# Electromagnetic Coupling through Slot Apertures into Cavities with Loaded Wires

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Electromagnetic coupling is a critical factor in electromagnetic compatibility (EMC) and electromagnetic interference (EMI). The coupling to structures through slot apertures has gained much attention and has been investigated by a variety of authors in the past. The techniques vary but the main goal is to estimate a bound on the signals coupled to a given system. Due to the complexity of real-world systems, it is generally not possible to model the structure in its entirety. Thus, most methods identify the major features of the system and model them using appropriate electromagnetic techniques.

The hybrid method presented here uses the transmission line model of Warne and Chen (IEEE Transactions of EMC, Vol EMC-34, No. 3, August 1992), which is solved via the method of moments (MOM), to model the aperture. This model incorporates slot depth, wall losses and allows gaskets to be incorporated in a simple and straightforward fashion. The interior of the cavity is solved using the finite element method (FEM) (Jedlicka, Castillo and Warne, IEEE Transactions on Antennas and Propagation, Vol AP-48, No. 3, March 2000) – it allows metallic and lossy dielectric objects to be included within the cavity region. Wires within the cavity, which can significantly alter the frequency response and coupling level, are included via a filamentary MOM representation. The model presented here is based upon that of Lail and Castillo (IEEE AP-S International Symposium and USNC/URSI Radio and Science Meeting, Volume III, pp. 290-293, 16-20 June 2002, San Antonio, Texas.); however, the moment method boundary conditions are modified to incorporate loads on and at the ends of the wires.

The basic formulation is predicated on the following integro-differential equation,

$$\left[2H_{1,M,z}(a,z) + \frac{\Delta Y_L}{2}\frac{d^2 I_M(z)}{dz^2} - \frac{\Delta Y_C}{2} I_M(z)\right] - H_{2,J,z}(\rho_o, z)$$
$$- \Delta H_z(\rho_o, z) = -2H_{inc,z}$$

$H_{inc,z}$ is the component of the incident field aligned with the slot (here oriented along the z axis), $H_{1,M,z}$ and $H_{2,J,z}$ are the magnetic fields due to the magnetic current along the equivalent antenna representing the slot aperture and the electric current along the wire, respectively. $\Delta H_z$ is the difference field obtained by solution of the FEM problem.

In addition to the formulation of the problem and computer implementation of the code, an experimental setup was constructed and the electromagnetic coupling to a cavity, through narrow slot apertures, was measured for a variety of wire and load conditions. The presence of an unloaded wire impacts the coupling to the cavity, the variation depends upon the orientation of the wire with respect to the major fields within the structure. Loads on the ends of the wire further modify the result. The numerical computations are compared to measured results for a variety of configurations and load conditions. For example, placing 50 Ω loads on the ends of the wire modifies the peak coupling level by 10 – 15 dB or more.