1P2-8

Comparison of contact/non-contact measurement of speed of sound for a tissue-mimicking phantom 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音波伝搬速度の接触・非接触計測の比較

Toshiaki Okubo‡, Shinnosuke Hirata, Hiroyuki Hachiya (Sch. Eng., Tokyo Techy)
大久保 俊朗‡, 平田 慎之介, 蜂屋 弘之 (東工大 工学院)

1. Introduction

Quantitative ultrasound (QUS), one of the bone assessment techniques, is widely used as a screening diagnostic for osteoporosis. The speed of sound (SOS) and the broadband ultrasound attenuation (BUA) in the cancellous bone are measured in QUS. In typical QUS devices, it is necessary to apply an ultrasound gel between surfaces of ultrasound transducers and heel sides, then transducers are brought into contact with the heel to propagate ultrasound efficiently into the heel. Therefore, there are problems such as restriction of inspected parts, their scales and shapes. In this research, we have proposed a non-contact QUS that detects ultrasound passed through the heel [1]. The SOS or BUA in the heel can be calculated from the time of flight (TOF) or the frequency spectrum of the pass-through ultrasound.

2. Non-contact QUS

In non-contact QUS for heel, ultrasound propagate from the air into the heel, then from the heel to the air. The pass-through wave is extremely attenuated by large reflections on heel sides. Therefore, we have proposed a method to greatly improve the signal-to-noise ratio (SNR) by M-sequence pulse compression. The M-sequence is one of the binary pseudo-random codes. The SNR of the pass-through wave is improved according to the length of the M-sequence. Then, the TOF can be determined from the wave form of the pass-through wave. The SOS in the heel can be estimated from the difference of TOFs with and without the heel, lengths of propagation paths and SOS in the air, as illustrated in **Fig. 1**.

In this report, we compared contact and non-contact measurements of SOSs in a tissue-mimicking phantom with inclined sides to evaluate the proposed method.

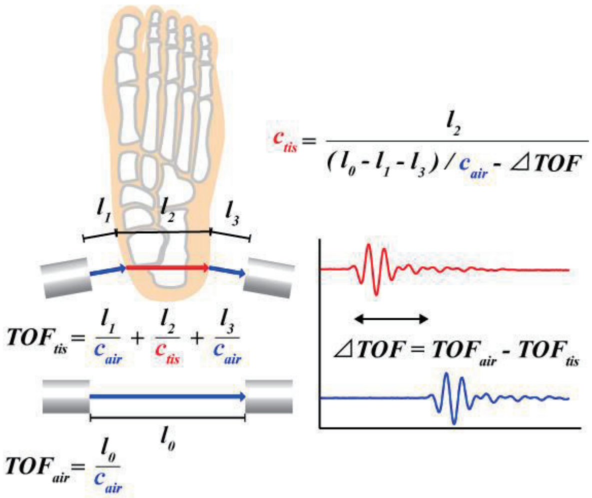

Fig. 1 Estimation of SOS in the proposed non-contact QUS.

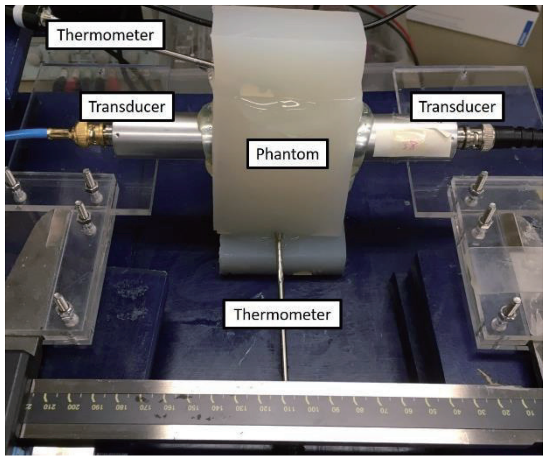

Fig. 2 Experimental setup for the typical QUS.

