUP telecommand for implementation of the peak-up operation. *This will be implemented as a TC(8,4) command with FunctionID = 0xC0 and ActivityID = 0x40*..

The format of the PERFORM_PEAKUP command to the OBS is detailed in AD02. The list of arguments to the command are reproduced here to allow easier understanding of the following procedure:

1. DCUDATAMODE – defines the DCU data frame type to be generated
2. PIXEL – location of pixel to be used in the DCU data frame
3. STARTCHOPPOSN – minimum chop position value
4. CHOPPOSNINCR – increment in BSM chop position value between observations on the chop axis
5. NCHOPPOSNS – number of positions on chop axis to observe
6. STARTJIGGPOSN – minimum jiggle position value
7. JIGGPOSNINCR - increment in BSM jiggle position value between observations on the jiggle axis
8. NJIGGPOSNS – number of positions on jiggle axis to observe
9. CHOPOFFSET – offset in chop axis to 'off-source' position when chopping
10. JIGGOFFSET – offset in jiggle axis to 'off-source' position when chopping
11. NCHOPCYCLES
12. CHOPCYCLEPERIOD
13. NBSMFRAMES – number of BSM frames generated at each chop position
14. NDCUFRAMES – number of DCU frames generated at each chop position
15. DCUFRAMESDELAY – time delay before sampling DCU data at each chop position
16. CHOPSCALE – converts distance between each observing position on the chop axis to output units
17. JIGGSCALE – converts distance between each observing position on the jiggle axis to output units
18. OUTPUT – determines if a S/C or BSM offset is required (0 = S/C, 1 = BSM)

Note: Output units on both axes are fixed at 1/100 arcsecs for S/C offseting

During an observation, the Peak-up procedure will, therefore, consists of the following:

1. Stop the DCU and MCU science data generation (The OBS will not need data from the SCU so it is not necessary to stop this data stream)
2. Flush the DCU and MCU FIFO (This clears all detector data from the DPU buffers)
3. Set the DCU Sampling frequency
4. Set the BSM sample frequency

5. Send a (PERFORM _PEAKUP) command to the instrument to start the Peak-up operation – the result is either a TM event packet causing the telescope to move to the correct position or an update to the BSM centre position.
6. Wait (TBD) seconds for the operation to be completed

The observation may then be continued – note the BSM Offsets should be set back to zero at the end of the observation

Performing the procedure in this way puts constraints on the parameters of the PERFORM_PEAKUP command and the OBS should check that these constraints are met before starting the peak-up operation and if any check fails the OBS should issue an event

PKP-PRO-020: The OBS shall check that the following constraints on the Peak-up command arguments are met:

1. The DCU data generated by each chop operation executed as part of the peak-up operation shall be less than one half of the DCU FIFO size. *This ensures that the DCU 'FIFO half full' interrupt is never triggered by the observation. Thus the OBS can be sure that the data it requires is available in the FIFO when it needs to read it.*
2. The combination of the number of positions in one axis of the observed cross and the scaling factor shall not generate an offset exceeding the maximum allowed (10 arcsec). i.e int(*NCHOPPOSNS/2) * CHOPSCALE must be less than 1000 and int(NJIGGPOSNS/2) * JIGGSCALE must be less than 1000.*
3. *NCHOPPOSNS and NJIGGPOSNS shall be odd numbers*

PKP-PRO-030: In the event that a constraint check fails the OBS shall issue an information event , TM(5,1) and abort the operation

PKP-PRO-040: As a result of the PERFORM_PEAKUP command, it shall be possible for the OBS to generate a TM(5,1) event indicating the offset to be applied to the telescope pointing

The format of the TM(5,1) event packet (Peak-Up Report) to be issued by the Peak-up command is detailed in both AD02 and the appendix.

