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Ultrasound Speckle Reduction by Randomly Changing Bandwidth of Transmission

送信帯域の不規則な変化を用いたスペックル低減法

Haruka Suzuki[1†], Norio Tagawa[1], and Kan Okubo[1] ([1]Graduate School of System Design , Tokyo Metropolitan Univ.)
鈴木晴佳 [1†]，田川憲男 [1]，大久保寛 [1] ([1] 首都大学東京大学院　システムデザイン研究科)

1. Background, Motivation and Objective

Recently, diagnostic imaging is often used in a clinical medical field. In particular, ultrasonography is comparatively safe among various imaging techniques, because it can be carried out without danger of the radiation exposure like X-ray imaging. In recent years, to detect small tumors and perform accurate diagnosis using medical ultrasound images, fine imaging has become increasingly important. In this study, we propose a method to reduce noise in ultrasonic echo images. In particular, speckle patterns are generated by the interference of the reflected waves from small scatterers along the propagation path of a transmitted ultrasonic beam. Ultrasound speckle patterns are sometimes considered as a valuable information for diagnosis. On the other hand, those interfere with weak signal detection in echo signals, and hide small targets required to be imaged. This means that speckle patterns have become one of major factors which degrade the image quality of ultrasound images.

Typical methods for speckle reduction can be largely grouped into following: frequency compound methods or spatial compound methods. Frequency compound methods, which use several echoes measured in the different frequency bands, cause image distortion when the reflection of the imaging target has frequency dependent characteristics. Spatial compound methods use multiple images measured from several different directions respectively to generate one image by an image registration technique. These methods need a movable scope for a transducer on a body surface and an accurate control and a record of a position of a transducer. Additionally, image blur tends to be caused by registration of multiple images each of which has different geometric distortion.

On the other hand, realization of the mechanism of stochastic resonance (SR) in engineering has been variously studied [1,2]. SR can be viewed as a noise-induced enhancement of the response of a nonlinear system to a weak input signal, and naturally appears in many neural dynamics processes. In this study, we propose a new method based on SR to solve the problems of the conventional methods.

2. Method

The fundamental idea of our method is that the speckle is expected to be reduced with keeping the amplitude and the shape of signals through temporal averaging of echoes by giving temporal randomness to the speckle. There are some ways to add fluctuations to the transmitted beams. We have proposed two methods so far. The first one is the “vibrating method", in which the thickness of the water layer shown in **Fig. 1**. However, changing the thickness of the water layer is hard to be implemented. The second one is the “focusing method", in which the focus point is changed. However, because to change the focus point, signal blur is caused in principle.

Hence, in this study, the fluctuations of speckle patterns are caused by changing the frequency bandwidth of the transmitted signals. Unlike the Frequency compound methods, to obtain multiple echo signals by varying frequency bandwidth randomly and slightly. Therefore, our method does not require multiple probes each having a different frequency band and a movable scope for a transducer on a body surface.

3. Simulation method

We confirmed the feasibility and the effectiveness of the our method through simulations using PZFlex, a standard code for FEM. **Fig. 1** describes the simulation model used in this study.

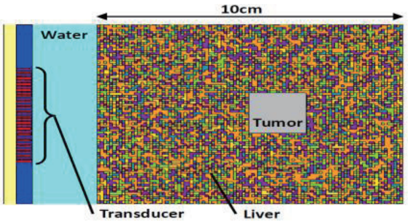

Fig. 1: Simulation model mimicking living body.

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haruka.s615@gmail.com

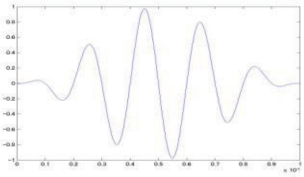

Fig. 2: Example of the transmitted signal.

We put a tumor in a liver tissue in the simulation model that assumes an inside of a body. In this simulation, we use a common density value of 1000g/cm^3 for all, and values of sound speed are follows: water is 1500 m/s, the liver tissue is 1520-1580 m/s and the tumor is 2050 m/s.

