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Wave propagation phenomena in metamaterials for retrieving of effective parameters

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In the talk we give an overview of the developed restoration procedures and discuss their pros and cons in connection of assigning effective parameters (EP) to metamaterials (MMs). There are plenty of notorious physical phenomena preserving the unambiguous retrieving of EP, like strong coupling between constitutive elements, multipoles resonances, multimode or photonic crystal (diffraction type) regimes. There are also technical limitations of the retrieval methods connected with very strong losses, branching ambiguity, convergence to bulk parameters, etc. Moreover, most of the simple methods reveal so-called wave effective parameters, assigned for particular ligh propagation direction in numerical or real experiments. Therefore, finding the EP is a tricky problem, which still requires a lot of contribution to get deeper insight in it.

We report on our advances in restoration MMs EP taking into account propagation of eigen-waves in multilayered structures (thicknesses 10-100 unit cells). Thus, the question of parameters convergence is naturally resolved in our approach. The method has been tested on complex three-dimensional structures like a split-cube-in-carcass and with circular polarized waves on chiral MMs [1, 2].

Elaborating our approach the new method has been established, where the unit-cell volume and face field averaging procedures define wave and input (Bloch) impedances correspondingly. The first part of the method involves the extraction of the dominating (fundamental) Bloch modes from the simulation data of the field distribution in several unit cells [3]. Then, we explicitly perform either volume or surface averaging of the electric and magnetic fields of the dominant forward-propagating Bloch mode over the unit cell. The ratio of the surface averaged fields provides the value of the Bloch impedance and, respectively, enables the retrieval of wave EPs. The volume averaging of fields of forward propagating fundamental Bloch wave provides the wave impedance, which is needed for the retrieval of the materials parameters. The method is illustrated with several examples.

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