Probabilistic Modelling and an EM-Compatibility Calculus

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***Abstract*— We define the ElectroMagnetic Compatibility of a system quantitively as the probability that the states of a system are within the margins of its operational model. We show that under rather weak conditions, such a compatibility coefficient allows one to judge on the consequences of substituting system parts by replacement parts comparing only their respective compatibility coefficients.**

***Keywords*— ElectroMagnetic Compatibility, Stochastic environments, Component Obsolescence, Compatibility Calculus, Compatibility Algebra**

I. Introduction

ElectroMagnetic Compatibility is usually defined in a qualitative way and the proper operation of a system is judged on the basis of experiments or computations of certain cases believed to be critical and/or representative. In this paper, we develop a "compatibility calculus" based on a quantative, probabilistic, definition of ElectroMagnetic Compatibility of sub-systems. The essential property we want this calculus to have is that the overall compatibility of a system with its environment can be evaluated by combining the compatibility coefficients of its parts. Although, the complexity of the non-localisable electromagnetic interactions makes that the complete calculus remains rather complicated, there is one property which is of much practical use and allows one to make quick comparisons where obsolete components are to be replaced by new ones. In such cases, there is a simple rule that overall compatibility of the system does not diminish when the compatibility coefficients do not diminish. This implies, that the compaibility coefficient of a subsystem has an individual meaning as a measure of its quality (see Fig. 1).

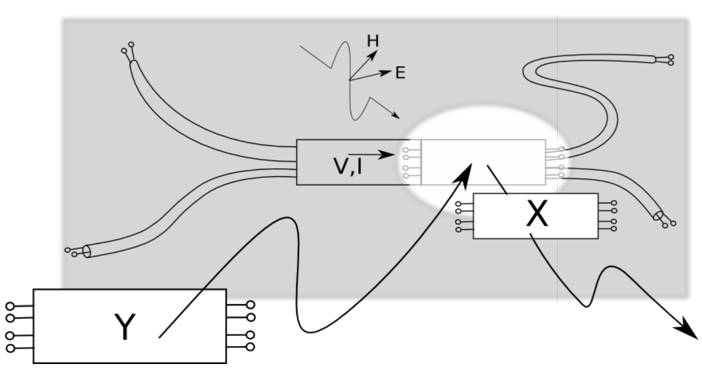

Figure 1. Replacing component X by a component Y with equal or higher compatibility coefficient, will not degrade the compatibility of the system as a whole

II. Stochastic closure of sub-system propositions

In order to test the functionality of a (sub-)system one needs a closure relation representing the (sub-)systems operational environment. As the operational environment is never deterministically controlled, the closure model is of a probabilistic nature. The states of closed system are therefore stochastic processes on every level of the assembling hierarchy. The designer of a sub-system obtains the appropriate stochastic environment from the designer of the embedding system and, using the nominal functionalities of the components of his design, he computes the stochastic environments of the various components, which he passes on to the designers of the respective components, and so on and so forth. This is the top-down specification phase. Now any realisation of a sub-system can be tested with the given stochastic closure applying to the sub-system. If the sub-systems stochastic states would match perfectly with the stochastic states defining the operational model, it would be indistinguishable from the nominal functioning and we cannot hope to get a better realisation. This situation should correspond to maximal compatibility because the states of the system are such as they appear with the nominal system.

III. Application

We will show the results of a compatibility coefficient computation for an interconnect system in an electromagnetic environment with noise sources. We first compute the stochastic environment of a chosen sub-system X. The electromagnetic noise in the environment of the complete system is represented by a covariance operator corresponding to a stochastic plane wave. Using a complete electromagnetic hybrid model for multi-port systems, we can explicitly compute the noise sources in the environment and uncertainties in the wanted port-excitations of the chosen sub-system (see [1]). From the stochastic states of the complete nominal system, we use the standard deviations of the port voltages and currents as representing the operational margins, i.e., we say that if a sub-system realisation has voltages within a distance of one standard deviation from the nominal state the system is within spec.'s. (Alternative definitions of what it means to operate within the spec.'s will be presented as well). We then compare the computed compatibility coefficients of various sub-system realisations to the over-all performance.

References

[1] B. L. Michielsen. Probabilistic modelling of stochastic interactions between electromagnetic fields and systems. *Comptes Rendus de l'Académie des Sciences: Physique*, 7:543–559, August 2006.