System-by-Design Paradigm for the Design and Optimization of New Generation Electromagnetic Systems

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Abstract

The "System-by-Design" Paradigm can be defined as a functional ecosystem to handle complexity in the design of large systems. Its first objective is the exploitation and, whenever needed, suitable customization of existing solutions to achieve short and medium term objectives in the design of complex system comprising several different components/agents (e.g., autonomous systems, innovative materials, advanced platforms). Towards this end, the System-by-Design paradigm is based on the definition of a set of "building-blocks" within any synthesis process, which can be used/ substituted according to the needs and constraints of the specific application. In this scenario, this work is aimed at presenting the possible exploitation and customization of the System-by-Design Paradigm to the framework of the Multiscale Research of Materials, as well as of the design and development of New Affordable Materials for Phased Arrays and Radar Applications with the aim of reducing the time and costs for the synthesis and the deployment of the chosen solution.

Introduction

System-by-design (*SbD*) is an innovative paradigm that has been recently introduced by Prof. A. Massa at the ELEDIA [Electromagnetic Diagnostics] Research Center [1] and whose origin is linked to the necessity of solving complex antenna/microwave synthesis problems through integrated design procedures [2]-[4] that combine several different functional blocks (e.g., to perform the analysis, modeling, optimization, and numerical simulation of interconnected devices) in a seamless way. Recently, such a framework has gained significant attention because of the increasing necessity to replace critical and rare materials through artificial or engineered new affordable materials based on multi-scale structures, as well as of the need to develop innovative design methods that enable the reduction of costs and time for the synthesis and deployment of complex platforms.

As an example, the necessity to develop, design, simulate, realize, and measure Multi-scale and Affordable Materials able to substitute the functionalities of critical traditional materials is currently leading to a complete renovation of traditional devices in terms of system architecture (architecture-by-design), electromagnetic properties (material-by-design), and control strategies (algorithm-by-design). Accordingly, the System-by-Design Paradigm has emerged as a "process for the task-oriented design, definition, and integration of system components to achieve desired performance with the minimum costs, maximum scalability, and reconfigurability" [1]. A typical application of the System-by-Design Paradigm to the design of Multi-scale Innovative Materials starts from the definition of the problem constraints and requirements, and comprises a design loop made of several blocks. In particular, exploiting the manufacturing capabilities and the available materials, the unit cell of the multi-scale material is properly modeled by using few fundamental parameters that enable the characterization of its behavior by means of fast electromagnetic simulation tools. This allows the use of advanced optimization algorithms for the definition of the most effective, and affordable unit cell that is then used for the manufacturing of the complex device.

The application of this new framework is intrinsically heterogeneous and general-purpose, and can be applied to a variety of synthesis problems of industrial interest. As an example, in the field of Phased Array for Radar Applications [1] the ELEDIA Center has developed several "building blocks" (e.g., for the electromagnetic analysis, simulation, modeling, design, optimization, and tuning of the array systems) that can be combined and customized through the System-by-Design Paradigm in order to reduce the costs and time for the synthesis of the array system.

Accordingly, the aim of this work will be that of developing instances of the SbD Paradigm in several applicative scenarios including, but not limited to, multiscale research of materials, new affordable materials for phased arrays and radar applications, and antenna design and optimization.

References

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