# COMPUTER SIMULATION OF LINEAR AND HARMONIC ULTRASOUND IMAGING

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An extensive study for computer modeling of B-mode ultrasound imaging is carried out. Computer models for generating linear and harmonic B-mode ultrasoud images are developed.

The linear imaging model is based on a novel frequency domain approximation that greatly improves the computational efficiency and is applicable to both linear and phased array transducers. Computations are based on an approximation that is less restrictive than the Fresnel approximation, usually used in simulations of this type. The model was compared to results obtained with the exact time domain impulse response method, regarded as the "gold standard" for pulsed beam calculations. In a typical application errors in simulated rf waveforms are less than 1% regardless of the steering angle, yet computation times are on the order of 1/150 of those using the exact method. This model takes into account the effects of frequency-dependent attenuation, backscattering, and dispersion. Modern beam forming techniques such as apodization, dynamic aperture, elevational focusing, multiple transmit focusing and dynamic receiving focusing can be simulated. , espeically when elevational focusing is applied.

Nonlinear image modeling is based on numerical solutions to the KZK (Khokhlov-Zabolotskaya-Kuznetsov) equation. The incident ultrasound pulse is modeled using the KZK equation, however the echo signal is modeled using linear propagation becasue its amplitude is much lower than that of the incident pulse. Both time domain and frequency domain numerical solutions to the KZK equation were studied. Realistic harmonic images of spherical lesion phantoms were generated for scans by a circular focused transducer. THis model can be a very useful tool for studying harmonic buildup and dissipation processes in a nonlinear medium., and it can be applied for studying a wide variety of topics related to B-mode and harmonic imaging.

A Parrallel computing technique was developed and applyed to solve the KZK equation for beams produced by rectangular sources. To achieve this a very efficient message passing interface and scheme was developed to solve first for diffraction and attenuation, then for nonlinear propagation. The model was run successfully on 32 and 64 node Cray computers.

The accuracy of models is establishe1d via comparision with some benchmark numerical or analytical solutions, and also via direct experimental measurements. The computer models developed in this dissertation take into account nearly all aspect of ultrasound imaging: media properties, transducer configuration and signal processing. It can be a very useful too for ultrasound researchers and manufacturers. Also in this dissertation, many examples are presented on how computer modeling can be used to understand and improve B-mode ultrasound imaging.