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Author(s):
Meshksar, Neda; Ferraioli, Luigi; Mance, Davor; Ten Pierick J.; Zweifel, Peter

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GRS vs. OMS Calibration in LISA Pathfinder Data Analysis

Neda Meshksar[1], Luigi Ferraioli[1], Davor Mance[1], Jan ten Pierick[2,1], Peter Zweifel[1] and Domenico Giardini[1] for the LISA Pathfinder Colaboration

[1] Department of Earth Sciences, ETH Zurich, Sonneggstrasse 5, 8092 Zurich, Switzerland
[2] Physik-Institut, University of Zurich,Winterthurerstr. 190, 8057 Zurich, Switzerland

E-mail: `neda.meshksar@erdw.ethz.ch`

Abstract. On board LISA Pathfinder spacecraft the test mass displacement along the main measurement axis is sensed in two different ways: optically and electrostatically. We have monitored the relative calibration between the two measurements during the mission science phase. The trend sensitivity of the relative calibration has been computed for different physical parameters, such as temperature, magnetic field, test mass bias voltage and current.

1. Introduction

LISA Pathfinder (LPF) spacecraft (SC) uses two test masses (TM) as proof bodies of the gravitational reference sensor (GRS). TM movement on board LISA Pathfinder SC is sensed according to the optical and electrostatic readout methods [1]. Based on optical readout method the optical metrology system (OMS) measures the displacement of the drag-free TM relative to the SC and also relative to the other TM, along the main measurement axis, labeled x. It also measures the rotation of both test masses around y and z. On the other hand, the GRS provides the electrostatic readout of the displacement and rotation along all degrees of freedom for both test masses.

We have monitored the data resulted from system identification experiments during the LPF science operation (March - June 2016) and we present the calibration of GRS measurements with respect to OMS for displacements along x-axis. The relative gain and relative offset have been obtained by a linear fit of GRS vs. OMS readout. We have excluded any straightforward correlation with temperature and non-linearity in the GRS electronics. We observed that the relative calibration gain does not obey a clear trend. The origin of such oscillation dependency is still under investigation.

2. Method overview

GRS provides an electrostatic measurement of the displacements of both test masses with respect to the SC. Along the main measurement axis, x, we label the TM1 and TM2 displacements x_1^{GRS} and x_2^{GRS}, respectively. The differential displacement along x is thus calculated as

$$x_{12}^{\mathrm{GRS}} = x_2^{\mathrm{GRS}} - x_1^{\mathrm{GRS}}. \tag{1}$$

On the other hand, the OMS does not directly sense the displacement of TM2. It measures the position of TM1 with respect to the SC and the differential displacement between the two test masses. The latter is labeled x_{12}^{OMS}. Thus, the displacement of TM2 along x with respect to the spacecraft is given by

$$x_2^{\mathrm{OMS}} = x_1^{\mathrm{OMS}} + x_{12}^{\mathrm{OMS}}. \tag{2}$$

Figure 1 illustrates GRS and OMS in the LISA Technology Package (LTP). A description of the coordinates is given in figure 2.

In order to compare the measured displacement by GRS and OMS we calibrate the data by means of a linear fit. A linear fit of the GRS data to the OMS data provides a gain and an offset, which are parameters for matching the GRS data to the OMS data:

$$x_i^{\mathrm{GRS}} = \mathrm{gain} \cdot x_i^{\mathrm{OMS}} + \mathrm{offset}, \quad i = 1, 2, 12 \tag{3}$$

Figure 1. Illustration of GRS and OMS in the LTP. In the nominal state the test masses are at the centre of the inertial sensors.

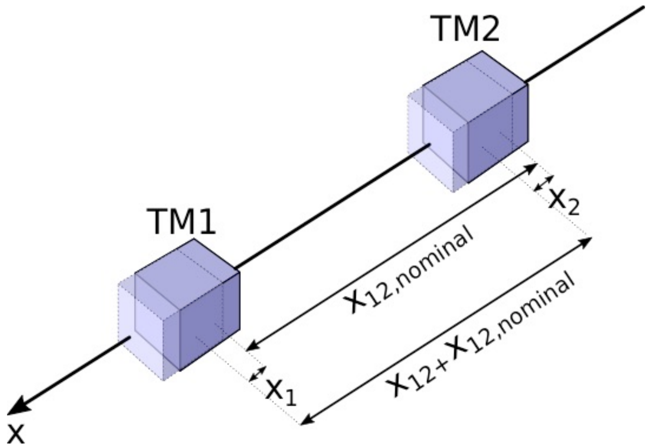

Figure 2. Illustration of test mass displacements and labelling the coordinates along the main measurement axis, x.

3. Observation

In order to understand any correlation of the gain with the other parameter, we have monitored the data resulted from the system identification experiments during the LPF science operation (March - June 2016). To calibrate the displacement for TM1 we used the data of drag-free injections [2]. For TM2 and also for the differential displacement, x_{12}, we used the data of suspension injections. The gain trend for x_1, x_2 and x_{12} obtained by the linear fit are reported in figure 3. The gain does not obey a clear trend as shown in the figure.

