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Study on Weighted Delay Multiply And Sum Beamforming for Medical Ultrasound Imaging

医用超音波イメージングにおける重み付け遅延乗和ビームフォーミングの初期検討

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1. Introduction

In medical ultrasound imaging with a phased array transducer, beamforming is the signal processing technology that intensifies transmitted and received ultrasonic waves for a specific direction. Generally, the delay and sum (DAS) beamforming has been used in ultrasound medical imaging systems [1]. Although it is superior in terms of processing performance in real time, the spatial resolution still needs improvement. In order to improve the spatial resolution of DAS, the delay multiply and sum (DMAS) beamforming [2] achieving high resolution instead of complicated calculation processing developed. As an alternative to the conventional method, beamforming having various performances such as DMAS and minimum variance (MV) [3] has been developed.

In this paper, we present a new beamforming with weighted processing [4] added to DMAS. In order to improve spatial resolution, weighting processing to DMAS (Weighted-Delay Multiply And Sum:W-DMAS) was applied. The performance of the proposed method was verified via numerical simulation of the ultrasound image.

2. Method

The ultrasonic waves are transmitted from a transducer and they are reflected in a target. The reflected ultrasonic waves are received by each element of the transducer. The received waves are processed through a beamforming to improve a signal while eliminating interference from outside scanning directions as much as possible. In DAS, the received signals are subjected to time delay for each receiving element according to a scanning direction and they are summed. The processed signal in beamforming is output as a two-dimensional image through signal processing such as envelope detection and logarithmic compression.

DMAS is beamforming added the signal multiplication process to DAS. The signals received at each element are delayed time and multiplied in pairs. The number of signal pair combination to be multiplied is

$$\begin{pmatrix} M \\ 2 \end{pmatrix} = \frac{M^2 - M}{2}. \qquad (1)$$

Where M is the number of receiving element. Subsequently, the computer cross-correlation is normalized by taking a signed square root as below

$$\hat{s}_{ij}(t) = sign(s_i(t)s_j(t)) \cdot \sqrt{|\ s_i(t)s_j(t)\ |}, \qquad (2)$$

where $s_i(t)$ is the signal of i^{th} receiving element, and $s_j(t)$ is the signal of j^{th} receiving element. The signal $y_{DMAS}(t)$ obtained by adding all multiplied signals is

$$y_{\mathrm{DMAS}}(t) = \sum_{i=1}^{M-1} \sum_{j=i+1}^{M} \hat{s}_{ij}(t). \qquad (3)$$

Since the output signal contains a second harmonic component, it is removed with a band-pass filter.

In this study, the signal weighting processing to DMAS was added. The weighting coefficients based on the Hanning function were set for each element. The multiplied signals were applied with weighting coefficients obtained by multiplying weighting coefficients set for elements of a multiplied signal with each other. By applying this processing, the multiplied signals of the elements which are located at the center in the receiving elements, are emphasized.

3. Results

The proposed method was evaluated using ultrasonic image simulation "Field II" [5]. By using this simulation, the target was a phantom containing circular cysts and scatters having multiple sizes. The output results of DAS, DMAS, and W-DMAS were investigated.

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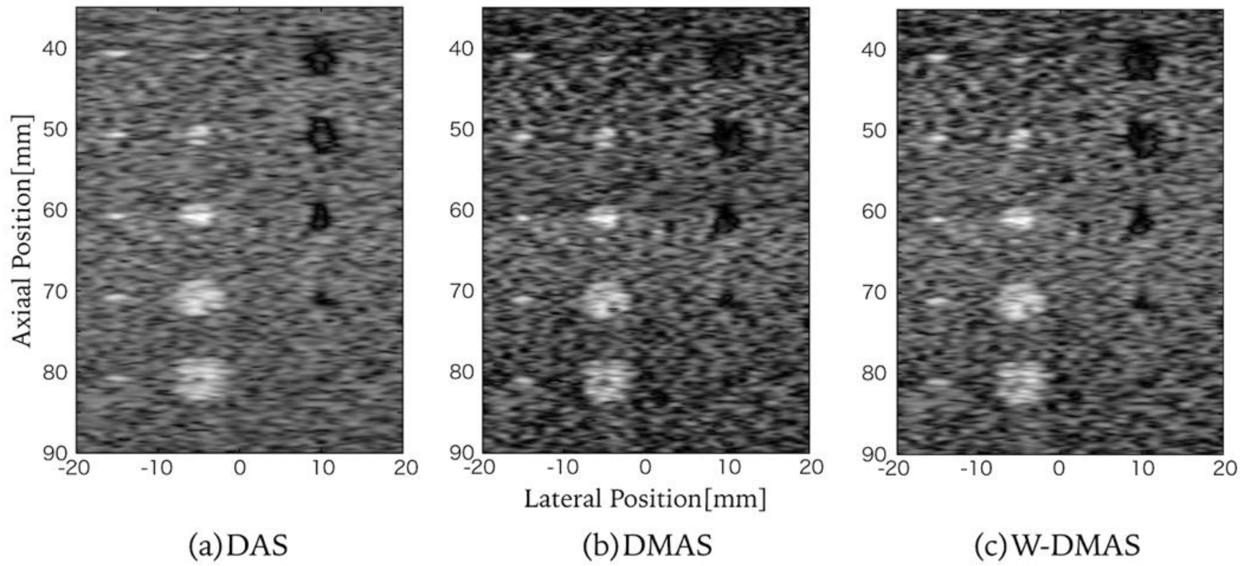

Fig. 1 Phantom images obtained with (a) DAS, (b) DMAS, and (¥c) W-DMAS beamforming. Images are displayed over a 60 dB dynamic range.

As results, it was found that the contrast ratios of DMAS and W-DMAS were higher than that of DAS, as shown in **Fig. 1**. The lateral resolution near focal points with various methods are shown in **Fig. 2**. It can be seen that the cyst, which is located at lateral position of 10 mm, appears more clearly in W-DMAS than that of DMAS.

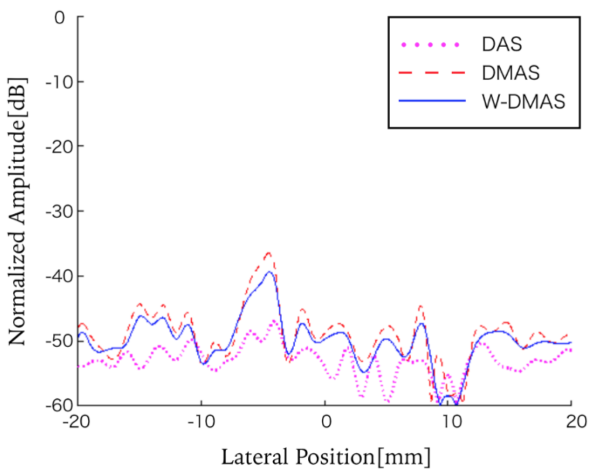

Fig. 2 Lateral resolutions of the DAS (dotted line), DMAS (dashed line) and W-DMAS (straight line) images at 61.5 mm depth. Focal depth is 60 mm.

4. Conclusion

In this study, the effect of adding weighting processing to the DMAS was investigated. In the W-DMAS, higher contrast ratio than the DAS was confirmed. The cyst image was also visualized clearly. It can be seen that W-DMAS has a potential to improve spatial resolution.

References

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