ID 055

Statistical model for coupling of EM energy through apertures

The random coupling model

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Abstract— **A statistical model for the coupling of electromagnetic radiation into enclosures through apertures is presented. The model gives a unified picture bridging deterministic theories of aperture radiation, and statistical models necessary for capturing the properties of irregular shaped enclosures. The enhancement of coupled radiation due to aperture resonances will be emphasized, and general formulas for the statistics of the radiation entering the cavity and reaching an antenna in the cavity will be presented. In the high and low loss cases these formulas have particularly simple forms that can be used to assess coupling in specific cases**

Keywords: Aperture, quality factors, voltage statistics

I. INTRODUCTION

The coupling of electromagnetic radiation into enclosures or cavities through apertures both electrically small and large has attracted the interest of electromagnetic community for many years. Full solutions of this problem are particularly complicated because of the mathematical complexity in the solution of the boundary-value problem and because of the sensitivity of the solution to the detail of the enclosure's dimensions, content, and the frequency spectrum of the excitation. These difficulties have motivated the formulation of a statistical description (known as the random coupling model, RCM [1], [2]) of the excitation of cavities, in particular the linear relation between voltages and currents at ports in the cavity, when the ports are treated as electrically small antennas.

The RCM has recently been extended to the case of apertures [3] of arbitrary size. In this treatment the aperture is characterized by an admittance matrix that relates the amplitude of the tangential component of the electrical field in the aperture to the amplitude of the transverse components of magnetic field. Field components are represented as a superposition of basis functions whose amplitudes are voltages and currents related by the admittance matrix. The matrix takes on two generic forms: a radiation admittance that applies to the case in which the aperture faces free space and a cavity admittance that applies when the aperture is backed by a cavity. The cavity admittance is a statistically fluctuating quantity, with properties derived from random matrix theory, that account for the uncertainties in the spectrum and properties of modes of the cavity in question. The cavity is then characterized by the spectral density of modes and an average loss factor.

Coupling to an antenna in the cavity is included in the model by augmenting the admittance matrix of the aperture with the impedance matrix of the antenna, including a load impedance on the antenna. This results in a matrix circuit equation that gives the voltage on the antenna's load in terms of the amplitude of a plane wave incident on the aperture.

A sample plot of power delivered to the load as a function of frequency is shown in Fig. 1. Interestingly, the resonant frequencies of the aperture are not in the range of frequencies displayed in Fig.1. Yet they play a strong role in the large enhancements in coupled power depicted. A general expression describing this effect will be presented.

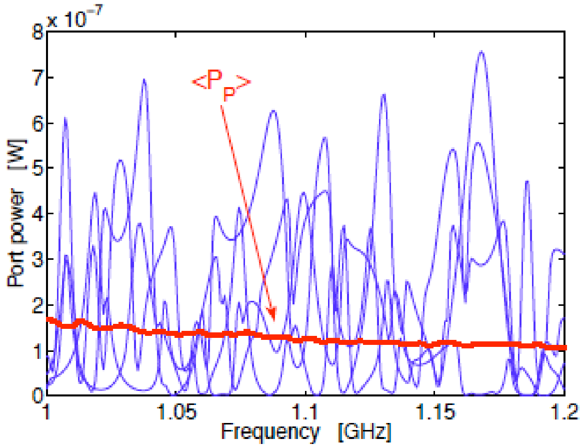

Figure 1. Power coupled through a 25 cm by 2 cm aperture in a cavity wall to a small antenna. Shown in blue are several individual realizations of the cavity, and in red the average over 800 realizations.

Supported by the Office of Naval Research

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