Optimization of Metamaterial WAIM for Planar Arrays

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For wide-angle scanning planar arrays, the magnitude of the reflection coefficient may change substantially with scan angle, scan plane and wave polarization. The conventional solution to this problem consists in the use of wide-angle impedance matching (WAIM) structures made up of a stack of dielectric layers. Much greater flexibility may be achieved by employing anisotropic slabs with controllable spatial dispersivity. Artificially structured materials (or metamaterials) make this approach feasible by allowing the simultaneous control of dielectric and magnetic properties in the different directions (S.Sajuyigb et al., IET Microw. Antennas Propag., 4(8), 1063-1072, 2010).

In this contribution, an innovative optimization strategy is proposed for the design of a metamaterial WAIM consisting of a number of planar periodically printed layers, whose unit cell is small with respect to the wavelength. This kind of structures can be efficiently analyzed by modeling the periodic layers as Floquet-wave multiport networks connected by transmission line branches, and applying the Bloch theory (E. Martini, G.M. Sardi, and S. Maci, Technical Reports of Contract No. W911NF-09-1-0575 for U.S. Army Research Laboratory, 2010). This leads to a quasi-analytical description of the metamaterial in terms of few Bloch parameters, from which a set of equivalent constitutive tensors can be derived. The resulting model is at the same time complete enough to accurately describe the electromagnetic behavior of the WAIM and simple enough for the application of effective optimization strategies.

Since the unknown Bloch parameters are represented by means of real variables, an algorithm adapt for the optimization over continuous spaces is taken into account (P. Rocca et al., Inverse Problems, 25(123003), 1-41, 2009). Moreover, due to the complexity of the arising optimization problem, a multiple-agent stochastic global optimizer is considered able to simultaneously sample the solution space at different points and to avoid ‘local minima’ (i.e., suboptimal solutions) of the cost function at hand.

Thanks to flexibility of the optimization technique, a-priori information available from the physics of the problem or additional constraints, for example about the tolerance of the manufacturing of metamaterials, can be included in a straightforward manner in order to guarantee the feasibility of the final solution as well as to improve the convergence rate of the optimization process.