A Comprehensive Comparison of FFT-Accelerated Integral Equation Methods vs. FDTD for Bioelectromagnetics

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The performance of two FFT-accelerated integral equation methods—the adaptive integral method (AIM) and GMRES-FFT—and the finite-difference time-domain (FDTD) method are systematically compared for their use in bioelectromagnetic (BioEM) analysis. The comparison involves four steps: (i) *A BioEM benchmark is developed.* The power absorbed by a human model illuminated by an impressed time-harmonic source is selected as the problem of interest. The benchmark consists of three inhomogeneous models (a multilayered spherical head phantom, an anatomical male model, and an anatomical female model), two types of models (pixel or surface based), and three frequencies in the ultrahigh-frequency (UHF) band (402 MHz, 900 MHz, and 2.45 GHz). (ii) *Error and cost measures are identified*: The time-average power absorbed in different tissues and the time-averaged cell-averaged absorbed power density are compared to either analytical results or results from other methods. The peak memory requirement and computation time of the simulations are recorded. (iii) *The benchmark problems are solved using each method with optimized parameters*. (iv) *Plots of results, errors, and computational costs are presented.* The tradeoff between increased accuracy and cost is quantified for each method. The data show that when surface-based models can be used AIM generally outperforms GMRES-FFT and FDTD: AIM achieves lower errors at the same computational cost or costs less to achieve the same error. When restricted to pixel-based models, however, FDTD generally outperforms GMRES-FFT and AIM: All three methods yield comparable errors, in most cases FDTD is less costly than GMRES-FFT (especially for anatomical models and higher frequencies), and GMRES-FFT is slightly less expensive than AIM. These results suggest that, for the type of BioEM analysis represented by the benchmark, AIM should be used whenever surface-based models are available and FDTD should be used if only pixel-based models are available.