Coupling of Electromagnetic and Electrostatic Waves in Inhomogeneous Plasmas

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It is well known that electromagnetic (EM) waves are mode converted to electrostatic (ES) waves in inhomogeneous plasmas. We examine this issue in a three-dimensional multi-fluid numerical model. First, we derive a set of coupled linear wave equations when a one-dimensional inhomogeneous density profile is assumed in a cold and collisionless plasma. The massive ions are considered as fixed because we are interested in high frequency waves in plasmas. It is shown that the EM mode satisfies the 0th order modified Bessel equation near the resonant region where the frequency matches the local electron plasma frequency. It is expected that the EM waves are coupled and damped to the ES waves owing to the logarithmic singular behavior at such resonances. Second, we numerically test the same case in a 3-D multi-fluid model. An impulsive input is assumed to excite EM waves in the inhomogeneous 3-D box model. The wave spectra of electric and magnetic fields are presented and compared with the analytical results. Our results suggest that the EM energy is irreversibly converted into the ES energy wherever the resonant condition is satisfied. Finally we discuss how the mode conversion appears in both electric and magnetic fields by analyzing time histories of each component. We also compare our results with MHD wave coupling. It is numerically confirmed in this study that the coupling of EM and ES waves is similar to that of compressional and transverse MHD waves.