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Simulation of mode conversion process from Upper-Hybrid wave to Z-mode and LO-mode waves

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A large variety of waves can exist in plasmas depending on the condition of the medium. The refractive index for plasma wave is a function of plasma parameters such as ion or electron density and magnetic field strength. Therefore, in a case that these parameters are function of position in plasmas, the local value of the refractive index is also to be a function of position. The mode conversion occurs where a wave of one wave mode is linearly coupled to other propagation mode. There are various phenomena related to the mode conversion process: terrestrial continuum radiation, Auroral kilometric radiation, and Jovian decametric emissions. Stix (1965) investigated a theoretical basis for the conversion mechanism, while analytical methods have been proposed by using the full dispersion relation approximating as cold, warm and hot plasma conditions for the propagating plasma medium. Afterwards, Tang (1970) carried out a more precise investigation for the same situation, and Oya (1971) clarified the mode conversion from electrostatic to electromagnetic mode over a wide frequency range. A mechanism of double mode conversion of beam radiation was proposed by Oya (1974) for Jovian decametric radiation and was extended to AKR by Benson (1975). Jones (1976) proposed that the source mechanism of terrestrial non-thermal radiation is generated by Cerenkov radiation coupling to the O-mode of radiation, which can propagate in the region of lower plasma density. However, we often find observational results related to the mode conversion process in the region where theoretical assumptions are not valid; e.g., electromagnetic radio emissions observed near the plasmapause during a geomagnetically disturbed period where WKB approximation might violated. To discuss these phenomena, we should evaluate the conversion process quantitatively by numerical experiments. For this purpose, we use Electron Hybrid code which is originally developed by Katoh (2003) to study resonant scattering process of energetic electrons. In this scheme hot electrons are treated as particles while cold electrons are treated as a fluid. We assume two-dimensional simulation system where the uniform magnetic field B_0 is assumed to be parallel to the y axis and the density gradient is introduced along the x axis. Frequencies are normalized by electron cyclotron frequency, f_{ce} (= 4.397 x 10 rad /s). The grid points are composed 2500 and 150 points in x and y coordinates, respectively. The size of the simulation box used in the present study corresponds to 107.175 and 6.43 km, respectively. We generate plasma waves by oscillating E_x and E_y components in the generation region assumed in the simulation system. We assume damping regions at the both edges of the simulation system to supress the reflection of outgoing waves. First, the verification of the developed simulation code is carried out. By considering a plane wave, we perform several test for a case of homogeneous plasma for comparing dispersion relation and polarization in different wave modes, such as RX-mode, LO-mode and Upper-Hybrid wave, and for oblique propagation of these wave modes. As for a next step, we consider an inhomogeneous case with a spatial density gradient perpendicular to the ambient magnetic field direction. Also we considered the homogeneous case with the same characteristics (such as time steps and size) as a comparison case. We discuss how the wave coupling occurs in magnetized cold plasma by performing FFT analyses on wave electric field to examine spatial distribution of frequency/wavenumber spectra and by considering the polarization of wave modes propagating in the simulation system. Based on the simulation results showing the generation of electromagnetic LO-mode and Z-mode waves through the mode conversion process, energy transfer rates from Upper Hybrid wave into Z-mode and LO-mode waves under the assumed plasma condition is quantitatively discussed.