

**Detection of Hertz Frequency Multi-Harmonic Field Lines Resonances  
at Low-L ( $L \sim 1.2$ ) during Van Allen Probe Perigee Passes**

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Figure S1, similar electric field spectral signatures from probe B during perigee pass from January 2 to 30, 2018.

Figure S2, unusual, electric field spectral signatures from probe B during a perigee pass on September 10, 2018.

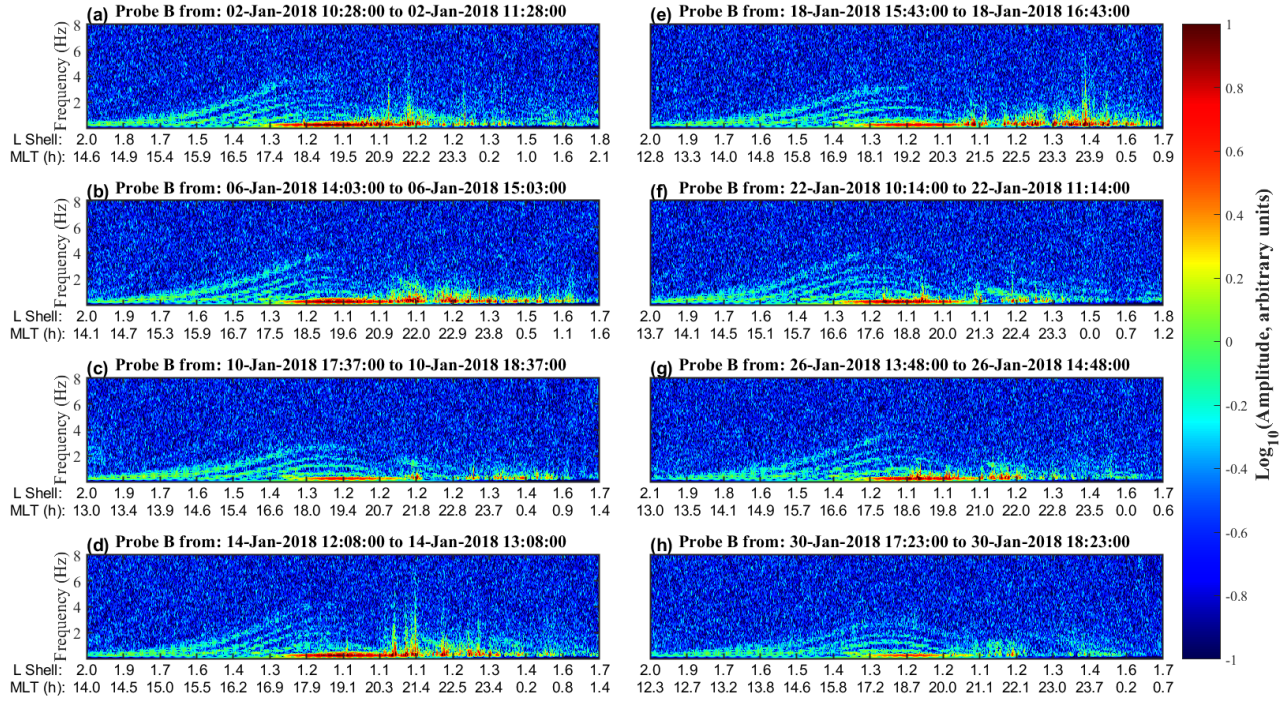
Figure S3, electric field spectral signatures from probe B detected below 257 km during the de-orbiting perigee lowering interval on March 13, 2019.

## Introduction

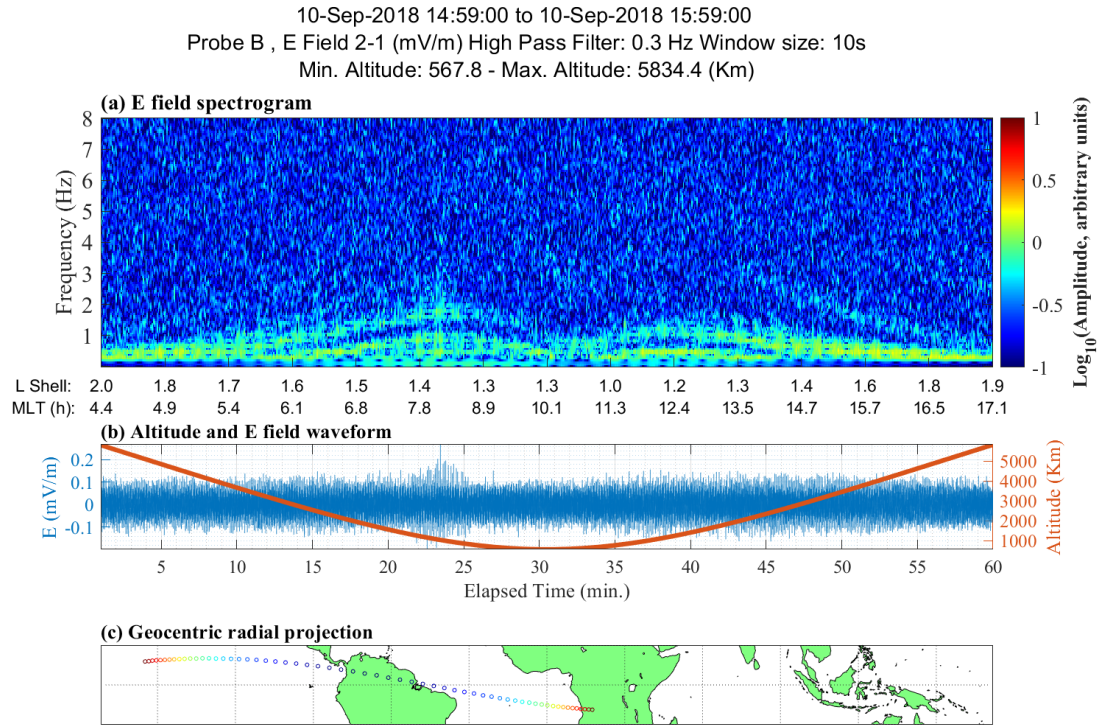
Figure S1 presents eight one-hour long 8 Hz spectrograms of the electric field high-pass filtered (0.3 Hz) data from Van Allen probe B. The data is perigee-centered and consists of an amplitude spectral plot. The horizontal axis presents the L-shell parameter as well as the Magnetic Local Time (MLT) 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 arbitrary units.

