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Strategic Lateral Undersampling with Weighted Filtered Delay Multiply And Sum Beamforming

WFDMAS における戦略的な横方向空間間引き

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1. Introduction

Beamforming processing is the method for reconstructing the obtained echo signals in medical ultrasound imaging. The most standard technique is delay and sum (DAS) beamforming algorithm [1]. because of its low computation complexity. However, the image quality is to be improved.

As a solution, filtered delay multiply and sum (F-DMAS) was proposed by Matrone et al. [2]. The F-DMAS is a nonlinear beamforming algorithm to achieve an increased dynamic range and better quality of ultrasound B-mode images.

In a previous study, a weighted filtered delay multiply and sum (WF-DMAS) beamforming, which incorporates a weighting and cross-correlation process called apodization, was proposed [3]. The results showed that the WF-DMAS has a higher rendering capability in lateral resolution than the DAS and F-DMAS. In this paper, the robustness of the WF-DMAS against several lateral undersampling schemes, is evaluated using numerical simulations.

2. Method

The block diagram of WF-DMAS algorithm is illustrated in **Fig. 1**. First, the obtained RF signals are delayed and split into 2 signal groups using 2 different apodization functions. Subsequently, the multiplied signal is normalized by taking a signed square root as below

$$\hat{s}_{ij}(t) = sign\left(s_i\,(t)\,s_j\,(t)\right)\sqrt{\left|s_i\,(t)\,s_j\,(t)\right|}\,,$$

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

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

Since the output signal contains base-band and the 2nd harmonic components, the 2nd harmonic is extracted using a band-pass filter, then the F-D MAS signal $y_{FDMAS}(t)$ is obtained.

After developing the 2 F-DMAS signals $rx_1(t)$ and $rx_2(t)$, normalized cross-correlation (NCC) is performed to calculate the degree of similarity between the signals. The obtained NCC is then filtered by a soft thresholding filter (STF) as below

$$STF = exp((NCC - 1) \times \alpha)$$

where, α is a curve parameter and set to 100 in this study. This filter decreases the NCC exponentially to emphasize the difference between signals.

Whereas, the F-DMAS signals are simply combined and then multiplied with the filtered NCC. Consequently, Hilbert transform and log compression are performed, and then WF-DMAS signal is obtained.

In this study, a numerical simulation is performed in MATLAB (The MathWorks, Natick, MA, USA) by using the Field II simulator [4]. A 192-element linear array is modeled with an element height of 3 mm, width of 170 μm, kerf of 30 μm (pitch = 200 μm) and a fixed elevation focus at 15 mm. Transmitted signal is a 2-cycle sinusoidal burst at center frequency of 12 MHz with Gaussian window. 129 scans are performed over the plane, covering a plane area ranging from x= -12.8 mm to 12.8 mm. A 32-element aperture is used for transmission and transmit focus is fixed at distance 15 mm. In the reception, 64 elements are used and dynamic focusing is applied to some of them. The band-pass filter applied after DMAS beamforming is implemented by applying a Tukey window (a=0.5, 6-30 MHz) to the beamformed signals in frequency domain. In this study, the number of signals used for beamforming will be changed from 64 full aperture to 32.

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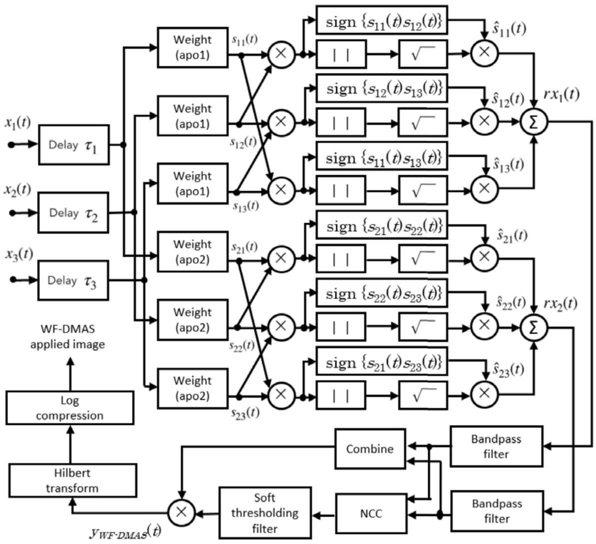
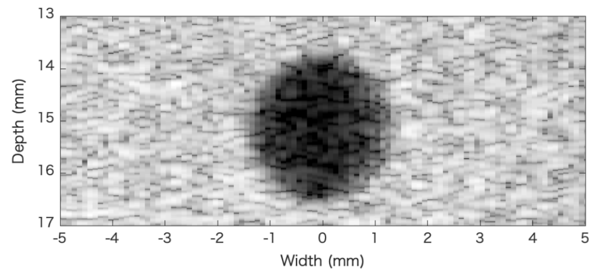


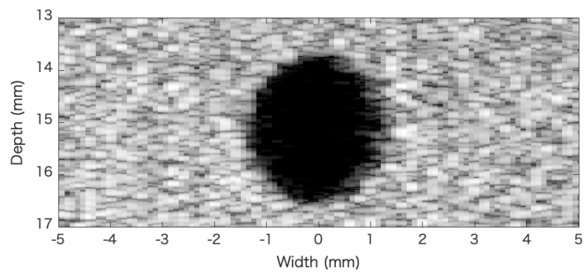
Fig. 1. Block diagram of WF-DMAS [3].

3. Results

Figure 2 shows the obtained B-mode images using DAS, F-DMAS and W-FDMAS beamforming methods.



(a)



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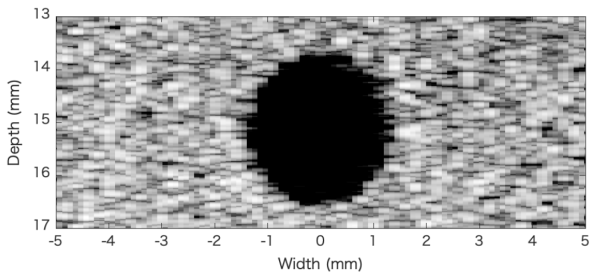

(c)

Fig. 2. B-mode images of cyst phantom. (a) DAS, (b) F-DMAS, and (c) WF-DMAS.

4. Conclusion

In this paper, the B-mode images of cyst phantom using several beamforming methods were obtained. In a future work, a fundamental evaluation of the WF-DMAS against the lateral understanding will be investigated.

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References

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