PKP-PRO-050: As a result of the PERFORM_PEAKUP command, it shall be possible for the OBS to set the offset for the BSM centre position. *This offset will be used by all subsequent BSM operations.*

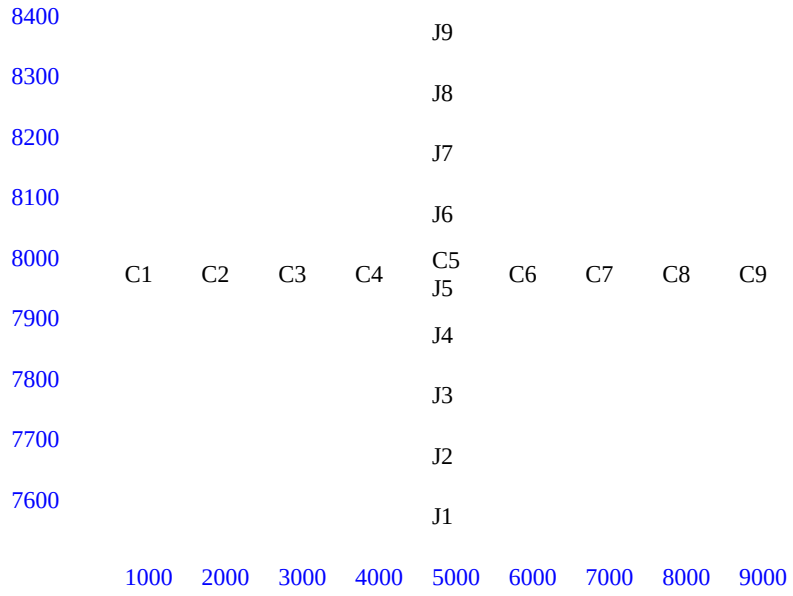
PKP-PRO-060: It shall be possible for a Command List to read the BSM Offset positions

PKP-PRO-070: The OBS shall issue an TM(5,1) event if it is unable to determine the offset from the peak-up operation.

3. PEAK-UP OPERATION

3.1 Visited Positions

Following RD01, the Peak-up operation has to take data at positions corresponding to a cross, in the Chop and Jiggle directions, centred on the position corresponding to the central pixel lying on the source position.
For example for a 9 x 9 cross the following pattern will be covered:



The positions to be sampled are defined by the following parameters to the Peak-up command

- STARTCHOPPOSN
- CHOPPOSNINCR
- NCHOPPOSNS ($\mathbf{N_{chop)}}$
- STARTJIGGPOSN
- JIGGPOSNINCR
- NJIGGPOSNS ($\mathbf{N_{jigg)}}$

For example the operation shown above would be described by
STARTCHOPPOSN = 1000
CHOPPOSNINCR = 1000
NCHOPPOSNS = 9
STARTJIGGPOSN = 7600
JIGGPPOSNINCR = 100
NJIGGPOSNS = 9

The order in which the positions are visited is not specified

3.2 Data at each position

The data taking at each position will be done using the CHOP Command List. This takes the following parameters:

1. Chop on-source position - determined in section 3.1

2. Jiggle on-source position - determined in section 3.1
3. Chop off-source position = Chop on-source position + CHOPOFFSET
4. Jiggle off-source position = Jiggle on-source position + JIGGOFFSET
5. Number of Chop Cycles ($\mathbf{N_{cycles}}$) = NCHOPCYCLES
6. Period of Chop cycle = CHOPCYCLEPERIOD
7. DCU Frame Type = DCUDATAMODE
8. No of DCU frames per Chop position ($\mathbf{N_{DCU}}$) = NDCUFRAMES
9. Delay from chop movement to start of DCU frames = DCUFRAMESDELAY
10. No of BSM fames per Chop position = NBSMFRAMES

Each execution of the CHOP Command List will generate $\mathbf{N_{DCU}}$ DCU frames on-source followed by $\mathbf{N_{DCU}}$ DCU frames off-source, repeated $\mathbf{N_{cycles}}$ times. These will be collected into the DCU FIFO.

Each frame contains a single sample for each pixel in the DCU array being sampled. The value of the argument PIXEL gives the offset in (16 bit) words into the frame from the start of the frame (including the Block Length and Frame ID). For example if the PSW array is being sampled the first detector sample is at PIXEL=2.

