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Conditions for Nonlinear Whistler-Mode Wave Generation in the Earth's Magnetosphere

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Gyro-resonant electron interaction with whistler-mode chorus waves is a key mechanism for producing relativistic electrons in the Earth's outer radiation belt. In addition, chorus-induced pitch-angle scattering of electrons into the loss-cone can cause significant electron loss from the inner magnetosphere and subsequent precipitation into the atmosphere. Here we examine conditions under which (nonlinear) chorus can be generated in the Earth's magnetosphere. We present a criterion whereby if the maximum value of the linear growth rate of whistler-mode waves exceeds a certain critical bound, then fully-nonlinear wave growth occurs and chorus waves are generated. This criterion corresponds to a "boundary curve" in (n/N, A) space where n is the hot electron number density, N is the cold electron number density and A is the thermal anisotropy. Chorus waves are generated in the region above the boundary curve, while no chorus waves are generated below the boundary curve. To a good approximation, the boundary curve takes the form of a hyperbola in (n/N, A) space. We are able to confirm the validity of the criterion and the associated boundary curve by comparing our results with a set of independently published particle simulations of chorus. This simple concept of the theoretical boundary curve based on linear theory is expected to be useful in guiding the choice of parameters in future simulations of chorus and also of practical use in interpreting experimental chorus wave data. Chorus is generated if the linear growth rate exceeds a certain bound M. Corresponding to a given set of system parameters, an appropriate narrow band of M-values can be determined by a limited set of trial simulations. While nonlinear theory naturally applies in the chorus generation region in (n/N, A) space, it is noteworthy that the boundary of the chorus generation region is well approximated by linear theory.