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Comparison of Different Sound Field Correction Methods on Backscatter Coefficient Analysis

後方散乱係数解析における異なる音場補正法の比較検討

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1. Introduction

The quantitative ultrasound tecnique based on the frequency-based analysis, e.g. backscatter coefficient (BSC), provides insight into tissue strucures such as scatterer diameter and volume fraction. In general, it is known that calculated BSC based on the reference phantom method has higher accuracy than the reflector method when the linear phased array transducer is used to acquire the RF data [1]. The reference phantom method do not require the correction of the sound field characteristics that derermined from complicated transmission and reception conditions. In other words, if the sound field characteristics can be sufficiently corrected, the BSC may be accurately evaluated by the reflector method, which is a simple measurement method. Since theoretical studies with linear phased array transduers are difficult, basic studies with single-element transducers that allow easy understanding of sound field characteristics are essential.

In this study, the method of calculating BSC (reflector and reference phantom methods) was compared to evaluate the diffrence of sound field corresction methods. The experimental results were also compared to the theoretical BSC derived from Faran model.

2. Materials and Methods

2.1 RF data acquisition of phantoms

The target objects were self-made phantoms that simulate human tissue. The phantoms had the scatter sizes of 10, 20, and 30 μm, respectively. The volume fraction was set to 0.5 % and 5 % for each phantom. During the measurement, each phantom was fixed in a water tank filled with degassed water.

RF echo signals were acquired in three-demension (3D) using laboratory-made scanner and three single-element transducers (**Table I**), and were digitized to 12-bits with the sampling frequency of 250 MHz. The focal depth was at approximately 3 mm from the surface of each phantom.

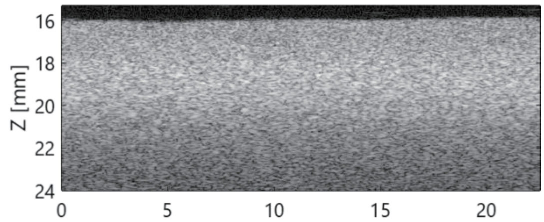

Fig. 1　Example of B-mode image of phantom

Table I. Property transducers

Transducer	F#	Center Freq. [MHz]	Focal depth [mm]	-6 dB Bandwidth [MHz]
V326 (Olympus)	5.3	5	50.1	3-7
V328 (Olympus)	2.0	15	19.2	8-19
PT25 (Toray)	1.8	25	10.2	19-37

Figure 1 shows an example B-mode image of the phantom (scatter size: 20 μm, volume fraction: 5 %) that imaged from RF data accumlated with a single-element transducer of 15 MHz. The dynamic range was from -40 to 0 dB.

2.2 Backscatter coefficient analysis

In calculating BSC, we used two methods for compensating transmission and reception sound field: the reflector method and the reference phantom method. The measured BSC_{meas} was computed using the reference phantom method from the signals obtained by each transducer as follows:

$$BSC_{meas}(f) = BSC_{ref}(f)\frac{P_{meas}(f)}{P_{ref}(f)}[A(f,\alpha) - A(f,\alpha_{ref})], \quad (1)$$

where f is the frequency, $BSC_{ref}(f)$ is the theoritical BSC derived by Faran model. $P_{meas}(f)$ and $P_{ref}(f)$ are the power spectra for the measured phantom and reference phantom. $BSC_{ref}(f)$ is the theoritical BSC calculated by the faran model. The phantom with volume fraction of 0.5% at each scatter size was used as a reference phantom. Attenuation compensation function $A(f)$ is defined as Eq. (2).

$$A(f,\alpha) = e^{4\alpha(f)x}\left\{\frac{2\alpha(f)L}{1-e^{-2\alpha(f)L}}\right\}^2\left\{1+\left\{\frac{2\alpha(f)L}{2\pi}\right\}^2\right\}^2. \quad (2)$$

where α and α_{ref} is attenuation coefficient of the analyzed and reference phantoms, and x is the distance between the surface of the phantom and the top of an analysis window.

