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Fully Kinetic Simulations of Radio Emission from a Propagating Electron Beam

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Type III radio bursts are usually associated with energetic electrons that are accelerated by solar flares and propagate out from the corona. The standard theoretical paradigm links these emissions to a conversion of electrostatic Langmuir oscillations excited by the bump-on-tail instability into electromagnetic waves. Since the electron beams are observed to propagate to large heliospheric distances where they continue to generate Langmuir and radio waves, the instability must be finely balanced so as not to completely disrupt the beam propagation. In this study, we perform 2D PIC simulations in a large system and without imposing periodic boundary conditions to more accurately model the beam propagation, its interaction with background plasma and the evolution of the waves. The results demonstrate that the beam decouples from electrostatic oscillations it excites in the injection region and propagates freely through the background plasma. Only 15% of the beam energy density is lost during the initial relaxation process. The instability continues to operate only at the front of the beam, where velocity gradients are maintained by the time-of-flight effects. The main body of the beam reaches a quasi-steady state, where it no longer loses energy to wave generation. This stable beam can then propagate to larger heliospheric distances. Radio emissions at plasma frequency and its second harmonic are observed in the simulation. They are generated primarily near the injection region, where classical signatures of the three-wave conversion processes are detected. The main body of the beam may become unstable again and generate radio emissions only if it propagates into regions where background plasma is colder or less dense. The simulation results are consistent with satellite data that show that electron beams often continue to generate Type III radio bursts even beyond 1 AU.

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