High-Order Particle-in-Cell Simulations of Incoherent Scatter Radar Spectra

Alex Fletcher, William Longley, Meers M Oppenheim

Abstract

Incoherent scatter radar (ISR) is one of the primary means for studying the Earth's ionosphere. The measured frequency spectrum allows the extraction of plasma density, temperatures, drift velocities, current densities, and more. In this study, we present electrostatic particle in cell (PIC) simulations of the background ionosphere and examine the spectra. In particular, we use two different codes: a new high-order code and a benchmark well-tested second-order code named EPPIC. Advances in numerical methods and computing power have facilitated the development of high-order, massively parallel particle in cell simulations of plasmas for studying small scale processes in the space environment. The high-order method used herein is straightforward and simple to implement relative to other high-order particle in cell methods. We briefly discuss the details and choices made in constructing each step of the particle in cell algorithm at fourth order accuracy. Each code was used to simulate the ambient conditions at the peak of the F region at three different resolutions in two spatial dimensions. We compare the simulation results to predicted spectra parallel, perpendicular, and nearly perpendicular to the Earth's magnetic field. The simulated spectra have the expected "double hump" shape that is characteristic of incoherent scatter radars. However, there are wavenumbers where both simulations agree with theory and wavenumbers where they do not. As expected, the high-order method requires far fewer computational particles to obtain the same signal-to-noise ratio but also requires significantly more expense per particle.