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Fast Data Simulation for Synthetic Aperture Imaging

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Synthetic aperture imaging applications process large amounts of scattering data densely sampled versus an aspect angle and the frequency [1], [2]. Some three-dimensional (3D) imaging modalities are even based on data collection versus both azimuth and elevation angles. Consequently, design and testing of such systems requires simulation of monostatic or multi-static scattered fields over a range of transmitter/receiver aspect angles and frequencies. In addition, the range of distances to the target is often such that, for the desired frequencies, it is within the target's near field. This simulated data is of great importance for verification of imaging algorithms as well as for training automatic target recognition techniques. At high frequencies, the physical optics (PO) approximation appears to be an attractive technique for generating reasonably accurate scattered data. A high frequency field interaction with a complex scatterer can represented as series of localized scattering events, termed bounces, each described by a PO integral. For large scatterers, evaluation of the PO integrals for a large number of aspect angles and frequencies is characterized by prohibitively high computational complexity (CC), especially in the case of multi-bounce scattering.

In this work, we employ two types of fast algorithms, whose applicability depends on the complexity of scatterer geometries. The first type is used for scattering from relatively simple scatterers producing only the "single-bounce" (SB) and "double-bounce" (DB) contributions. Both SB [3] and DB [4] fast-PO algorithms treat all aspect angles and frequencies in a combined manner, thus leading to relatively low CCs. Furthermore, these techniques assume that the visibility is a slowly varying function of aspect angles and can be determined using some auxiliary methods. For scattering from complex geometries involving multiple bounces and self-shadowing effects, we resort to a second type algorithm of the class of fast iterative physical optics (FIPO) techniques [5]. The algorithm comprises two types of nested iterations: reflection ("bounce") iterations and self-shadowing iterations. The nested iterative formulation is accelerated by using the multilevel non-uniform grid algorithm. In the FIPO approach, each aspect angle and frequency is treated separately, thus resulting in less advantageous complexity, while providing higher generality. Examples of data simulation and subsequent imaging of various scatterers will be presented.

References

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