Coupling to a Printed Circuit Board Inside a Cavity from a Wire Penetrating an Aperture

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An important EMC problem that arises in various contexts is the electromagnetic coupling from an exterior field to a circuit component on a printed-circuit board (PCB) inside a conducting cavity (shield) via a direct connection from a wire or cable that penetrates an aperture in the cavity. This type of coupling mechanism can be very important in determining the signal levels on the PCB due to the coupling from an exterior field, and it may be the dominant coupling mechanism. Therefore, an accurate and efficient methodology for calculating this type of coupling is important.

One difficulty in the numerical analysis of such coupling problems is treating the disparate levels of feature size. The cavity dimensions may be on the order of a wavelength or more. However, on the circuit board the feature size is often much smaller than a wavelength. Furthermore, a complicated conductor trace pattern may exist on the PCB, requiring a fine level of discretization in a purely numerical scheme. Hence, a method that allows for an efficient analysis of the coupling to the component on the PCB without requiring a complete discretization of the entire problem is desirable.

In this presentation, a hybrid technique for calculating the signal level on the PCB due to an exterior field incident on the cavity is discussed. The technique separates the analysis of the cavity/wire from that of the conductor trace on the PCB, thus enabling an efficient calculation. The method allows a Thévenin equivalent circuit to be obtained at any point on the circuit board (a definable "port"), such as a point where the conductor trace meets a circuit component on the board. Hence, the voltage level at the input to a device on the PCB that results from the exterior incident field can be calculated.

To obtain the Thévenin port voltage, transmission-line theory is used to first obtain an equivalent input impedance seen by the coupling wire at its junction with the conductor trace when an open circuit is placed at the desired port. A full-wave analysis, which accounts for the effects of the cavity, is then used to obtain the current on the coupling wire with the PCB trace replaced by its equivalent impedance. The Thévenin voltage at the port is then found by summing the port voltages that arise from two contributions. The first contribution, which is found from transmission line theory, is the port voltage due to the direct current injection from the coupling wire at the contact point. The second contribution is the port voltage induced by coupling from the current on the wire to the PCB trace. This contribution is found from transmission-line theory, using a distributed source model. The Thévenin impedance can be found from a similar analysis, i.e., by placing a short circuit at the port and then determining the short-circuit current at the port.

Results will be presented to verify the accuracy of the proposed method for various PCB substrate thicknesses within realistic cavity sizes, and to study the effects of cavity resonances on the coupling to the PCB.