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Analysis of Ultrasound Echo in Low Frequency Oscillation for Detection of Microcalcification

微細石灰化検出を目的とした
低周波加振下における超音波エコーの解析

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1. Introduction

A phenomenon called twinkling artifact (TA) [1] appears when strong reflecting medium like a calcification in soft tissue is scanned in Doppler mode. TA has been expected in clinical application such as detection of calcifications[2]. Several hypotheses of mechanism of TA have been proposed such as complex multiple reflections[1], phase jitter[3], micro oscillation[4,5]. However, the mechanism has not been clarified yet. Our goals are to clarify the mechanism and to develop a microcalcification detection method. This study's objective is to investigate ultrasound echo signals in detail while controlling environmental disturbances.

2. Method

Figure 1 describes a block diagram of an experiment setup. A transparent poly (vinyl alcohol) hydro (PVA-H) gel soft tissue-mimicking phantom embedding a glass bead with a diameter of 595 μm was used. For scanning the tissue-mimicking phantom, a medical ultrasound machine (GE Healthcare Japan, LOGIQ S8 pilot unit) and the linear phased array probe (GE Healthcare Japan, ML6-15-D) were used. The ultrasound scanning conditions are summarized in **Table I**.

To control environmental disturbance, the probe was fixed with a clamp attached to a stage and the stage was placed on the vibration-isolated table that was far enough from all oscillation machines including the ultrasound machine.

An audio speaker (Geneva Sound System, Model S, 15x2 Watt RMS) was used as an oscillator and placed at the front of the phantom. The oscillation waves were sinusoidal with various frequencies from 60 to 150 Hz. Both the displayed images in color flow mode and the echo signals of successive packets were stored and analyzed.

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Table. I Ultrasound scanning conditions

Scan mode	Color flow (CF)
Center frequency	5 MHz
Packet size	32
Number of frame	20
PRF	300, 600, 1000 Hz

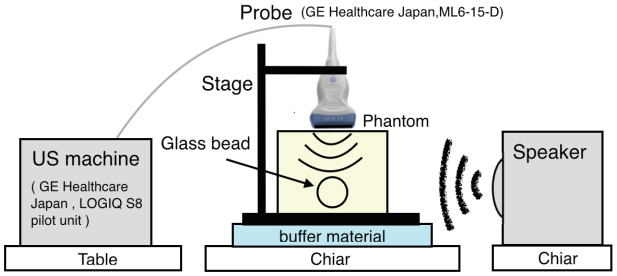


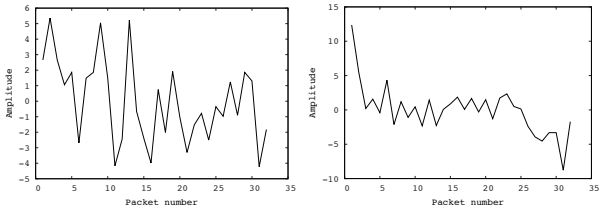
Fig. 1 Block diagram of experimental setup.

3. Result

Figure 2 shows peak values of amplitude of echoes among packets of 1 frame without oscillation. **Figure 3** shows the frequency spectra of 20 frames. It is noted that there was no TA in color flow images.

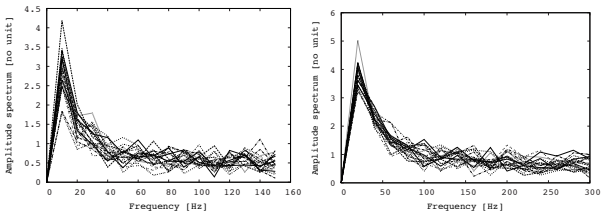
In oscillation with frequency of 60 Hz, TA appeared only on a glass bead as shown in **Fig. 4**. It is found that The TA increases with lower PRF. **Figure 5** shows peak values of amplitude of echo among packets of a frame. **Figure 6** describes the frequency spectra of Fig. 5.

