

Full-Wave Propagation of Short-Pulse Wavepackets in Ray-Chaotic Billiards

Vincenzo Galdi¹, Innocenzo M. Pinto¹, and Leopold B. Felsen²

(1) *Waves Group, Department of Engineering, University of Sannio, Benevento, Italy*

(2) *Dept. of Aerospace & Mechanical Eng., Boston University, USA (part-time)*
Also, University Professor Emeritus, Polytechnic University, Brooklyn, NY USA

During the last decade, there has been a growing interest in electromagnetic (EM) propagation environments featuring *ray-chaotic* behavior. Apart from intrinsic theoretical aspects (ray theory describes wave dynamics in the zero-wavelength limit), this interest is motivated by the possibility of designing novel devices and components (microlasers, resonators, etc.) where ray chaos has been demonstrated to play a key role (see, e.g., C. Gmachl *et al.*, *Science*, **280**, p. 1556, 1998). Since *ray chaos* implies *exponential* separation of nearby-originating *ray trajectories*, this concept *cannot* be used to describe *finite* (nonzero) *wavelength* dynamics; the *linear* wave equations *do not* exhibit exponential sensitivity to initial conditions in deterministic environments. Nonetheless, it is widely accepted that one should expect “signatures of ray-chaos” in some *wave* solutions.

In a recent investigation (V. Fiumara *et al.*, *Proc. ICEAA '99*, Turin, Italy, Sept. 13-17, 1999, p. 357), we have explored the possibility of utilizing the ray-chaotic properties of a stadium-shaped cavity excited by a pulsed (wideband) wavepacket to create a “pulsed reverberation enclosure,” with potential applications as a testbed for EM interference (EMI) and/or EM compatibility (EMC). Ideally, equipment under test placed in such an environment should be exposed to pulsed illumination with nearly *uniform* distribution in arrival direction, *independent* of position and/or orientation of the target, thus allowing for assessment of figures of merit like shielding effectiveness, spurious emission, etc. Our preliminary analysis was based on the highly-idealized assumption that the wavepacket launched in the cavity behaves as a *nondiffracting bullet*, which preserves its shape and space-time localization while propagating inside the cavity and undergoing multiple reflections at the boundaries. This assumption allows for a purely *kinematic* (i.e., ray) qualitative analysis which confirms the above expectations.

In this paper, we go one step further by solving the *full-wave* propagation problem of a short-pulse wavepacket in a stadium-shaped enclosure, using a finite-difference time-domain (FDTD) code. In this connection, various field statistics (e.g., space-time correlations) are computed and analyzed. Furthermore, a wave-oriented *local spectral analysis* (in terms of pseudo-Wigner distributions) is performed in order to parameterize phase-space features of particular interest (e.g., the distribution of arrival angles). Preliminary results indicate the presence of distinct features in the field distribution and statistics, which are of potential interest in EMI/EMC applications. These features do not seem to have any resemblance to those found in “regular” (e.g., rectangular and circular) billiards, and may thus be viewed as *ray-chaos signatures* in the *full-wave* regime.