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Validity of gyro-averaging method for oblique whistler-mode wave particle interaction

HSIEH, Yikai[1*] ; OMURA, Yoshiharu[1]

[1]Research Institute for Sustainable Humanosphere, Kyoto University, Kyoto, Japan.

We perform test particle simulations of energetic electrons interacting with oblique whistler-mode waves in the Earth's magnetic field. We first solve exact equations of motion of test electrons under the electric and magnetic fields of obliquely propagating coherent wave with right-hand polarization. In this test, the energetic electrons undergo multiple cyclotron resonances. We also apply gyro-averaging method by treating electron motion as its guiding center motion to simplify the complicated cyclotron motion [1,2]. The result shows that the gyro-averaging motion is successfully consistent with the direct motion of the electron. Applying this result we can just use the guiding center motion of electrons to represent the completed motion of electrons. Therefore, these method can be utilized in the particle simulations of oblique propagation waves to reduce the relativistic equations of motion and minimize the computation resources, which makes simulations of multiple particles more feasible.

References
[1] Bell (1984), The nonlinear gyroresonance interaction between energetic electrons and coherent VLF waves propagating at an arbitrary angle with respect to the Earth's magnetic field. *J. geophys. Res.* 89, 905.
[2] Nunn and Omura, A computational and theoretical investigation of nonlinear wave particle interactions in oblique whistlers, Submitted to *J. Geophys. Res.*.

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