Magnetic Schumann Resonances in Swarm ASM Burst Mode, VFM HF and e-POP Data?

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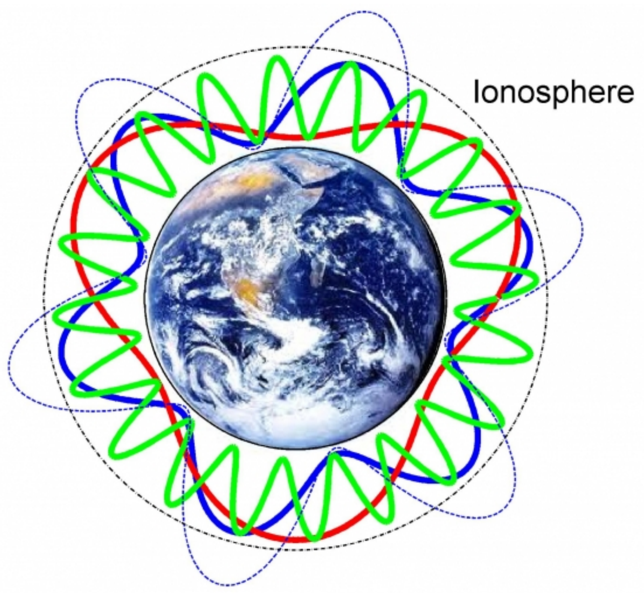
Overview

The **Schumann Resonances** (SR) consist of a series of peaks in spectral power in the magnetic and electric field at frequencies of around 8, 14, 22 and 27 Hz. They arise from the continuous occurrence of **equatorial lightning strikes** [1]. The broadband electromagnetic emission from each lightning strike is contained within a **waveguide**, bounded by the Earth's surface and the ionosphere at around 80 km in altitude.



The SR are detectable on the ground using sensitive **search-coil magnetometers.** They have a large Q-factor (i.e. broad peaks) and an obvious diurnal and seasonal variation due to the location of landmasses.

Although, the **electric field** SR have been detected in space using the C/NOFS satellite in 2010/11 at altitudes of 600 km [2], there have been **no confirmed measurements using magnetic field instruments**. There are theoretical arguments that the ionosphere acts to fully shield the magnetic signal from penetrating out of the atmosphere to Swarm altitudes, though other models suggest some secondary signals occur [3].

We examine data from the **Swarm Absolute Scalar Magnetometer Burst Mode** (250 Hz), the **Swarm Vector Field Magnetometer High Resolution** (50Hz) and **enhanced Polar Outflow Probe** (e-POP) **Magnetic Field** (160 Hz) instruments collected on the 19-Jan-2014 during the commissioning phase of the mission to look for SR signals.

Schumann Resonances on the Ground

On the Earth's surface SR can be measured using induction (or search) coils with a suitably high sampling frequency (>50 Hz). The BGS operate two horizontal coils at the Eskdalemuir Observatory (**ESK**:55.3°N, 3.2°W) which sample at a cadence of 100 Hz.

The time-series are band-pass filtered (at 3-40 Hz) in the time domain, then Welch Transformed using time slices of 100 seconds allowing the first six SR to be identified. In addition, the instruments pick up a 25 Hz sub-harmonic of the UK power grid.

Figure 1 shows the spectrogram of the 19-Jan-2017 (left) and the daily average of the 864 periodograms forming the spectrogram, showing the broad SR (right).

