PROPAGATIVE AND EVANESCENT BEHAVIOUR OF ELECTROMAGNETIC WAVES IN COLD PLASMAS

K. Crombé[1,2], D. Van Eester[1], R. Koch[1], V. Kyrytsya[1]

[1]*Laboratory for Plasma Physics, Association "EURATOM - Belgian State" Trilateral Euregio Cluster, Renaissancelaan 30 Avenue de la Renaissance, B-1000 Brussels, Belgium*
[2]*Department of Applied Physics, Ghent University, Sint-Pietersnieuwstraat 41 B4, B-9000 Ghent, Belgium*

Plasma heating by launching radio frequency (RF) power in a plasma with antennas is one of the methods used to achieve the necessary temperatures for nuclear fusion. While very successful in heating the plasma, the method is often accompanied by detrimental effects (material release from walls, local overheating of surfaces and changes in edge transport). According to theory, these effects are all consequences of the rectification of an unwanted component of the RF electric field generated by the antenna. Avoiding these effects will be essential in future fusion reactors, but a good description is still lacking.

In view of a self-consistent description of the dynamics of a plasma and electromagnetic waves in the presence of metallic objects, a coupling between slow and fast time scale effects will be necessary. Density modifications (on a slow time scale) in front of Radio Frequency (RF) antennas due to rapidly oscillating electric fields have been explained in [1] by means of a ponderomotive force effect. A 1D description of electromagnetic wave propagation (on the fast time scale) in plasmas with varying densities has been given in [2].

We present an extension of [2] to a 2D model. The simulation domain is a rectangular box of dimensions 0.5 m x 1.0 m, which is of the same scale as a RF antenna for heating of fusion plasmas. The actual antenna geometry is not yet taken into account, since this would require a 3D simulation domain and be very demanding on computer power. The antenna is simplified by a current density or electric field excitation. Cold plasma description as formulated by Stix [3] has been assumed for the plasma. For sufficiently high densities, the wave propagation is split into a slow and fast wave branch. Examples with different densities and 2D density gradients are shown, also including lower hybrid and ion cyclotron resonance layers. The evanescence of waves with short wavelengths was found to create numerical difficulties. Slow and fast wave excitations on the antenna will be compared. The orientation between the static magnetic field and the electric field of the waves mixes slow and fast wave effects and influences the electric field pattern in the box. The amplitude of the magnetic field has an influence on the location of the ion cyclotron resonance layer.

First steps towards an iterative approach that couples the RF part and plasma response are discussed.

[1] D. Van Eester, K. Crombé and V. Kyrytsya, ‘Ion cyclotron resonance heating-induced density modification near antennas’, Plasma Phys. Control. Fusion, Vol. 55, 025002 (2013)
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[3] T.H. Stix, Waves Plasmas (New York: Springer) (1992)