Full wave analysis of ICRF waves in helical plasmas including the finite Larmor radius effects

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Full wave analysis including the finite Larmor radius (FLR) effects is necessary to describe Bernstein waves, cyclotron harmonic resonance and the influence of energetic particles. There are three approaches to describe the FLR effects in the full wave analysis. The dielectric tensor involving differential operators easily describes the FLR effects up to the second order of $k_\perp \rho$ where $k_\perp$ and ρ are the wave number perpendicular to the magnetic field and the Larmor radius, respectively. This approach, however, cannot be applied to the case $k_\perp \rho \gtrsim 1$ and the extension to the third or higher harmonics is very complicated. The second approach is to use the spectral method in the three dimensional configuration space. Since all the wave field spectra in the direction of inhomogeneity are coupled with each other, the coefficient matrix of the linear matrix equation is dense and very large computer resources are required solve it. The third approach is to use an integral form of the dielectric tensor. The current induced by waves is usually calculate by integrating the perturbed momentum distribution function in the velocity space. By applying an appropriate variable transformation, the integrals in the velocity space can be rewritten as the integrals in the configuration space; one is the distance from the guiding center to the position where a particle carries current, and the other is the distance from the guiding center to the position where the particle affected by the wave electromagnetic field. With this transformation, the wave dielectric tensor becomes an integral operator on the wave electric field. Since the integral is spatially localized within several Larmor radius, the requirement of computational resource can be much reduced compared with the spectral method. The integral operator approach was implemented in the three-dimensional full wave code TASK/WM and applied to the toroidal helical configuration such as the LHD plasmas. The Maxwellian momentum distribution function is assumed. Mode conversion to the ion Bernstein waves at the two-ion hybrid resonance and absorption at the higher harmonics are studied. Comparison with the results of the differential operation approach and the effects of energetic particle will be presented. Extension to an arbitrary momentum distribution function and the effect of inhomogeneity along the magnetic field will be also briefly discussed.