A propos du centre ou de la direction fonctionnelle

Located at the heart of the main national research and higher education cluster, member of the Université Paris Saclay, a major actor in the French Investments for the Future Programme (Idex, LabEx, IRT, EquipeX) and partner of the main establishments present on the plateau, the centre is particularly active in three major areas: data and knowledge, safety, security and reliability; modelling, simulation and optimisation (with priority given to energy).

The 450 researchers and engineers from Inria and its partners who work in the research centre's 28 teams, the 60 research support staff members, the high-level equipment at their disposal (image walls, high-performance computing clusters, sensor networks), and the privileged relationships with prestigious industrial partners, all make Inria Saclay Île-de-France a key research centre in the local landscape and one that is oriented towards Europe and the world.

Contexte et atouts du poste

Hyperbolic metamaterials are artificially engineered anisotropic materials which exhibit some unusual properties, such as negative refraction and backward wave propagation. An important physical phenomenon linked to the hyperbolic metamaterials is the fact that waves with low frequencies propagate only in selected directions (while being evanescent in others).

Hyperbolic metamaterials are used in the super-resolution imaging [Salandrino, Engheta 2006], stealth technologies [Narimanov et al. 2010], control of spontaneous emission in the quantum communications [Jacob et al. 2012, Ferrari et al. 2015]. Remarkably, materials exhibiting properties similar to the hyperbolic metamaterial properties appear also in nature [Narimanov, Kildishev 2015], [Podolychny et al. 2015].

Despite their importance for applications, and abundance of the literature in the fields of physics and engineering, there are very few works in applied and numerical mathematics dedicated to the underlying models. Mathematically, the particularity of the models for hyperbolic metamaterials lies in the fact that they are described by hyperbolic boundary-value problems in the frequency domain. While the Cauchy problems (or, more precisely, mixed problems) for this kind of PDEs had been well studied (cf. e.g. the monograph [Petermander 1983, 1985]), there are much fewer results on purely boundary-value problems for hyperbolic metamaterials. It is nonetheless well-known (see the work [John, 1941] for the wave equation) that their well-posedness depends heavily on the geometry of the domain. Let us finally remark that from the point of view of numerical analysis, these models are quite ill-posed.

Principales activités

In physics [Cummer 2004] the question of the choice of the boundary conditions is often reduced to the free space wave propagation. That is why in this PhD thesis we are going to study one of the simplest hyperbolic models of the free space wave propagation in a strongly magnetized cold plasma, described by the Maxwell’s equations with a diagonal electromagnetic tensor in 3D. The tensor depends on the frequency, in the low-frequency regime, its eigenvalues are of different signs, which accounts for the hyperbolic behaviour.

The thesis consists of two main parts :

1) the justification of the well-posedness of the model in the free space: radiation condition, limiting absorption principle, limiting amplitude principles. We plan to combine the ideas of the work [Becache et al. 2017] on the splitting of the cold plasma Maxwell’s equations into (roughly speaking) hyperbolic (similar to the Klein-Gordon equation) and elliptic part (similar to the Helmholtz equation), with the ideas of [Carlet, Kachanovska, in preparation] on handling the hyperbolic Klein-Gordon equation.

2) development of the numerical method for the resolution of the cold plasma Maxwell’s equations in the free space. Again, this consists in :

2.1) construction of the transparent boundary conditions (for a fixed geometry). Typically such conditions are expressed in terms of non-local boundary operators.

2.2) their numerically tractable approximation (as e.g. absorbing boundary condition)

2.3) well-posedness of the resulting model with absorbing boundary conditions.

2.4) construction and analysis of the appropriate numerical method to handle the problem (now posed in the bounded domain) with absorbing boundary conditions. Its implementation.

Compétences

We are looking for a candidate with a strong background in numerical analysis for PDEs. Skills in programming and analysis of PDEs are desired (but not necessary).

Avantages

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working
hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of teleworking (after 6 months of employment) and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage

Rémunération

Monthly gross salary: 1,982 euros (1st and 2nd year), 2,085 euros (3rd year)