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Validation of short pulse reflectometry diagnostic turbulence measurements in the TCV tokamak with synthetic diagnostic based on gyrokinetic modeling

O. Krutkin[1], U. Kumar[1], S. Mazzi[2], S. Brunner[1], S. Coda[1], M. van Rossem[1] and the TCV team*
[1] Swiss Plasma Center, École Polytechnique Fédérale de Lausanne
[2] Institut de recherche sur la fusion magnétique, CEA Cadarache
*See Reimerdes et al 2022 (https://doi.org/10.1088/1741-4326/ac369b).
e-mail (speaker): oleg.krutkin@epfl.ch

A Short Pulse Reflectometer (SPR) diagnostic has been developed for the TCV tokamak [1]. It utilizes short (~1 ns) microwave pulses to probe plasma in the presence of a cut-off. Pulse delays corresponding to different probing frequencies are then used to reconstruct the electron density profile similar to conventional fast-sweeping reflectometry. Recently, a fluctuation SPR (FSPR) method for obtaining the amplitude and radial correlation length of the turbulence from statistical properties of pulse delays was developed [2]. The method is expected to possess advantages over traditional fluctuation and radial correlation reflectometry. It was validated with full-wave numerical modeling utilizing ad-hoc turbulence with a simplified geometry.

Within this work, the first experimental application of the FSPR is presented for shots with L-mode Ohmic plasma. In particular, measurements are carried out in shaped plasma with positive and negative triangularity (PT and NT respectively), reproducing the decrease of the turbulence amplitude previously observed with other turbulence diagnostics [3, 4]. The difference in measured turbulence amplitude is presented in Fig. 1, where the normalized fluctuation amplitude in a wide radial range is shown for the two selected pulses.

During the previous validation efforts [2], the FSPR method was shown to be particularly sensitive to the curvature of the cut-off surface. This curvature was different between PT and NT discharges in the probing area, casting doubt on the obtained measurement. Thus to further validate the method under conditions as realistic as possible and confirm the interpretation of experimental results, a synthetic TCV SPR diagnostic was developed.

First, realistic density fluctuations related to microturbulence were computed with the flux-tube version of the gyrokinetic GENE code. Simulations were run with the experimental magnetic equilibrium and density and temperature profile and included collisions and impurities. Profiles were varied within experimental error bars to match the experimental heat fluxes.

Next, density fluctuations produced by GENE together with the experimental density profile were used as an input for the full-wave code CUWA [5]. The code was modified to have a pulse microwave source and a Gaussian antenna pattern close to the experimental one. For each timestep of the GENE output a synthetic pulse delay was computed resulting in over 1000 samples for each probing frequency. The FSPR method was then applied and geometrical effects were shown to not be responsible for the measured difference between PT and NT.

Finally, the GENE output was rescaled to include a radial variation of turbulence amplitude as a way to overcome the limitations of the flux-tube model. This allowed us to obtain a direct match between synthetic and experimental FSPR results, confirming experimental measurements and further validating the FSPR method.

References
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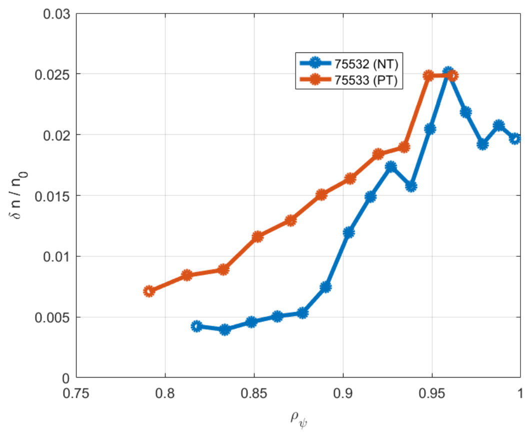

Figure 1. Radial profiles of turbulence amplitude measured in NT (blue line) and PT (red line) discharges using FSPR.