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Software-type Wave-Particle Interaction Analyzer: direct measurements of wave-particle interactions in planetary magnetospheres

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Abstract

We present a new instrumentation "Wave Particle Interaction Analyzer (WPIA)" for measurement of the energy transfer process between energetic electrons and plasma waves in the magnetosphere. The WPIA measures a relative phase angle between the wave electric field vector (E) and velocity vector (v) of each particle and computes an inner product (E dot v), which is equivalent to the variation of the kinetic energy of energetic electrons interacting with plasma waves. The WPIA will be firstly realized by the Software-type WPIA in the ERG satellite mission to measure interactions between energetic electrons and whistler-mode chorus in the Earth's inner magnetosphere. We also present feasibilities of SWPIA in planetary magnetospheres.

1. Introduction

In the collision-less magnetospheric plasma, energy exchange or momentum transfer among plasma particles is achieved through the electromagnetic fields. A typical example is wave-particle interactions between energetic electrons and whistler-mode chorus emissions, occurring in the equatorial region of the Earth's inner magnetosphere. By referring to the velocity distribution of energetic electrons and frequency spectra of whistler-mode waves individually measured in situ by a satellite orbiting in the magnetosphere, we have discussed evolution of the velocity distribution with the observed wave spectra. However, it has been difficult to directly measure the wave-particle interactions, because the time resolution of conventional plasma instruments is not enough to resolve the wave period of plasma waves in the inner magnetosphere. So as to overcome the difficulty of the direct measurement of wave-particle interactions, we have proposed a new instrumentation "Wave-Particle Interaction Analyzer (WPIA)" [1-3]. The WPIA measures a relative phase angle between the wave electromagnetic field vector (E or B) and velocity vector (v) of each electron and computes physical quantities such as an inner product between E and v, which is the time variation of the kinetic energy of energetic electrons interacting with plasma waves.

2. Software-type WPIA

The WPIA will be firstly realized by the Software-type WPIA (SWPIA) to be installed in the upcoming JAXA satellite mission ERG (Exploration of energization and Radiation in Geospace; [4]) as a software function running on the onboard CPU of the satellite. The prime target of SWPIA on board ERG is direct measurement of nonlinear wave-particle interactions between energetic electrons and whistler-mode chorus, which play important roles in the acceleration process of radiation belt electrons in the inner magnetosphere. The feasibility of SWPIA has been demonstrated by quasi-measurements in the numerical experiments reproducing chorus generation process [2-3].

3. Feasibility of SWPIA for measurements in planetary magnetospheres

One of the significant points of SWPIA is its feasibility in reducing telemetry data size transferred from spacecraft to the ground. If SWPIA works perfectly and enables us to identify the energy transfer process between waves and particles on board, we can only transfer accumulated physical quantities by SWPIA to the ground, without sending huge amount of observed waveform and plasma particle data used in the onboard computation. This is a strong advantage of SWPIA for measurements in planetary magnetospheres, where we often suffer the limitation of the amount of telemetry from spacecraft to the ground.

4. Summary

In the present study, we demonstrate the feasibility of the WPIA for direct measurement of wave-particle interactions in the magnetosphere. We show the results of quasi-measurements of SWPIA in the simulation results of the chorus generation process. By a relative phase angle between E (or B) and v of each electron, we can also study the distribution of energetic electrons in the wave phase space, which is essential for discussion of both chorus generation and relativistic electron acceleration processes. In addition to the computation of an inner product between E and v, we will conduct various analyses of wave-particle interactions by the SWPIA on board the ERG satellite.

References

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Single particle motion This report focuses on â€œSingle Particle Motionâ€ since it is possible to trace the trajectories of charged particles in external fields just based on the Lorentz equation as given below. The effect of the Earth's gravitational field on the motion of these charged particles is neglected.Â For example, a phase-space plot would provide much insight into the type of particles that resonantly interact with and are trapped by the background electric and/ or magnetic waves.Â Apart from drift interactions with a low frequency global m=2 toroidal mode wave, it is also possible for cyclotron interactions with a higher frequency local circularly polarized Alfven wave. In the case of multiple waves Fig. These waves are important not only in planetary magnetospheres, heliospheres and astrophysical systems but also in laboratory plasma experiments and fusion reactors. Through measurement of charged particles and electromagnetic fields with NASAâ€™s Magnetospheric Multiscale (MMS) mission, we utilize Earthâ€™s magnetosphere as a plasma physics laboratory. Here we confirm the conservative energy exchange between the electromagnetic field fluctuations and the charged particles that comprise an undamped kinetic AlfvÃ©n wave.Â Waveâ€“particle interactions. Given the demonstrated validity of the plane-wave approximation for Î”Ep, the electron-pressure-gradient-driven electric field was estimated at a single spacecraft, for example, MMS4, using âˆ'ik Â· e/(nee). Wave-Particle Interaction. Related terms: Magnetosphere.Â In this review, we discussed the role of wave-particle interactions in driving loss of radiation belt electrons, with an emphasis on observational signatures of this process. These include direct measurements of precipitation, wave properties, and variations in the trapped electron population as a result of cyclotron resonance.Â This may suggest that two types of plasma waves are responsible for the precipitation at different times, but this hypothesis requires further investigation. Such a study could suggest trends for which plasma waves are responsible for pulsating auroral precipitation at a given magnetic local time.