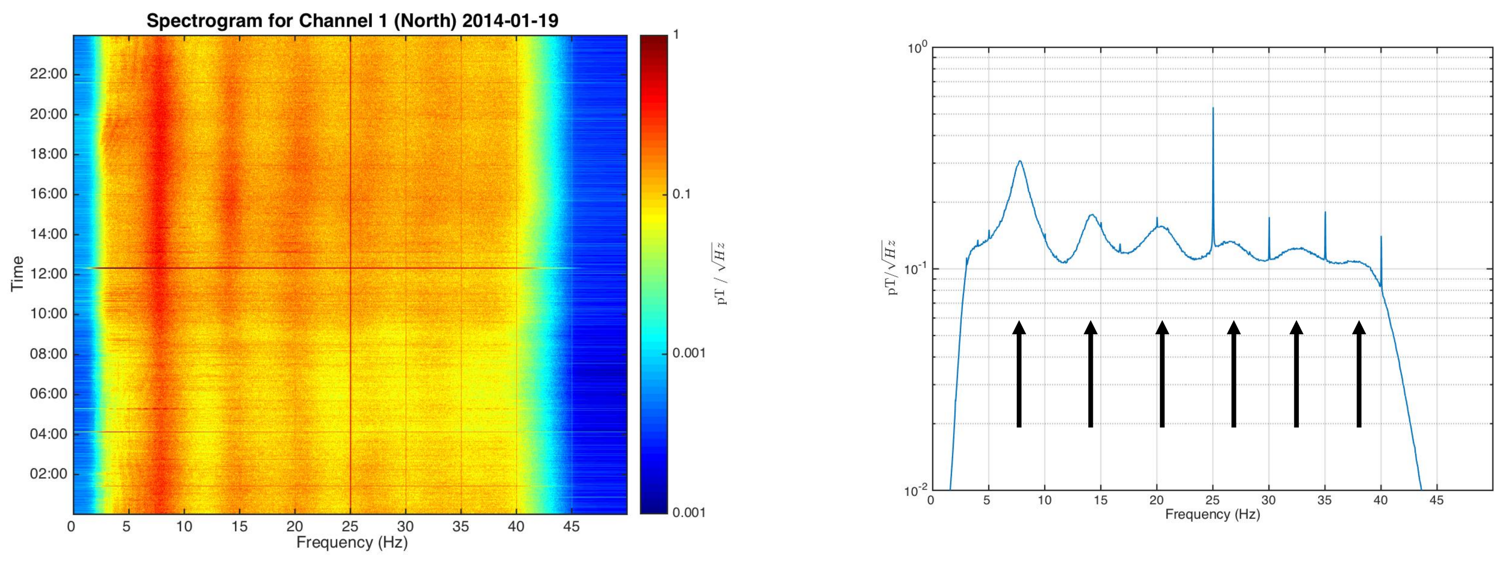


Figure 1: Bandpass filtered (3-40 Hz) induction coil from Eskdalemuir (CH1:North-South). Left: Spectrogram consisting of 864 100-second time slices. Right: Average of the 864 periodograms. The first six Schumann Resonances are distinguishable.

Swarm ASM Burst Data

The experimental Swarm ASM Burst Mode runs at 250 Hz [4]. A single day 19-Jan-2014 has been processed and released. These data have been analysed in a similar manner to the Eskdalemuir data. However, despite extensive searching, there were no unambiguous detections of the SR peaks. Instead the low frequencies are dominated by instrumentally generated spectral lines, typically harmonics of the 3.05 Hz laser modulation frequency. **Figure 2** shows a spectrogram for the high latitude regions (>|60°|) only, as suggested by [3], for Swarm B data (left) and average of these (right).

