HIFI Spacecraft-Instrument Alignment Matrix (SIAM)

Issue 1.0 of 2/10/2008, by W. Jellema

Abstract

This document describes the definition and contents of the HIFI SIAM.

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Document approval

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Revision history

Version	Date	Changes	Author
Draft 0.1	17/4/2008	New document	W. Jellema
Issue 1.0	2/10/2008	Added new section 4.1.3 to illustrate HIFI apertures at the sky. Added introduction to section 4 clarifying the distinction between this document, future SIAM release notes and the actual content of the SIAM.	W. Jellema

Applicable documents

Doc. ref.	Title

Reference Documents

Doc. ref.	Title
RD-1	ICD: Herschel Spacecraft / Instrument Alignment History, PT-HMOC-FD-ICD-2111-OPS-GFT, Issue 1.3, 7 October 2006
RD-2	Herschel Pointing Calibration Plan – Calibration Plane for Commissioning and PV Phases, HERSCHEL-HSC-DOC-1139, Issue Draft 0.1, 16 April 2008
RD-3	Quasi-Optical Beam Parameters in the HIFI Focal-Plane, SRON-G/FPU/TN/2006-1, Issue 1.0, 21 October 2007
RD-4	HIFI Instrument Interface Document Part B, SCI-PT-IIDB/HIFI-02125, Issue 3.3, 21 October 2005
RD-5	FM FPC Users Manual, FPSS-01000, Issue 1, 3 January 2007
RD-6	Herschel Telescope Specification, SCI-PT-RS-04671, Issue 7/0, 26 July 2004

Contents

1 Introduction

1.1 Purpose of document

The pointing offsets between the instrument lines of sight and the Attitude Control and Measurement System (ACMS) coordinate system are contained in the Spacecraft-Instrument Alignment Matrix (SIAM). This interface is controlled per ICD (RD-1). The SIAM is required to point the telescope along the desired instrument line of sight. Nominal ground-based pointing information will be contained in the SIAM prior to the Focal Plane Geometry (FPG) calibration carried out in the COmmission Phase (COP) after which the SIAM is subject to regular updates following subsequent pointing calibration activities (RD-2). This document defines the HIFI SIAM and contains the data for the SIAM release to date.

1.2 Nominal Focal Plane Geometry

The nominal focal plane geometry of the HIFI optics is described in RD-3. The situation is depicted in Fig. 1. HIFI has 7 mixer bands spatially separated along the spacecraft Y-axis (RD-4). Each mixer band contains two mixers operating on orthogonal polarizations, referred to as –H and –V designating Horizontal resp. Vertical mixer polarization, which are nominally co-aligned in the Focal Plane. The HIFI Focal Plane Chopper (RD-5) provides focal-plane chopping functionality for each band around its central postion with throw along the spacecraft Z-axis (RD-4). The two chopped positions which are separated by 1.5' at the sky are indicated in Fig. 1. together with the corresponding chopper rotation angle resp. focal plane position label "±Z".

