New Perspectives on Fundamental Electromagnetic Theory and Applications

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We provide new overall view on recent research in fundamental applied electromagnetic theory with elaborations of how the new development may lead to deeper understanding of existing research besides opening the doors for different types of applications. In particular, we focus on two major areas explored recently:

1. Foundations of near field theory and near field engineering.

2. Novel methods to model generic antenna systems.

The paper will present an overall view of antenna near fields, including a revision of the our state of knowledge in this area and how the new theory can help answering basic questions such as how antennas radiate and the nature of energy. The topic of reactive energy will be revisited in a new way and a generalized program for the study of fundamental antenna limitations will be proposed. The limitations of the reactive energy concept will be pointed out and the inability of circuit-based quantities like port parameters to model the complex electromagnetic behavior in the near zone will be emphasized.

A new approach to understanding the physics of electromagnetic radiation based on the decomposition of the field into propagating and nonpropagating modes will be introduced and illustrated. In terms of energy, it will be shown that three different types of energies exist in antenna systems 1) reactive energy, 2) localized energy, 3) stored energy. The utilization of antennas as efficient devices working in proper well-designed electromagnetic environments depends on careful understanding and distinction between the three types mentioned above, especially in light of recent interest in applications like energy retrieval and wireless power transfer.

The paper will then introduce the antenna current Green's function (ACGF) formalism as a general method capable of describing generic antenna systems in the spatial domain. The formalism can be used as a systematic method to exhibit the electromagnetic response of any device to arbitrary near field illumination and hence it is expected to become fundamental in near field engineering. Some other applications being now pursued involve novel methods to model and compute mutual coupling in antenna arrays, MIMO and DoA systems, and antenna synthesis.

The dipole model will also be introduced as an approximate technique to model unknown current sources and to design antenna arrays for special applications. The method relies on measuring near field data in limited area and is capable of using restricted input to reconstruct the fields around the antenna almost everywhere. Together with ACGF, the dipole model method combines theory and measurement in an efficient way to provide efficient techniques that avoid cumbersome repeated full-wave analyses or measurements.