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COMMON-MODE FIELD TRANSFERS BETWEEN CIRCUIT BOARDS AND CHASSIS STRUCTURES

The myth: Digital (high frequency spectra) circuit boards can be ***isolated*** from chassis structures.

The reality: Digital (and all high-speed, high-frequency spectra) circuit boards are ***always*** coupled to chassis!

Of all of the "myths" and "realities" reported within the descriptions of systems and system-product implementation, probably one of the most controversial (and least understood) is founded upon the topic of "isolation versus grounding" of circuit boards with respect to conductive chassis structures. Once that topic is opened, the controversy seems to quickly move from "grounding" as single-point versus "multi-point" positions in levels of increasing (discussion) intensity. Since the concept originates with the field-transfer (coupling) relationships between circuit board and chassis, that is an appropriate place to start to examine the controversies and their related processes.

When a circuit board is positioned above a conductive chassis structure, an *immediate* form of coupling occurs: distributed capacitance. The magnitude of the capacitance is determined by the surface area of the circuit board over the chassis plane, and the distance of separation between the two structures. Since distributed capacitance is a simple fact of the dimensional relationships between these structures (board and chassis), one fact is inescapable: *the boards are coupled to chassis!* This observation moves the discussion quickly not to the "fact" of coupling, but rather to the magnitude of coupling and the performance significance of that magnitude. Due at the minimum to distributed capacitance, another inescapable fact appears: *at higher frequency spectra, there is no such thing as a truly "isolated" circuit board* from conductive chassis structures! Note that distributed capacitance values as small as 10 Pico farads will yield coupling transfers in the region of a few tens of Ohms in the spectra from approximately 300 MHz and higher.

Viewing the detail of circuit board construction, a sequence of "patterned layout inductance" is established by layout details, including routing patterns and holes "Swiss-cheesed" through the ground and power planes. The routing patterns and "Swiss-cheese" effect setup a form of "*distributed inductance*". When common-mode electrical currents are impressed across these holes and patterns, *electrical potentials* occur as a sequence of losses. These potentials are the beginning of electromagnetic waves and their related impedances. In effect, a distributed transmission line process is immediately formed: inductance patterned in the circuit board; and, distributed capacitance between the board and any conductive chassis plane. It is observed that all transmission lines, distributed or intentional, are characterized with some value of impedance.

Now, if electrical potentials are formed across the board and if these "find" the impedance of distributed capacitance, *electrical currents* will be displaced through the impedance set up by distributed capacitance. Note that the currents formed are developed across relatively "low" impedance values of distributed capacitance. Since the impedance of any electromagnetic wave at any point is equal to the value of the "E-Field intensity" (in Volts/meter) divided by the "current" or H-Field intensity (in Amperes/meter), the coupling between the circuit board and the chassis immediately becomes "a spectral electromagnetic field" by nature and structure.

So, when viewed as an impedance formed through a distributed transmission line coupled process, or considered as an electromagnetic wave transfer function, circuit boards will indeed be coupled to chassis planes. In terms of approximate magnitude for consideration, it is noted that near fields (close to sources at, for example, 0.5 centimeters) with magnetic field dominance (described by sources that have low impedance for current formation with higher current – all digital circuit board tend to meet that criteria of low impedance and high current) will propagate in impedances below 40 Ohms at frequencies below 1GHz. These same conditions will exhibit electromagnetic field transfers below 20 Ohms at frequencies below approximately 500 MHz. From this observation, the discussion may be expanded not to the fact of coupling, but rather to the design consequences of that coupling.