

Composite materials for electromagnetic shielding applications: multiscale modeling via semi-analytical homogenization techniques

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ABSTRACT

A transition from the microscopic scale to the macroscopic scale is necessary when modeling composite-based structures for shielding applications. It is usually accomplished by applying electromagnetic homogenization techniques to the studied composite. Semi-analytical homogenization methods exploit the benefits of numerical simulations (studying complex materials, wide range of frequencies, modeling electrical contact, etc.), while allowing facilitated access to effective properties through well-known analytical formulas. They can, for example, broaden the application domain of classical analytical mixing rules by adapting these models based on numerical simulation results. This is demonstrated in [1] where skin effect is integrated, through finite element simulations of a unidirectional fiber composite, into the Maxwell-Garnett model to adapt it for microwave frequencies.

Moreover, semi-analytical techniques allow for the extraction of electrical properties when classical mixing rules reach their limits. In this work, a homogenization technique based on finite element simulations and inverse problem solving is presented. It is applied to composite materials made of woven conductive fibers (figure 1) in the frequency range [500MHz; 40GHz]. For a plane wave excitation with normal incidence, the first step consists in estimating transmission and reflection coefficients of the composite using numerical simulations. An analytical formula is then used to compute the effective properties of a homogeneous medium that will have the same response as the composite. Results obtained in [2] prove the capabilities of the proposed technique to correctly homogenize this type of material. Additionally, this study is extended to obliquely incident plane waves in both Transverse Electric TE and Transverse Magnetic TM configurations. The computed effective medium is shown to be an intrinsic characteristic of the material, as it is independent of the angle of incidence and wave configuration. This suggests that realistic case studies where the electromagnetic wave is incident obliquely to the composite structure can be simulated by homogenizing the material based on a normal incidence approach.

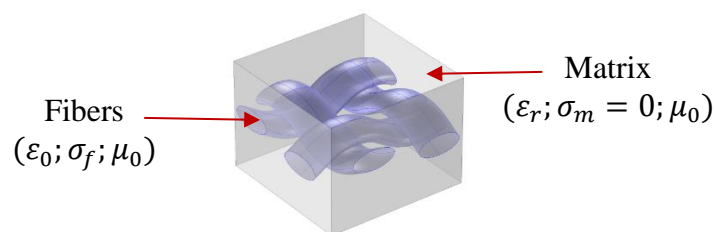


Figure 1 : studied composite sample with woven conductive fibers.

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