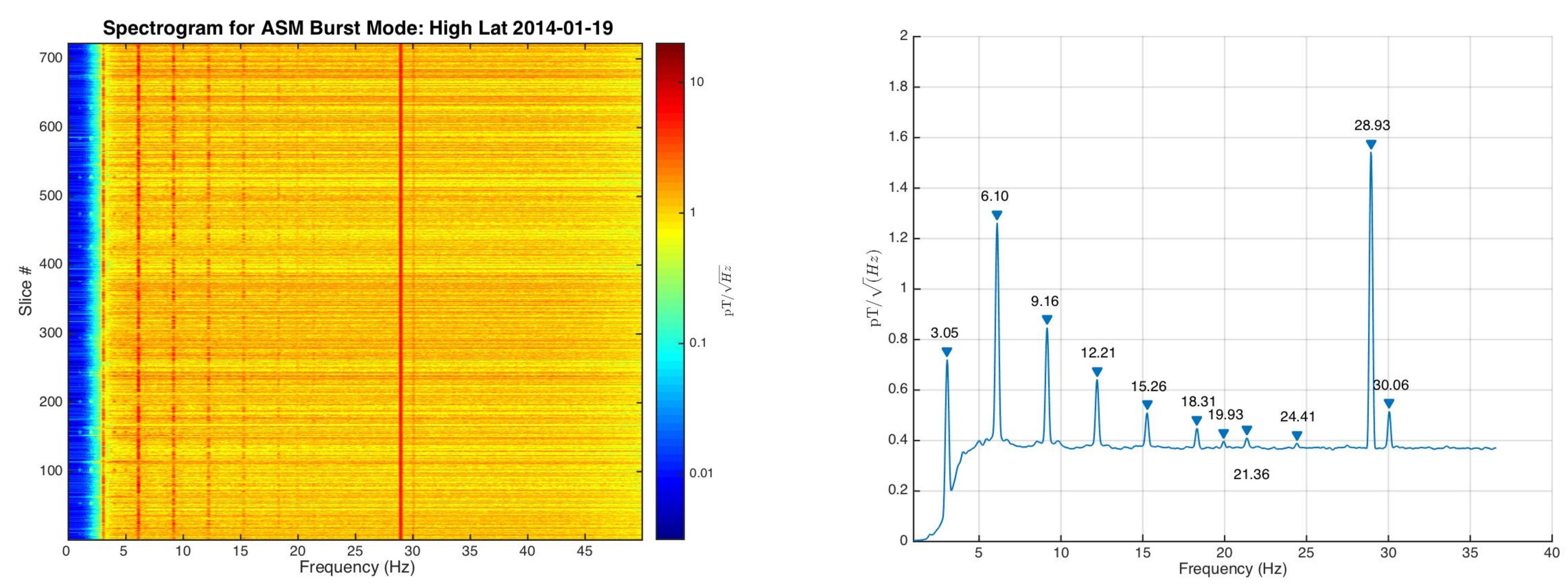


Figure 2: Swarm ASM data. Left: Spectrogram consisting of 705 30-second time slices. Right: Average of the 705 periodograms, showing the primary peaks found in the data. Most are related to the 3.05 Hz laser modulation frequency.

Swarm VFM HF and e-POP MGF Data

The Swarm Vector Field Magnetometer has a 50Hz high-frequency (HF) mode. The e-POP on the Canadian Cassiope satellite has a magnetometer experiment (MGF) measuring the field with a cadence of 160 Hz. Data for 19-Jan-2014 were analysed.

Again, despite extensive searching, there were no unambiguous detections of the SR peaks. The Swarm VFM HF data show an occasional 20Hz line but no other consistent spectral features (though plasma bubbles can be detected around the equator etc).

The low frequencies of the e-POP MGF data are dominated by instrumental and system noise from the satellite body [5]. The MGF also has a much lower sensitivity compared to Swarm. **Figure 3** (left) shows an example spectrogram for Swarm VFM HF of 40 seconds of data. The right panel shows 20 seconds of e-POP MGF data.

