

# Apparent Motion and Temperature Dependence of Backscattered Energy in Ultrasonic Images

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## Abstract

Previously, we have investigated techniques for measuring temperature-dependent change in backscattered energy (CBE) in 1D ultrasonic signals. Extension of those techniques to 2D images is limited by apparent non-rigid motion of tissue as temperature changes. Our recent experimental data comes from a Terason 2000 laptop-based ultrasound system equipped with a 7MHz linear array probe, model 10L5. Typical image sets cover 37 to 50°C with 0.5°C steps. After compensation for apparent movement, image data was squared and averaged to form backscattered energy at each pixel. The tissue appeared to move between 0.5 and 1 mm laterally and axially. This movement was estimated by maximizing the cross-correlation of image regions at adjacent temperatures. Two measures were computed to characterize the CBE over an image region, the standard deviation over the whole region and the means of all positive- and all negative-going pixels in the region. These results are consistent with theoretical expectations and continue to support the possibility of using CBE in ultrasound as a tool for noninvasive thermometry. (Supported by NIH grant R21-CA90531 from the National Cancer Institute and the Wilkinson Trust at Washington University in St. Louis)

## Goals

- Evaluate the change in backscattered energy for a diagnostic ultrasound image at temperatures ranging from 37 to 50 °C and its potential use as a noninvasive temperature measure.
- Develop and evaluate algorithms for tracking tissue regions that show apparent motion using the correlation of image regions at adjacent temperatures.

## Procedures

### Experimental Setup

Measurements were made with the experimental configuration depicted in Figure 1. Tissue samples were heated in an insulated tank that was filled with deionized water, which had been degassed by vacuum pumping in an appropriate vessel. Tissue was placed in the focal zone of a 7MHz linear array probe, model 10L5. Temperature in the tank was set by a heater that circulated the water in the tank. The temperature in the tissue was monitored by a thermometer, which used an indwelling needle RTD thermistor. After temperature in the tank reached equilibrium, the image was saved to disk. The temperature range covered was 37 to 50 °C in 0.5 °C increments.

### Data Analysis

For a given region, motion was compensated by first estimating the motion, or displacement, of the region from one temperature measurement to a second measurement and then transforming the second image by the measured displacement. This is done for multiple regions within a tissue sample.

Once the apparent tissue motion was accounted for the change in backscattered energy was calculated over the range of temperatures. The compensated images were demodulated with the Hilbert transform and smoothed with a 3x3 running average filter. Values were squared to determine the backscattered energy at each pixel. The backscattered energy image at 37°C was used as the reference to CBE images at each 0.5°C step.

### Experimental Setup

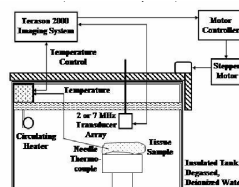


Fig. 1. Configuration for the measurement of backscattered ultrasound from tissue samples. Deionized and degassed water in the tank was heated to equilibrium, as monitored by an invasive RTD thermistor probe in the tissue. Images were saved at every 0.5 °C from 37 to 50 °C.

## Results

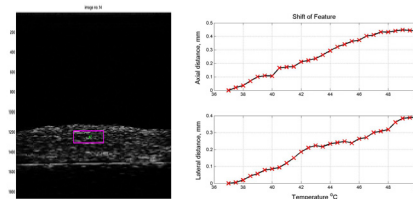


Fig 2. Ultrasound image acquired at 37 °C. The area outlined in the rectangle was compensated for apparent motion. Analysis is shown in the figures below.

Fig 3. Plot of apparent motion of tissue in the axial and lateral dimensions due to the temperature increase. This motion was compensated for using cross correlation.

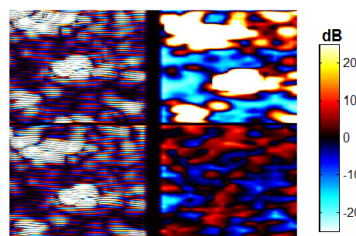


Fig 4. RF images (left) of the segmented region uncompensated (top) and compensated (bottom) for motion. The top right is the corresponding backscattered energy color map at 50 °C, and the bottom right shows relative backscattered energy at 50 °C normalized to the reference image at 37 °C. The color map was chosen to show positive and negative excursions in the relative backscattered energy.

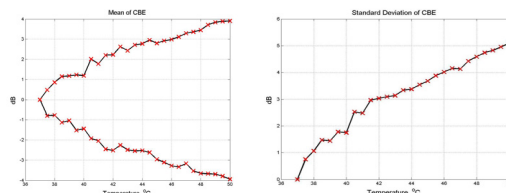


Fig 5. The mean (left plot) of the positive and negative excursion regions (represented by the red and blue respectively in the color map of fig 4) for the relative change in backscattered energy for the region of interest shown in the ultrasound image (fig 2) and the standard deviation (right plot) of the change in backscattered energy for this region as the temperature rises from 37 to 50 °C.

## Results

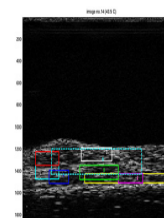


Fig 6. Ultrasound image acquired at 37 °C. The areas outlined in the colored rectangles were compensated locally for apparent motion. Analysis is shown in the figures below.

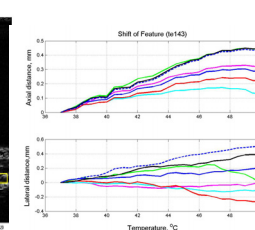


Fig 7. Plot of apparent motion of tissue in the axial and lateral dimensions due to the temperature increase for the segment of tissues shown. This motion was estimated by using cross correlation.

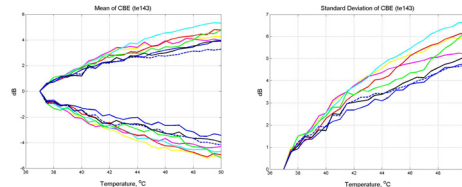


Fig 8. The mean (left plot) of the positive and negative excursion regions for the relative change in backscatter energy for the regions of interest shown in the ultrasound image (fig 6) and the standard deviation (right plot) of the change in backscatter energy for these regions as the temperature rises from 37 to 50 °C.

## Discussion and Conclusions:

Analysis of ultrasound images taken at 0.5 °C steps for the temperature range from 37 to 50 °C showed apparent motion in both the lateral and axial direction. This motion was compensated for by using a cross correlation technique that maximized the correlation at adjacent temperatures to track regions of interest within the tissue sample. After compensation the backscattered energy relative to the baseline at 37 °C was analyzed at each pixel within this region. The analysis showed both positive and negative excursions in the relative backscattered energy similar to what we had seen previously in the 1-D case (Arthur et al. Med Phys. 2003 Jun;30(6):1021-9). The standard deviation of these positive and negative excursions tracked monotonically with temperature in the 37 to 50 °C range. Motion in the elevation direction has not been taken into account in these experiments. We expect this motion to have less of an effect on the relative backscattered energy than in the axial and azimuthal directions since the transducer we are using is not well focused in the elevation direction. The results from this study are consistent with theoretical expectations and continue to support the possibility of using CBE in ultrasound as a tool for noninvasive thermometry.

### Future Directions:

3-D mapping of the backscattered energy by motoring the ultrasound transducer in the elevation direction.

Refinement and study of data analysis to increase the accuracy of tissue motion compensation and to investigate the optimum technique to infer temperature.