Coupled RF wave propagation and DC plasma biasing in the SOL of tokamaks.

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In the prospect of future long-pulse magnetic fusion devices with high-*Z* plasma facing materials, the interaction of waves in the Ion Cyclotron Range of Frequencies (ICRF, 30-80MHz) with the Scrape-Off Layer (SOL) remains a challenge. The intense time-harmonic RF electric fields **E** emitted in the SOL at frequency ω_0 are suspected to cause RF oscillations $V_{RF}\exp(-i\omega_0 t)$ of the sheath voltage at plasma-wall interfaces. Non-linear rectification of these oscillations then produces a Direct-Current (DC) self-biasing of the SOL plasma. Ion acceleration across the larger DC potential V_{DC} is suspected to enhance the plasma-surface interactions locally. Sheaths also modify the RF wave reflection at material boundaries, in a way depending on V_{DC}.

The first part of the talk will present the simulation tools developed to address these issues. Simulations over spatial scales comparable to ICRF antenna dimensions couple simple models of RF full-wave propagation for **E** and DC SOL biasing for V_{DC} *via* non-linear sheath boundary conditions applied at plasma-facing material boundaries. An intermediate step computes the complex oscillating voltages V_{RF} at sheath boundaries. The coupled model is implemented using the Newton-Raphson scheme in the multiphysics Finite Element solver COMSOL. Open questions on mathematical and numerical aspects of the code will be reviewed.

At the inner part of the simulation domain, we emulate radiation to infinity using Perfectly Matched Layers (PMLs) adapted for gyrotropic media. Inside PMLs, spatial coordinates are stretched into the complex plane, turning propagative waves into evanescent ones. The main restriction is to avoid coexisting forward and backward waves. PMLs are implemented as lossy inhomogeneous materials with artificial dielectric and magnetic tensors depending on the plasma parameters, the stretching function and the stretched coordinates. In toroidal devices it might be clever to stretch the “natural” coordinates of the plasma geometry instead of Cartesian ones. The second part of the talk therefore focuses on a PML formulation generalized to any orthogonal system of coordinates. Numerical tests of the method were performed for radial PMLs of cold magnetized plasmas in cylindrical geometry. In this case cylindrical waves play a similar role as plane waves with Cartesian coordinates. Specificities associated with the local curvature of the geometry will be highlighted. The real part of the radial coordinate stretch affects the reflection of propagative waves *via* an artificial displacement of the inner metallic boundary towards regions of lower or higher curvature. This radial stretch can therefore reduce curvature effects, at the expense of refined meshing. The PML loses efficiency when the real part of the stretched radius becomes negative. This is probably related to the crossing of a singular point of the coordinate system inside the PML domain. For given plasma and fixed PML settings, a critical azimuthal mode number *m* of the cylindrical waves always exists above which the radial PML loses efficiency. The critical *m* value can be made arbitrarily high by increasing the real or imaginary radial stretching, so that all *m* values relevant for a realistic simulation can behave correctly. The associated numerical cost depends on the requirements about azimuthal resolution.