The gain dependency on the different parameters, such as the temperature, magnetic field, current and the TM bias voltage are investigated. Figure 4 shows the results for x_1. We cannot recognise any gain correlation with the temperature, magnetic field and the TM bias voltage. However, it seems that the gain has a correlation with the +5 V digital line consumption current in GRS. This correlation is still under investigation.

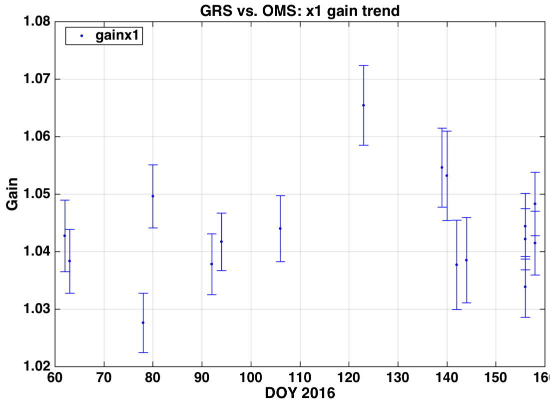

Figure 3. Gain trend resulted from the linear fit of GRS data to OMS data for TM1 (left-hand side), TM2 (right-hand side, red) and the differential displacement (right-hand side, blue).

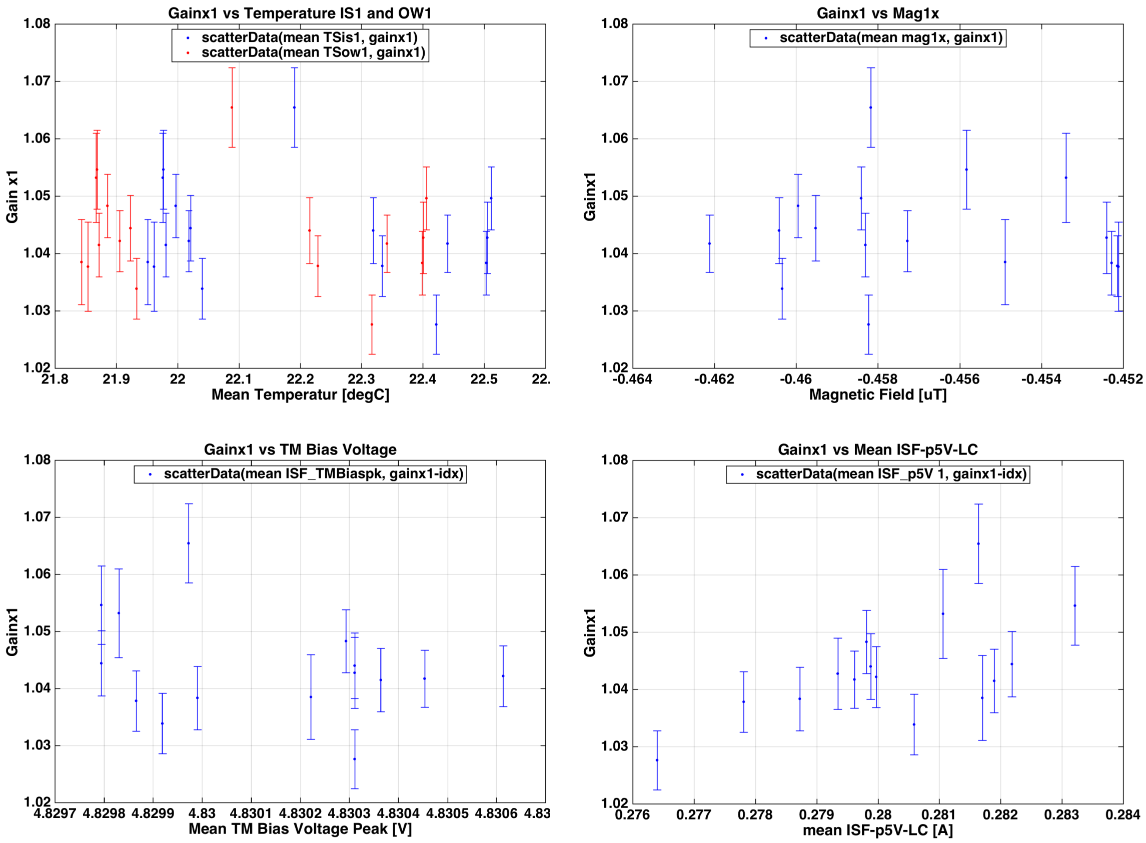

Figure 4. Gain trend for TM1 displacements with respect to the following parameters: temperature of the inertial sensors (left-hand side, top, blue), temperature of the optical window (left-hand side, top, red), TM bias voltage (left-hand side, bottom), magnetic field (right-hand side, top) and +5 V digital line consumption current in GRS (right-hand side, bottom).

4. Conclusion and outlook

We have investigated the time estimation of the relative calibration between GRS and OMS readout on board LISA Pathfinder spacecraft. The relative gain does not obey a clear trend. The observations do not show any straightforward correlation with the temperature, magnetic field and the test-mass bias voltage. The fluctuation of the gain trend and especially the effect of the GRS readout consumption current is still under investigation.

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