

Geophysical Research Letter

Supporting Information for

Detection of Hertz Frequency Multi-Harmonic Field Line Resonances at Low-L ($L=1.1$ to 1.5) during Van Allen Probe Perigee Passes

F. R. Lena^{1,2}, L. G. Ozeke¹, J. R. Wygant³, S. Tian³, A. W. Breneman³ and I. R. Mann¹

¹Department of Physics, University of Alberta, Edmonton, Alberta, Canada.

²Sao Carlos School of Engineering, University of Sao Paulo, Sao Carlos, Sao Paulo, Brazil.

³School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455, U.S.A.

Correspondence to: L. G. Ozeke (lozeke@ualberta.ca)

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Introduction

Figure S1 presents eight one-hour long 8 Hz spectrograms of the electric field high-pass filtered (0.4 Hz) data from Van Allen probe B. The data is perigee-centered and consists of an amplitude spectral plot. The horizontal axis presents the L-shell parameter as well as the Magnetic Local Time (MLT) obtained from the probe's ephemerides. Panels (a to h) are spaced by about 4 days starting from January 2 to 30. The spectral signatures are clearly visible as spaced arches starting from $L = 1.9 \sim 1.7$ which are similar through the entire month. The frequency domain data for this and all the other spectrograms shows the wave amplitude in mV/m.

Figure S2 illustrates an event obtained from the perigee pass of probe B on September 10th 2018, between 15:00 and 14:00 UTC, where the spectrogram of the measured waves had a different shape to the spectrograms detected during January 2018, presented in Figure S1 and in the main paper. Figure S2 shows an example of an event where the frequency did not continuously increase as the probe moved onto lower L-shells. Instead the frequency dipped as the probe reached the lowest L-shells, suggesting that the plasma mass density along the magnetic field lines encountered by the probe was significantly different to that encountered by the probe during January 2018. The spectrograms presented in Figure S2 also occurred during a more active time, with $K_p=5.0$ and solar wind dynamic pressure of 5.4 nPa, compared to the event presented in Figure 1, with $K_p=1.0$ and solar wind dynamic pressure of 1.5 nPa.

To end the NASA Van Allen Probe mission a series of de-orbiting maneuvers, were performed in early 2019 as illustrated in Figure S3, lowering the probes' perigee into the atmosphere, ultimately disposing of the spacecraft. Figure S4 shows an example of the EFW spectrogram from probe B on March 13 2019 during this perigee lowering interval, indicating that multi-harmonic Hertz frequency waves occur even at altitudes below 257 km.

The frequency response of the Finite Impulse Response (FIR) filter used to remove the spin tone of the spacecraft from the time series data before the calculation of the spectrograms presented in the paper and the supporting material is shown in Figure S5. The filter has a cut-off frequency of 0.4 Hz and a stop band attenuation of 60 dB.

