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Evaluation of non-contact measurement for acoustic properties in tissue-mimicking phantoms with inclined sides
側面が傾斜した生体模擬ファントムを対象とした非接触音響特性計測の評価

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1. Introduction

Ultrasonic bone assessment using the speed of sound (SOS) or broadband ultrasound attenuation (BUA) in a cancellous bone is known as quantitative ultrasound (QUS) and one of the diagnoses methods of osteoporosis. The QUS inspection is widely applied in clinical screening because it is minimally invasive and free from X-ray exposure. In typical devices for QUS, a heel is held by ultrasonic transducers through an ultrasonic gel for the effective propagation of ultrasound. In this study, non-contact QUS using airborne ultrasound passed through a heel has been proposed to enable the easy-repeatable and low-cost inspection.[1,2] In the proposed method, an M-sequence-modulated ultrasound is irradiated to a side of the heel. The pass-through ultrasound is extremely attenuated due to large reflections at boundaries between the heel sides and air. To detect the pass-through ultrasound, the signal-to-noise ratio (SNR) of the received signal is greatly improved by the cross correlation with the transmitted M-sequence (pulse compression). The SOS in the heel can be estimated from the time of flight (TOF) of the pass-through ultrasound and the heel width. In this report, SOS measurement in non-contact QUS is evaluated by using different-SOS tissue-mimicking phantoms with inclined sides.

2. Non-contact QUS

The measurement setup of non-contact QUS for a tissue-mimicking phantom with inclined sides is illustrated in **Fig. 1**. A tissue-mimicking phantom is placed between ultrasonic transducers. First, each transducer and laser range finders at its both sides are rotated by each motorized stage. When the outputs of laser range finders become equal, the side of the phantom and the surface of the transducer are parallel. Then, each motorized stage is rotated at appropriate angle so that the pass-through ultrasound which refracts at phantom sides vertically goes to the transducer for reception. Finally, the M-sequence-modulated ultrasound is transmitted and received to determine the TOF the pass-through ultrasound.

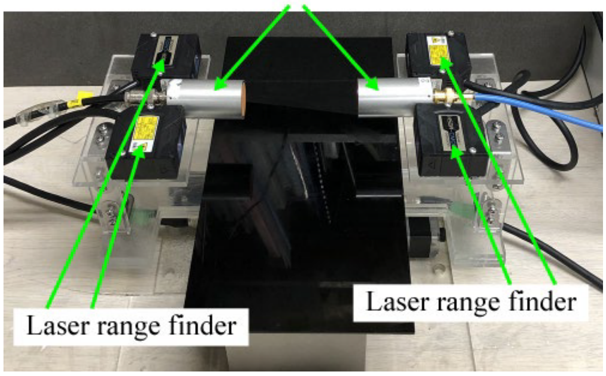

Fig. 1 Measurement setup of non-contact QUS for a tissue-mimicking phantom with inclined sides.

3. Materials and methods

The measured tissue-mimicking phantoms were WRTMM01 and WRTMM02 (OST). The SOSs of phantoms are 1520 and 1540 m/s at 29.5°C, respectively. The density and attenuation are 1070 kg/m^3 and 0.94 dB/cm/MHz. Three sine waves, whose center frequency is 555.6 kHz, was assigned to 1 bit in 13th-order M-sequences. The M-sequence-modulated ultrasound was transmitted from the transducer B0.6K20N (Japan Probe). The applied voltage of the transducer was 140 Vpp. The received signal was amplified 1000 times, then passed through the HPF with a cutoff frequency of 1 kHz, after that saved on the oscilloscope with sampling frequency of 20 MHz.

