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Full Wave Simulations for Fast Wave Heating and Power Losses in the Scrape-off Layer of Tokamak Plasmas

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Because fast waves in the ion cyclotron range of frequency (ICRF) have been used successfully to sustain and control the plasma performance, they will play an important role in the ITER experiment. Recent experimental studies of high harmonic fast wave (HHFW) heating on the National Spherical Torus eXperiment (NSTX) have shown that substantial HHFW power loss (up to 60% of the coupled HHFW power can be lost) can occur along the open field lines in the scrape-off layer (SOL). This paper examines the power loss by using the full wave code AORSA, in which the edge plasma beyond the last closed flux surface (LCFS) is included in the solution domain. A collisional damping parameter is used as a proxy to represent the real, and most likely nonlinear, damping processes, and it is applied to specific NSTX discharges in order to predict the effects and possible causes of this power loss. Full wave simulations demonstrate a direct correlation between the location of the fast wave cut-off layer, the large amplitude of the RF fields in the scrape-off region, and the power losses in the SOL (driven by the RF field) observed in the NSTX experiments. A strong transition to higher SOL power losses has been found when the FW cut-off is moved away from in front of the antenna by increasing the edge density. When evanescent waves become propagating waves in the SOL, due to higher density in front of the antenna, the power losses start to increase significantly, commensurate with the amplitude of the RF field found in the SOL. This same behavior is also confirmed by 3D AORSA results where the full antenna spectrum is reconstructed. Moreover, the 3D simulations show that the absorbed power in the SOL is largest near the LCFS and near the front of the antenna, as experimentally observed. Numerical simulations for "conventional"tokamaks with higher aspect ratios, such as DIII-D, are also performed showing similar behavior found in NSTX and NSTX-U. A prediction for the NSTX-U experiment is also presented indicating a favorable condition for the experiment due to a wider evanescent region in edge density.
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