Efficient Pattern Computation for Metasurface Antenna Design Scheme using Div-Conforming Annular-Ring Entire Domain Basis Functions

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The design and optimization of Metasurface (MTS) has been the subject of many recent articles and considered a very important topic in the community. Entire-domain, spectral basis functions (EBF) have witnessed recent interest in the integral-equation analysis of large MTS antennas modeled via homogenized Impedance Boundary Conditions (IBC). The authors recently submitted a formulation employing classical Galerkin test via Rao-Wilton-Glisson (RWG) functions, yet assembled to represent div-conforming annular EBF (F. Vernì, M. Righero and G. Vecchi, "On the Use of Entire-Domain Basis Functions and Fast Factorizations for the Design of Modulated Metasurface", IEEE Transactions on Antennas & Propagation, 2019). The problem addressed was the reduction of the numerical complexity for the analysis of repeated solutions of planar MTS via IBC and the associated surface integral equation (IBC-SIE). Typically, in the analysis of large MTS antenna, a large number N_Λ of RWG (Λ) is necessary to guarantee a stable solution at the current-density level. The use of div-conforming EBF (Ψ) compresses and regularizes the system matrix, keeping the solution accuracy controllable with a limited number $N_\Psi \ll N_\Lambda$ of degrees of freedom.

In this work the emphasis is given to the pattern computation, as necessary in optimization endeavors. Here we introduce an efficient computation of the pattern generated by the annular-ring EBF, which reduces the overall cost of pattern computation. Existing works considered either non-div-conforming EBF radiation on only circular domain or the radiation of the div-conforming annular-ring EBF solution expressed as combination of RWG. In this new scheme, the 3D radiation pattern-matrix is computed in a semi-closed form, straight from the N_ψ EBF, before the begin of the optimization routine. The radiation integrals have a negligible cost due to a numerical integration only over a few points along the radial component. Thus, the compression effect of the EBF allows also the storage of the 3D pattern-matrix. Once the matrix is stored, at each step of the optimization, the 3D radiation pattern is shaped by only a mat-vec multiplication between the pattern-matrix of size $[(N_\theta \cdot N_\phi) \times N_\psi]$ and the one-dimensional array containing the N_ψ EBF solution coefficients and N_θ, N_ϕ are the number of point along θ and ϕ, respectively.