The TOF of pass-through ultrasound was determined from the cross-correlation function between the received signal and the transmitted M-sequence. The width of phantom where ultrasound

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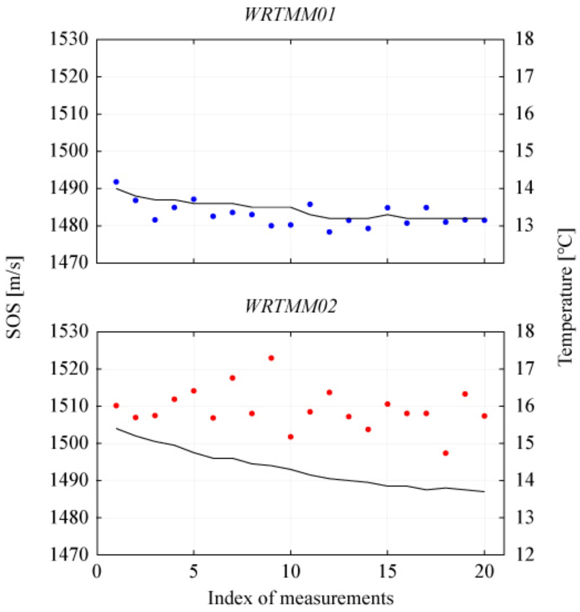

Fig. 2 Estimated SOSs of WRTMM01 and WRTMM02 by non-contact QUS and temperatures during measurements.

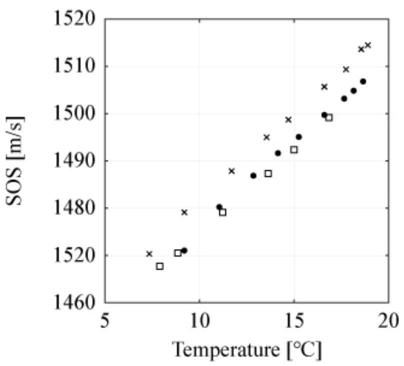

Fig. 3 Estimated SOSs of WRTMM02 by typical QUS and temperatures in 3-times measurements.

propagated were estimated from the angle and distance between the phantom and the transducer. Then, the SOS was estimated from the TOF and the phantom width, the SOS in the air.

4. Results and discussion

The estimated SOSs of phantoms and temperatures during measurements are illustrated in **Fig. 2**. To evaluate the SOSs, the effect of temperatures has to be calibrated because the SOS changes with the temperature. Therefore, the SOS of WRTMM02 was estimated for calibration in the contact method (typical QUS). The estimated SOSs in typical QUS and temperatures are illustrated in **Fig. 3**. The SOS of the phantom seems to increase linearly according as the temperature. The

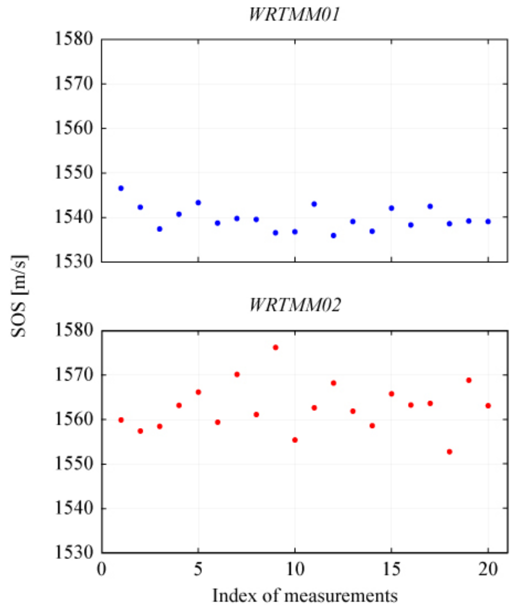

Fig. 4 Calibrated SOSs of WRTMM01 and WRTMM02 by non-contact QUS

proportionality constant of those SOSs was 3.53 m/s/°C. The calibrated SOSs of phantoms are illustrated in **Fig. 4**. Averages and standard deviations of calibrated SOSs are 1540±2.7 and 1563±5.5 m/s, respectively. Both SOSs were larger than true values by approximately 20 m/s. These differences may have occurred by offset errors of phantom widths.

4. Conclusion

In this report, SOS measurement of tissue-mimicking phantoms with inclined sides by non-contact QUS is evaluated. Phantoms of different SOSs were measured and estimated SOSs were calibrated by their temperatures. As a result, there are offset errors of approximately 20 m/s. Otherwise, calibrated SOS were accurate and stable. Future works are removing the offset error and measurement of BUA in non-contact QUS.

Acknowledgment

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References

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