Kinetic full wave analysis of electron cyclotron waves in a tokamak plasma using finite element method

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Full wave analysis including kinetic effects of plasmas has been extensively employed in studying ion-cyclotron (IC) heating and lower-hybrid (LH) current drive in tokamak plasmas. Most of previous analyses of wave propagation and absorption in an inhomogeneous plasma are based on the response in a uniform plasma and the wave number has an essential role in describing the plasma-wave interactions. The dielectric tensor in a hot plasma has been usually expressed as a function of wave number. In order to describe the response of plasma without wave number, it is appropriate to use an integral form of dielectric tensor derived by integrating along an unperturbed particle orbit. Maxwell's equation with the integral form of dielectric tensor is numerically solved as a boundary-value problem by means of the finite element method (FEM). Numerical analysis with FEM may have higher performance with parallel processing owing to sparse coefficient matrix. Though the integration is localized in an element in usual FEM for differential equations, coupling between elements in a localized region occurs in the FEM for integro-differential equations. In a magnetized plasma, guiding center motion along an inhomogeneous magnetic field and cyclotron motion perpendicular to the magnetic field are considered for deriving the dielectric tensor as an integral operator. This scheme was applied to electron-cyclotron (EC) waves. In the first case of one-dimensional analyses, cyclotron damping in the presence of magnetic field inhomogeneous along the field line is studied to obtain the power deposition profile in magnetic beach heating. In the second case, the O-X-B mode conversion in spherical tokamaks is studied. Mode conversion to the electron Bernstein wave and strong absorption at the cyclotron resonance are described. The mode-conversion efficiency is consistent with analytical estimates. The extension to two-dimensional analyses in an equatorial plane and a poloidal cross section of tokamak plasmas is also discussed. Computational performance of integro-differential equation solver using FEM will be also discussed.