Numerical study of whistler interactions with energetic electrons in the Earth's radiation belt.

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Interactions between electromagnetic waves in the very-low-frequency (VLF) range of 1-10 kHz (whistlers) and energetic electrons in the inner magnetosphere of the Earth have been studied for more than four decades. One of the main focuses of these studies is the explanation of generation of so-called secondary (triggered) emissions. Controlled experiments conducted at the Siple station in Antarctica during 1970-1980 established that under certain conditions injected VLF signals trigger larger amplitude whistler waves and cause enhanced precipitation of the relativistic electrons. Although the basic features of the triggering process have been revealed, many important questions remain unanswered and require detailed numerical studies. This paper presents results of numerical modeling of interaction of whistler waves, propagating along the inhomogeneous background magnetic field with energetic electrons by means of a hybrid fluid-particle code. Our ultimate goal is to identify the initial parameters of the background distribution of energetic electrons and of the pump wave, that result in the generation of secondary waves with amplitudes well-exceeding that of the primary wave.

To model interactions between whistlers and energetic electrons we develop a hybrid fluid-particle model where two populations of electrons with different temperatures and densities exist. The dynamics of the colder and denser population are described with the electron MHD equations. The dynamics of hotter and less dense populations are described with the equations of motion for each energetic particle. Thus, the numerical algorithm describing the coupled dynamics of cold and hot electrons consists of fluid and particle-in-cell (PIC) models for the electrons only. To make the results from this study more closely related with observations the numerical model is developed in the dipole magnetic field geometry. This geometry lets us treat the parallel inhomogeneity of the background magnetic field which is an important factor affecting triggering process in the Earth's magnetosphere.

The main conclusion derived from this study is that the generation of secondary emissions with amplitudes significantly larger than the amplitude of the triggering signal can be achieved when the distribution function of the energetic particles is marginally stable. In this case even a small-amplitude trigger wave with a frequency matching frequency of the most unstable modes generated by the hot particles can be significantly amplified by the wave-particle interaction. Triggering leads not only to a significant amplification of the initial, trigger signal, but also to an amplification of other harmonics generated by the energetic particles. The amplitude of the secondary waves depends on the amplitude of the trigger, but this dependence is non-linear.