Electromagnetic materials optimization tools to minimize radar signature of objects

Reduction of Radar Cross Section (RCS) of potential targets is a major challenge in the field of defence. This can be obtained either by playing on the shape of the objects or by coating them with structured absorbing materials. When the characteristic length of the objects is of the same order of magnitude as the wavelengths, their electromagnetic response can be calculated only with methods solving Maxwell equations. To this end, one can use commercial software or open-source codes based on different methods: finite elements, integral methods, finite difference methods, Mie theory, etc.

During this internship proposed by the French Atomic Energy Commission (CEA), I2M and IMS laboratories of the University of Bordeaux, you will study the case of a circular cylinder coated by a spatially inhomogeneous material (Figure 1). This multi-layer structure, which can be obtained by additive manufacturing process available at the CEA, allows controlling the propagation of electromagnetic waves, and then the radar response of the coated cylinder, through a dedicated design process involving both material and geometric design variables.

The problem to be solved at the end of the project will be decomposed into several steps. Firstly, classical hybrid multilayer plate/shell-like configuration will be investigated by formulating (and solving) a constrained non-linear programming problem where both geometric and material properties will be optimised to satisfy the requirements of the problem at hand. Secondly, the problem will be generalised by introducing a topological descriptor to optimise, concurrently, both the topology and material distribution of the composite structure. A particular attention will be put on the problem formulation, on the description of the electromagnetic responses and on the integration of both the numerical model and the design requirement in the problem formulation as cost function and as constraint functions.

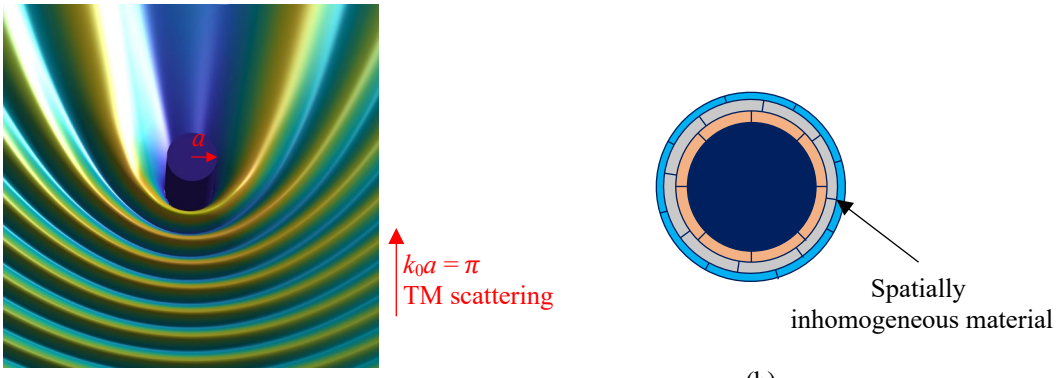

Figure 1: (a) Diffraction of an uncoated cylinder normally illuminated by a plane wave (analytic solution) (b) a circular cylinder coated by a spatially inhomogeneous material

Before starting topological and material optimization, the initial stage consists in selecting the appropriate electromagnetic simulation tool and in validating its convergence through a dedicated study. Your knowledge in numerical analysis simulation will allow you to develop build a full wave two-dimensional electromagnetic calculation tool applied to this case study (commercial software or open-source code). The validation of the code tool will be assessed via dedicated convergence criteria and a comparison between provided (measure or other simulation) and calculated RCS. The code will be developed by interfacing Python with a commercial software or with an open-source code. The resulting scripts will be then interfaced with the topology optimization algorithm SANTO (SIMP And NURBS for Topology Optimization) developed at I2M laboratory. Once this first step will be achieved (i.e., validation of the code tool via convergence criteria and comparison with results available at CEA and in the literature), the internship will continue by focusing on the development of optimization tools for electromagnetism by enhancing those already available at I2M laboratory for mechanical and thermal problems.

During this project, you will have to interact with researchers from different domains: applied mathematics, mechanics, electromagnetism, and materials. You will develop new skills in numerical analysis, modelling and electromagnetic characterization of materials in microwave domain. This internship may be continued by a PhD.

Your Profile:

- Last year of scientific master (university or engineering school) in computational physics, electromagnetism or optics.
- With a solid foundation in physics or/and in applied mathematics, you are comfortable in programming and agile in IT environments.

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