Simultaneous O- and X-mode plasma probing with a shared dual-polarisation reflectometer front-end: a full-wave feasibility study

F. da Silva[1]*, A. Silva[1], J. Santos[1], T. Ribeiro[2], S. Heuraux[3]
[1]*Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal*
[2]*Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, D-85748 Garching, Germany*
[3]*Institut Jean Lamour, UMR 7198 CNRS-Université de Lorraine, F-54000 Nancy, France*
*Corresponding author: e-mail tanatos@ipfn.tecnico.ulisboa.pt

Microwave reflectometry probes the plasma either in Ordinary (O-mode) or Extraordinary (X-mode) polarisation, with cut-offs depending, respectively, on the electron density alone or on both density and magnetic field. Operating both modes over the same line of sight extends the measurements to the very edge of the plasma via the X-mode upper cut-off, while the cross-comparison of simultaneous O- and X-mode measurements, demonstrated on ASDEX Upgrade, validates the density profiles and can provide estimates of the magnetic field [1]. Serving both modes from a single compact front-end is therefore attractive.

We propose a concept in which a bistatic pair of horn antennas, emitter (Tx) and receiver (Rx), each served by its own rectangular waveguide, is installed with the broad wall aligned with the toroidal direction. The fundamental TE10 mode then radiates with the electric field perpendicular to the toroidal magnetic field, probing the plasma in X-mode. The orthogonal TE01 mode of the same guide, with E parallel to the toroidal field, probes in O-mode. O-mode operation covers several standard bands (e.g. K to W), the waveguide, fundamental at the lowest band, becoming progressively oversized at the higher bands [2]; X-mode uses a band matched to the upper cut-off of the scenario, with lower cut-off probing also contemplated [1]. At this stage, only the terminal waveguide sections and the antennas are modelled, with the aperture shape chosen to control the radiation pattern of each polarisation, leaving the full transmission line to a subsequent machine-specific implementation.

The feasibility study is carried out with the 3D finite-difference time-domain full-wave code REFMUL3 [3,4], supported by the 2D full-polarisation code REFMULF [2]. Since the simulations give direct access to the fields inside the waveguides, the signal returning to the Tx antenna is also analysed, allowing bistatic and monostatic operation to be compared. The proof of principle uses a slab plasma of manageable size, with density and magnetic field parameters approaching those of a Low Field Side scenario of DTT, a probable implementation environment [2,3]. A prospective extension to a full DTT study, in line with previous O-mode assessments for this machine [2,3], is discussed.

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[3] F. da Silva et al. (2025) JINST, 20, C09004.
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