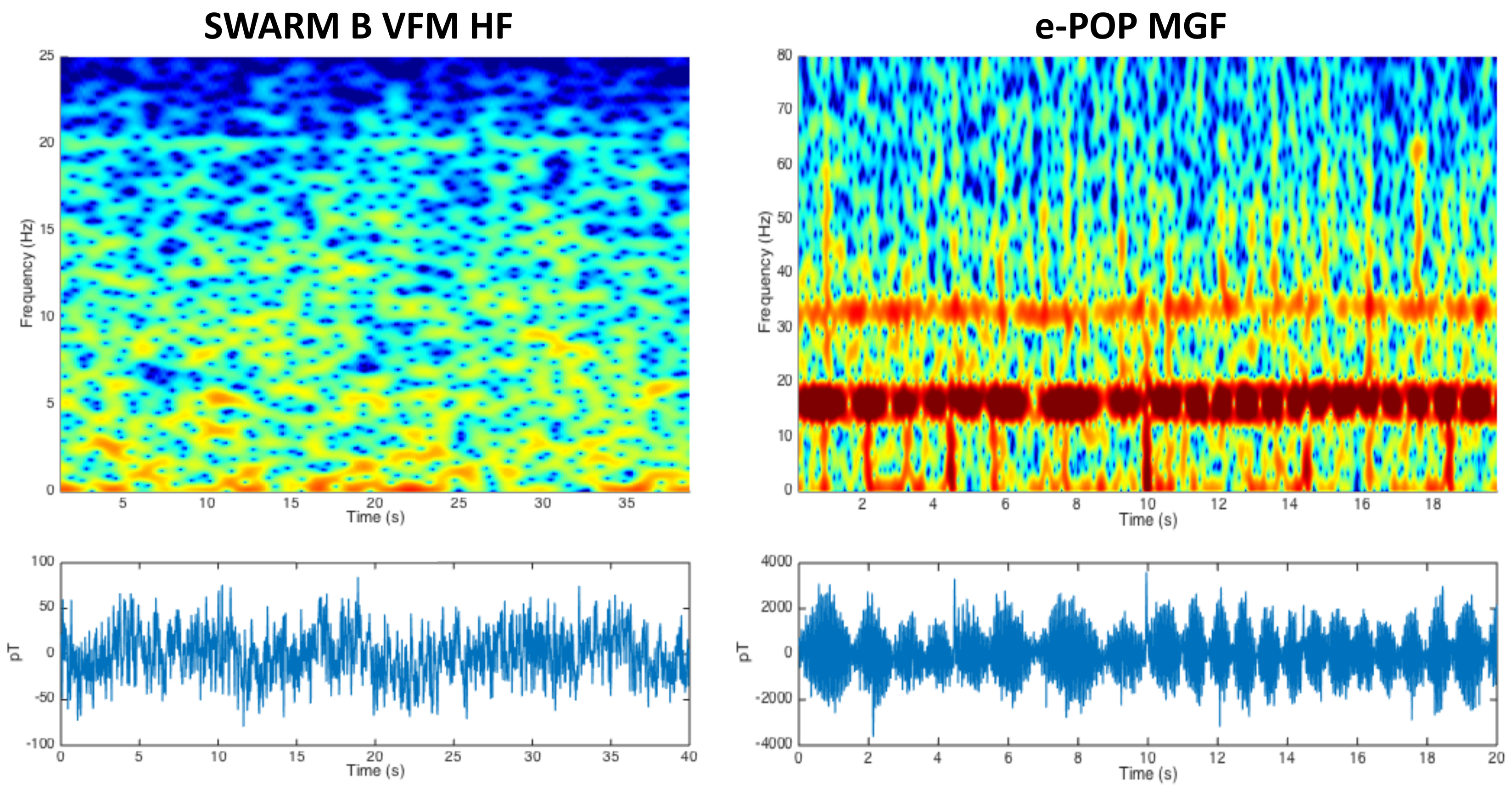


Figure 3: Spectrograms and time-series (units: pT) of Swarm VFM (left) and e-POP MGF (right) instruments. Note the spectrogram axes are orientated opposite to those of Figures 1 and 2.

Instrumental Power Spectral Densities

The power spectral density (PSD) is a measure of instrumental sensitivity and the effective noise floor. **Figure 4** shows the PSD of the Swarm ASM and VFM and ESK instruments using an entire day of data. Only a single orbit was used for e-POP MGF. Note that the ESK is not bandpass filtered as in Figure 1. The Swarm ASM and VFM instruments have approximately similar spectral power, while e-POP is around two orders of magnitude larger, and ESK is about an order of magnitude smaller.

