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Influence on Amplitude Envelope Analysis due to Mixture of Scatterers with Different Acoustic Characteristics

音響特性が異なる散乱体の混在による振幅包絡統計解析への影響

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1. Introduction

Quantitative ultrasound for tissue characterization can be accomplished using the signal analysis method based on the amplitude envelope and power spectrum of radiofrequency (RF) echo signal. However, it is difficult to discuss the correlation between characteristics of RF echo signals and tissue properties in detail only from actual measurement results.

To evaluate the property of RF echo signal from a complexed scatterer mediums with different acoustic characteristics, we confirmed the relationship between echo amplitude envelope and a mixture rate of different kind of scatterers which have different acoustic impedance by computer simulation.

2. Computer simulation methods

The echo simulation of this study was performed with Field II (J.A. Jensen, Tech. Univ. of Denmark) based on calculation of the spatial impulse response[1]. **Fig. 1** shows the schematic image of the simulation set-up (a), and the one line of transmitted sound field with a transducer (b). A single element concave transducer with an aperture of 5.4 mm, and a focus depth of 10.3 mm was simulated. The transmission and reception frequency was 28.1 MHz, and the sampling frequency was 250 MHz. The speed of sound was 1488 m/s. Point spread function (PSF), i.e. -6 dB bandwidth, was 0.05 mm in depth * 0.11 mm in lateral direction.

Simulation echo data was acquired from the scattering field in 0.01 mm lateral intervals. The size of the scattering field was 2 * 2 mm^2, and two kinds of scatterers were put inside its area. The number density of random placed scatterers was 5, 20, 100 per PSF. One scatterer with different scattering amplitude, i.e. different contrasts of acoustic characteristics, was also located at the center of the scatterinfg field in addition to random placed scatterers. The scattering amplitude (assumed as

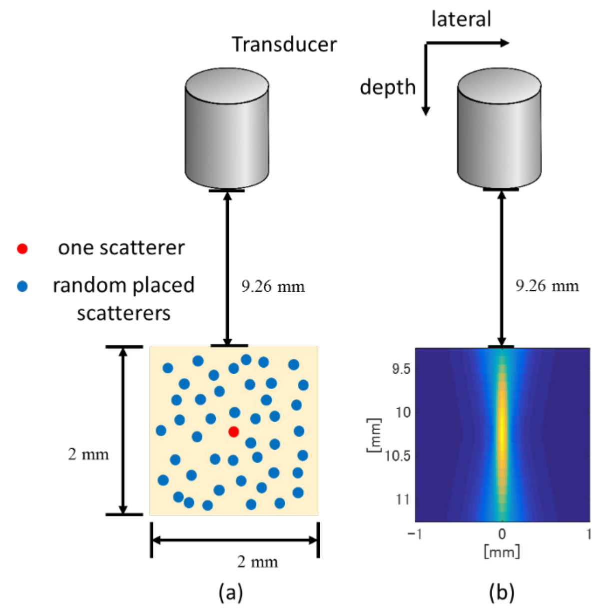

Fig. 1 Schematic image of the simulation set-up (a) and transmitted sound field of used transducer (b).

same meaning as the acoustic impedance) of random placed scatterers follows a normal distribution with an average of 0 and a variance of 1, and its one scatterer was constant to 1, 3, 6, 9, 12, 15.

3. Statistical analysis

The relationship between scatterer medium and echo amplitude envelope characteristics was investigated. In this study, Homodyned-K distribution, which can distinguish coherent from diffuse signal components, was fitted for probability density function (PDF) of simulated echo data.

Homodyned-K distribution is defined as

$$p(x) = \int_0^\infty zJ_0(z\varepsilon)xJ_0(zx)\left(1+\frac{z^2\sigma^2}{2}\right)^{-\alpha} dz. \quad (1)$$

where x is amplitude envelope, and J_0 is the Bessel function of the first kind of order 0. Homodyned-K distribution has three parameters: the parameter of coherent signal power ε^2, the scatterer clustering parameter α, and the scaling parameter σ. The structure parameter $\kappa = \varepsilon^2/2\alpha\sigma^2$ is defined as the ratio of the coherent signal power to the diffuse signal power[2].

