One of the common goals in experimental magnetically confined fusion research is characterization of the plasma turbulence. To that end, TCV tokamak features a novel short-pulse reflectometry (SPR) diagnostic, which can potentially be utilized to measure properties of the turbulence.

It is essentially a radar system, where the plasma is probed by a short (under ns) microwave pulse in the presence of the cut-off (reflection) area from which the pulse reflects back into the probing antenna. The position of the cut-off for a particular probing frequency (in 50-75 GHz) range is determined by the plasma electron density. Thus, by measuring the delay between probing and reflected beam corresponding to different probing frequencies, the information about the electron density profile is inferred including its turbulent perturbations.

Unfortunately, the complex interaction of microwaves with magnetized plasma makes it difficult to establish the connection between SPR measurements and properties of the turbulence. Numerical modeling utilizing the synthetic diagnostic approach was carried out to establish this connection for the case of low turbulence amplitudes (linear regime). However, the case of large turbulence amplitudes (nonlinear regime) is yet to be explored.

Within the project a systematic analysis of the SPR diagnostic in the nonlinear regime will be carried out. The numerical finite difference code CUWA, which solves the wave equation for a given plasma density and provides synthetic reflected pulse will be utilized. The main goal of the project is identifying markers that can be used to determine if the diagnostic is operating in the nonlinear regime and assessing the possibility of determining the turbulence parameters regardless. Time permitting, the results of this analysis will be applied to the interpretation of experimental measurements and possibly used to develop a machine learning approach to analyzing SPR data.

Specifically, the project plan is as follows, with the last two steps depending on the available time.

1. Getting familiar with the principle behind the SPR diagnostic and the CUWA code.
2. Running CUWA for a wide range of turbulence parameters and finding the patterns corresponding to nonlinear regime. Particular emphasis will be placed on the symmetry of SPR delay distribution and the shape of the reflected pulse.
3. Establishing data-driven criterion for nonlinear SPR operation, connection between the measurement and the turbulence amplitude and cut-off position.
4. Applying obtained results to the experimental data.
5. Developing a neural network for the interpretation of the SPR data in the nonlinear regime.