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Relation between statistical properties of sound speed distribution and average sound speed estimation

音速分布の統計的性質と平均音速推定との関係

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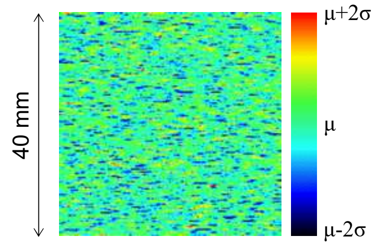
1. Introduction

The speed of sound (SoS), which is the propagation speed of a longitudinal waves, is expected to be effective for early detection and monitoring of diseases, and some methods have been proposed. Above all, the methods using the backscattered wave is expected to be useful because it enables the use of a handheld probe in the clinical field.[1-5] It has been already known that the estimation of the average SoS based on the phase aberration correction is the simplest and it is possible to make a reasonable estimation for a homogeneous medium, but the error when applied to a inhomogeneous medium has not been clarified yet. In general, even if a homogeneous medium was assumed, the actual medium is inhomogeneous. Therefore, for improving the reliability of average SoS in the future clinical application, it is important to investigate the effect of the degree of inhomogeneity on the estimation of the average SoS.

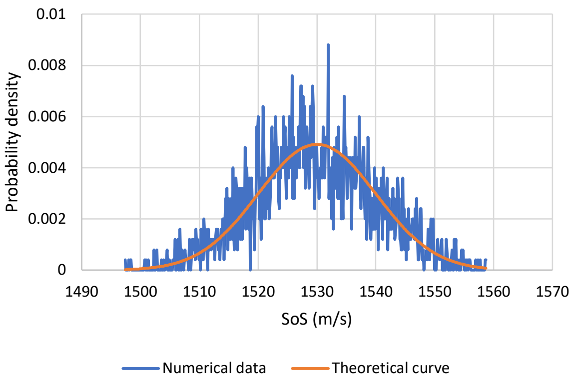
In this study, we numerically evaluated the effect of statistical properties of SoS distribution (the degree of inhomogeneity) on the estimation of average SoS.

2. Materials and Methods

Fig. 1 shows the SoS distribution assumed in this study. 2500 scatterers were placed in a 40 x 40 x 1 mm cubic region using uniform random numbers. The SoS value of the minute region where each scatterer exists was given by using Gaussian random numbers with a mean μ and a standard deviation σ. **Fig. 1(a)** shows the SoS distribution in the cubic region, and **Fig. 1(b)** shows the probability density function when the mean value μ = 1530 m/s and the standard deviation σ = 10 m/s. The statistical properties of SoS distribution is provided by changing σ within the range of 0 to 20 m/s while the mean value μ is fixed at 1530 m/s. For such a SoS distribution, the channel data (161 channels) of backscattered waves were calculated by using our simulator.[6] This simulator can calculate backscattered wave signals at high speed by superimposing pulse waveforms based on the time of flight (TOF) along an arbitrary raypath (but straight raypath in this study) which reflects the SoS distribution between the two points (element and scatterer). To calculate the backscattered wave signals for estimating the average SoS, a strong scattering point at the center (at a depth of 20 mm) in **Fig. 1(a)** was placed, and a focused beam with a frequency of 3.75 MHz was irradiated at that position. Then the backscattered channel data were acquired.



(a)



(b)

Fig. 1 SoS distribution assumed in this study. (a) shows the SoS distribution in the cubic region, and (b) shows the probability density function when μ = 1530 m/s and σ = 10 m/s.

The Focusing[1] and the Coherence[3] methods based on the phase aberration correction were used as the estimation method of the average SoS in this study. An example of those estimation results is

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shown in **Fig. 2**. **Fig. 2(a)** shows the estimation result by using the Focusing method, and searches for the test SoS value that maximizes the amplitude of the aperture synthetic wave in the range of 1400 to 1700 m/s. **Fig. 2(b)** shows the estimation result by using the Coherence method, and searches for a test SoS value at which the slope of the coherence function between channels is the most gentle.