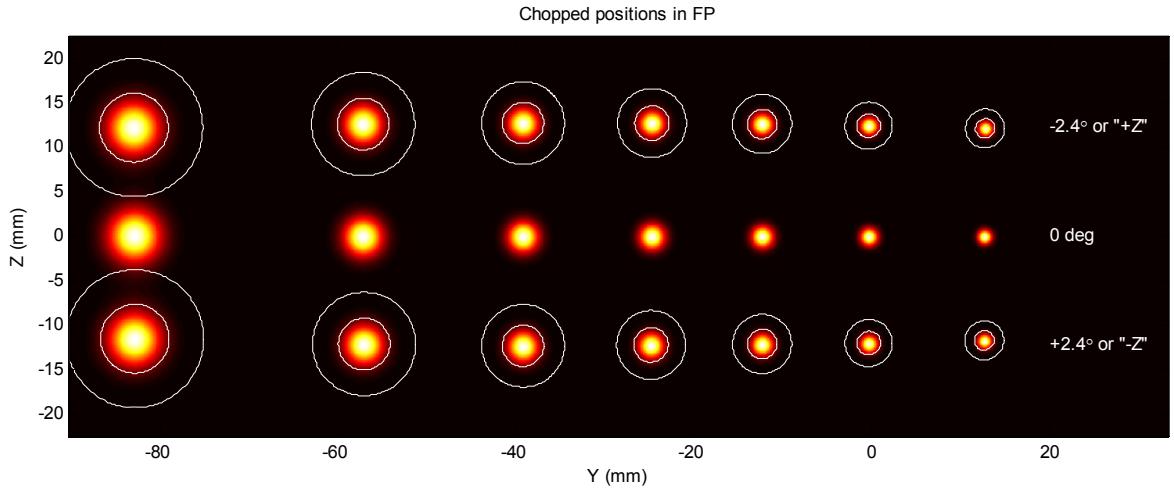

Figure 1 – Nominal Focal Plane Geometry of HIFI

2 Definition of the HIFI Apertures

The total number of apertures required by HIFI is defined as follows:

- HIFI has 7 independent mixer bands
- In each mixer band there are 2 LO subbands (frequency dependence)
- In each mixer band there are 2 mixers operating on orthogonal polarizations (polarization dependence)
- In each mixer band there are 2 relevant chopper positions (chopper dependence)

In each mixer band we therefore include frequency (2 sub-entries), polarization (2 sub-entries) and chopper (2 sub-entries) dependence in the SIAM. The total number of apertures to be included in the SIAM is therefore 7 x 2 x 2 x 2 = 7 x 8 = 56 entries.

2.1 Frequency dependence

It is verified by analysis that the HIFI beams are not frequency dependent as far as pointing is concerned. However, in each mixer band there are two LO subbands designated by “A” and “B” that subdivide the mixer bands into two LO frequency subbands. Since in each subband the mixers are pumped differently with possibly opposite balance, the H/V mixer performance is generally different in each LO subband.

2.2 Polarization dependence

Nominally the –H and –V mixers are co-aligned. Furthermore the balance of mixer performance is generally good enough to allow for co-adding the spectra observed through the individual mixers channels. Ground measurements however reveal that actual pointing offsets can be as large as 10-20% of the FWHM in bands 1 to 5. In the worst-case scenario of observing point-like sources, one is therefore generally much better off when pointing at an average sky position than at one of the individual mixers and loosing aperture efficiency in the other (which can be as large as 7%). By default we therefore define a synthesized pointing entry, labelled as “S”, for co-added –H and –V spectra for which we point somewhere in between the –H and –V sky positions. Nominally we define the synthesized position S as the average H/V pointing, but together with the frequency dependence described above, this dimensionality of the SIAM allows in principle for future sensitivity-weighted synthesized pointing refinements. Apart from the default S entry in the SIAM we nominally use the H mixer as the second sub-entry. This choice is based on the fact that the –H mixer is on average the most sensitive mixer channel and because the comb-generator of the WBS-H spectrometer is strongest and expected to have the longest lifetime.

2.3 Chopper dependence

For observing modes not employing focal-plane chopper functionality the default position is the central position on M3 (pick-up mirror) in Fig. 1. The (primary) chopped position (the position from where the beam is thrown by 1.5' at the sky to the other (secondary) chopped position) is chosen to coincide with the mechanical rest position of the focal plane chopper. This mechanical rest position of the chopper nominally coincides with the "-Z" or "+2.4°" position (towards the internal Calibration Source Assembly) in the HIFI Focal Plane.

