Study on EMIC rising tone emissions observed by THEMIS probes

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Abstract

Electromagnetic ion cyclotron (EMIC) triggered emissions are intense electromagnetic waves with a bursty amplitude growth and an increasing frequency. This study is intended to reveal the characteristics of the EMIC rising tone emission based on observation. We analyze the magnetic field data of the THEMIS probes.

Chapter 1 provides an outline of plasma waves observed in the Earth’s magnetosphere. We present a brief overview of past studies of EMIC waves in the Earth’s magnetosphere and the objectives of the thesis.

In Chapter 2, we show theories of EMIC waves. EMIC waves have a complex dispersion relation and some characteristic frequencies because EMIC waves are related to many species of ions. It is commonly accepted that EMIC waves are driven in the Earth's inner magnetosphere by the temperature anisotropy of protons. We explain a nonlinear wave growth theory, which describes nonlinear dynamics of trapped protons interacting with an EMIC wave.

Chapter 3 reports the result from the analysis of the THEMIS probe data. We found various types of emissions mainly on the dayside at radial distances of 5-10 R_E, and study three distinctive events in detail. The first is a typical event with an obvious rising tone emission. In the second event, rising tone emissions were simultaneously excited in two different frequency bands. In the third event, which occurred near local noon, rising tone emissions were excited in an extended region near the magnetospheric equator where the field-aligned B gradient was much reduced because of the strong compression of the magnetosphere by the solar wind. We compare these events with the nonlinear wave growth theory. In all events, the observed bursty growth of wave amplitude can be explained by the nonlinear wave growth theory.

In Chapter 4, we report "subpacket structures" found in EMIC rising tone

emissions. Subpacket structures mean the fine structures in wave amplitudes. Overall, a single rising tone consists of two to six subpackets, and each subpacket occurs 10 seconds or longer apart. We investigate three typical cases in detail. The first case shows a continuous single rising tone with obvious four subpackets, and the second case is characterized by a patchy emission with multiple subpackets triggered in a broadband frequency. The third case has a smooth rising tone without any obvious subpackets in the FFT spectrum, while its amplitude contains small peaks with increasing frequencies. We show that the time evolution of the observed frequency and amplitude, time span of each subpacket, and peak amplitudes can be reproduced consistently by the nonlinear wave growth theory.

In Chapter 5, we develop an automated classification method of EMIC wave events based on the characteristics of frequency changes. We report several statistical properties of frequency changes in EMIC waves observed by THEMIS probes from January 2012 to December 2014. We classify each 20-minute time segment according to whether rising tones or falling tones were observed. We find that EMIC rising- or falling-tone events are seen in about half of the total EMIC wave events, and that rising tone events are more often detected than falling tone events. The dayside magnetosphere is a preferential region for those EMIC frequency changes. We show that the occurrence and distribution of EMIC rising tones are related to the AE index, solar wind dynamic pressure, and interplanetary magnetic field. Frequency increase tends to be large at ~10 MLT near the magnetospheric equator, and as the frequency increase is larger, the amplitude tends to be larger. Subpacket structures appear mainly in large amplitude EMIC emissions. Most of dayside EMIC emissions have subpacket structures. These features are consistent with the nonlinear wave growth theory.

Chapter 6 summarizes the new results from the analysis. A very limited number of EMIC wave events have been reported previously, but in this thesis, by analyzing a large amount of satellite data, we have demonstrated that EMIC triggered emissions are the common phenomena at radial distances of 5-10 R_E in the equatorial magnetosphere. In addition, we have clarified detailed features of EMIC rising tone emissions, and found that most of these features are consistent with the nonlinear wave growth theory. We thereby conclude that the EMIC rising tone emissions are excited by the nonlinear wave growth process.