Large-amplitude upper-band chorus emissions observed by Van Allen Probes

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Abstract

We find large-amplitude upper-band chorus emissions near the magnetic equator measured by the EMFISIS (Electric and Magnetic Field Instrument Suite and Integrated Science) instrument package on the Van Allen Probes. The emissions propagate quasi-parallel to the geomagnetic field line. In setting up the parameters of seed electrons exciting the emissions based on theoretical analyses and observational results measured by the HOPE (Helium Oxygen Proton Electron) instrument, we calculate threshold and optimum amplitudes obtained by the nonlinear growth theory. The linear growth rates, on the other hand, are negative in the high-frequency part of the emissions. Furthermore, some chorus emissions each of which has a narrow gap at half the cyclotron frequency of electrons can also be interpreted in terms of the nonlinear growth theory and the nonlinear damping mechanism at half the cyclotron frequency $f_{ce}/2$.

1. Introduction

Chorus emissions with highly oblique wave normal angles have been observed by Cluster satellites [1] and Van Allen probes [2]. Santolik et al. (2014), on the other hand, reported that the wave normal angles of the emissions tend to be closer to be parallel to the geomagnetic field line as their wave amplitudes increase.

According to the simulation analyses of electrons interacting with chorus emissions with parallel propagation [4], chorus emissions play key roles in radiation belt dynamics as a generator of MeV electrons and a scattering factor of energetic electrons into the atmosphere.

Li et al. (2011) reported that upper-band chorus waves propagate more obliquely than lower-band chorus waves based on the observational results of Time History of Events and Macroscale Interactions during Substorms (THEMIS) [5]. In the present study, we focus on upper-band chorus emissions with large wave amplitudes and investigate their generation process.

2. Large-amplitude upper-band chorus

Undertaking the data analyses used by the EMFISIS instrument package on the Van Allen Probes, we study upper-band chorus emissions. Figures 1 and 2 show examples of the upper-band chorus emissions combined with lower-band and upper-band chorus emissions.

Figure 1. Measurements of RBSP-A EMFISIS on 12 January 2013.

(a) Sum of the three magnetic power spectra $B_{sum}$. The gray line corresponds to half the cyclotron frequency.

(b) Polar angle $\theta$ plotted between blue ($\theta = 0^\circ$) and red ($\theta = 90^\circ$).

(c) Polar angle $\theta$ satisfied with $B_{sum} > 10^{-7} \text{nT}^2/\text{Hz}$ plotted between blue ($\theta = 0^\circ$) and red ($\theta = 30^\circ$).

Figure 2. The same as Figure 1 but measurements on 20 January 2013.

(a) $B_{sum}$

(b) $\theta$

(c) $B_{sum} > 10^{-7} \text{nT}^2/\text{Hz}$
3. The nonlinear growth theory


\[ B_{th} = 25\pi^3 \frac{m_e e V_p s^2 V_{\parallel}}{e Q^2 \omega_e^2 \sqrt{\omega_e^2 - 2 \omega_e^2 \Omega_e^2}} \left( \frac{\partial^2 \omega_e}{\partial \theta^2} \right)^2 \exp \left( \frac{v_p^2}{V_{\parallel}^2} \right), \]

\[ B_{op} = 0.81\pi^{-5/2} \frac{m_e Q^2 \omega_e^2 V_{\parallel} V_p v_{\gamma}^2}{e^2 a \omega_e V_{\parallel}} \exp \left( -\frac{v_p^2}{V_{\gamma}^2} \right). \]

Figure 3. 

4. Conclusion

5. References


