TWO-DIMENSIONAL PARTICLE SIMULATIONS OF ELECTROMAGNETIC EMISSIONS FROM ELECTROSTATIC SOLITARY WAVES

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ABSTRACT

We study formation process of two-dimensional electrostatic solitary waves observed by recent spacecraft and possible emission process of electromagnetic waves from the solitary waves. We performed two-dimensional electromagnetic particle simulations of electron beam instabilities with open boundary conditions. In the open system, spatial structure of electrostatic solitary waves varies depending on the distance from the source of the electron beam. We also found that two-dimensional solitary waves are accompanied by electromagnetic field perturbations. Conversion efficiency from electrostatic to electromagnetic energy is discussed with different electron plasma-to-cyclotron frequency ratio.

INTRODUCTION

We present particle simulations of electrostatic solitary waves (ESW) observed by the GEOTAIL spacecraft and other recent spacecraft in the Earth's magnetosphere. Previous simulations in uniform periodic systems demonstrated that ESW correspond to BGK electron holes generated by electron beam instabilities. These simulations also showed that obliquely propagating electrostatic modes such as whistler waves and lower hybrid waves are excited through coupling with solitary potentials drifting parallel to the ambient magnetic field. However previous simulations were performed with electrostatic codes. Meanwhile, recent spacecraft observed enhancement of electromagnetic fields associated with electron holes. In the present study we performed electromagnetic particle simulation to study possible emission process of electromagnetic waves from ESW.

SIMULATION RESULTS

In the open system, spatial structure of electron holes varies depending on the distance from the source of the electron beam. In the region close to the source of the electron beam, the potential structure becomes two-dimensional through modulation by oblique plasma waves excited by interaction with electron holes. As the two-dimensional potentials propagate along the magnetic field, they are aligned in the direction perpendicular to the magnetic field through coalescence. As a result potential structure becomes one-dimensional in regions far from the source.

We varied electron plasma-to-cyclotron frequency ratio for different simulation runs. Under a strong magnetic field with the frequency ratio equal to 1.0, we found enhancement of electromagnetic fields associated with two-dimensional electron holes. Although the electromagnetic fields propagate along the magnetic field with the same drift velocity of electron holes, the wavelength of the electromagnetic wave is much longer than that of electron holes. Electrons drift in the z direction due to the perpendicular electric filed of the electron holes and external magnetic field. The electron ExB drift causes emission of electromagnetic waves from the two-dimensional electron holes. Under a weak magnetic field with the frequency ratio equal to 4.0, electron holes disintegrate through the decay instability. Though the electrostatic filed of the electron hole vanishes by the instability, electromagnetic waves radiated from the electron holes can propagate along the magnetic field.

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