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Invariant imbedding theory of mode conversion in inhomogeneous plasmas

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In an inhomogeneous plasma, the plasma waves become complicated due to the existence of local cutoff, coupling and resonances. Since the plasma wave equations become coupled, it is often difficult to obtain the analytical solution. Mode conversion often appears at resonances, which are associated with the singularities in wave equations. We develop a new version of the invariant imbedding theory of wave propagation in inhomogeneous media, and derive new invariant imbedding equations for the propagation of arbitrary number of coupled waves in arbitrarily-inhomogeneous stratified media. Using the invariant imbedding equations, we are able to calculate the matrix reflection and transmission coefficients and the field amplitudes inside the inhomogeneous plasmas exactly and efficiently, even in the cases where the material parameters change discontinuously at the boundaries and inside the inhomogeneous medium. In this paper, we apply our method to the theory of mode conversion in various kinds of inhomogeneous plasmas: 1) cold and unmagnetized plasmas, 2) warm and unmagnetized plasmas, 3) cold, magnetized plasmas with the external magnetic field parallel or perpendicular to the direction of density inhomogeneity, and so on. We further discuss the application of this new technique in a complex problem of plasma wave coupling.

Keywords: mode conversion; plasma wave; invariant imbedding method.