Early results from Swarm's Absolute Scalar Magnetometers burst mode

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Summary

Swarm's Absolute Scalar Magnetometers (ASM) provide absolute scalar measurements of the magnetic field with high accuracy and stability on the three satellites of the mission. These ASMs nominally run at 1 Hz. But they can also run at 250 Hz frequency using a so-called "burst" mode. This possibility has been taken advantage of during commissioning, the burst mode having been run simultaneously on all three satellites over several days. These burst mode sessions were driven by the engineering need to explore the high frequency spectral content of the signal measured by the ASMs, to identify issues that could affect not only the nominal 1 Hz scalar data but also the 1 Hz vector data that the ASM simultaneously deliver on an experimental basis.

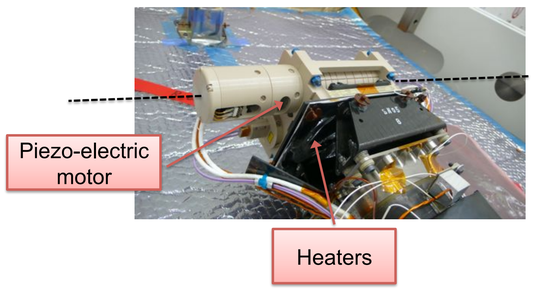
Two unexpected issues have been identified, one related to the activation of a **piezo-electric motor** built in the instrument (panel 2), the other related to the **heaters** used to keep the instruments within operating temperature range (panel 3). Fortunately, none of the issues affect the nominal 1 Hz scalar data of the mission and their impact on the 1 Hz experimental vector data can be handled. These burst mode data can now be used to look for meaningful high frequency geomagnetic signals.

1 ASM instrument and setting

- The core of the ASM instrument is a **magnetic field to frequency** converter based on atomic spectroscopy of the ^4He in its metastable level 2^3S_1. It exploits the Zeeman effect, with the signal being amplified by optical pumping. The magnetic field modulus B_0 is directly proportional to the magnetometer's resonance frequency F :

$$\mathbf{B_0 = F / \gamma^4 He}\ , \quad \text{with } \gamma^4He / 2\pi \approx 28GHz/T$$

- The sensor, including the ^4He cell, is based on an isotropic design with a static and a rotating part, optimal resonance conditions are controlled by a piezo-electric motor, which is irregularly activated (on average 500 times per orbit).
- The instrument has a [0-100 Hz] bandwidth and can be run at a **250 Hz Burst mode,** investigated in this poster.
- The instrument is located at the tip of the boom, fixed on a bracket with heaters that maintain it within an appropriate temperature range.



Burst acquisition	Period	Satellites
1	27/11/2013	A B C
2	11/12/2013	A B
3	7-8/1/2014	A B C
4	19/1/2014	A B C
5	28/1/2014	B C
6	8-9/2/2014	A B C
7	22-23/2/2014	A B C

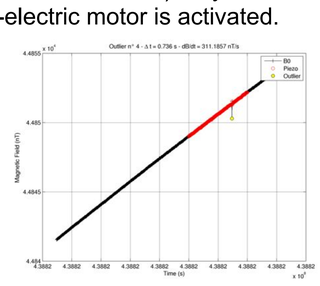
5 Conclusions

- The analysis of Burst mode data revealed perturbations produced by the piezo-electric motor and the heaters.
- None of these perturbations affect the nominal 1 Hz scalar data.
- Only the piezo-electric motor produces a significant perturbation in the experimental 1 Hz vector data.
- The background geomagnetic noise level is compatible with experimental 1 Hz ASM vector measurements.
- Corrected Burst mode data can now be used to look for meaningful high frequency geomagnetic signals.
- High frequency signals are found in the equatorial region in the night sector, possibly related to plasma bubbles. Further investigation is needed.
- The last 2 burst mode acquisitions occurred during geomagnetic active periods and have still to be analyzed.

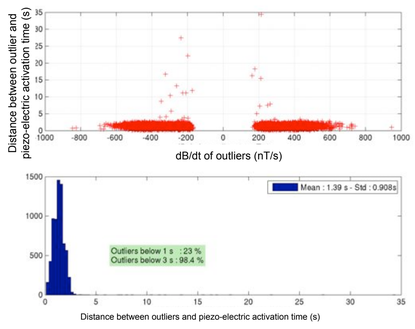
2 Impact of piezo-electric motor activation

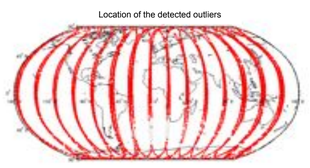
Identification of the issue

- An outlier (large value of dB/dt) may occur in burst data each time the ASM piezo-electric motor is activated.



