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Investigation of two formulations using curl-conforming basis functions for the MFIE

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ABSTRACT

The magnetic field integral equation (MFIE) is widely used in method of moments (MoM) for electromagnetic scattering analysis of arbitrarily shaped three-dimensional conducting objects. Besides the well-known Rao–Wilton–Glisson (RWG) basis functions, the curl-conforming $\mathbf{n}\times\mathbf{RWG}$ basis functions are also used in MFIE to improve its accuracy. However, there are two different impedance matrix element formulations that result from the use of the $\mathbf{n}\times\mathbf{RWG}$ basis and testing functions to the MFIE in the literature. Moreover, one of the formulations is more complicated than the other. This stimulates us to explore which formulation is more efficient in improving the accuracy of the MFIE. This paper investigates the efficiency of two impedance matrix element formulations resulting from the use of the curl-conforming $\mathbf{n}\times\mathbf{RWG}$ basis and testing functions to the MFIE. Details to calculate the impedance matrix elements are studied. Numerical results show that the radar cross section (RCS) results of the first formulation are more accurate than those of the second one while consuming only about half of the time to fill the impedance matrix for the second formulation. Thus, compared with the second formulation, the first formulation resulting from the use of the curl-conforming $\mathbf{n}\times\mathbf{RWG}$ basis functions to the MFIE is a better choice for scattering analysis of three-dimensional conducting objects.

1. Introduction

The method of moments (MoM) [1] has been widely used to solve electromagnetic scattering problems involving conducting objects. For arbitrarily shaped conducting objects with closed surfaces, the electric field integral equation (EFIE) and the magnetic field integral equation (MFIE) combined with the Rao–Wilton–Glisson (RWG) [2] basis functions are extensively used. However, it is reported that the MFIE using the RWG basis functions is less accurate than the EFIE [3,4] not only for objects with sharp edges or corners but also for objects with smooth surfaces such as a conducting sphere [5]. When discretized with a typical density of RWG basis and testing functions, the MFIE requires approximately four times as many unknowns to produce the same accuracy in Radar cross section (RCS) as the EFIE [3]. To improve the accuracy of the MFIE, efforts have been dedicate to the use of appropriate solid-angle factor [4], more accurate calculation of the impedance matrix elements [5], the use of new basis functions including the curl-conforming $\mathbf{n}\times\mathbf{RWG}$ functions [6–9], the monopolar RWG set [10], the linear–linear functions [11], etc. Among all these techniques, the use of more suitable new basis functions is most effective. The curl-conforming $\mathbf{n}\times\mathbf{RWG}$ function was previously used in [12] to represent the magnetic current in the EFIE operator for homogeneous dielectric scatterers. This basis function was firstly used in MFIE in [6] by Peterson and it is shown that the curl-conforming $\mathbf{n}\times\mathbf{RWG}$ basis functions have the potential advantage that they produce bounded magnetic fields at cell boundaries. In [7], the $\mathbf{n}\times\mathbf{RWG}$ basis and testing functions were employed in MFIE to get the RCS of objects with sharp edges or corners. Recently, a different formulation using the $\mathbf{n}\times\mathbf{RWG}$ basis and testing functions to the MFIE was also developed in [8]. Besides, curl-conforming basis functions with constant tangential/linear normal, linear tangential/linear normal and linear tangential/quadratic normal behavior are also considered in [9]. Both MFIE formulations using the curl-conforming $\mathbf{n}\times\mathbf{RWG}$ basis and testing functions proposed in [7,8], respectively, are effective in improving the accuracy of the MFIE compared to that using the RWG basis and testing functions. However, the formulation developed in [8] is much more complicated than the one in [7]. This paper compares the efficiency of these two formulations using the curl-conforming $\mathbf{n}\times\mathbf{RWG}$ basis and testing functions. Section 2 gives a detailed derivation of these two formulations. After a comparison of these two formulations in Section 3, it is shown that the second formulation needs more integrals to be calculated compared to the first one. Section 4 shows the RCS of several small conducting spheres using several methods, the RCS results and the corresponding CPU time filling the impedance matrix for both formulations using curl-conforming $\mathbf{n}\times\mathbf{RWG}$ basis and testing functions are also displayed. Finally, Section 5 gives a conclusion that the first MFIE formulation using

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