Figure S2 illustrates an event obtained from the perigee pass of probe B on September 10<sup>th</sup> 2018 where spectrogram of the measured waves had a completely different shape to the spectrograms detected during January 2018, presented in Figure S2 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 on September 10<sup>th</sup> 2018 was significantly different to that encountered by the probe during January 2018.

To end the NASA Van Allen Probe mission a series of de-orbiting maneuvers starting from January 12, 2019, were performed lowering the probes perigee into the atmosphere, ultimately disposing of the spacecraft. Figure S3 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 altitude below 257 km.

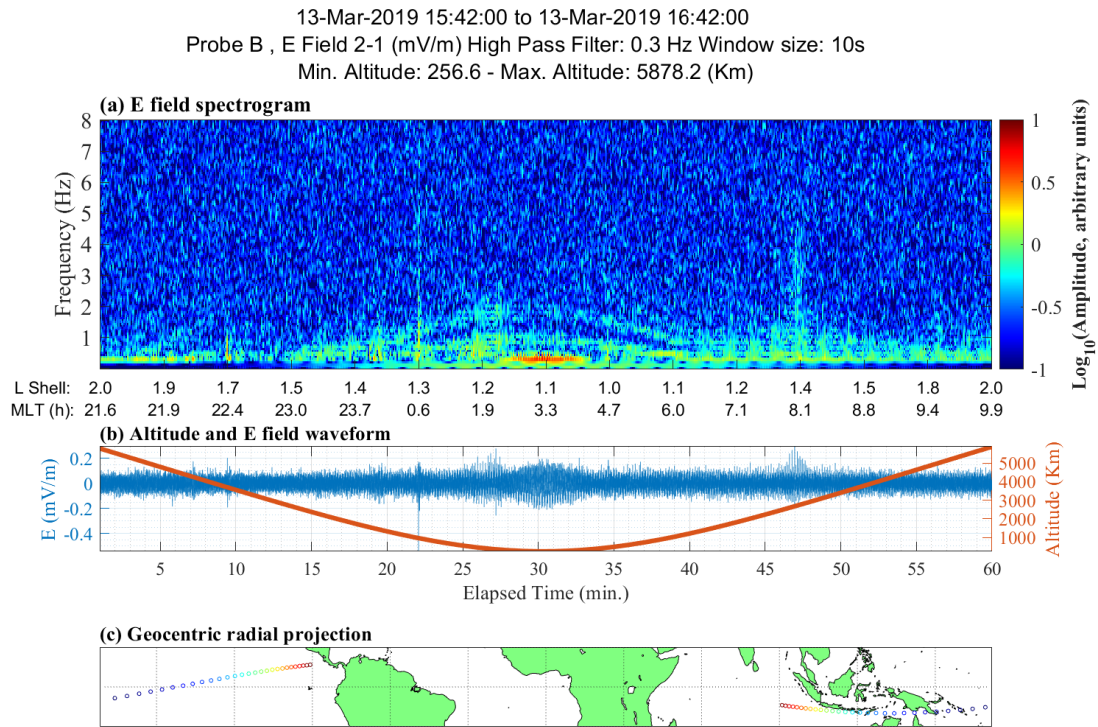


**Figure S1.** 8, 4-days spaced, January 2018 EFW spectrograms from perigee passes of probe B. Note that the discrete spectral wave signatures are present during all perigee passes with similar shapes, and frequency spacing.



**Figure S2.** Unusual spectrogram detected by the EFW instrument on probe B during the September 10<sup>th</sup>, 2018 perigee pass starting at 14:59 UTC.

**Figure S3.** Spectral signatures from probe B electric field from March 13, 2019.



**Figure S3.** Probe B EFW spectrogram from the March 13<sup>th</sup>, 2019, perigee pass starting at 09:11 UTC. This perigee occurred during the de-orbiting perigee lowering interval at the end of the mission. The wave frequency signatures are present even at the lowest altitudes < 257 km.

