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Conjugate ground-spacecraft observations of VLF chorus elements

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Extended Abstract

We present the results of simultaneous observations [1] of VLF chorus elements at the ground-based station Kannuslehto in Northern Finland and on board Van Allen Probe A. Visual inspection and correlation analysis of the data reveal one-to-one correspondence of several (at least 12) chorus elements following each other in a sequence. Poynting flux calculated from electromagnetic fields measured by the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) instrument on board Van Allen Probe A shows that the waves propagated at small angles to the geomagnetic field and oppositely to its direction, that is, from northern to southern geographic hemisphere. The spacecraft was located at $L \simeq 4.1$ at a geomagnetic latitude of -12.4 degrees close to the plasmapause and inside a localized density inhomogeneity with about 30% density increase and a transverse size of about 600 km.

The observed waves are part of a long-lasting (about two hours) wave event including both chorus and hiss-like emissions. A ray tracing study for this event [2] shows that the observed duct could be important for guiding them both from the generation region to the ground and from the ground to the spacecraft with low enough wave normal angles.

The time delay between the waves detected on the ground and on the spacecraft is about 1.3 s, with ground-based detection leading spacecraft detection. The measured time delay is consistent with the wave travel time of quasi-parallel whistler-mode waves for a realistic profile of the plasma density distribution along the field line. Therefore, chorus wave packets were detected first at Kannuslehto on the ground, and then in 1.3 to 1.4 s they reached the Van Allen Probe A on the opposite side of the magnetic equator.

Taking into account the common knowledge about near-equatorial location of chorus generation region, the only realistic scenario which satisfies the observation facts suggests downward propagation of chorus wave packets from the generation region to the ionosphere, partial transmission to the ground, partial reflection from the ionosphere and coming back to the near-equatorial region where they were detected by the spacecraft. A fairly large amplitude of chorus waves measured by the Van Allen Probe A speaks in favor of either good reflection from the ionosphere, or additional cyclotron amplification in the equatorial region on the path from the ionosphere to the spacecraft.

The results suggest that chorus discrete elements can preserve their spectral shape during a hop from the generation region to the ground followed by reflection from the ionosphere and return to the near-equatorial region.

References

[1] A. G. Demekhov, J. Manninen, O. Santolık, and E. E. Titova, "Conjugate ground–spacecraft observations of VLF chorus elements," *Geophysical Research Letters*, **44**, No.23, pp. 11,735–11,744, doi:10.1002/2017GL076139.

[2] E. E. Titova, A. G. Demekhov, J. Manninen, D. L. Pasmanik, and A. V. Larchenko, "Localization of the sources of narrow-band noise VLF emissions in the range 4–10 kHz from simultaneous ground-based and Van Allen Probes satellite observations," *Geomagnetism and Aeronomy*, **57**, No.6, pp. 706–718.