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Acceleration of relativistic electrons due to resonant interaction with oblique monochromatic whistler-mode waves generated in the ionosphere.

Ilya Kuzichev and David Shklyar
Space Research Institute of RAS, Space Research Institute, Russian Federation (mar-cuss@yandex.ru)

One of the most challenging problems of the radiation belt studies is the problem of particles energization. Being related to the process of particle precipitation and posing a threat to scientific instruments on satellites, the problem of highly energetic particles in the radiation belts turns out to be very important. A lot of progress has been made in this field, but still some aspects of the energization process remain open. The main mechanism of particle energization in the radiation belts is the resonant interaction with different waves, mainly, in whistler frequency range. The problem of special interest is the resonant wave-particle interaction of the electrons of relativistic energies. Relativistic resonance condition provides some important features such as the so-called relativistic turning acceleration discovered by Omura et al. [1, 2]. This process appears to be a very efficient mechanism of acceleration in the case of interaction with the whistler-mode waves propagating along geomagnetic field lines. But some whistler-mode waves propagate obliquely to the magnetic field lines, and the efficiency of relativistic turning acceleration in this case is to be studied.

In this report, we present the Hamiltonian theory of the resonant interaction of relativistic electrons with oblique monochromatic whistler-mode waves. We have shown that the presence of turning point requires a special treatment when one aims to derive the resonant Hamiltonian, and we have obtained two different resonant Hamiltonians: one to be applied far enough from the turning point, while another is valid in the vicinity of the turning point. We have performed numerical simulation of relativistic electron interaction with whistler-mode waves generated in the ionosphere by a monochromatic source. It could be, for example, a low-frequency transmitter. The wave-field distribution along unperturbed particle trajectory is calculated by means of geometrical optics. We show that the obliquity of propagation leads to a crucial difference as compared with parallel propagation. First, it results in strong asymmetry of the effective resonant amplitude with respect to geomagnetic equator. Such an asymmetry leads to trapped particle escape from the resonance just after the particle crosses the equator, and, ultimately, enhances energy gain of trapped particles. In the same time, there is similar asymmetry of the effective resonant amplitude with respect the turning point. This asymmetry leads to particle detrapping after the turning point, thus decreasing the efficiency of the mechanism of relativistic turning acceleration.

[1] Omura, Y., N. Furuya, and D. Summers (2007), Relativistic turning acceleration of resonant electrons by coherent whistler mode waves in a dipole magnetic field, J. Geophys. Res., 112, A06236, doi:10.1029/2006JA012243.
[2] Furuya, N., Y. Omura, and D. Summers (2008), Relativistic turning acceleration of radiation belt electrons by whistler mode chorus, J. Geophys. Res., 113, A04224, doi:10.1029/2007JA012478.