The OBS may therefore extract the value from each frame for the pixel of interest.

4. PEAK-UP CALCULATION

PKP-CAL-010: The OBS is then required to execute the following algorithm to obtain the position of maximum signal in the Chop and Jiggle directions (**ChopIndex** and **JiggleIndex)**:

1. Set **JiggleSignal** = 0
2. Set **JiggleIndex** = 0
3. Set BSM Offset values to 0
4. Set **sample** = 0
5. For j = 0 to NJIGGPOSNS
    a. Flush DCU FIFO
    b. **ChopPosn =** STARTCHOPPOSN + (int(**N_{chop}** /2) * CHOPPOSNINCR)
    c. **JigglePosn =** STARTJIGGPOSN + (j ***** JIGGPPOSNINCR)
    d. Execute CHOP(**ChopPosn, JigglePosn, ChopPosn +** CHOPOFFSET **, JigglePosn +** JIGGOFFSET**, N_{cycles} ,** CHOPCYCLEPERIOD, DCUDATAMODE, NDCUFRAMES, DCUFRAMESDELAY, NBSMFRAMES)
    e. For **N_{cycles}**
        i. For **N_{DCU}** frames
            1. Add the value for pixel PIXEL to **sample**
        ii. For **N_{DCU}** frames
            1. Subtract the value for pixel PIXEL from **sample**
    f. If **sample** is greater than **JiggleSignal**
        i. **JiggleSignal** = **sample**
        ii. **JiggleIndex = j**
6. Set **ChopSignal** = 0
7. Set **ChopIndex** = **0**
8. Set **sample** = 0
9. For c = 0 to NCHOPPOSNS
    a. Flush DCU FIFO
    b. **JigglePosn =** STARTJIGGPOSN + (int(**N_{jigg}** /2) * JIGGPOSNINCR)
    c. **ChopPosn =** STARTCHOPPOSN + (c ***** CHOPPOSNINCR)
    d. Execute CHOP(**ChopPosn, JigglePosn, ChopPosn +** CHOPOFFSET **, JigglePosn +** JIGGOFFSET**, N_{cycles} ,** CHOPCYCLEPERIOD, DCUDATAMODE, NDCUFRAMES, DCUFRAMESDELAY, NBSMFRAMES)
    e. For **N_{cycles}**
        i. For **N_{DCU}** frames
            1. Add the value for pixel PIXEL to **sample**
        ii. For **N_{DCU}** frames
            1. Subtract the value for pixel PIXEL from **sample**
        iii. If **sample** is greater than **ChopSignal**
            1. **ChopSignal** = **sample**
            2. **ChopIndex = c**
10. Flush DCU FIFO
11. If OUTPUT = 0
    a. **ThetaY =** (int(**N_{chop}** /2) - **ChopIndex**) * CHOPSCALE
    b. **ThetaZ =** (int(**N_{jigg}** /2) - **JiggIndex**) * JIGGSCALE
    c. If (abs(**ThetaY)** < 1000) and (abs(**ThetaZ**) < 1000) // check offsets are less than 10 arcsecs
        i. Issue TM(5,1) S/C Offset event
    d. Else
        i. Issue TM(5,1) Peak-up failure event
12. Else
    a. **BSMChopOffset** = (int(**N_{chop}** /2) - **ChopIndex**) * CHOPPOSNINCR
    b. **BSMJiggOffset** = (int(**N_{jigg}** /2) - **JiggIndex**) * JIGGPOSNINCR
    c. Store **BSMChopOffset** in BSM Chop Offset Value
    d. Store **BSMJiggOffset** in BSM Jiggle Offset Value

PKP-CAL-020: The OBS will issue an TM(5,1) event packet to notify the telescope of the movement required The contents of the event packet are defined in the Appendix. The format of the event packet is:

0 0 0 0 1	APID1
1 1	Count
Length =31	
0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1	
0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0	
TIME	
EVENTID = 0x0504	
SID = 0x5101	
OBSID	
BBID	
EVENTCOUNT	
INSTRID	
THETAY	
THETAZ	
Checksum	

