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Study on Influence of Frequency Dependent Attenuation for Wideband Pulse Compression Imaging

広帯域パルス圧縮画像化における周波数依存減衰特性の影響について

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1. Introduction

For the purpose of obtaining finer B-mode medical ultrasonic images, spatial resolution and signal-to-noise ratio (SNR) are important. In a living body, due to the frequency dependent attenuation (FDA), higher frequency components of the echo wave from deeper region attenuate greatly. It is said that higher SNR can obtain B-mode ultrasonic images at deeper region and utilize a higher frequency wave, and thus, spatial resolution becomes better. For obtaining broadband signal, multiple resonance transducers have been developed [1,2]. For the sufficient SNR, pulse compression is very useful. Especially, it is generally said that linear chirp is the most robust code against the characteristics of a living body. However, even the chirp wave is attenuated by the FDA, and the shape of spectral amplitude of obtained echo wave does not become flat.

In this study, we propose an attenuation compensation method for high resolution B-mode ultrasonic images of arbitrary region of interest (ROI) at even deep body. In our method, transmitted chirp is deformed by changing the amplitude according to the frequency so that the shape of the echo wave becomes ideal after suffered from the FDA. To examine the effectiveness of our attenuation compensation method, finite element method (FEM) simulations are conducted.

2. Method

The high frequency components of the obtained echo wave are attenuated greatly due to the FDA, and this attenuation depends on the propagation distance and the condition of tissue. Hence, adaptive compensation depending on the ROI is required.

At first, a chirp wave is transmitted, and the echo wave is received. The ratio of the spectral amplitude of the transmitted chirp wave and that of the echo wave is calculated. This ratio is approximated with an exponential function. The real and the imaginary part of the transmitted chirp wave are multiplied by the approximated exponential function. The compensated wave is calculated by taking IFFT.

Secondly, the compensated wave is transmitted to the target again, and the echo wave is obtained. The shape of the spectral amplitude of the echo wave is flat. These operations are repeated adaptively if the target moves. Therefore, the spectral amplitude of the echo wave keeps ideal.

3. Simulation Procedure

In this study, a standard FEM simulator for ultrasound propagation “PZFlex” is used. **Figure 1** shows a simulation model. A phased array transducer which consists of 11 pieces of the PZT (0.40 mm × 0.32 mm × 0.40 mm) is located in a water tank and has a backing layer and a matching layer. The parameter of the attenuation of the water is set as 4 dB/cm/MHz. The voltage of the chirp wave of which the center frequency is 4 MHz, the bandwidth is 2 MHz, and the time duration is 10 μs is transmitted and the echo wave is obtained.

Before utilizing the proposed method, to excite the arbitrary waveforms, the relation between the applied voltage and the excited acoustic pressure needs to be investigated. In a preliminary simulation, a simulation with the propagation medium has no FDA, is conducted. Using a echo wave and the complex processing, the transmitted chirp wave is offset so that the spectral amplitude of the echo wave without the FDA becomes ideal.

3. Simulation Results

The voltage of the chirp wave offset for the characteristics of the transmitted system is inputted to the transducer, and the echo wave is obtained. **Figure 2** shows the echo wave and the spectral amplitude. It is shown that the high frequency

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components are greatly attenuated. The ratio of the spectral amplitude of transmitted wave and that of the echo wave is shown in **Fig. 3** (black line). The red line in Fig. 3 shows the approximated exponential function minimizing the mean square error. This approximated ratio is multiplied by the transmitted wave in the frequency domain. The echo wave generated by the transmitted wave which is compensated for the FDA and its spectral amplitude are described in **Fig. 4**.

By the same way, the transmitted wave is compensated again. **Figure 5** shows the echo wave and its spectral amplitude of the transmission.

4. Conclusion

In this study, we proposed a novel attenuation compensation method for the FDA, which is adaptively applied. It is confirmed that the spectrum of the echo wave becomes ideal by repeating the compensation method.

In the future, we should simulate with the simulation model which is close to the real living body. The experiments are also required.

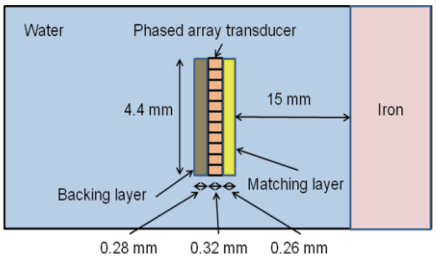
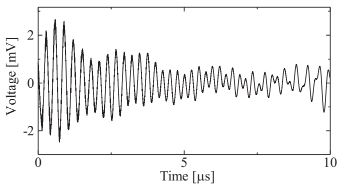
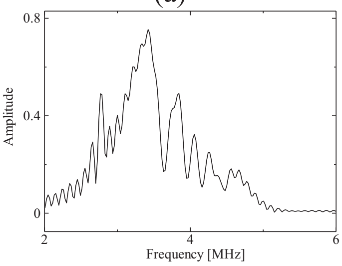


Fig. 1 Simulation model.



(a)



(b)

Fig. 2 Echo wave with only offset for characteristics of transducer system. Inputted chirp wave without attenuation compensation. (a) Echo wave, and (b) spectral amplitude.

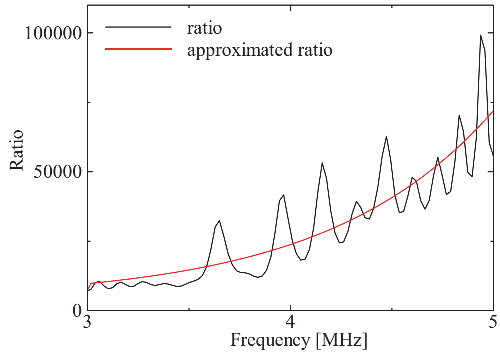
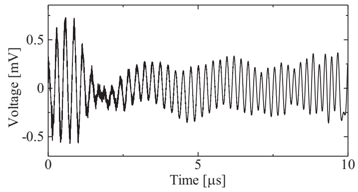


Fig. 3 The ratio of the spectral amplitude of transmitted wave and that of echo.



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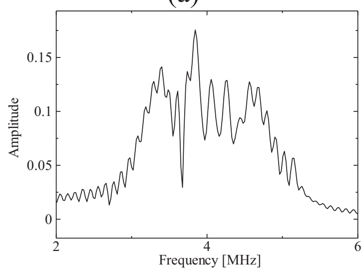
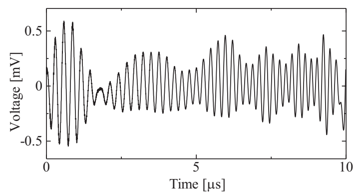
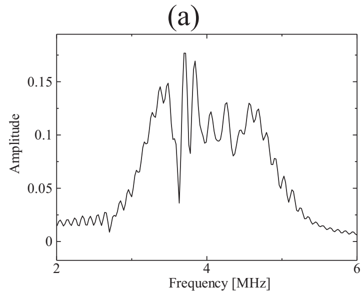


(b)

Fig. 4 Echo wave by applying attenuation compensation one time. (a) Echo wave, and (b) spectral amplitude.



(a)



(b)

Fig. 5 Echo wave by applying attenuation compensation second time. (a) Echo wave, and (b) spectral amplitude.

References

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