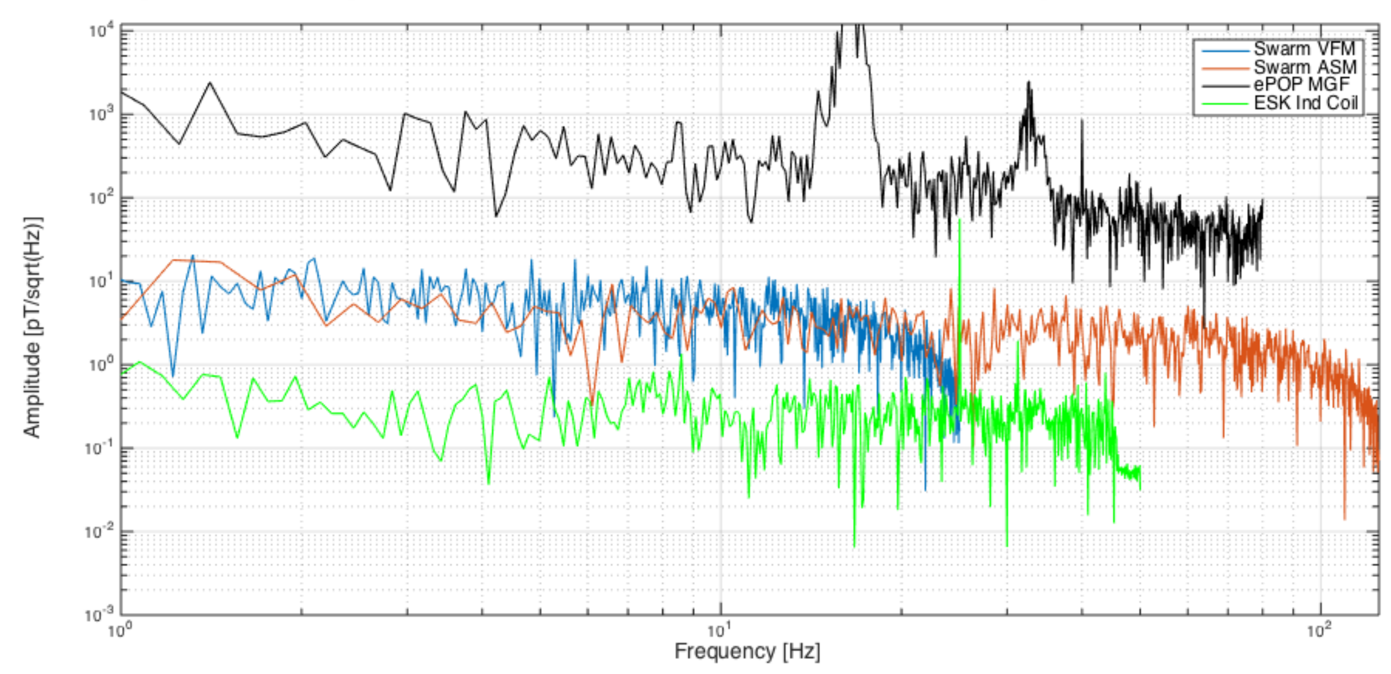


Figure 4: Power Spectral Density (units: pT/√(Hz)) of the e-POP MGF, Swarm ASM, Swarm VFM and ESK induction coil instruments.

Conclusions

Theoretical considerations [3] suggest that the magnetic signature of SR may be detectable at satellite altitudes. However, though the electric field SR have been detected [2], we could find no definitive evidence for them in our analysis.

This leads to the conclusions that either (a) **magnetic SR do not penetrate** through the ionosphere or (b) that satellite **instrumental sensitivity is still too low** compared to ground-based instruments.

Presently, there is no obvious way to distinguish proposition (a) from (b) with the available satellite datasets.

References

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