Efficient spectral/spectral-element methods for transformation electromagnetics

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Transformation electromagentics (or optics) has become a very powerful tool to design devices with novel and unusual physical properties. Typically, these involve simulations with stringent accuracy and efficiency requirement for solving Maxwell and Helmholtz equations with inhomogeneous material coefficients, which are obtained from a certain coordinate transformation between the virtual space and physical space. In this talk, we introduce several semi-analytic techniques for high-order computations of such wave scattering problems with bounded scatterers.

From the perspective of the inside-out (or "inverse") cloak, we introduce an absorbing layer through a real coordinate transformation that compresses wave propagations in an infinite domain to a finite layer. However, it is believed that any real mapping technique will result in an infinitely oscillatory solution near the outer boundary of the finite layer and such fast oscillations can not be resolved by which can not be represented by any finite-resolution grid. In other words, this layer can not be nonreflecting. Here, we show that with an understanding the pattern of the oscillation component of the outgoing wave, we can essentially eliminate the oscillations and compute the non-oscillatory component. Moreover, this can be accomplished by modifying the spectral-element basis functions without changing the equation.

Alternatively, we introduce efficient ideas how to seamlessly integrate classical nonreflecting boundary conditions based on global Dirichlet-to-Neumann (DtN) with the local spectral elements.

In addition, we provide some deep insights into the interface conditions (at the interface where material coefficients are singular) to achieve perfect cloaking effects for the cylindrical, spherical and polygonal invisibility cloaks.

This talk is largely based on joint works with Zhiguo Yang at Nanyang Technological University, Singapore.