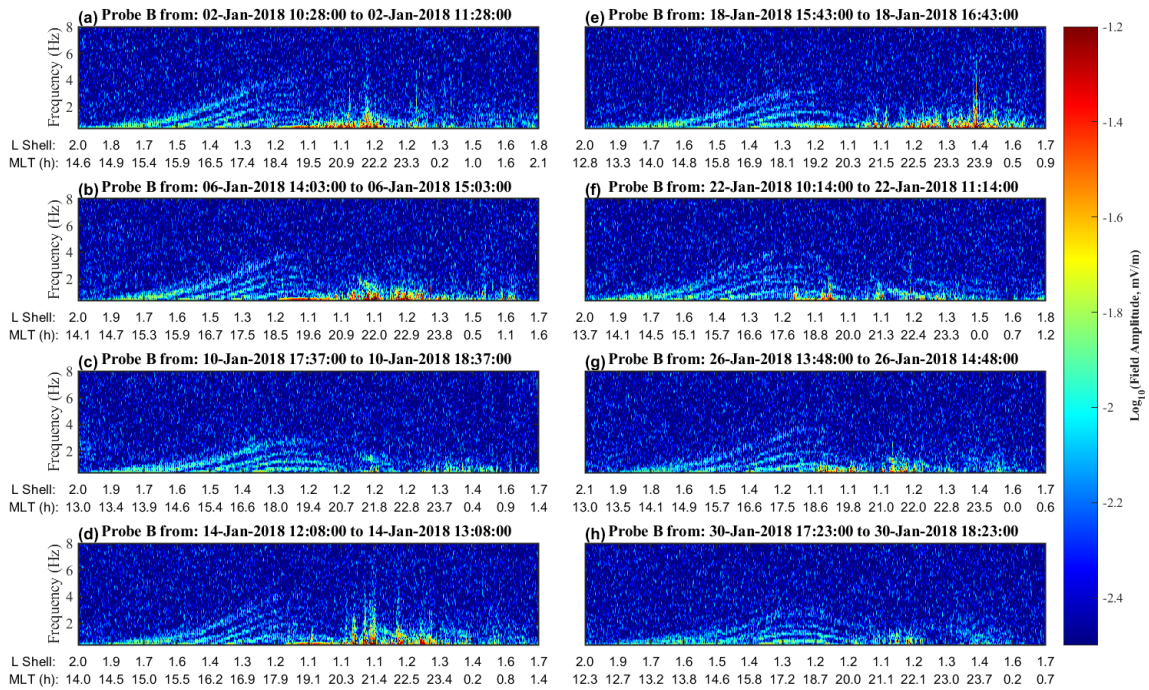


Figure S1. Eight, 4-days spaced, EFW spectrograms from perigee passes of probe B during January 2018, in a similar format to the spectrogram presented in Figure 1. Note that the discrete spectral wave signatures are present during all perigee passes with similar shapes, and frequency spacing.