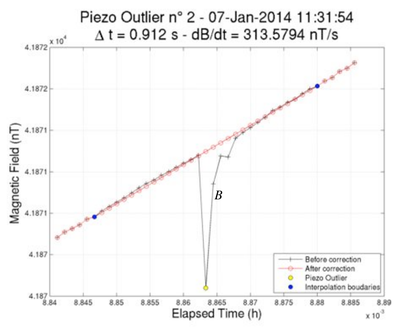
- Most of them (**98.4 %**) occur at most **3 s** after the motor activation





Correction in burst mode

- Burst data can be easily cleaned of the piezo-electric motor effect using a linear interpolation



Impact on nominal 1Hz data

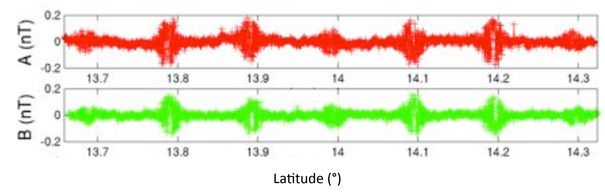
- A differential test using two RMN magnetometers and the EQM ASM model still available on the ground has shown the impact to be **less than 10 pT** on the nominal scalar data.
- A non-negligible impact is found in the experimental 1 Hz vector data that the ASM simultaneously delivers

3 Impact of heaters activation

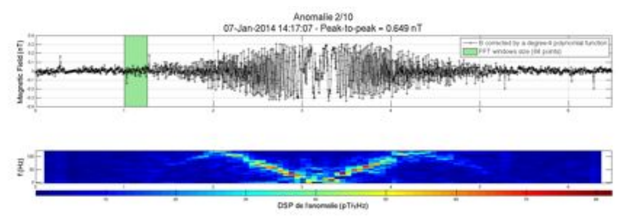
Identification of the issue

- The ASM heaters are powered by a 58 kHz square signal that may interfere with the radiofrequencies used to detect the resonance frequency F (recall panel 1). This can be expected to happen every time the magnetic field to be measured is close to:

$$B = B_0 * (1 + 2k) \quad k \in N, \quad B_0 = 2069.5\,nT$$

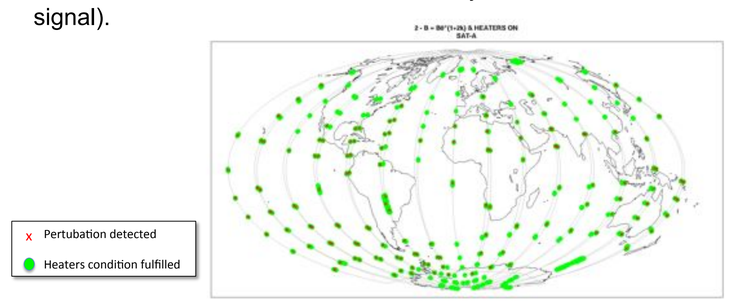


The perturbations caused by the heaters consist in a train of several anomalies



Each anomaly contains two frequency ramps

- These signals occur only when interferences are expected (note however that interferences do not always lead to a detectable signal).



- Theses anomaly trains can last a significant amount of time (most often a few seconds but sometimes 3 minutes).
- For the time being, we simply replaced them by a linear interpolation (replacing the signal by "silence").

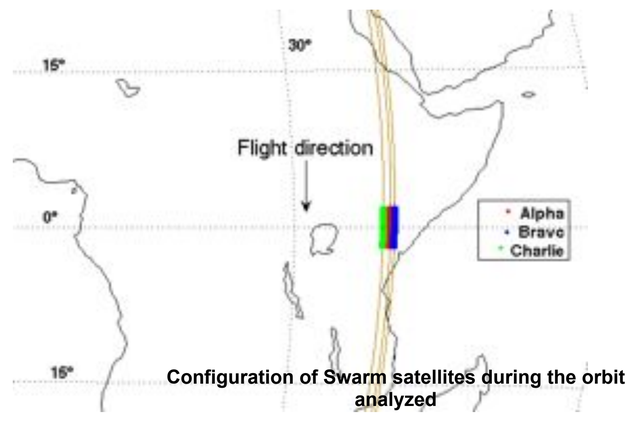
Impact on nominal 1Hz data

- When running in nominal 1 Hz mode, these interferences may also be expected to possibly perturb the data.
- However, implementing the filter of the 1 Hz mode to the Burst mode data shows the impact to be within the range of **a few 10 pT at most**.
- Note that such interferences also have little impact on the experimental 1 Hz vector data.

4 Geophysical signals

Detection of high frequency signals

- We use wavelet analysis to identify regions where high frequency signals are detected by Swarm satellites.
- The preliminary results presented here were acquired during January 19, a geomagnetic quiet day.
- We analyze the same region as seen by the three satellites, when they crossed the equator.
- A short signal around 31 Hz is observed by the three satellites, this could be a signature of small scale irregularities in the equatorial ionosphere.



Configuration of Swarm satellites during the orbit analyzed