ABSTRACT

CHARACTERIZING TISSUE MICROSTRUCTURE USING AN ULTRASOUND SYSTEM-INDEPENDENT SPATIAL AUTOCORRELATION FUNCTION

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The research described in this dissertation is related to characterization of tissue microstructure using a system-independent spatial autocorrelation function (SAF). The SAF was estimated using a reference phantom method, which employed a well-defined "point-scatterer" reference phantom to account for instrumental factors. In this method, the ratio of the echo signal power spectrum of the "unknown" sample to that of the reference phantom allows calculation of the SAF of the unknown sample, as long as the same instrumental settings are used when data were acquired from both samples. The system bandwidth requirement was studied by simulations involving two autocorrelation models.

The SAF's were estimated for several tissue-mimicking (TM) phantoms with various scatterer diameter distributions as well as for fresh dog livers. Both phantom tests and *in vitro* dog liver measurements showed that the reference phantom method is relatively simple and fairly accurate, providing the bandwidth of the measurement system is sufficient for the size of the scatterer being involved in the scattering process.

Implementation of the reference phantom method in clinical scanner requires that distortions from patient's body wall be properly accounted for. The SAF's were estimated for two phantoms with body-wall-like distortions. The beam distortion parameters measured for one phantom agree with the mean values of ten human cadaver abdominal wall specimens. The experimental results demonstrated that body wall distortions have little effect on the estimated SAF's if echo data are acquired from a large scattering volume. Insensitivity of the SAF estimates to the simulated body wall distortions may pave the way for clinical implementation of the reference phantom method.

One interesting application of the SAF is to form a parametric image, "scatterer size image". The scatterer size image may help providing significant diagnostic tools for those diseases in which the tissue microstructure is different from the normal. In addition to the SAF method, the BSC method utilizes information contained in the frequency dependence of the backscatter coefficient to estimate scatterer sizes and further to form a scatterer size image. The SAF technique produced fairly accurate scatterer size images of homogeneous

TM phantoms and the BSC method was proven to be capable of generating accurate size images for heterogeneous phantoms, i.e., phantoms with different diameter distributions at different spatial locations. The scatterer size images of fresh dog livers indicated that there exist at least two groups of scattering structures in a dog liver---one group dominates the scattering in the low frequency range (less than 1.0MHz), and the other dominates in the high frequency range (around 5.0MHz). In the scatterer size image of dog kidneys, the contrast-to-noise-ratio (CNR) between renal cortex and medulla was improved dramatically compared to the gray-scale image formed using the same RF data. This indicates that scatterer size image may provide information otherwise missed in conventional B-mode images.

The effect of nonlinear propagation on the estimation of SAF was investigated by using a custom-designed phantom with overlaying TM fat layer. The results showed that the correlation length of the measured SAF's decreased when the transmitting power increased. The results support the assumption that nonlinear propagation generates harmonic energies and changes "apparent" frequency dependence of the backscatter coefficient, and thus causes underestimation of scatterer diameters. Nonlinear propagation can be further enhanced by those materials with high B/A value --- a parameter which characterizes the degree of nonlinearity. Nine versions of TM fat and non-fat materials were measured for their B/A values using a new measurement technique, the "simplified finite amplitude insertion substitution"

(SFAIS) method. B/A values of several reference materials measured using the new technique are in excellent agreement with those previously published values by other authors.