The transducer in Fig. 1 consists of 32 elements of PZT, and the focal point of it is 50 mm. An example of the transmitted signal is shown in **Fig. 2**, and is the Hamming weighted pulse, which has a center frequency of 5 MHz and consists of 5 cycles. The amplitude voltage is 200V.

We have obtained the multiple echoes by changing the frequency bandwidth of the transmitted signals. All transmitted signals are set the center frequency to 5MHz, and each bandwidth is determined using a Gaussian random distribution in the range of 3.5-6.5 MHz or 2.5-7.5MHz.

4. Results and discussion

Fig. 3 shows RF signals before and after performing the proposed method. We confirmed that the desired signal is preserved by the proposed method and speckle pattern is reduced. In addition, **Fig. 4** shows the amount of signal-to-noise ratio (SNR) which is improved by the proposed method. As the many echoes are used for averaging, the SNR is improved largely. Maximum amount of the improved SNR is 1.95dB (frequency bandwidth : 3.5-6.5MHz) and 5.75dB (frequency bandwidth : 2.5-7.5MHz).

5.Conclusion and future works

In this study, we propose a new scheme to reduce speckle patterns by adding frequency fluctuations to the transmitted beams. Unlike the traditional methods, our proposed method is easy to be implemented. In the future work, we will continue to study the details of the appropriate frequency bandwidth of transmitted signal. Also, we are going to conduct experiments using a phantom imitating a living body.

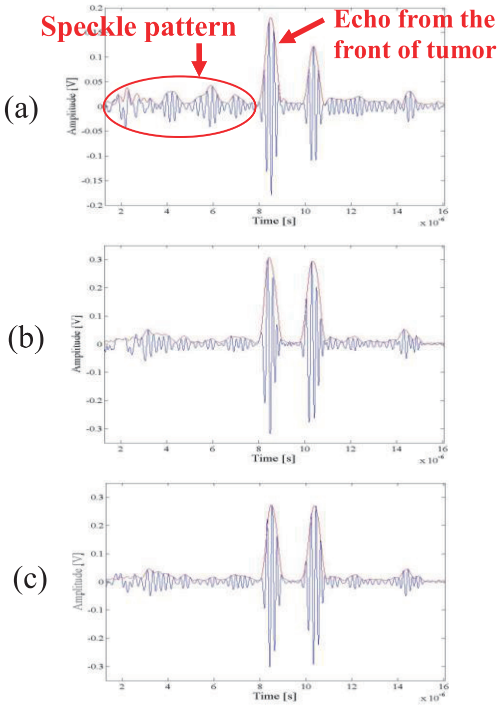

Fig. 3: RF echo signals before and after the proposed suppression; (a) without suppression, suppression result with frequency bandwidth of (b) 3.5-6.5 MHz and of (c) 2.5-7.5MHz.

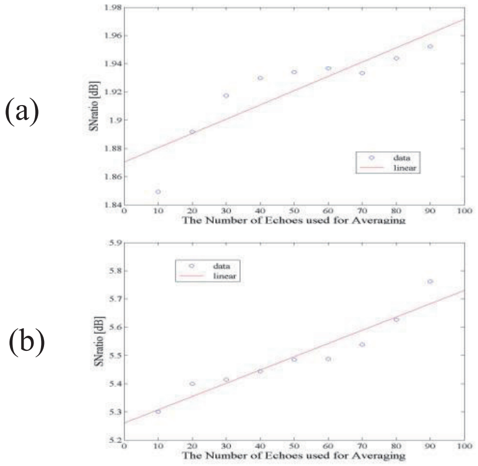

Fig. 4: Averaged amount of signal-to-noise ratio; suppression result with frequency bandwidth of (a) 3.5-6.5 MHz and of (b) 2.5-7.5MHz.

Acknowledgment

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