Full-wave Electromagnetic Field Simulations of Lower Hybrid Waves in Tokamaks

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The most common method for treating wave propagation in tokamaks in the lower hybrid range of frequencies (LHRF) has been toroidal ray tracing, owing to the short wavelengths (relative to the system size) found in this regime. Although this technique provides an accurate description of 2-D and 3-D plasma inhomogeneity effects on wave propagation, the approach neglects important effects related to focusing, diffraction, and finite extent of the RF launcher. Also, the method breaks down at plasma cut-offs and caustics. Recent adaptation of full-wave electromagnetic field solvers to massively parallel computers [1] has made it possible to accurately resolve wave phenomena in the LHRF. One such solver, the TORIC code has been modified to simulate LH waves by implementing boundary conditions appropriate for coupling the fast electromagnetic and the slow electrostatic waves in the LHRF. In this frequency regime the plasma conductivity operator can be formulated in the limits of unmagnetized ions and strongly magnetized electrons, resulting in a relatively simple and explicit form. Simulations have been done for parameters typical of the planned LHRF experiments on Alcator C-Mod, demonstrating fully resolved fast and slow LH wave fields. Significant spectral broadening of the injected wave spectrum and focusing of the wave fields have has been found, especially at caustic surfaces. Comparisons with toroidal ray tracing have also been done and differences between the approaches has been found, especially for cases where wave caustics form. The possible role of this diffraction-induced spectral broadening [2] in filling the spectral gap in LH current drive will be discussed.

In collaboration with M. Brambilla (IPP), C.K. Phillips (PPPL), and P.T. Bonoli, MIT and the Wave-Particle Interactions SciDAC

Work supported by US DoE Contract No. DE-FC02-01ER54648

[1] J.C. Wright et al., Phys. Plasmas 11, 2473 (2004).
[2] G. Pereverzev, Nucl. Fusion 32, 1091 (1992).