Ultrasonic bone assessment using a backscatter difference technique

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Background

Osteoporosis is a degenerative bone disease that causes normally porous bone tissue called cancellous bone to become even more porous and susceptible to fracture. The human and economic costs associated with osteoporotic fractures are predicted to increase as the population ages.[1-3]

Our laboratory recently introduced an ultrasonic method for diagnosing osteoporosis called the Backscatter Difference Technique that may be able to detect changes in bone caused by the disease.[4] The technique is based on an analysis of the normalized backscatter difference spectrum.

Objectives

- Determine the frequency dependence of the normalized backscatter difference spectrum.
- Understand how the normalized backscatter difference spectrum depends on the portion of the backscatter signal that is analyzed.

Methods

Ultrasonic backscatter measurements were performed on 55 excised cubes of human cancellous bone using a 3.5 MHz transducer. Backscatter signals are generated as the ultrasonic wave interacts with the porous microstructure of the bone tissue.

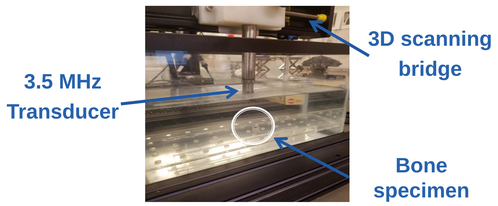

Figure 1: 3.5 MHz transducer and bone specimen positioned in a water tank

Methods

A computer controlled scanning bridge was used to acquire backscatter signals from multiple locations on each specimen. All 6 sides were scanned. Figure 2 shows example backscatter signals from a high and low density specimen of bone.

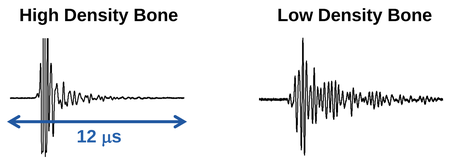

Figure 2: Example backscatter signals from high and low density specimens of bone.

As shown in Figure 3, analysis gates were used to select two different portions of each signal for processing.

Figure 3: Analysis gates placed on a backscatter signal.

As shown in Figure 4, the normalized backscatter difference spectrum is obtained by subtracting power spectra (in dB) from the two gated portions of the signal and dividing by $\tau_w + \tau_s$.

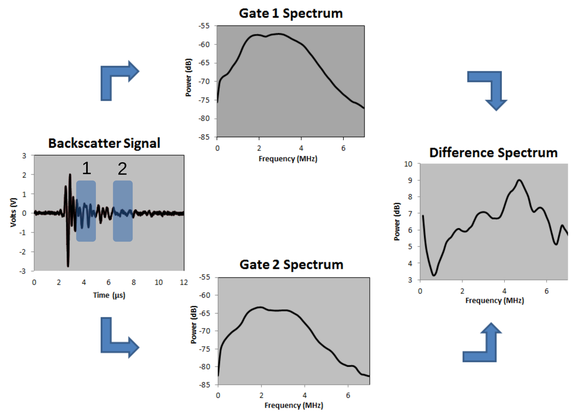

Figure 4: The backscatter difference spectrum is obtained by subtracting power spectra (in dB) from the two gated portions of the signal.

Results

Difference spectra were averaged over all measurement sites on all specimens. Difference spectra were determined for different combinations of gate separation τ_s, gate delay τ_d and gate width τ_w shown in Table 1.

Gate separations (µs)	Gate delays (µs)	Gate widths (µs)
0, 1, 2, 3	2, 3, 4, 5, 6	1, 2, 3

Table 1: Gate settings used for this study.

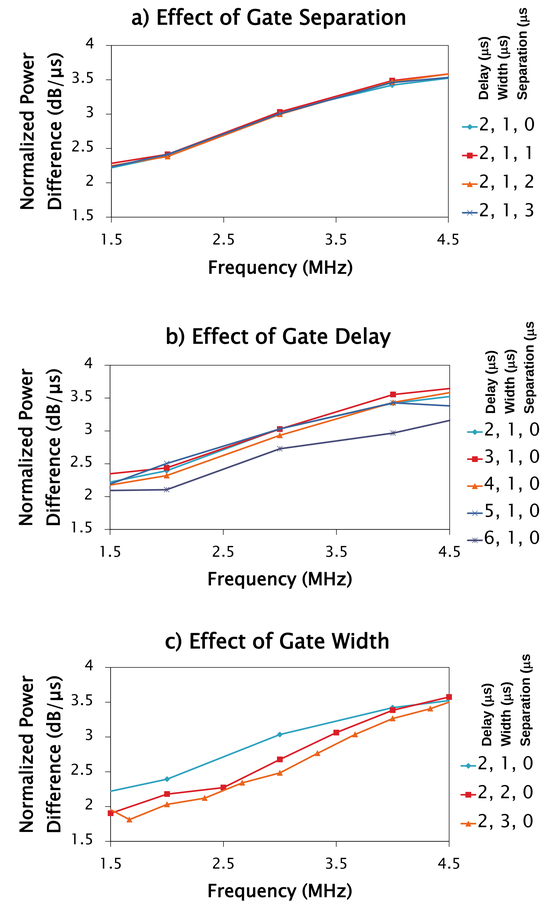

Figure 5: Effects of a) gate separation τ_s, b) gate delay τ_d and c) gate width τ_w on the normalized backscatter difference spectra.

Discussion

A seen in Figure 5, the normalized backscatter difference spectrum increases approximately linearly with frequency for all gate choices. Gate separation has very little effect on the normalized backscatter difference spectrum (Fig. 5a). However, gate delay and gate width do appear to have more of an effect.

In Figure 5b, the normalized backscatter difference spectra are similar for all gate delays except τ_d = 6 µs. This may be caused by weak signal to noise ratio for the longest delay.

In figure 5c, The slopes of the normalized backscatter difference spectra appear to increase slightly as gate width is increased.

Conclusions

- The normalized backscatter difference spectrum increases approximately linearly with frequency. This suggests that parameters based on the slope and intercept of the normalized backscatter difference spectrum may be useful bone assessment parameters.
- The normalized backscatter difference spectrum does not appear to depend strongly on the choice of gate separation and gate delay (as long as the signal to noise ratio is good). Choice of gate width may have a greater effect.

References and Acknowledgements

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[4] B. K. Hoffmeister, A. R. Wilson, M. J. Gilbert, and M. E. Sellers, "A backscatter difference technique for ultrasonic bone assessment," J. Acoust. Soc. Am. 132, 4069-4076 (2012)

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