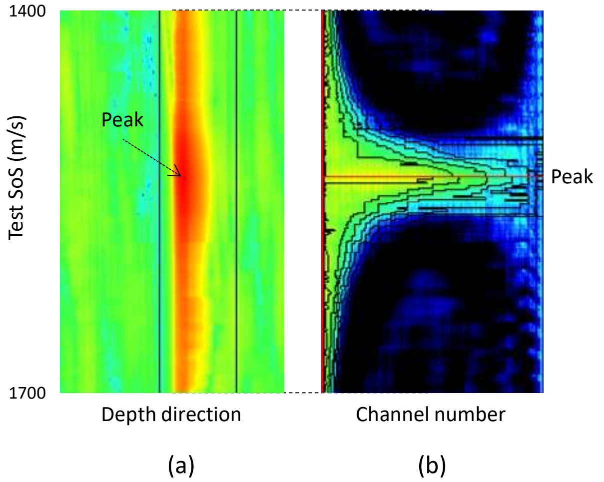

Fig. 2 An example of average SoS estimation. (a) shows the estimation result by using the Focusing method, and (b) shows the estimation result by using the Coherence method.

3. Results

Fig. 3 shows the estimation result of the average SoS when the mean value μ in the SoS distribution is fixed at 1530 m/s and the standard deviation σ is changed in the range of 0 to 20 m/s as the statistical properties of the SoS distribution. **Fig. 3(a)** shows the estimation result by the Focusing method, and **Fig. 3(b)** shows the estimation result by the Coherence method. Ten measurements were conducted for each standard deviation σ. The Focusing and Coherence methods reasonably estimated the mean value of the SoS distribution μ = 1530 m/s for any standard deviation σ in the range 0 to 20 m/s, but the variation of measurement increased when the standard deviation σ become larger. Consequently, the reliability of the estimation of the average SoS decreased. From the viewpoint of the reliability of the average SoS estimation, it can be predicted that the allowable value of σ of the SoS distribution is probably around 5 m/s.

4. Conclusions

In this study, the standard deviation σ in the SoS distribution with Gaussian random numbers was changed as the change of statistical property, and the relationship with the estimation of average SoS was investigated. As the results, it was found that the reliability of the average SoS estimation may be maintained if the standard deviation σ was around 5 m/s. In future work, experimental study will be needed.

Acknowledgment
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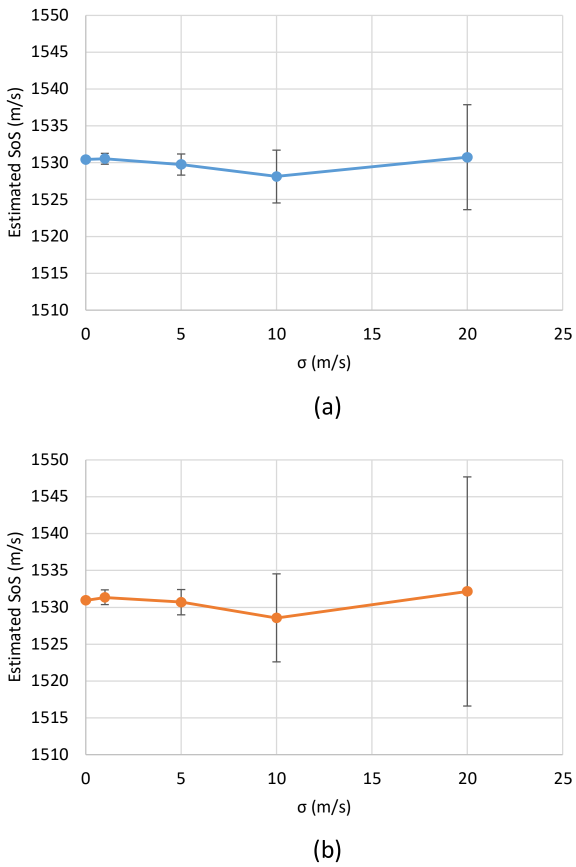

Fig. 3 Estimation results of the average SoS when the mean value μ in the SoS distribution is fixed at 1530 m/s and the standard deviation σ is changed in the range of 0 to 20 m/s. (a) shows the estimation result by the Focusing method, and (b) shows the estimation result by the Coherence method.

References

1. N. Hayashi, et al.: Proc. 4th Meeting of the WFUMB, p. 520.
2. H. C. Shin, et al.: Ultrasound. Med. & Biol. **36** (2010) 623.
3. M. Imbault, et al.: Phys. Med. Biol. **62** (2017) 3582.
4. M. Jaeger, et al.: Ultrasound Med. & Biol. **41** (2015) 235.
5. M. Jakovljevic, et al.: J. Acoust. Soc. Am. **144** (2018) 254.
6. N. Nitta: Proc. IUS 2019, pp. 1466-1469, 2019.