Utilizing deep learning for characterization of tokamak edge density perturbations

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The Edge Localized Modes (ELMs) that accompany the H-mode operation regime are particularly dangerous for current and next generation tokamaks, due to the enhanced heat loads on the divertor plates. In this work a combination of a simulated microwave beam propagating through ELM-like structures and a deep neural network (NN) is proposed for fast characterization of tokamak edge perturbations.

An in-house 2D FDTD code is developed to simulate a 140 GHz microwave beam that propagates through a magnetized tokamak plasma. The ELM is expressed analytically as density perturbation added to the homogeneous background plasma and adjusted through parameters that control the amplitude and the mode number. Once added, the ELM effect on the microwave propagation is monitored. The spatial distribution of the wave power is measured after the interaction with the ELM and compared against the equilibrium case.

A dataset of 3,000 individual simulations is collected and used to train a NN. The input layer of the network consists of a parametrized curve of the wave power, while the output layer is returning the amplitude and the mode number of the ELM. Essentially, the NN is capable of linking the scattered wave power to the specific ELM that caused this scattering profile. The NN demonstrates an excellent performance, which translates to errors less than 2% on unseen data.

The proposed framework could potentially be used for fast ELM prediction through microwave diagnostics. The next step of this project is to use a more realistic ELM profile, ideally a measured experimental profile from a tokamak device. Extending the simulations into a 3D domain is also planned for the future, in order to investigate if the toroidal extend of the ELM can affect the microwave beam.