3P2-8

Measurement accuracy of speed of sound in tissue-mimicking phantom using path-through airborne ultrasound

生体模擬ファントムを透過した空中超音波による非接触音波伝搬速度計測の計測精度

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1. Introduction

Quantitative ultrasound (QUS), ultrasonic bone assessment using the speed of sound (SOS) or broadband ultrasound attenuation (BUA) in the cancellous bone, is one of the diagnosis methods of osteoporosis. The QUS method is widely applied in clinical screening because it is minimally invasive and free from X-ray exposure. In typical devices for QUS, ultrasonic transducers brought into contact with tissue surfaces through an ultrasonic gel to effectively propagate ultrasound in the tissue. In this study, non-contact QUS using airborne ultrasound passed through a tissue has been proposed to enable the easy-repeatable and low-cost examination. In the proposed method, the M-sequence-modulated ultrasound is transmitted to the heel side. Then, the pass-through wave which is extremely attenuated due to large reflections at boundaries between air and the heel is received. To detect the pass-through wave, the signal-to-noise ratio (SNR) of the received signal is greatly improved by pulse compression, cross correlation with the M-sequence code. The SOS in the heel can be estimated from the time of flight (TOF) of the pass-through wave and the heel width.

In the previous report, accuracy of SOS measurement by the proposed method was verified [1]. However, SOSs in tissue-mimicking phantoms or actual heels haven't been estimated with sufficient accuracy. In this report, improvement of SOS measurement focused on TOF determination is described.

2. SOS measurement in the proposed method

The proposed method of SOS measurement is illustrated in **Fig. 1**. In non-contact QUS, TOFs of ultrasound when there is a heel and nothing between transducers are determined. The SOS in the heel c_{tis} is estimated from the difference of TOFs ΔTOF, the propagation path in the heel l_2 and the SOS in the air c_{air}. In the previous report, ΔTOF have been determined from the peak in the cross-correlation function between two received signals. However, the peak position might not indicate the difference of wave fronts. Therefore, TOF determination is verified by the experiment using a tissue phantom.

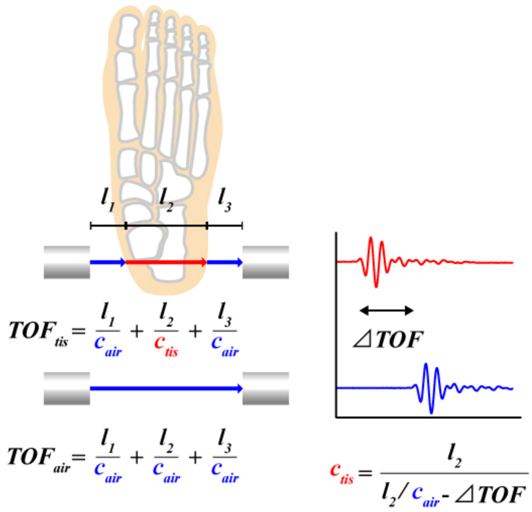

Fig. 1 Proposed method of SOS measurement in heel.

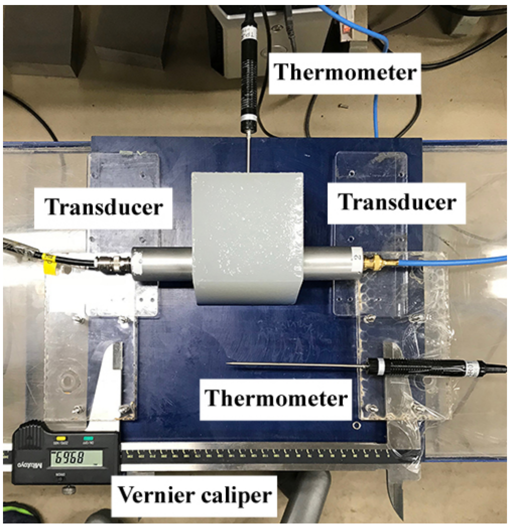

Fig. 2 Experimental setup.