In calculating BSC using the reflector method, BSC is expressed as Eq.(3)

$$BSC_{meas}(f) = 2.17\frac{\gamma^2F^2}{A_0\Delta x}\frac{\overline{P_{meas}(f)}}{\overline{P_{acry}(f)}}A(f,\alpha). \quad (3)$$

where $\overline{P_{meas}(f)}$ and $\overline{P_{ref}(f)}$ are the power spectra from the measured phantom and the acrylic board (reflector); γ is the pressure reflection coefficient of the planer reflector; F is the focal depth of the transduucer; and A_0 is the aperture area of the transducer. Δx is the length of the ROI and $A(f)$ is defined as Eq. (2).

The analysis area was defined as the entire phantom except for the surface of phantom. Within the analysis area, 3D ROI that size was normalized at 10 times of the wavelength and 5 times of the lateral resolution of each transducer.

3. Results and discussion

Figure 2 shows the BSC results by the reflector (plotted by cool colors) and the reference phantom methods (plotted by hot colors). As an overall trend, the BSCs were lower (several 20 dB) than Faran model, which is the theoretical model. The BSC calculated using the reference phantom method for different transducers was continuous. This continuous curve is considered to reflect the backscatter property compensated of transmission and reception sound field.

Comparing the difference between the BSC calculation by the reflector and the reference phantom methods, the reference phantom method shows stronger frequency dependence. However, depending on the scatterer conditions, the deviation from the theoretical value is also confirmed.

Considering the application for clinical study, data acquisition using linear phased array transducer and the BSC calculation based on the reference phantom method are more realistic. Hence, BSC_{ref} requires to calculate the BSC of the anlyzed medium. Faran model needs to know particle information such as diameter, density, and poisson ratio. If unknown particle used, BSC_{ref} should be calculated other theory such as the reflector method. Thus, it is necessary to assess the difference or correspondence of the BSC between Faran model and reflector method.

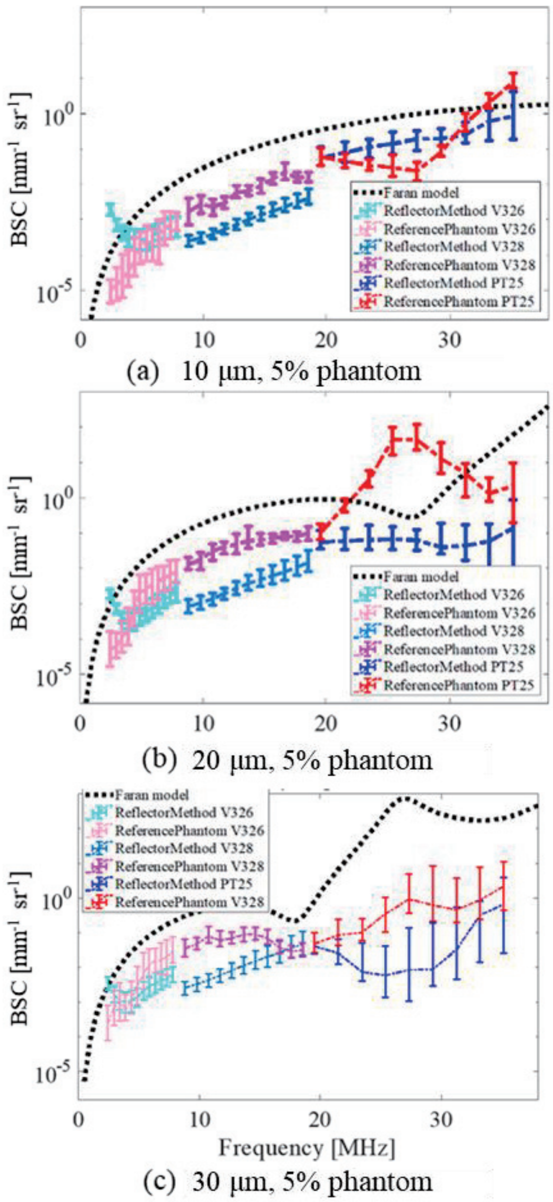

Fig. 2 Evaluated BSCs using three transducers

4. Conclusion

The accracy of the estimation of BSC was high in the reference phantom method compared with the reflector methods in low frequency band, and the frequency dependace was varied with the scatterer conditions in high frequency band.

Acknowledgment

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