3 Definition of HIFI SIAM format

3.1 SIAM entry allocation and indices

According to the SIAM ICD (RD-1) the HIFI SIAM entries are labelled by Hnm_s where n, m and s are indices of the matrix. Note that s refers to Solar Aspect Angle (SAA) dependence of the pointing which we assume to be negligible. Therefore we nominally set s to 0 which corresponds to no SAA dependence (this is presently assumed by all three instruments, the SAA dependence assumption will however be verified as described in RD-2 and the SIAM in principle allows for SAA dependence to be included at a later stage). The main indices into the SIAM matrix used by HIFI are therefore n and m. We use n to refer to the active mixer band. The remaining index m (non-zero positive integral index) is composed on the basis of the bit pattern of a 3-bit number. If we denote the least-significant bit by p, the next significant bit by f and the most-significant bit by c, then $m = 1 + c * 2^2 + f * 2^1 + p * 2^0$, where p = polarization (0 = S, 1 = H), f = frequency (0 = LO subband A, 1 = LO subband B) and finally c = chopper (0 = M3 center, 1 = chopped). The HIFI aperture naming schema can therefore be summarized as follows:

- Aperture coding Hnm_s
- Default s = 0 (no SAA dependence)
- Index n = HIFI band (1, 2, …, 7)
- Index m = 1 + 3 bit number = $1 + c * 2^2 + f * 2^1 + p * 2^0$ with:
  - Least-significant bit p = polarization (0 = S, 1 = H)
  - Next significant bit f = frequency (0 = LO subband A, 1 = LO subband B)
  - Most-significant bit c = chopper (0 = M3 center, 1 = chopped)

3.2 Aperture identifier descriptions

The HIFI aperture identifiers Hnm_s as defined in RD-1 have descriptions as listed in Table 1 and 2 assuming no SAA dependence exists.

Table 1 – HIFI aperture identifier description along index n

Aperture identifier Hnm_0	n	Description
H1m_0	1	HIFI band 1
H2m_0	2	HIFI band 2
H3m_0	3	HIFI band 3
H4m_0	4	HIFI band 4
H5m_0	5	HIFI band 5
H6m_0	6	HIFI band 6
H7m_0	7	HIFI band 7

Table 2 – HIFI aperture identifier description along index m

Aperture identifier Hnm_0	m	Bit pattern	Chopper	Frequency	Polarization
Hn1_0	1	000	M3 center	LO subband A	S(ynthesized)
Hn2_0	2	001	M3 center	LO subband A	H(orizontal)
Hn3_0	3	010	M3 center	LO subband B	S(ynthesized)
Hn4_0	4	011	M3 center	LO subband B	H(orizontal)
Hn5_0	5	100	Chopped	LO subband A	S(ynthesized)
Hn6_0	6	101	Chopped	LO subband A	H(orizontal)
Hn7_0	7	110	Chopped	LO subband B	S(ynthesized)
Hn9_0	8	111	Chopped	LO subband B	H(orizontal)

4 Example SIAM Data File Contents

4.1 Introduction

The actual HIFI SIAM is a deliverable to HSC and the SIAM files themselves will be maintained and distributed separately from this document with their own release notes. For illustration purposes only the description of the initial and nominal HIFI SIAM is provided in this document. As future updates of the SIAM might involve a completely different method of generation, using e.g. SIAM information from the other Herschel focal-plane instruments, we would already here like to refer to the specific release notes that will go with the delivery of future SIAM versions.

4.2 Release 0000_0001

4.2.1 Release notes

Filename:	0000_0001.SIAM
Description:	HIFI nominal SIAM
Date of generation:	2008-04-11, 11:41:43
Valid from:	2008-04-01, 00:00:00
Changes:	First HIFI SIAM release. Nominal SIAM based on nominal FP coordinates assuming no SAA dependence.

4.2.2 Method of generation

Assuming a nominal telescope focal length of f = 28.5 m (RD-6) the positions in the focal plane can be converted to pointing offsets at the sky through θ_Y = +atan (Z/f) and θ_Z = -atan (Y/f), where θ_Y, θ_Z are the Euler rotation angles around the nominal Y resp. Z axis of the spacecraft coordinate system. We assume that there is no rotation around the X axis. The Direction Cosine Matrix (DCM) is then calculated as a 3-2-1 Euler rotation matrix, i.e. DCM = M_Z * M_Y * M_X.