The results of appearance of TA and peak frequency of echo are summarized in **Table II** and **III**, respectively. The frequency precision is limited by the packet size and PRF. Each precision is ±10 Hz at PRF 300 Hz, ±20 Hz at PRF 600 Hz and ±33.3 Hz at PRF 1000 Hz. In Table III, observed frequency is highlighted in boldface type when the observed peak frequency of peak values of echoes is in good agreement with the oscillation frequency. As a result, almost oscillation frequencies are observed in echo signals from the glass bead.



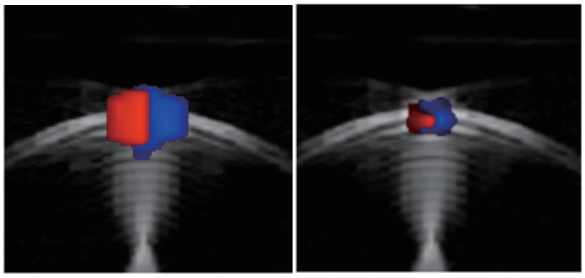
(a) (b)

Fig. 2 Peak values of amplitude without oscillation in PRF of (a) 300 and (b) 600 Hz.



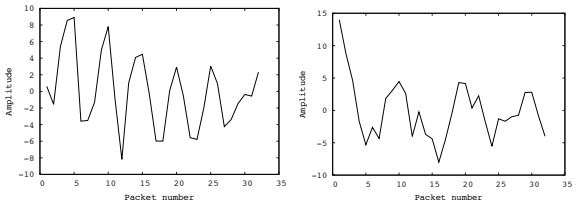
(a) (b)

Fig. 3 Frequency spectra without oscillation in PRF of (a) 300 and (b) 600 Hz.



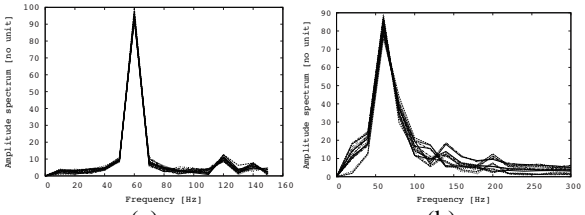
(a) (b)

Fig. 4 Color flow images of glass bead with oscillation of 60 Hz in PRF of (a) 300Hz and (b) 600Hz.



(a) (b)

Fig. 5 Peak values of amplitude with oscillation of 60 Hz in PRF of (a) 300 and (b) 600 Hz



(a) (b)

Fig. 6 Frequency spectra with oscillation of 60 Hz in PRF of (a) 300 and (b) 600 Hz.

Table II Appearance situation of the TA

Oscillation frequency [Hz]	PRF300Hz	PRF600Hz	PRF1000Hz
60	○	○	×
70	○	○	×
80	○	○	×
90	○	○	○
100	○	○	○
110	○	○	○
140	○	○	○
150	○	○	×

Table III Peak frequency of echo with each oscillation

Oscillation frequency [Hz)	PRF300Hz	PRF600Hz	PRF1000Hz
60	**60**	**60**	99.9
70	**70**	**60**	**66.6**
80	100	**80**	**99.9**
90	**90**	**80**	**99.9**
100	**100**	**100,120**	**99.9**
110	**110**	**120**	**133.2**
140	**140**	**160**	**166.5**
150	**150**	**160**	**166.5**

4. Conclusion

In this study, we investigated a state of TA in color flow mode and analyzed echo signals from the glass bead with and without oscillation in order to investigate the effect of environmental disturbance on echo signal and TA. The results showed TA appeared on glass bead in lower frequency oscillation, and oscillation frequency was almost observed from echo signal from the glass bead.

From these results, there is some possibility that ultrasound echo is affected by environmental disturbances. If environment disturbance could emphasize TA in color flow images, disturbances would contribute detection of smaller glass. As a future work, investigation on smaller glass beads will be conducted.

References

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