Characterization of Electromagnetic Fields in Complex Systems Through Phase-Space Techniques

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In this presentation, we describe how field-field correlation functions may be efficiently propagated using ideas based on ray propagation. The key point is to make a connection between the field-field correlation function and the corresponding Wigner function, which is obtained from it by Fourier transformation.
The Wigner function underlying this approach originated in quantum mechanics, where it can be used to make an analogy between the evolution of the wavefunction and the evolution in phase space of the underlying classical trajectories. In the context of EM problems, the Wigner-function approach has been championed by Marcuvitz using the "quasiparticle" picture of wave evolution (N. Marcuvitz, Proc. IEEE, 79-10, 1991). In the approach we propose, to approximate the propagation of field-field correlation functions by propagating phase-space densities of ray families, which is effectively a lower-dimensional calculation and therefore easier to compute.
As an example, we consider a model problem in which the field-field propagator is evaluated in free space. For the case of short source correlation, an approximate solution is presented in terms of a map in phase-space, called as Perron-Frobenius operator. The solution works from the near- to the far-field and serves as a proof-of-principle for propagation in more complex environments. The limitations of the approximate solution are also discussed.
In particular, the Wigner-function approach can be extended to boundary-value problems by using the results of the random matrix theory. We show that this philosophy has common aspects with that adopted in the formulation of the Maryland Random Coupling Model for complex electromagnetic enclosures.