Mode conversion characteristics of the electrostatic hybrid waves in a magnetized plasma slab

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Mode conversion characteristics of electrostatic hybrid surface waves due to the magnetic field orientation in a magnetized plasma slab have been investigated. The dispersion relations for the symmetric and anti-symmetric modes of hybrid surface waves are derived for two different magnetic field configurations: parallel and perpendicular. For the parallel magnetic field configuration, we have found that the symmetric mode propagates as upper-and lower-hybrid waves. However, the hybrid characteristics disappear and two non-hybrid waves are produced for the anti-symmetric mode. For the perpendicular magnetic field configuration, however, the anti-symmetric mode propagates as the upper-and lower-hybrid waves and the symmetric mode produces two non-hybrid branches of waves.

1. Theory and calculations

We consider a magnetized dusty plasma slab with the sharp boundaries at $x=0$ and $x=L$ such that the characteristic length of plasma is much greater than the scale length of the inhomogeneity. Then, the specular reflection condition can be used as the boundary condition for the study of surface waves [1,2]. This boundary condition yields the dispersion equation for electrostatic surface waves propagating in the z direction in an isotropic plasma slab represented by [3]

$$1+\frac{1}{\pi}\int_{-\infty}^{\infty}\frac{dk_\perp\, k_\parallel}{k^2\varepsilon_l(\omega,k)}\left(\frac{1\mp e^{ik_\perp L}}{1\pm e^{ik_\perp L}}\right)=0$$

where ω is the wave frequency, $k_\perp(=k_x)$ and $k_\parallel(=k_z)$ are the *x*- and *z*-components of the wave vector **k**, respectively, ε_ℓ is the longitudinal component of the plasma dielectric permittivity.

When the parallel magnetic field $\mathbf{B}_0=B_0\hat{\mathbf{z}}$ is applied to the boundary surfaces, the longitudinal plasma dielectric permittivity in dusty plasma for $kv_{T\alpha}$, ω_{cd}, $\omega_{ci} << \omega << \omega_{ce}$ is obtained as follows [22]:

$$\varepsilon_{l,\parallel}(\omega,k_x,k_z)=1+\frac{\omega_{pe}^2k_x^2}{\omega_{ce}^2k^2}-\frac{\omega_{pe}^2k_z^2}{\omega^2k^2}-\frac{\omega_{pi}^2}{\omega^2}-\frac{\omega_{pd}^2}{\omega^2}$$

where $\omega_{p\alpha}=\left(4\pi n_\alpha q_\alpha/m_\alpha\right)^{1/2}$ is the plasma frequency of species α ($=e, i, d$ for electron, ion and dusty grain, respectively) and $\omega_{c\alpha}=q_\alpha B_0/m_\alpha c$ is the cyclotron frequency of species $\omega_{c\alpha}=q_\alpha B_0/m_\alpha c$.

Then the integral equation can be performed to derive the dispersion relation for the surface waves in the magnetized plasma slab.

2. Results

2.1. Symmetric mode

$$\left[\left(1+\frac{\omega_{pe}^2}{\omega_{ce}^2}-\frac{\omega_{pi}^2+\omega_{pd}^2}{\omega^2}\right)\left(1-\frac{\omega_{pe}^2+\omega_{pi}^2+\omega_{pd}^2}{\omega^2}\right)\right]^{\frac{1}{2}}+\tanh\left[\frac{1}{2}F_\perp(\omega)k_zL\right]=0$$

2.2. Anti-symmetric mode

$$\left[\left(1+\frac{\omega_{pe}^2}{\omega_{ce}^2}-\frac{\omega_{pi}^2+\omega_{pd}^2}{\omega^2}\right)\left(1-\frac{\omega_{pe}^2+\omega_{pi}^2+\omega_{pd}^2}{\omega^2}\right)\right]^{\frac{1}{2}}+\coth\left[\frac{1}{2}F_\perp(\omega)k_zL\right]=0$$

3. References

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