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Properties of intense field-aligned lower-band chorus waves: Implications for nonlinear wave-particle interaction

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Resonant interactions between electrons and chorus waves are responsible for a wide range of phenomena in the near-Earth space (e.g., diffuse aurora and acceleration of > 1 MeV electrons). Although quasi-linear diffusion is believed to be the primary paradigm of describing such interactions, an increasing number of investigations suggest that nonlinear effects are also important in controlling the rapid dynamics of energetic electron fluxes. This study addresses the relative contribution of nonlinear resonant processes to the radiation belt dynamics: (I) We show that while as many as 10–15% of chorus wave packets are sufficiently intense to interact nonlinearly with relativistic electrons, most of them are short (include less than 10 wave periods), reducing the efficacy of such interactions. (II) We construct the kinetic equation to describe the nonlinear resonant interaction of radiation belt electrons with such short, intense wave packets, and demonstrate that this type of nonlinear interaction produces similar effects as the quasi-linear diffusion. (III) To investigate effects of sufficiently long (large) wave-packets, we introduce a method to incorporate these effects (namely, phase trapping and nonlinear scattering) into the kinetic equation describing the evolution of the electron distribution function. Solutions of this equation indicates that nonlinear resonant effects lead to electron distributions similar to results of the quasi-linear diffusion, but with much faster evolution in the electron distribution.