Parameter	Comment
EVENTID	0x0504
SID	0x5101
OBSID	Observation ID
BBID	Building Block ID
EVENTCOUNT	Sequential counter for TM(5,1) events
INSTRID	Instrument ID = 0x0002
THETAY	Rotation angle about Y axis (= **ThetaY**
THETAZ	Rotation angle about Z axis (= **ThetaZ**)

APPENDIX

1. FORMAT OF PEAK-UP EVENT PACKET TO BE GENERATED BY SPIRE

This definition comes from IID Part A (section 5.12.5)

SPIRE uses an event packet (service TC(5,2)) to command the spacecraft a new pointing target based on:
- the previous inertial target (inertial pointing only)
- two µ-rotation angles (<10 arcsec) derived from the peak-up packet

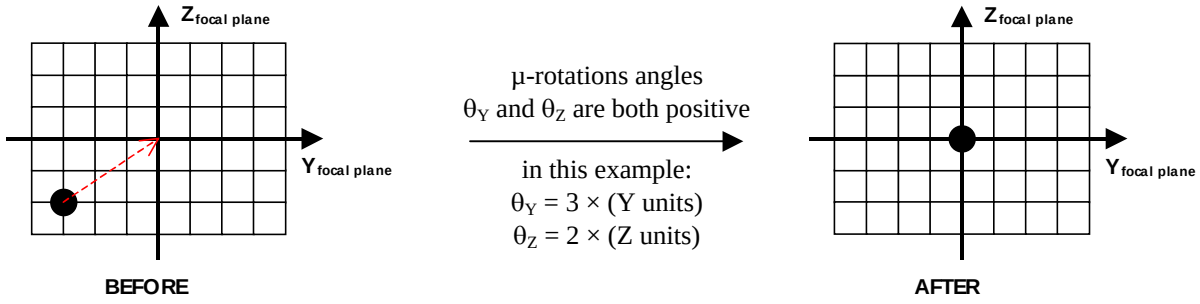
In order to have a consistency between the spacecraft and the instruments, and to have the same interface for both HIFI and SPIRE, the following interface is defined:

The event packet shall contain the following parameters:
- the relevant instrument (HIFI or SPIRE), coded on 16 bits (HIFI: 1, SPIRE: 2)
- the µ-rotation angle θ_Y, coded on 16 bits (see format below)
- the µ-rotation angle θ_Z, coded on 16 bits (see format below)

The normal to the focal plane is X, positively oriented as for the satellite X axis.

Sign convention:
The commanded µ-rotation angles correspond to the desired translation of the image inside the instrument focal plane frame. Note that with this convention, θ_Y (resp. θ_Z) does not represent the rotation around Y (resp. Z).

The signs shall follow this convention:



1.1 Absolute value convention:

The absolute value of both µ-rotation angles shall be given as 16-bit signed integers.
In accordance with the PS-ICD:
- bit 0 shall be the most significant bit
- bit 15 shall be the least significant bit

Bit 0 shall be used as the sign bit (0 for plus, 1 for minus)

1.2 Format of SPIRE packet parameters:

SPIRE identifier																µ-rotation angle Y																µ-rotation angle Z															
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	M	.	.	.	.	.	.	.	.	.	.	.	.	.	L	M	.	.	.	.	.	.	.	.	.	.	.	.	.	L

Additional information required from instruments:
Some data are needed by the spacecraft to transform the peak-up parameters into attitude angles. They may be reprocessed by the ground after in-flight calibration.
The following set shall be provided for each instrument.

- $\mathbf{Y_{FP}}$ = 3 components of $Y_{\text{focal plane}}$ in satellite frame
- $\mathbf{Z_{FP}}$ = 3 components of $Z_{\text{focal plane}}$ in satellite frame
- $\mathbf{k_Y}$ = value of low significant bit used for µ-rotation angle Y, to transform integer θ_Y into radians. Angle [in rad] = k × integer.
- $\mathbf{k_Z}$ = value of low significant bit used for µ-rotation angle Z, to transform integer θ_Z into radians. Angle [in rad] = k × integer.