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High-Frequency Microturbulence within the Foot of a Supercritical Perpendicular Shock

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In supercritical shocks a fraction of the incoming ions is reflected at the steep front and stream across the magnetic field within the foot, making it a site of plasma instabilities excited by the relative drifts between beams of incoming and reflected ions, and incoming electrons. The drift U_{re} of the reflected ions versus the electrons across the B-field can easily destabilize waves in the electron cyclotron frequency range. By means of linear analysis, it is shown that several Bernstein harmonics are unstable, the number of harmonics being directly proportional to U_{re} yet limited by the reflected ions' temperature.

By means of elecromagnetic PIC simulations restricted to the foot, we investigate the nonlinear characteristics of these waves. Depending on the drift U_{re} they saturate at weak intensity levels or they reach significant levels and exhibit a nonlinear evolution marked by two phases. First, cyclotron harmonics with high $k\rho_e$ values develop, in good agreement with linear dispersion properties. Second, as the high-k modes saturate by trapping of the reflected ion beam, an inverse cascade takes place whereby the spectral power shifts toward lower k-modes to eventually accumulate on the fundamental harmonic branch at the cyclotron frequency Ω_{ce}. The phase is characterized by the development of a magnetic component to the spectrum that had so far been mostly electrostatic. It exhibits also a significant energy transfer from the ion beam to the electrons, which experience a marked increase in their temperature. The dynamics of the ions and the electrons is analyzed and discussed.