Chapter 6

COMPLEX COMPUTATIONAL ELECTROMAGNETICS USING HYBRIDISATION TECHNIQUES

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Abstract: A number of different computational electromagnetics methods are in widespread use at the present time. The reason that a single method has not come to dominate is because different methods have different advantages and disadvantages. An outstanding case is the distinction between quasi-optical methods and methods based on solutions of Maxwell’s equations. The quasi-optical methods rely on the classical approximations of geometrical optics and diffraction theory, in which structures and their details are presumed to be either electrically very large compared with a wavelength or else electrically very small. The intervening region, where structures and their details have dimensions approximately comparable with the wavelength, must be handled by a more exact application of Maxwell’s equations. The treatments that satisfy this requirement can be further subdivided into integral equation methods and differential equation methods, each with distinctive advantages and disadvantages. Integral equation methods can give very good verisimilitude in representation of metallic structures, but they run into severe problems of computer capacity requirements when handling penetrable dielectric volumes or modelling relatively large structures. Differential-equation based methods have no difficulty with penetrable dielectric volumes, but the size of the structure they may model is also limited and the representation of curved and other arbitrarily-oriented surfaces or wires can suffer from significant problems of discretisation error.

The logical conclusion is that a range of methods should be available to handle real-world problems, with different parts of the problem being handled by the most appropriate method. This is known as a hybrid method. The boundary between any two of the formulations has to be treated as a surface populated with virtual sources whose excitations have to be determined, for example using the Equivalence Principle. Implementation in a reliable computer algorithm and segmentation of the task volume have been addressed by a number of research groups and the method has now been become accepted as a sound and reliable approach.

Key words: Hybrid methods; Method of Moments (MoM); Finite-difference time-domain method (FDTD); Integral-equation time-domain method (IETD); Equivalence Principle.
1. INTRODUCTION

As with most aspects of computational engineering, the computation of electromagnetic field distributions has to proceed either by the calculation of analytical formulae, or else by discretisation (digitisation) of a multi-dimensional problem space and then the calculation of the parameters of each digitised element as an approximation to the real continuous system. The straightforward calculation of analytical formulae is only valid for a very limited number of cases where the physical structure of the problem corresponds to a standard analytical shape that can be described by closed-form algebraic expressions. This situation rarely appears in the real world and hence the discretised representation becomes the norm.

Discretised representations of electromagnetic problems fall into two broad categories, which have their roots deeply in the history and philosophy of physics. They may be conveniently named integral equation and differential equation methods and their principal characteristics are as follows.

1.1 Integral Equation Methods

These function by integrating the interaction of all of the (discretised) portions of the physical structure of an electromagnetic system with each of the same discretised portions, notionally considered in sequence. In its most common form, this means that currents in discretised segments of a conducting structure each contributes a component of magnetic field at a specific segment that is being used to observe their effect and thus it can be seen that this corresponds with the Newtonian concept of the representation of force fields as ‘action at a distance’. This means that the method does not take any interest in the behaviour of fields in the intervening space, provided that this space can be presumed to be homogeneous. The analogy with the original Newtonian problem of the interaction of gravitational fields of planets in a solar system will be obvious.

1.2 Differential Equation Methods

These methods are based on a fundamentally different philosophy, of which Michael Faraday is normally thought to be a key originator. This is the ‘field’ philosophy, in which fields of force are presumed to exist as real entities, independently of the forces acting on charged and current carrying