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Integrated Microwave Diagnostic Design Workflow - a PPR antenna design use case

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This work presents the development and application of an advanced engineering design workflow for the planning, design, and assessment of future fusion plasma diagnostics. The workflow leverages advanced simulation techniques and synthetic diagnostics for system performance evaluation and prediction, crucial in the decision-making process of the design cycle. A key component of this workflow is the integration of realistic representations of system components, including wave launcher structures and vessel wall structures. The procedure involves the use of CAD models of these structures, combined with parameterizable CAD models of the launcher, to produce a description suited for Finite Difference Time Domain (FDTD) 3D simulation. They can include electron density data from plasma scenarios obtained from proven state-of-the-art integrated modeling codes such as JINTRAC for the core plasma, and SOLEDGE2D-EIRENE or SOLPS-ITER for the scrape-of-layer and pedestal region. All used CAD models are shared between the wave propagation code and thermal, structural and neutronic simulators, being iterated according to the analysis of the various simulation results. The validation of this workflow is demonstrated through the design of a set of antennas for the DTT's High-field-side (HFS) Plasma Position Reflectometry (PPR) system. Given the severe space and access constraints, optimized small-footprint bistatic and monostatic hog-horn antenna designs were proposed. The viability of the PPR implementation was confirmed through 3D full-wave simulations, laboratory measurements of a 3D-printed bistatic antenna prototype, and a preliminary thermal analysis of the antenna embedded in the plasma-facing wall structures under standard plasma operation conditions. This use case illustrates the power of the proposed workflow in addressing complex design challenges in the field of fusion plasma diagnostics.

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