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The BepiColombo mission to Mercury and the Italian Spring Accelerometer (ISA) role in the Radio Science Experiments measurements

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Abstract

The BepiColombo mission to Mercury [1, 10] of the European Space Agency (ESA) aims to perform a set of experiments, the so called Radio Science Experiments (RSE), that will be devoted to the study of the gravity field and rotational state of Mercury [8] as well as to verify the theory of general relativity to an unprecedented level of accuracy [9]. One of the key ingredients in order to reach the very ambitious objectives of this mission, in the context of the RSE, is represented by the measurements of the onboard accelerometer [5, 2]. The Italian Spring Accelerometer (ISA) has been selected by ESA to measure and then allow to remove, *a posteriori*, the disturbing non-gravitational accelerations acting on the Mercury Planetary Orbiter (MPO) surface. This paper is devoted to describe the accelerometer characteristics and performance and to introduce some of the experimental procedures in order to calibrate its measurements on ground and during the nominal phase of the mission.

1. RSE and ISA measurements

The RSE are a complex mix of measurements and scientific objectives, and it is not possible to separate them neatly in independent experiments. These experiments are based, from one side, on a sophisticated and very precise tracking system [6], both in range and range–rate, that will use a full 5–way frequency link from Earth's ground stations to the MPO (X-band, Ka-band and a mixed mode). From the other side, a precise orbit determination software and procedure is needed in order to reconstruct the orbit of the MPO around Mercury, and of Mercury center–of–mass around the Sun, while solving in a complex least–squares fit for local and global parameters [8, 9].

The main target of ISA is to measure the complex and subtle non-gravitational accelerations in the strong radiation environment of Mercury, which is characterized by severe day/night asymmetries and a huge variation of the solar irradiance during the sidereal year of Mercury around the Sun. The non–gravitational accelerations are proportional to the area–to–mass ratio of the spacecraft, and are very difficult to be properly modeled for a complex in shape and active satellite like the MPO. Indeed, the modeling depends on a set of parameters related with the physical properties of the satellite surface and structure, which will be strongly influenced, and with completely unknown laws, by the strong radiation environment in the surroundings of Mercury. ISA allows to remove the non–gravitational accelerations from the equation of motion in such a way to reconstruct the pure gravitational orbit of a reference point of the accelerometer box. The strongest orbital disturbing effects are due to the direct solar radiation pressure [7], up to 10^{-6} m/s^2, with a main component at the orbital period of the MPO around Mercury, about 8,355 s. In order to reach their objectives, the RSE need an orbit accuracy reconstruction of about 10^{-8} m/s^2 in acceleration, over a time span equal to the orbital period of the MPO [3]. This acceleration corresponds to an along–track accuracy of about 1 m over the same time span.

ISA is a flexural harmonic oscillator [5, 2] with an intrinsic noise of about 10^{-9} m/s^2/$\sqrt{Hz}$ in the frequency band $3 \cdot 10^{-5} - 1 \cdot 10^{-1}$ Hz and a measurement accuracy of about 10^{-8} m/s^2. Therefore, ISA has all the characteristics in order to fulfill the RSE goals. ISA will be sensitive to all the non inertial forces acting on the MPO. Therefore, its measurements will be also very useful to estimate the speed variations produced by the onboard thrusters firings during the offloading maneuvers of the spacecraft reaction wheels [4]. Thales Alenia Space (Milano, Italy) is the industrial contractor, of the, in charge of building and testing the space version of ISA, funded by Italian Space Agency (ASI).

2. ISA calibration procedures

A full exploiting of the instrument capabilities will be possible only by a proper calibration of the instrument. With this term, we mean the measurement of the quantities needed to obtain the actual value of the acceleration vector acting on ISA reference point. We notice that the instrument is equipped with control plates that enable providing it with known acceleration signals to the sensing masses. Some of the measurements will be performed on ground, while other once in orbit around Mercury (also calibration in the cruise low noise environment is foreseen).

The on ground calibration procedures will be aimed at characterizing the instrument as much as possible in the laboratory environment. Mechanical and thermal sensitivities will be measured, together with transfer function and linearity. The transduction factor, which enables conversion between tension read at the capacitive bridge and acceleration acting on the sensing mass, will be measured. The electromechanical actuation factor, characterizing the control plates, will be also measured. A fundamental activity will be the measurement of the sensing axes directions, to correct for the small misalignments from the ideal orthogonality of the three sensing elements; giving a known acceleration in a precisely determined direction and measuring the instrument output, it is possible to measure the actual sensing direction for each of the three elements. To this aim, a dedicated facility is being developed.

Once in orbit, it is foreseen to calibrate the instrument transduction factor before each measurement arc, by means of the control plates. In the same calibration slot, the measurement and adjustment of the capacitive bridge working point will be performed. A backup procedure will employ, if needed, dedicated MPO manoeuvres to provide the instrument with known acceleration signals.

References

[1] Grard, R., Balogh, A.: Returns to Mercury: science and mission objectives. Plan. Space Sci. 49, 1395-1407, 2001.

[2] Iafolla, V., Fiorenza, E., Lefevre, C., Morbidini, A., Nozzoli, S., Peron, R., Persichini, M., Reale, A., Santoli, F., Italian Spring Accelerometer (ISA): a fundamental support to BepiColombo Radio Science Experiments, Plan. Space Sci. 58, pp. 300-308, 2010.

[3] Iafolla, V., Lucchesi, D.M., Nozzoli, S., Santoli, F.: ISA accelerometer onboard the Mercury planetary orbiter: error budget. Celestial Mech. Dyn. Astr. 97, pp. 165-187, 2007.

[4] Iafolla, V., Lucchesi, D.M., Nozzoli, S., Santoli, F.: The BepiColombo mission to Mercury: Reaction wheels desaturation manoeuvres and the ISA accelerometer ΔV measurements. Plan. Space Sci. 59, pp. 51-62, 2011.

[5] Iafolla, V., Nozzoli, S.: Italian spring accelerometer (ISA) a high sensitive accelerometer for "Bepi-Colombo" ESA CORNERSTONE. Plan. Space Sci. 49, pp. 1609-1617, 2001.

[6] Iess, L., Boscagli, C.: Advanced radio science instrumentation for the mission BepiColombo to Mercury. Plan. Space Sci. 49, pp. 1597-1608, 2001.

[7] Lucchesi, D.M., Iafolla, V.: The non-gravitational perturbations impact on the BepiColombo radioscience experiment and the key role of the ISA accelerometer: direct solar radiation and albedo effects. Celest. Mech. Dyn. Astron. 96, pp. 99-127, 2006.

[8] Milani, A., Rossi, A., Vokrouhlick, D., Villani, D., Bonanno, C.: Gravity field and rotation state of Mercury from the BepiColombo Radio Science Experiments. Plan. Space Sci. 49, pp. 1579-1596, 2001.

[9] Milani, A, Vokrouhlicky, D., Villani, D., Bonanno, C., Rossi, A.: Testing general relativity with the Bepicolombo radio science experiment. Phys. Rev. D. 66, 082001, 2002.

[10] Spohn, T., Sohl, F., Wieczerkowski, K., Conzelmann, V.: The interior structure of Mercury: what we know, what we expect from BepiColombo. Plan. Space Sci. 49, pp. 1561-1570, 2001.