Derivation of PAA(M) alignment and actuation angles

Issue1 - Revision 1

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1 INTRODUCTION

The purpose of this technical note is to address lingering concerns regarding the correctness of the specification of the sign and orientation of the static offset angle of the TX beam point ahead and subsequently the point ahead mechanism on the optical bench assembly of the LISA IDS.

For this purpose, a minimalistic ray-tracer has been implemented that is simple enough for everyone to check easily for correctness, but still captures fully the effect of 3D coordinate transformations and surface angles.

2 INPUTS

2.1 Orbit and Constellation

All assessments made in this document are valid for the point ahead requirement associated with a “clockwise” orbit. That is a constellation that appears to be rotating clockwise about its barycenter when viewed from the heliocentric origin (aka the sun).

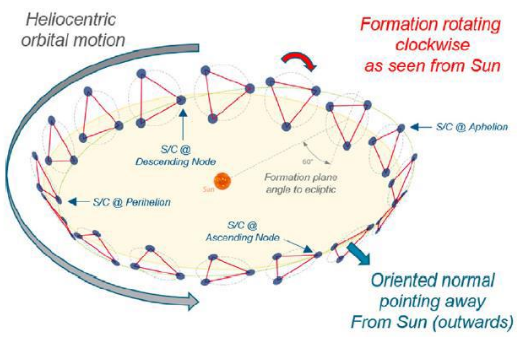

Figure 1: Overview of constellation motion for clockwise rotation (baseline) – from [RD2]

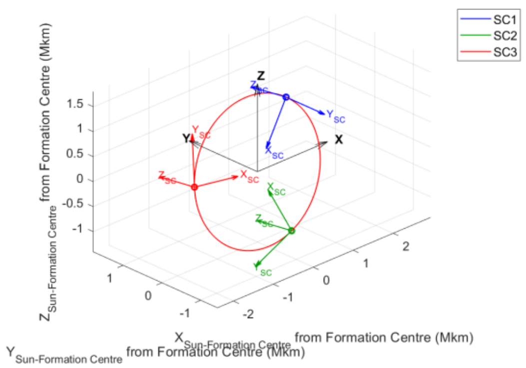

Figure 2: Spacecraft coordinate frames within the constellation – from [RD2]

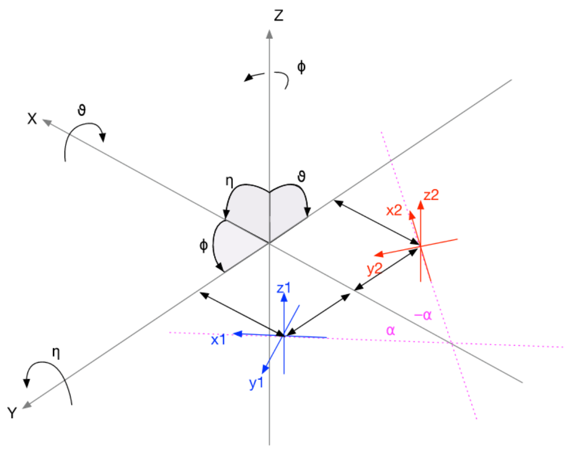

Figure 3: Nominal TM and SC reference frames - from [RD1]

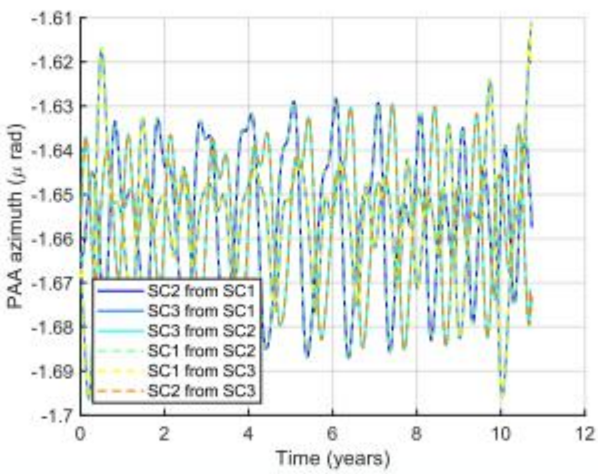

Figure 4: Point Ahead Azimuth in SC Frame, CW Orbits – from [RD2]

Figure 4 shows the resulting point ahead azimuth which is per definition [RD2]:

Point Ahead azimuth (angle in XY_{SC} plane, measured from RX direction, positive around $+Z_{SC}$)

These definitions and statements form the basis of the subsequent analysis.

2.2 Coordinate frames

Going from the point ahead angle in the SC frame down to the individual PAAM on the OB involves the following chain of elements which each can in principle introduce a change in the angle either from physics or convention that can ultimately lead to a wrong derived requirement.

- SC FRAME
- MOSA FRAME
- Telescope Transformation
- OB Frame
- OB elements in TX path

- PAAM

The important part here is to assert the co-alignment of all frames with the spacecraft Z axis which is the important reference for the initial specification of the point ahead angle [RD2]. This ensures that in the OB frame e.g. a negative Z point ahead angle is still a negative Z point ahead angle.

This assertion of this condition(s) can be made according to the following table:

IDS.DEF_SYS_140: requires the OB_MRF to be matched to the MOSA MRF

This needs to go with a requirement to have the Z axis of the MOSA and SC frames coaligned. This is assumed to be in place in the SC-PL-IRD???? … i.e. if the MOSA (or one of the MOSAs would be put into the SC upside down with respect to the other , the point ahead scheme would not work as intended.

However, the requirement to the IDS is now already specified in terms of the OB MRF

The IDS shall provide a static point-ahead angle offset between the TX and RX beams in the Phi degree of freedom of the OB MRF.

This means that effectively the responsibility for the correct SC->MOSA->OB flow down of the transformations is ultimately not IDS responsibility..

In the end, what really matters is the transformation that is applied to redirect the TX beam flying parallel to the optical bench away from the optical bench and towards the telescope interface.

??? are there any other possible optical configurations that could potentially be on the OB which would lead to a inversion of the beam angles at any point in the optical path

3 ANALYSIS

3.1 Definition of Reflection Matrix

The following Reflection Matrix definition is used to calculate the reflections in the optical path that is being studied:

$$R_N^K = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} - 2 \cdot \begin{bmatrix} n_x \\ n_y \\ n_z \end{bmatrix} \cdot \begin{bmatrix} n_x & n_y & n_z \end{bmatrix}$$

With K denoting the Frame of Reference in which the reflection is being defined (e.g OB), and N being a unique identifier (e.g. PBS1).

3.2 Definition of Transformation Matrix

3.3 Definition of PAAM Rotation Matrix

3.4 Definition of Surface Normals and Trace Path

3.5 Postprocessing

4 DISCUSSION

5 DERIVED REQUIREMENTS

In order to guarantee the correctness of the analysis presented so far, the following requirements need to be placed on the respective systems / subsystems:

6 CONCLUSIONS AND RECOMMENDATIONS

To be written

BIBLIOGRAPHY

[RD1] LISA-LCST-MIS-ST-001_Top-Level Nomenclature and Conventions in LISA_1.0

[RD2] ESA-LISA-EST-MIS-HO-034_ LISA Point Ahead Angle Corrections for Clockwise and Counterclockwise Formations_1.0

[RD3]