Space-time Parallel Methods for Multiscale Transient Electromagnetic Problems

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Over the past decades, time-domain computational electromagetics (CEM) methods have enjoyed considerable success in solving transient and broadband electromagnetic (EM) problems. Nowadays, the field of time-domain EM computations face new challenges. Due to the ever-increasing sophistications in EM systems and the continuous trend towards higher bit rates, a typical transient simulation may require hundreds-of-thousands or even millions of time steps. As a result, there is a strong demand to use the increasingly available high-performance computing (HPC) power to accelerate time-to-solution of these simulations. Currently the state-of-art time-dependent EM solvers are typically parallel only in space. The sequential-in-time nature of these solvers can achieve good parallel scaling when the number of spatial mesh points per core is large. But the parallel efficiency quickly deteriorates and even saturates if spatial parallelism has been fully exploited.

There is an enormous opportunity to leverage the space-time parallel computation to achieve high parallel efficiency, specifically for multi-scale EM problems with millions of time steps in temporal domain. Together with next generation computing hardware, it could lead to time dependent EM solutions orders of magnitude faster. The goal of this research is to study new fundamental algorithms that facilitate the development of this disruptive technology. We will discuss a new space-time building block methodology for transient EM analysis of IC and electronics. It breaks the sequential barrier of time integration by decomposing computational domain both in space and time. Moreover, it results in novel time integration schemes, which enjoy fully explicit in each level of discretization, exhibit high-order accuracy, and are excitation-aware. The weak and strong parallel performances of the proposed method are illustrated through different types of real-world applications on HPC systems. The advancements are applicable to a number of important time-dependent differential equations.