3. Experimental configuration

The experimental setup is illustrated in **Fig. 2**. Experiments were perfumed as l_1 and l_3 are zero to verify only TOF determination. Therefore, the 2 % agar phantom was held by transducers and l_2 was

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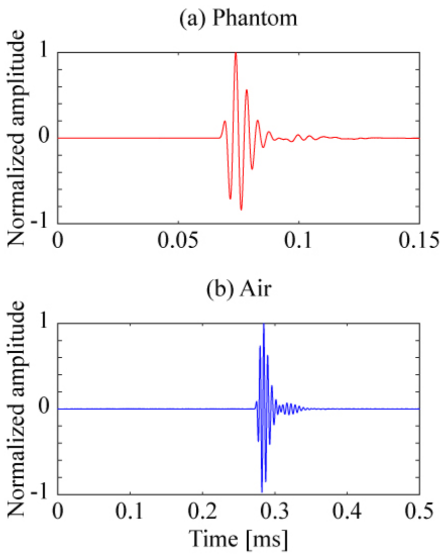

Fig. 3 Received signals when there is the tissue phantom and nothing between transducers.

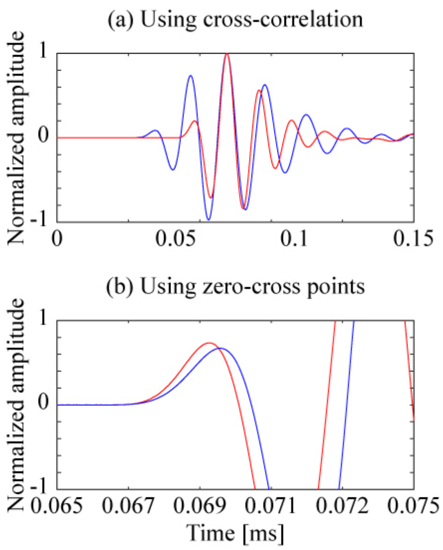

Fig. 4 Received signals of the tissue phantom and received signals of the air shifted by determined *ΔTOF*.

measured by the Vernier caliper. The frequency of transmitted ultrasound was 200 kHz and 1 sine wave was transmitted from left-side transducer in **Fig. 2**. The received signal of right-side transducer was amplified and passed through the high-pass filter of 2 kHz.

4. Experimental result

Received signals when there is the tissue phantom and nothing between transducers are illustrated in **Fig. 3**. In the proposed method, the time difference of wave fronts has to be accurately determined. First, *ΔTOF* was determined using cross correlation of received signals. The received signal of the air is shifted by determined *ΔTOF*, as illustrated in **Fig. 4 (a)**. *ΔTOF* couldn't be accurately determined because times of wave fronts are different. Secondly, *ΔTOF* was estimated using zero-cross points. Time differences of rise and decay zero-cross points in **Fig. 3** were determined. Then, the time difference of wave fronts was estimated by the polynomial approximation. The received signal of the air is shifted by *ΔTOF* which is estimated by the quartic approximation of 6 zero-cross points, as illustrated in **Fig. 4 (b)**. In this case, c_{tis} could be estimated from the accurate *ΔTOF*.

SOSs in the tissue phantom were measured by using zero-cross points. Temperatures of the tissue phantom changed from 15 to 22 degrees Celsius during the experiment. Estimated c_{tis} is illustrated in **Fig. 5**. For comparison, SOSs in pure water is also indicated in **Fig. 5**. Estimated c_{tis} were larger approximately 20 m/s than pure water.

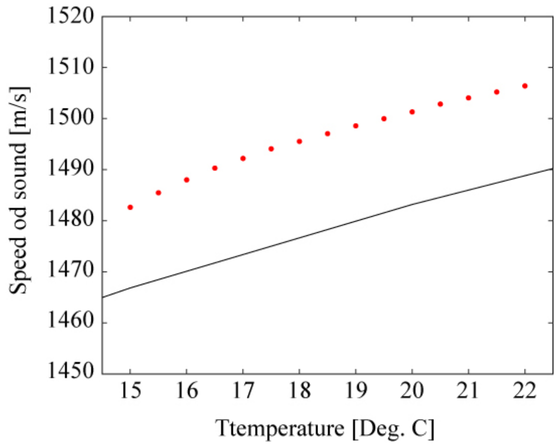

Fig. 5 Experimental setup.

5. Conclusions

In this study, non-contact QUS using airborne ultrasound passed through a tissue has been proposed. In this report, accuracy about TOF determination for SOS measurement in the proposed method is described. Time difference of path-through waves when there is the tissue phantom and nothing between transducers could be estimated from zero-cross points with high accuracy.

Acknowledgment

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References

1. D. Hanawa, S. Hirata and H. Hachiya: *USE2017* (Tagajo City Cultural Center, Tagajo, 2017) 3P2-6.