Efficient MoM analysis of multilayered periodic arrays of stacked rectangular patches. Application in the design of reflectarray antennas.

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Reflectarray antennas are an interesting alternative to reflector antennas for satellite broadcast and telecommunications missions owing to their reduced mass and volume, low cost, improved polarization performance, etc. The element consisting of stacked rectangular patches in multilayered configuration has proven to be a wideband unit cell for reflectarray antennas with dual beam and transmit-receive dual polarization capabilities (J. A. Encinar et al., *IEEE Trans. Antennas Propagat.*, 54, pp. 2827-2837, 2006; J. A. Encinar et al., *IEEE Trans. Antennas Propagat.*, 59, pp. 3255-3264, 2011). In the design of these reflectarray antennas under the local periodicity assumption, the electromagnetic analysis of the scattering of a plane wave by a periodic array of multilayered stacked patches is typically performed hundreds of thousands of times when an optimization routine is run to enforce the phase requirements at different frequencies. Therefore, to avoid the consumption of prohibitive CPU times, it is necessary to have efficient tools for the numerical analysis of such periodic structures. The numerical method traditionally employed for the analysis of those periodic multilayered structures is the MoM in the spectral domain (R. Mittra et al., *Proc. IEEE.*, 76, no. 12, pp. 1593-1615, 1988), but this method may not be fast enough since the determination of the MoM matrix elements requires the computation of slowly convergent double infinite summations. In this paper we present a faster and more accurate numerical method which is based on the spatial domain MPIE formulation of the MoM. In the new numerical method, the 2-D periodic Green's function for the scalar and vector potentials in the spatial domain are interpolated with great precision in terms of 2-D Chebyshev polynomials (Florencio et al., *IEEE Trans. Antennas Propagat.*, 61, pp. 5088-5099, 2013). In order to avoid inaccuracies, the behavior of the Green's functions around the singularities is extracted in closed-form before carrying out the interpolation as suggested in (Valerio et al., *IEEE Trans. Antennas Propagat.*, 57, pp. 122-134, 2009). The first images originated from thin layers (which are usual substrates of the metallizations in reflectarray antennas) are also extracted. The samples of the interpolated Green's functions are obtained by means of a combination of the discrete complex image method (involving an adequate substraction of the asymptotic behavior of the Green's functions for large values of the spectral variables) and Ewald's method. The elements of the MoM matrix are expressed as double integrals containing the periodic Green's functions, and cross-correlations of the basis functions which are obtained in closed form (for both sinusoidal basis functions and edge singularity basis functions). These double integrals contain both Green's function 1/R singularities and logarithmic singularities introduced by the cross-correlations between basis functions (in case edge singularity basis functions are used). The Green's function singularities are extracted and integrated in quasi-closed form. The logarithmic singularities are handled by means of Ma-Rokhlin-Wandzura quadrature rules (Ma et al., *SIAM J. Numer. Anal.*, 33, pp. 971-996), which have proven to be more efficient than the double exponential quadrature rule (Polimeridis et al., *IEEE Trans. Antennas Propagat.*, 58, pp. 1980-1988, 2010). After all these manipulations, the new spatial domain method has been found to be between one and two orders of magnitud faster than the traditional spectral domain method in the analysis of the periodic structure containing multilayered stacked patches for an accuracy of 1%. These CPU time savings are expected to increase when the new MoM spatial domain tool is applied to the design of a whole reflectarray antenna with optimized performance in a frequency band.