ICRF wave propagation and absorption modelling via machine learning

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A surrogate model of ICRF wave propagation and absorption in the National Spherical Tokamak eXperiment (NSTX) is presented. The surrogate model, based on a Random Forest Regressor (RFR), reduces inference time from 2-5 minutes for the ground-truth TORIC simulations to $\sim$50 us with high accuracy.

Radio-frequency (RF) wave heating systems in the ion cyclotron range of frequencies (ICRF) are widely used actuators in the operation of magnetic confinement fusion devices, and will play a major role in ITER. Available high-fidelity RF actuator modeling tools are still computationally expensive, making their application demanding for specific scenario optimization, unfeasible for inter-shot predictive modeling, and unattainable for real-time control. With the advent of Machine Learning (ML) multiple examples of high-fidelity surrogate models have been developed for various fusion energy applications where simulation times have been accelerated by several orders of magnitude.

The surrogate model developed is trained and tested using a database comprising numerical results from the "quasilocal" version of the TORIC code. The code allows to compute the full-wave propagation and absorption in the high harmonic fast wave (HHFW) regime present in the NSTX. The database is generated using the Latin Hypercube Sampling (LHS) method covering the electron temperature and density profiles and the toroidal mode number. The RFR-based surrogate model with the one dimensional electron/ion power density as targets, features an average mean squared error ($\overline{\text{MSE}}$) of 2.6×10^{-3}/ 6×10^{-2} with coefficient of determination $R^2 = 0.619/0.510$. Outlier identification and filtering allows to improve the model scoring to $\overline{\text{MSE}} = 2.1 \times 10^{-5}$/ 9.1×10^{-5} and $R^2 = 0.934/0.953$.

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