JOVIAN MAGNETOSPHERIC ION CYCLOTRON INSTABILITY
IN THE PRESENCE OF PARALLEL ELECTRIC FIELD

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Abstract. A dispersion relation for left hand circularly polarized electromagnetic wave propagation in an anisotropic magnetoplasma in the presence of a very weak parallel electrostatic field has been derived with the help of linearized Vlasov and Maxwell equations. An expression of the growth rate has been derived in presence of parallel electric field for ion-cyclotron electromagnetic wave in an anisotropic media. The modification made in the growth rate by introducing parallel electric field and temperature anisotropy has been studied for fully ionized hydrogen plasma with the help of observations made on Jovian ionosphere and magnetosphere at \(L = 5.6 \text{ R}_j\). It is concluded that the growth (damping) of ion-cyclotron electromagnetic wave is possible when the wave vector is parallel (antiparallel) to the static electric field and effect is more pronounced at higher wave number.

Introduction

The propagation of very low frequency (VLF) waves through the Jovian magnetosphere is well established (Gurnett et al., 1979b). A detailed study of this class of low frequency emissions in the Jovian magnetosphere reveals significant information about its structural and dynamical features. In particular the study of the propagational features of the observed VLF emissions yields valuable information about the spatial and temporal variations in the magnetospheric field and plasma parameters. During the last two decades electrostatic field measurements in the Earth's ionosphere and magnetosphere have been carried out by a number of workers using instruments on board rockets and satellites. Although in most cases the reported electrostatic field measurements revealed the existence of a transverse component, the existence of a parallel component of the electric field in the Earth magnetosphere was confirmed by experimental measurements and theoretical considerations only in the last decade. It is believed that the variability in the current system flowing parallel to the field lines gives rise to a corresponding variability in the transverse magnetic field which in turn generates a parallel component of the electric field. Further, because of turbulence, the plasma conductivity parallel to the field lines becomes finite and anomalous and thereby sustains the parallel component of the electric field. Although there is no direct experimental evidence for the existence of a parallel electric field in Jovian magnetosphere, the reported observations of auroral hiss in Jupiter's magnetosphere made by instruments on board voyager I can be taken to be directly related to the regions of parallel electric field and auroral particle precipitation there (Gurnett et al., 1979a). Further, there are strong theoretical arguments in support of the existence of field aligned currents at abrupt density gradients near the inner edge of the Io plasma torus.

In the magnetosphere one of the dominant energy exchange processes is the cyclotron resonance between left hand circularly polarized electromagnetic waves and the fully ionized hydrogen plasma which occurs when the wave frequency, as seen by the particles, has the same sense as that of the particles gyration. A significant amount of energy exchange may take place at this Doppler-shifted frequency, depending on the nature of the phase space distribution of particles and wave amplitude. For anisotropic plasma distribution, the energy transfer leads to the amplification of signals over a broad band of frequencies. Khosa et al. (1984) have studied the role of parallel electric field on the propagation of whistler mode waves in an isotropic Jovian magnetospheric plasma conditions and recently the effect of parallel electrostatic field on the amplification of whistler mode waves in an anisotropic bi-Maxwellian weakly ionized plasma for Jovian magnetospheric conditions has been reported by Ahmad et al. (1992b).

Therefore in this communication the effect of a weak electrostatic field on the amplification of ion-cyclotron electromagnetic waves in an anisotropic Maxwellian Jovian magnetospheric plasma has been studied. Firstly, a derivation is made for dispersion relation for ion-cyclotron electromagnetic wave for an anisotropic plasma having bi-Maxwellian distribution function. An expression for the growth rate in terms of the temperature anisotropy and electric field for ion-cyclotron electromagnetic waves has also been derived by using the dispersion relation of left hand circularly polarized wave and charge particles. In absence of electric field the growth rate expression becomes similar to the expressions of Kennel and Petschek (1966) and Cuperman and Landau (1974). Finally, we have computed the growth rates for Jovian magnetospheric condition at $L = 5.6 \, R_J$ and results have been discussed.

**Derivation of the Dispersion Relation**

The dispersion equation can be obtained either for the linearized collisionless Boltzmann equation or a perturbation analysis of the particle-orbit equation together with Maxwell’s equations. The left hand circularly polarized wave interacts strongly with the ionized hydrogen plasma in the vicinity of the ion-cyclotron frequency. The plasma under consideration is of infinite extend embedded with static magnetic field $B_0$ and electric field $E_0$ whose motion is governed by the equation

$$\frac{dV}{dt} + \frac{q}{m} (B_0 \times V) = \frac{q}{m} (E + V \times B),$$

where $q$ and $m$ are the charge and the mass of the particles. Here it is assumed that particle has a zero order velocity along and perpendicular to the zero-order magnetic field and a constant density in the direction perpendicular to the direction