Swarm Absolute Scalar Magnetometer Burst Mode: Observed ELF Signals and their Origins
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Swarm ASM burst-mode data

The absolute scalar magnetometers on-board each Swarm satellite nominally supply a 1Hz data product, down sampled from 50Hz. An experimental ‘burst-mode’ is also periodically switched on, operating at 250Hz, and thus allowing the bandwidth 0-129Hz to be investigated. Using version 0302c of this dataset, which includes the periods 2014 and 2018-2023 (Fig. 1), we investigate ionospheric signals using frequency-time domain analysis through spectrograms.

Minimal processing of the data product is performed we calculate the field residual using CHAOS and remove/replace outliers with a long wavelength fit to the residual, and thus spectral contamination of the frequencies of interest is prevented. We plot the band 15-129Hz, where we find a plethora of manmade, geophysical and instrumental signatures. Novel signals of unknown origin are found, of which we present two thought to be geophysical.

We give an overview of the signals found and describe their origins.

PLHR and ELF Communications

Powerline harmonic radiation (PLHR) lines to the power company transmitted signal at 50/60Hz in harmonics of nighttime orbits, while wave attenuation is lesser due to reduced plasma density. ELF communications, such as the Russian ZEVS transmitter, are also shown strongly up to 1000 km from the source.

Sweeps and Rainbows

Linear and quadratic chirps are found throughout the dataset with varying strength, power and shape, sometimes overlapping and in some examples repeated in same pattern on consecutive orbits. We suspect an instrumental effect however have thus far found no obvious correlation to geophysical parameters and do not find common examples between satellites within conjunctions.

PlasmaBubbles

Equatorial plasma bubbles are a nighttime phenomenon that result in damagistic signals in the burst-mode data which are often broadband in nature. They are observed in close correlation to the plasma bubble index product, which relies on the 50Hz data, as shown in Fig. 4.

Auroral Hiss

Auroral His Liz presents as incoherent structures and is generally banded between 60-100Hz in Swarm data. We find a link to strong field aligned currents but the plasma density also plays an important role. Figure 5 demonstrates how the plasma density can affect noise levels during measurements.

Hooks and Antarctic Waves

We find two novel waves we believe to be geophysical in origin in the burstmode data “hooks” (Fig. 6), which are only observed during magnetic local times around 0900 and 1900 and rising zonally features (Fig. 7) restricted geographically to the edge of the South Atlantic Anomaly (SAA) region. Hooks generally last 2-6 minutes but can last up to 20 minutes. In 2023 data, we observe correlated plasma density perturbations, and hook-oscillations (Fig. 2B, 2023) using the detection of an event on three craft simultaneously when in close proximity supporting a geophysical hook.

Antarctic waves are found only during periods of heightened geomagnetic activity and are restricted to the edge of the SAA region. We hypothesize a solar radiation effect, possibly related with the offset of the south magnetic pole, however further work is required to determine the resource mechanism.

Summary

- The ASM burst-mode data can detect ionospheric signals, both of manmade (e.g. powerline harmonic radiation) and geophysical (e.g. plasma bubbles) origin.
- Hooks are confined to magnetic local times 0900-1900, but no mechanism can be confidently speculated.
- Antarctic waves are confined to the South Atlantic Anomaly region and are possibly related to a solar ionisation effect coupled with high geomagnetic activity.