Analysis of Very Large Radio Telescope Antennas Using Multilevel Physical Optics Algorithm

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Analysis of very large multi-reflector antennas like that of RATAN-600 radio telescope presents a formidable computational challenge. At mm-wave frequencies of interest, the RATAN-600 main reflector measures roughly 20,000 by 1000 square wavelengths. Such reflector antennas are often analyzed as quasi-optical systems in two main steps. In the first stage, the field is propagated from the feed to an equivalent aperture using geometrical optics (GO), while in the second, the radiation pattern is computed by aperture integration, which for planar apertures can be accelerated using the Fast Fourier Transform (FFT) (R.E. Collin, Antennas and Radio Wave Propagation, McGraw-Hill, 1985). This line of modeling completely neglects the wave phenomena involved in the inter-reflector propagation and introduces phase errors due to introduction of the artificial planar equivalent aperture required for the radiation pattern evaluation using the FFT.

In this work, we develop and apply a comprehensive modeling approach based on the near- and far-field multilevel physical optics (MLPO) algorithms. The far-field MLPO (A. Boag and C. Letrou, IEEE Trans. Antennas and Propagation, 53, 2064-2072, 2005) is employed for the fast radiation pattern computation based on the field distribution on the main reflector. Furthermore, diffraction effects, that are important for accurate prediction of far sidelobes, can be incorporated in such radiation pattern evaluation by augmenting it with the PTD contour integration at minimal computational cost (C. Letrou and A. Boag, IEEE Trans. Antennas and Propagation, 60, 1182-1186, 2012). In our approach, field propagation between reflectors is performed using the recently developed near-field MLPO algorithm. The computational complexity of the near-field MLPO is comparable to that of its far-field counterpart. The proposed combined near- and far-field MLPO has been applied for the analysis of the RATAN-600 antenna and shown to produce as accurate results as the regular PO-PTD, with a computation time proportional to $N^2\log N$, rather than N^4 of the direct computation, with N being the problem electrical size.