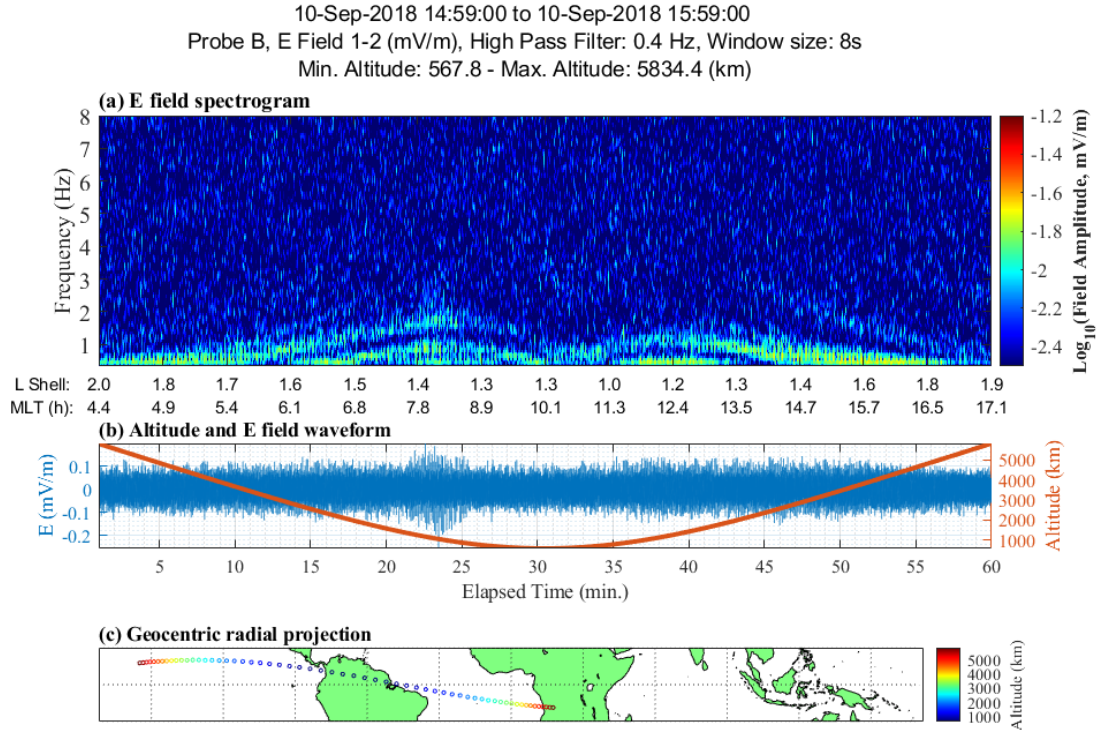


Figure S2. Unusual spectrogram detected by the EFW instrument on probe B during the September 10, 2018 perigee pass starting at 14:59 UTC. Panels (a) and (b) are in a similar format to the spectrogram, time series and spacecraft altitude profile presented in Figure 1. Panel (c) indicates the geocentric radial projection of the spacecraft above the Earth, with the color scale showing the altitude of the spacecraft. Note this event occurred during a more active time, with $K_p=5.0$ and solar wind dynamic pressure of 5.4 nPa, compared to the event presented in Figure 1, with $K_p=1.0$ and solar wind dynamic pressure of 1.5 nPa.

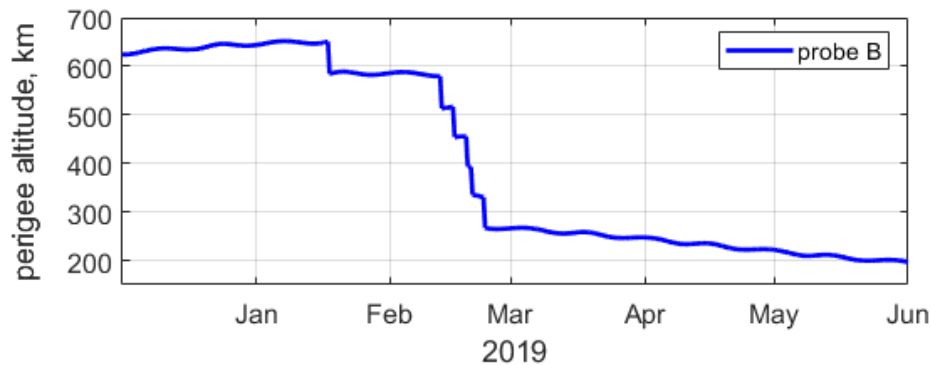


Figure S3. Perigee altitude of probe B illustrating the perigee drop that occurred during de-orbiting maneuvers in 2019 toward the end of the Van Allen Probe mission.

