Green's Function Method for Classical and Statistical Electromagntics

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The Green's function stands for the the fundamental solution of a partial differential equation. In the electromagnetic theory, the spatial Green's function describes the physics of the wave propagation from the source point $\mathbf{r}'$ to the receiving point $\mathbf{r}$. Over the past decades, Green's function methods have enjoyed considerable success in solving homogeneous media, pieciewise homogeneous media, layered media, and inverse electromagnetic (EM) problems. In this research, we will review our recent investigations of Green's function method in non-standard applications.

The first contribution is the platform Green's Function method for in-situ antenna analysis and design. The objective is to build a reconfigurable, reusable, and parallel model reduction platform towards transformative in-situ antenna optimization. The key idea is to introduce a separable and compressible platform Green's function in an up-front offline computation. Once obtained, the online computational complexity does not depend on the size of the in-situ platform. As a result, in-situ design and optimization of multi-antenna systems can be performed at the same cost as the free-space radiation. The advancements make high-fidelity in-situ antenna design orders of magnitude faster.

Next, we will discuss a space-time Green's function method for wave propagation in the spatial-temporal domain. A time-evolution Green's function is proposed to overcome the time-step limitation in traditional transient EM solvers. It can be considered as a non-standard time propagator comparing to the traditional time-stepping schemes. The method provides high accuracy, superlinear convergence, and good scaling efficiency. Since there is no discretization in the temporal dimension, it does not suffer from small time steps required for highly oscillatory wave problems

Finally, we present a stochastic Green's Function method, which represents the fundamental, probabilistic solution of the wave equation in chaotic environments. We recognize that the ergodic modes in the chaotic environments lead to certain universal statistical properties of EM fields. For instance, in overmoded reverberation chambers, the probabilistic EM fields present uniform phase distribution and Rayleigh distributed amplitude. The variance of the Rayleigh distribution is related to the quality factor of the chamber, instead of the exact shape of the enclosure or the location of the measurement. The homogeneous and structureless statistical behavior motivates the investigation of the stochastic Green's function, which describes the generic statistical properties of wave dynamics inside the chaotic media rather than detailed specifics in geometry and configuration.