Div-Conforming Entire-Domain Basis Functions for the Analysis of Modulated Metasurface Antennas on Circular Domains

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Metasurfaces are thin metamaterial layers characterized by unusual reflection properties of plane waves and/or dispersion properties of surface/guided waves. Metasurfaces can be realized at microwave frequencies by printing a dense periodic texture of small elements on a grounded slab. Metasurfaces can be effectively modelled as impedance surfaces, upon homogenization of the actual sub-wavelength patterning. The Impedance Boundary Condition (IBC) model highly improves the efficiency of the numerical solution of the problem: a Boundary Element Method (BEM) discretization (also known as Method of Moments – MoM – in computational electromagnetics) is particularly well suited for solving the electromagnetic problem associated with the IBC surface.

As well known, the use of entire-domain basis functions tailored to the specific problem under analysis can significantly increase the efficiency of a MoM analysis. The main benefit of such approaches is a significant compression of the problem size w.r.t. a classical mixed-element discretization (e.g., via Rao-Wilton-Glisson basis functions), although without affecting the asymptotical computational cost. This naturally implies reducing storage requirements for the system matrix, and often allows for a direct inversion of the matrix system: this is especially desirable when the linear system needs be solved numerous times, e.g. when an optimization of the IBC is sought. If the set of basis functions is properly chosen the conditioning properties of the matrix system can also be improved, particularly beneficial when an iterative solution is sought (due to finite precision arithmetic the ill-conditioning also affects the accuracy of the solution for direct solutions).

When the computational domain is circular, a particularly well suited set of entire-domain basis functions can be defined in terms of the modes of a circular waveguide. This approach was proposed in (P. Pirinoli, G. Vecchi, and M. Orefice, IEEE Trans. on Antennas and Prop., 52(9), 2415-2423, 2004) for ring patch antennas. Here we apply similar ideas to represent tangential fields onto IBC surfaces extending for several wavelengths on circular domains: although apparently limited in scope, many metasurface applications are realized as circular geometries, such as a significant portion of planar lenses and leaky wave antennas. A complete set of basis functions will be presented, and the representation properties of this basis will be discussed and analyzed, as well as its regularizing properties and its benefits in terms of computational costs. The dimensionality of the problem is typically reduced from tens of thousands to a few hundreds unknowns, on turn reducing by orders of magnitude the CPU time for obtaining a solution. Numerical results will be shown to support the theoretical conclusions.