Understanding Electromagnetic Properties of Complex Enclosures by Means of Wave Chaos

Bo Xiao, Thomas Antonsen Jr., Edward Ott, and Steven M. Anlage
Department of Physics and Department of Electrical and Computer Engineering
University of Maryland- College Park, MD 20742-4111, USA.

Because of the possibility of electromagnetic interference between neighboring electronic systems, there is an urgent need to quantify the entry and distribution of electromagnetic energy within complicated metallic enclosures and to understand the manner in which this energy couples to sensitive electronic devices within such enclosures. When the wavelength of the impinging radiation is much smaller than the typical length scale of the enclosure, the distribution of energy within such cavities is highly sensitive to small changes in the frequency, the structure of the cavity, as well as the nature of the channels which couple EM energy into the cavity. Thus, a statistical approach to understanding this problem is called for.

There is great interest in the wave and quantum properties of systems that show chaos in the classical (short wavelength) limit. These 'wave chaotic' systems appear in many contexts: nuclear physics, acoustics, two-dimensional quantum dots, and electromagnetic enclosures, for example. Random Matrix Theory (RMT) predicts the universal fluctuating properties of quantum/wave systems that show chaos in the classical/ray limit.

In this context we developed a stochastic model, the "Random Coupling Model" (RCM),[S. Hemmady, *et al*., Phys. Rev. Lett. **94**, 014102 (2005), X. Zheng, T. M. Antonsen and E. Ott, Electromagnetics **26**, 3 (2006); Electromagnetics **26**, 37 (2006)] which can accurately predict the probability density functions (PDFs) of voltages and electromagnetic field quantities on objects within such cavities, given a minimum of information about the cavity and the nature of its internal details. The RCM is formulated in terms of electrical impedance, essentially equivalent to Wigner's reaction matrix in quantum mechanics, rather than the more commonly studied scattering matrix. The RCM predictions have been tested in a series of experiments using normal metal and superconducting quasi-two-dimensional and three-dimensional electromagnetic billiards.[S. Hemmady, *et al.*, IEEE Trans. Electromag. Compat. **54**, 758-771 (2012); Z. B. Drikas, *et al.*, IEEE Trans. Electromag. Compat. **56**, 1480 (2014).] We have extended the RCM in a number of directions, for example by examining the effects of 'short orbit' ray trajectories that enter the cavity, bounce a small number of times, and then leave the cavity. We are able to account for the effects of these orbits using a semi-classical theory, and find excellent agreement between theory and experiment [J.-H. Yeh, *et al*., Phys. Rev. E **81**, 025201(R) (2010); Phys. Rev. E **82**, 041114 (2010)]. More recent work on extending the RCM to describe fading statistics in radio communications [J.-H. Yeh *et al*., Phys. Rev. E (R) **85**, 015202 (2012)] will also be discussed.

This work is funded by the ONR/Maryland AppEl Center Task A2 (contract No. N000140911190), the AFOSR under grant FA95500710049, the Office of Naval Research (contract No. N00014130474), and the Center for Nanophysics and Advanced Materials (CNAM). For more information see: http://anlage.umd.edu/AnlageQChaos.htm.