In this study, the ratio of the diffuse to total signal power $\kappa_{diffuse}$, i.e. 1/($1+\kappa$), was computed in a region of interest (ROI). The center of ROI (the size of 0.25 * 0.55 mm^2, i.e. five times of PSF) was located in the focus position. The more closer $\kappa_{diffuse}$ parameter is to 1, the more higher diffuse signal component is indicated in ROI.

4. Results and Discussions

Figure 2(a) and **2(b)** display examples of simulated amplitude envelope images in the ROI, and corresponding its PDF (gray bar). One hundred kinds of amplitude envelope bin was automatically calculated depending on its variance in the ROI. The blue, red, and green lines represent the PDF of Homodyned-K distribution and computed $\kappa_{diffuse}$ parameter in 5 (upper), 20 (middle), and 100 (bottom row) random placed scatterers per PSF, respectively. In 5 or 20 random placed scatterers per PSF, and including one scatterer with 9 scattering amplitude, the texture of one scatterer appears higher than the surrounding mediums in **Fig. 2(a)**. Moreover, the PDFs of echo amplitude envelope and Homodyned-K distribution also describe the heavy tail of PDF for high echo amplitude envelope.

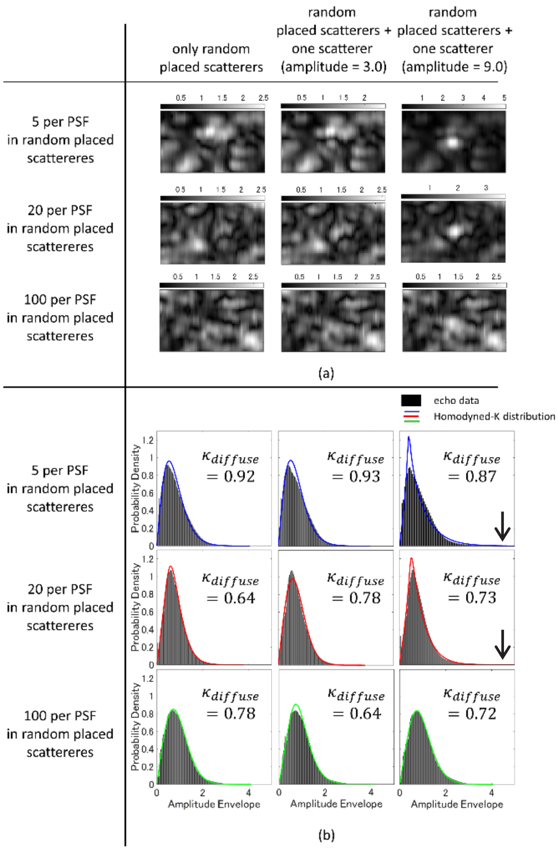

Fig. 2 Simulated amplitude envelope images (a), and its PDF and fitted Homodyned-K distribution (b) in the ROI.

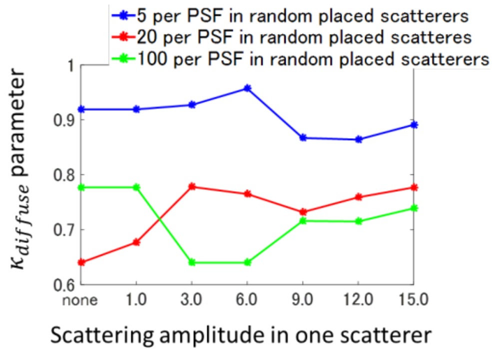

Fig. 3 Computed $\kappa_{diffuse}$ parameter of Homodyned-K in random placed scatterers with and without one scatterer having different scattering amplitude.

Figure 3 shows plots of computed $\kappa_{diffuse}$ parameters in random placed scatterers or one scatterer with different scattering amplitude in addition to them. The relationship between computed $\kappa_{diffuse}$ parameter and scattering amplitude in one scatterer cannot be displayed, however computed $\kappa_{diffuse}$ parameters even fluctuate in random placed scatterers with only one scatterer.

5. Conclusion

Echo envelope statistics analysis using Homodyned-K distribution was applied to simulation phantom composed of two kinds of scatterers. The characteristics of one scatterer with higher scattering amplitude (about over 3 times of its variance in random placed scatterers) was visible in the surrounding medium with low scatterer number density (< about 20 scatterers/PSF).

To model localized echo signals from scatterer mediums with different acoustic characteristics (diffuse or coherent components) separately and acculately, it is necessary to verify using multiple statistical models in the future.

Acknowledgment

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Refrence

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