Full-Wave Analysis of Tensorial Impedance Metasurfaces

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Metasurfaces are thin metamaterial layers characterized by unusual reflection properties of plane waves and/or dispersion properties of surface/guided wave. Metasurfaces can be described through a surface impedance boundary condition; the impedance, possibly tensorial, can be space-varying (by design) on the surface. Metasurfaces can be realized at microwave frequencies by printing a dense periodic texture of small elements on a grounded slab, with or without shorting vias. When the resulting structure is periodic, the metasurface can be accurately characterized in terms of uniform equivalent surface impedance, relating the tangential components of the average electric and magnetic fields. In this case, a rigorous analysis can be performed through a spectral Method of Moments (MoM). However, it is often of interest to consider aperiodic metasurfaces; by modulating the equivalent surface impedance it is possible to engineer the interaction of a given incoming field with the metasurface. This can be exploited, for instance, to change the propagation constant of surface waves, thus realizing planar lenses, or leaky-wave antennas. The very effect of metasurface antennas and lenses derives from the spatial variability of the (tensor) surface impedance, sought by design.

Verification of the synthetized modulated metasurface still remains an issue for full wave simulations. Here we propose a method, based on a surface integral formulation of the electromagnetic problem, to analyze numerically a metasurface with arbitrarily varying tensorial surface impedance. The equivalent surface current densities on the metasurface are determined imposing a surface tensor impedance boundary condition:

$$\underline{E}_t = \underline{\underline{Z}}_s \cdot \left(\hat{n} \times \underline{H}_t \right) \qquad (1)$$

where $\hat{n}$ is the unit versor normal to the surface, $\underline{E}_t$ and $\underline{H}_t$ are the electric and magnetic fields tangential to the surface, respectively. Our aim is to solve (1) by means of the Method of Moments (MoM). An approach for solving this problem was proposed in (A. W. Glisson, M. Orman, F. Falco, and D. Koppel, "Electromagnetic scattering by an arbitrarily shaped surface with an anisotropic impedance boundary condition", ACES Journal, vol. 10, no. 3, pp. 93–106, Nov. 1995); here we explicitely address continuity and regularity issues which play a crucial role. Different choices for performing the testing will be investigated, including bases that possess both div- and curl- conforming properties, such as Chen-Wilton (CW) or Buffa-Christiansen (BC) basis functions.