3. Method

3.1 Experiment for the typical QUS

The experimental setup for the typical QUS is shown in **Fig. 2**. The measurement target was the 2 % agar phantom. 3 burst sine waves, whose center frequency is 555.6 kHz, was transmitted. The sampling frequency of the function generator and applied voltage of the transducer was 20 MHz,

okubo@us.sc.e.tietch.ac.jp shin@sc.e.titech.ac.jp

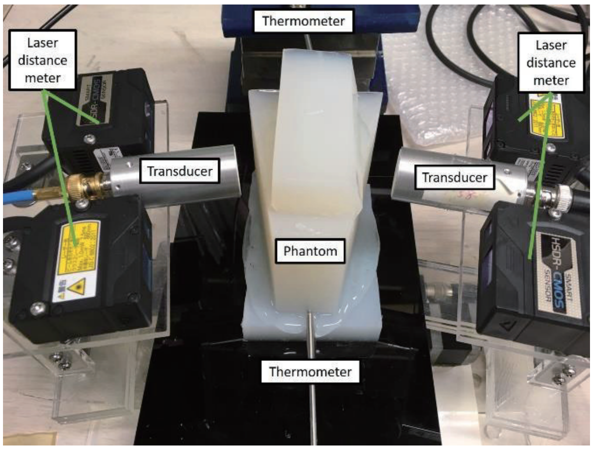

Fig. 3 Experimental setup for the non-contact QUS.

and 140 Vpp. The received signal was amplified to 10 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. An ultrasound gel was applied between the transducer and the phantom. The distance between the transducers was measured by the digital caliper. Temperatures of the phantom were measured by inserting tips of thermometers into the top and bottom.

3.2 Experiment for the non-contact QUS

The experimental setup for the non-contact QUS is shown in **Fig. 3**. 13th-order M-sequence modulated signal was transmitted. 3 burst sine waves were assigned to each binary character. The received signals were amplified 1000 times and 10 times when passing through the phantom and when measurements without the phantom, respectively. Other parameters in the transmission and reception were same as the typical method. Distances between transducers and the phantom were measured using 2 laser distance meters in each side. Talc powders were applied around the spot where the laser strike so that the laser effectively reflect on there. Laser distance meters and the transducer in each side can be rotated by each motorized stage. Therefore, the inclined angle of the phantom side can be measured by the output difference of laser distance meters and the stage angle.

4. Result and discussion

SOS measurement by the typical and non-contact QUS were performed 2 times, respectively.

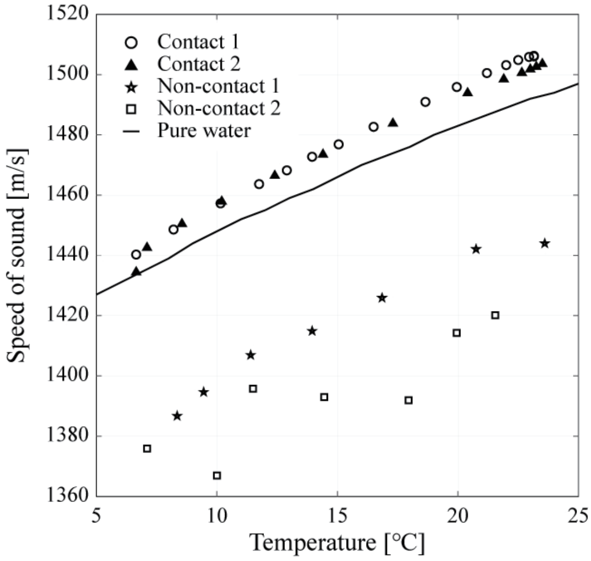

Fig. 4 Estimated SOSs by the typical and non-contact QUS.

Estimated SOSs and literature values in pure water are illustrated in **Fig. 4**. In the typical QUS, it can be confirmed that SOSs in the phantom are higher than those in water by approximately 10 m/s and increase as temperature of the phantom rises. On the other hand, in the non-contact QUS, fluctuations of SOSs are larger than the typical QUS. Furthermore, SOSs are lower than those of the typical QUS by approximately 60-80 m/s overall.

TOFs of pass-through waves seem to be accurately determined because their SNRs were sufficient. Therefore, we focused path lengths of ultrasound. Differences of SOSs correspond 0.3-0.5 mm in terms of distance. Then, they are close to thicknesses of surface's talc. Therefore, accuracy of the non-contact QUS may be improved by measuring or control talc thicknesses.

5. Conclusion

In this report, we compared the typical QUS and the non-contact QUS for SOS measurement of agar phantoms. As a result, SOSs estimated by the non-contact QUS weren't accurate and stable by talc powders on phantom sides. However, they may be able to improve by measuring or control talc thicknesses.

References

[1] S. Hirata, H. Hachiya: *2018 IEEE International Ultrasonics Symposium* (Portopia Hotel, Kobe, Japan, 2018).