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Three-dimensional Forward Solvers based on improved Formulations of the Extended Born Approximation

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A wide number of applications, like subsurface detection, medical imaging and non-destructive evaluation and testing, require the modeling of the full three-dimensional scattering in the complex scenarios. Integral equation method is one of the effective and powerful tools for solving such electromagnetic problems. However, their computational cost becomes expensive when a fine discretization of the computational domain is needed. In fact, depending on the frequency, the size and the contrast of the scatterer, a large number of cell might have to be employed and this leads to a full complex system to be inverted. In order to avoid prohibitive computational efforts, many different kinds of approximations have been widely used to develop faster forward solvers. First of all, in [1] Born proposed to replace the internal field with the distribution of the field in absence of the scatterer. Such a method has been shown to be suitable only for weak contrasts [2], limiting its actual range of application. As a matter of fact, the estimation of the field inside the scatterer has been improved by the so-called Extended Born approximation (EBA) [3], without significantly increasing the computational efforts with respect to the Born method. By means of a non-linear localized approximation, the field inside the scatterer is obtained projecting the background field onto a depolarization scattering tensor. Notwithstanding many works have shown the accuracy of the EBA if compared to that of the Born approximation, some lack of accuracy when the scattering medium is in close proximity of the source [4] still remains. In order to overcome this limitation, the source behavior has been taken into account in the scattering tensor, obtaining considerable improvements with respect to the standard EBA approximation. Successively, this approach has been extended [5] to the full three-dimensional case considering the source behavior by means of a Green function formulation. In particular, the Extended Born is applied firstly to the spatial distribution of the Green function tensor, so that the source excitation is taken into account in the scattering tensor. Certainly, such a procedure requires more resources if compared to the standard EBA approximation, but there is still a significant computational saving with respect to the full integral equation methods.

In this context, further numerical results will show that the original EBA has been effectively improved using a Green function formulation. Moreover, an innovative formulation of the EBA based on an higher order approximation will be discussed and compared with the other approaches. The results will show that such techniques may achieve accurate results in many situation of practical interest without requiring the inversion of a huge full complex matrix and thus avoiding the computational requirements of a full integral equation method.

REFERENCES

1. M. Born, Optik, Springer-Verlag, New York, 1933.
2. M. Nieto-Vesperinas, Scattering and Diffraction in Physical Optics, Wiley, New York, 1991.
3. T. M. Habashy, R. W. Groom, and B. Spies, "Beyond the Born and Rytov approximations: a non linear approach to electromagnetic scattering," *J. Geophys. Res.*, vol. 98, pp. 1759-1775, 1993.
4. C. Torres-Verdin and T. M. Habashy, "Rapid numerical simulations of axissymmetric single-well induction data using the Extended Born approximation," *Radio Sci.*, vol. 36, pp. 1287-1306, 2001.
5. A. Abubakar and T. M. Habashy, "A Green function formulation of the Extended Born approximation for three-dimensional electromagnetic modeling," *Wave Motion*, vol. 41, pp. 211-227, 2005.