CEA/CADARACHE
DIRECTION DES SCIENCES DE LA MATIÈRE (DSM)
INSTITUT DE RECHERCHE SUR LA FUSION PAR CONFINEMENT MAGNETIQUE (IRFM)
CEA/Cadarache - 13108 St Paul-lez-Durance Cedex - France

PhD PROPOSAL 2014

Supervisors : Stéphane HEURAUX (IJL Nancy) Sébastien HACQUIN (CEA Cadarache)	**e-mail :**	sebastien.hacquin@cea.fr
	phone :	+33 442 25 61 25
	secretary :	+33 442 25 62 33
Research Team : SCCP / GTTM		

Title : Experimental and numerical study of turbulence in fusion plasmas using gyrokinetics codes data in reflectometry synthetic diagnostics

Summary :
Good understanding and control of the plasma turbulence, as for instance the processes governing the transition towards improved confinement regimes (such as L-H transition [1]), is a key issue for optimised operation of fusion devices as tokamaks. Such a goal relies on accurate measurements of the main plasma parameters, which are essential for validation of the theoretical models. Based on radar technics microwave, reflectometry is a powerful diagnostic for the study of plasma turbulence [2]. The plasma region explored is defined by the position of the cut-off layer, which reflects the probing signal, and depends on various parameters: the probing frequency (typically in the 20 - 200 GHz range), the plasma electron density and temperature, the confining magnetic field. The quantitative interpretation of reflectometry data remains often challenging due to the variety of processes affecting the wave propagation (dispersion, diffraction, scattering, etc.) together with the multidimensional effects resulting from both plasma fluctuations in the transverse directions and divergence in the probing beam (imposed by the emitting and receiving antenna radiation patterns). Reflectometry simulation is of prime interest for better understanding of the diagnostic response and enhanced interpretation of experimental data. The continuous progress in processor speed has contributed to the development of "full-wave" reflectometry codes, which rely on numerically solving Maxwell's curl equations in the presence of plasma permittivity tensor or differential equations able to describe the plasma response induced by the probing wave [3].

Work plan :
The first objective of the work is to study the link (transfer function) between the fluctuations of the reflectometry signal that is measured and the density fluctuations which are to be characterised. Previous simulations using 1D reflectometry code and synthetic density fluctuations to model the plasma turbulence demonstrated the possibility to define such a transfer function [4]. Here it is proposed to refine these studies with 2D reflectometry full-wave code (taking into account the poloïdal density fluctuations) [5] and density fluctuations given by the flux-driven 5D gyrokinetic code GYSELA [6], which is particularly suitable to model the Ion Temperature Gradient (ITG) driven turbulence, and other turbulence codes adapted to the studied experimental cases, such as GENE, GEMR, etc. The modelled reflectometry spectra obtained from these simulations will be compared with the input fluctuation spectra given by the gyrokinetic code, this allowing the definition of the transfer function for a given set of input parameters (reflectometer configuration, plasma geometry and parameters, …). It will also be compared to those using synthetic density fluctuations with a flat spectrum established under the Born approximation assumption.
Once this first phase achieved, the simulation tools will be used for physics studies. Especially, reflectometry measurements would provide experimental k-spectra of turbulence by using the previously derived transfer function. These spectra will then be directly compared to those predicted by first principle simulation codes such as GYSELA, GENE, GEMR, etc. If time allows for, simulation results from other codes could also be considered, allowing for some code cross-comparison as well. Through the characterisation of the plasma turbulence in various tokamak regimes, this work will be closely linked and/or complement experimental studies carried out in the frame of other PhD theses on the turbulence dynamics during fast transport events such as relaxation processes (A. Medvedeva), L-H transition, ITG/TEM quasi-coherent modes (H. Arnichand).
Within this PhD work, the method to compute the transfer function will be validated, and turbulence code predictions will be compared to experimental data. Progress is expected at the same time in the understanding and analysis of experimental data and in numerical predictions. It requires complementary works between experimentalists and theoreticians involved in numerical simulations of tokamak plasma turbulence.

References :
[1] L. Schmitz *et al*, Physical Review Letters **108** 155002 (2012)
[2] G. Conway, Nuclear Fusion **46** S665–S669 (2006)
[3] R. Coelho *et al*, Fusion Science and Technology **63** (1) 1-8 (2013)
[4] S. Heuraux *et al*, Review of Scientific Instruments **74** (3) 1501 (2003)
[5] S. Hacquin *et al*, Journal of Computational Physics **174** 1–11 (2001)
[6] V. Grandgirard *et al*, Communications in nonlinear science and numerical simulation **13** (1) 81 (2008)

Skills : good knowledge of plasma physics highly desirable; interest for signal processing and ability for numerical simulation required (familiarity with Matlab, Fortran and/or C will be a strong asset)