For the nominal HIFI SIAM generated for this release we assume:

- No polarization dependence: matrix for S = matrix for H.
- No frequency dependence: matrix for LO subband A = matrix LO subband B
- Chopper dependence: values taken from RD-3, see also section 2.3 and 3.

4.2.3 Sky positions of HIFI apertures

The data taken from RD-3 can be represented at the sky as listed in tables 3 and 4 and as shown in figure 2. In table 3 and 4 the indices m and n corrrespond to their definition provided in section 3.1. In figure 2 all positions are shown as well as their FWHM and 2 * FWHM contours.

Table 3 – Sky positions of HIFI apertures: micro-rotations θ_Y about Y in arcsec.

m \ n	1	2	3	4	5	6	7
1	0.8	-0.1	-0.1	0.0	0.0	0.0	0.0
2	0.8	-0.1	-0.1	0.0	0.0	0.0	0.0
3	0.8	-0.1	-0.1	0.0	0.0	0.0	0.0
4	0.8	-0.1	-0.1	0.0	0.0	0.0	0.0
5	-83.1	-87.7	-88.7	-88.6	-87.8	-86.5	-84.6
6	-83.1	-87.7	-88.7	-88.6	-87.8	-86.5	-84.6
7	-83.1	-87.7	-88.7	-88.6	-87.8	-86.5	-84.6
8	-83.1	-87.7	-88.7	-88.6	-87.8	-86.5	-84.6

Table 4 – Sky positions of HIFI apertures: micro-rotations θ_Z about Z in arcsec.

m \ n	1	2	3	4	5	6	7
1	600.2	413.6	283.8	179.1	88.8	2.0	-92.2
2	600.2	413.6	283.8	179.1	88.8	2.0	-92.2
3	600.2	413.6	283.8	179.1	88.8	2.0	-92.2
4	600.2	413.6	283.8	179.1	88.8	2.0	-92.2
5	599.9	413.6	283.8	179.2	88.8	2.1	-92.0
6	599.9	413.6	283.8	179.2	88.8	2.1	-92.0
7	599.9	413.6	283.8	179.2	88.8	2.1	-92.0
8	599.9	413.6	283.8	179.2	88.8	2.1	-92.0

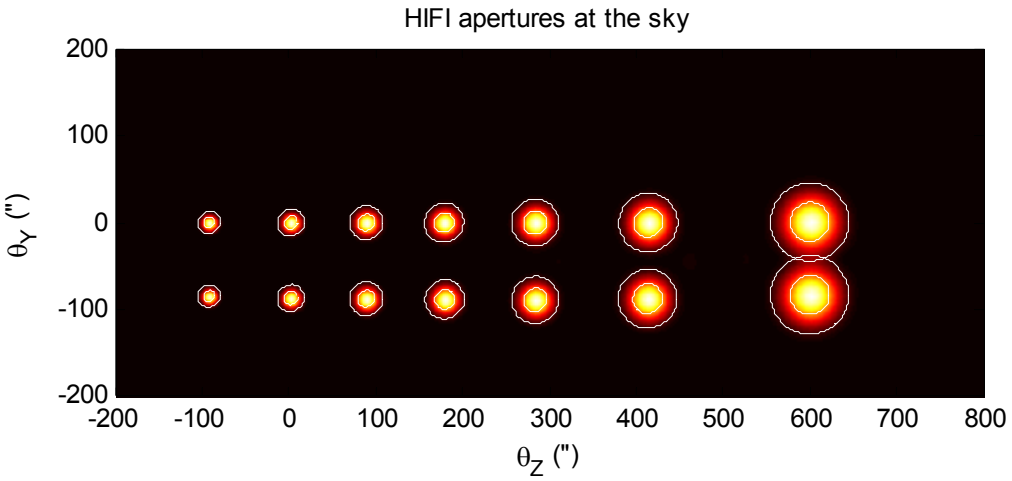

Figure 2 – Chopped and central positions of HIFI at the sky.

4.2.4 Data file contents

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0000_0001.SIAM.dat

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