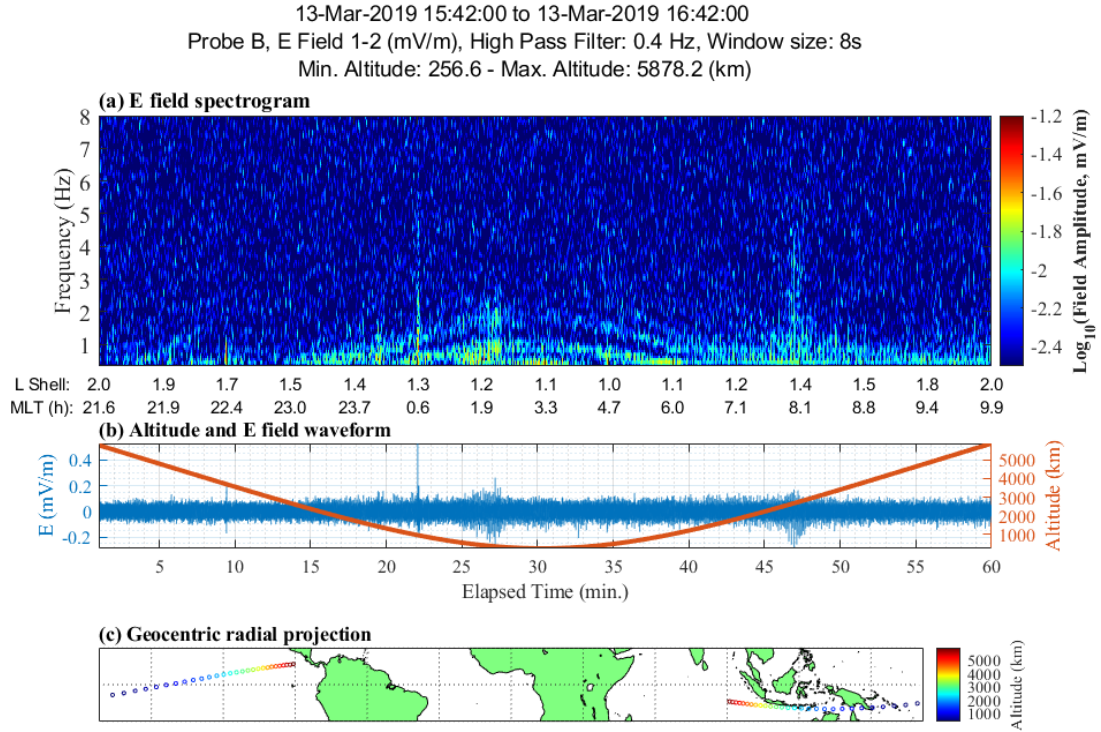


Figure S4. Probe B EFW spectrogram from the March 13, 2019, perigee pass starting at 09:11 UTC, in a similar format to the spectrogram presented in Figure S2. This perigee pass occurred during the de-orbiting perigee lowering interval at the end of the mission. The wave frequency signatures are present even at altitudes < 257 km.

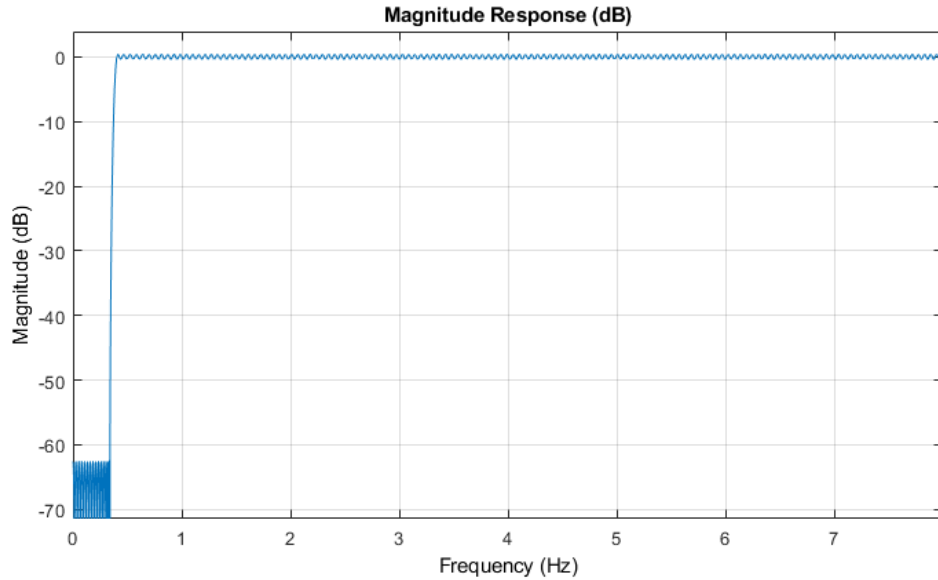


Figure S5. Frequency response of the Finite Impulse Response (FIR) filter used to remove the spin tone of the spacecraft from the time series data before the calculation of the spectrograms. The filter has a cut-off frequency of 0.4 Hz and a stop band attenuation of 60 dB.

