Ultrasonic Scatterer Size Estimation and Imaging with a Clinical Scanner

Anthony L. Gerig

Under the supervision of Professors James A. Zagzebski and Don D. Reeder
At the University of Wisconsin-Madison

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Estimating scatterer size using signals produced by echoed ultrasonic fields inevitably involves preliminary processing devoted to extracting system-dependent factors from spectral estimates to leave quantities that are solely dependent upon the properties of the scattering medium. One purpose of this research is to investigate the possibility of using a reference phantom to account for these system-dependent factors as an avenue for making the clinical implementation of scatterer size estimation and imaging feasible. Results of simulations and phantom experiments indicate that the reference phantom data reduction method produces accurate estimates and parametric images given that spectral estimate variation is reasonable.

The second purpose is to characterize, and investigate solutions to, other obstacles that are more intrinsic to scatterer size estimation itself. For example, scatterer size estimates have notoriously low signal-to-noise ratios. This work derives a theoretical approximation for size estimate variance that is subsequently verified with simulations. Based upon the results, it is concluded that size estimation with larger bandwidths and at higher frequencies that do not violate model limitations improve estimate precision. In addition, angular compounding is investigated extensively as a precision-improving technique that attempts to avoid dramatic sacrifices in resolution. A theoretical expression for the correlation between size estimates generated using data taken from a single region but at different angles of incidence is derived and compared with simulation results. Its utility for determining relationships between experimental system parameters and measures of performance and for technique optimization is discussed. The technique is also implemented on a clinical scanner and tested using tissue-mimicking phantoms. Results indicate that spatial compounding is effective for increasing image SNR, and that optimum acquisition angles may be found to minimize the computational burden. Finally, theoretical, simulation and experimental work is done on the effects of phase and amplitude aberration and scatterer population mixing on scatterer size estimates. Results indicate that aberration errors can be significant, although corrective filters can be applied, and that mixing errors can be especially great for large contaminating scatterers, although reductions can be achieved by appropriately shifting the frequency band used in size estimation.