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3D numerical modeling of nonlinear continuous wave ultrasound propagation

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ABSTRACT

Accurate simulation of an intensive ultrasound beam requires taking nonlinear propagation effects into account. A notable example in the field of biomedical ultrasound where the effect of nonlinearity may play a significant role is the high intensity focused ultrasound (HIFU) as a non-invasive energy-based treatment modality. In this work, a new 3D numerical model to simulate nonlinear propagation of continuous wave ultrasound beams in dissipative homogeneous tissue-like media is presented. The model implements a novel second-order operator splitting method in which the effects of diffraction, nonlinearity and attenuation are propagated over incremental steps. The model makes use of an arbitrary 3D source geometry definition method and a non axi-symmetric propagation scheme, which leads to a full 3D solution to the resulting nonlinear ultrasound field. Comparisons with other established linear and nonlinear numerical models as well as experimental data show great agreements. The proposed model is a particularly useful computational tool in carrying out accurate and efficient simulations of high intensity focused ultrasound beams in soft tissue where the effects of nonlinearity, diffraction, and attenuation are important.

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