Particle simulation of electromagnetic emissions from electrostatic solitary waves

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We present particle simulations of electrostatic solitary waves (ESW) observed by the GEOTAIL spacecraft and recent spacecraft in the Earth's magnetosphere. Recent particle simulations have demonstrated that ESW are Bernstein-Greene-Kruskal (BGK) electron holes formed through nonlinear evolution of electron beam instabilities. Since an electron hole is coherent electrostatic potential structure, electron beam instabilities were conventionally studied by electrostatic particle simulations. However, the FAST spacecraft observed electromagnetic field signatures associated with ESW. To study interaction between coherent electrostatic potential and electromagnetic waves, we extend the previous electrostatic particle simulations to electromagnetic particle simulations.

In a two-dimensional simulation, we found that multi-dimensional electron holes are accompanied by magnetic field components. On the other hand, one-dimensional electron holes do not have any electromagnetic signatures. Two-dimensional electron holes have perpendicular electrostatic fields Ey. Electrons lead to Ey x B0 drift in the z direction, and the current density Jz is enhanced at perpendicular edges of two-dimensional electron holes. Magnetic fields Bx and By are enhanced around the current Jz.

However, the current structure excited by the Ey x B0 drift of electrons is not closed in the two-dimensional simulation. In the real space plasma, we expect that the current structure may form a loop along the perpendicular edge of a multi-dimensional electron hole. Such a closed current structure will be studied by a three-dimensional simulation. We also study electromagnetic emissions from such moving current loops.