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Effect of Receive Aperture Size on Image Quality of Filtered Delay Multiply and Sum Beamforming

FDMAS における受信開口長が画質に与える影響

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1. Introduction

In medical ultrasound imaging, the standard technique used for image reconstruction is the delay and sum (DAS) beamforming algorithm [1]. Although its computation complexity is negligible, image quality is insufficient. To solve this problem, 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. This method is a modified version of delay multiply and sum (DMAS) which was introduced by Lim et al. [3] for the early detection of breast cancer using RADAR imaging.

The F-DMAS achieves better image quality, however, it cannot be used in real-time due to high calculation complexity. This complexity depends on the number of received echo-signals. Therefore, smaller receive aperture size contributes to lower calculation complexity, but it may lead to image degradation. In this study, the F-DMAS with various receive aperture sizes wss investigated using simulations.

2. Method

2.1 F-DMAS

The F-DMAS algorithm is schematically illustrated in the block diagram of **Fig. 1**. After the delay process, the received RF signals are combinatorically coupled and multiplied. In the multiplication process, the signals are normalized by taking a signed square root not to lose its sign, because the multiplied signal is a dimensionally squared, partially rectified non-zero mean signal, and therefore envelope detection cannot be applied. The DMAS beamformed signal is obtained as

$$\widehat{s_{ij}}(t) = \mathrm{sign}\left(s_i(t)s_j(t)\right) \cdot \sqrt{| s_i(t)s_j(t) |}, \quad (1)$$

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

$$y_{DMAS}(t) = \sum_{i=1}^{M-1}\sum_{j=i+1}^{M}\widehat{s_{ij}}(t). \quad (2)$$

Since the output signal contains both a DC and second harmonic component, the second harmonic component is extracted with a band-pass filter and the F-DMAS signal $y_{F\text{-}DMAS}$(t) is obtained. Thanks to the usage of the second harmonic component because the both the wavelength and f-number decrease. Note, however, the axial resolution is not altered, as the frequency bandwidth is the same as that of the fundamental component.

After obtaining the F-DMAS signal, envelope detection and log-compression are conducted to reconstruct B-mode image in the same way as traditional implementations.

In the F-DMAS algorithm, all the possible signal pair combinations are conducted. Thus, the number of signal pair combinations to be multiplied is

$$\binom{M}{2} = \frac{M^2 - M}{2}, \quad (3)$$

where M is the number of received RF signals. If M decreases to half, the number of multiplications becomes approximately 25 %.

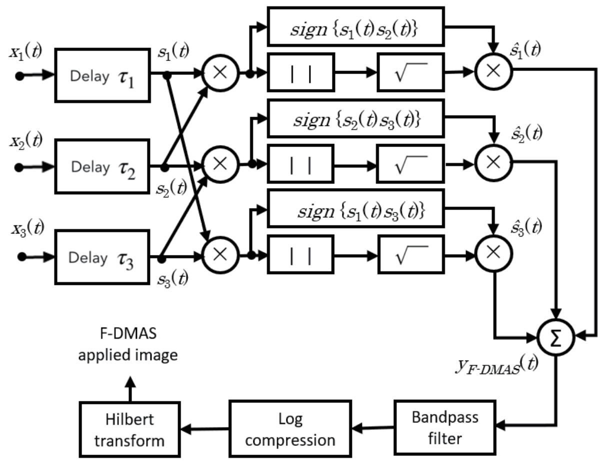

Fig.1. Block-diagram of F-DMAS.

2.2 Simulation condition

A simulation was performed in MATLAB (The MathWorks, Natick, MA, USA) by using the Field II simulator [4]. A 192-element linear array was modeled with an element height of 3 mm, width of 170 mm, kerf of 30 mm (pitch = 200 mm) and a fixed elevation focus at 15 mm. 129 scans were performed over the plane, covering a plane area ranging from x= -12.8 mm to 12.8 mm. Transmitted signal was a 2-cycle sinusoidal burst at center frequency of 12 MHz with Gaussian window. The sampling frequency was set to 100 MHz.

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A 32-element aperture was used for transmission and transmit focus was fixed at distance 15 mm. In the reception, 64 elements were used and dynamic focusing was applied to some of them. The band-pass filter applied after DMAS beamforming was 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 was changed from 64 full aperture to 32 and 16.

3. Result

The obtained PSFs at the transmission focal depth are shown in **Fig. 2**. Two-way normalized beampatterns at z = 15 mm are shown in **Fig. 3**.

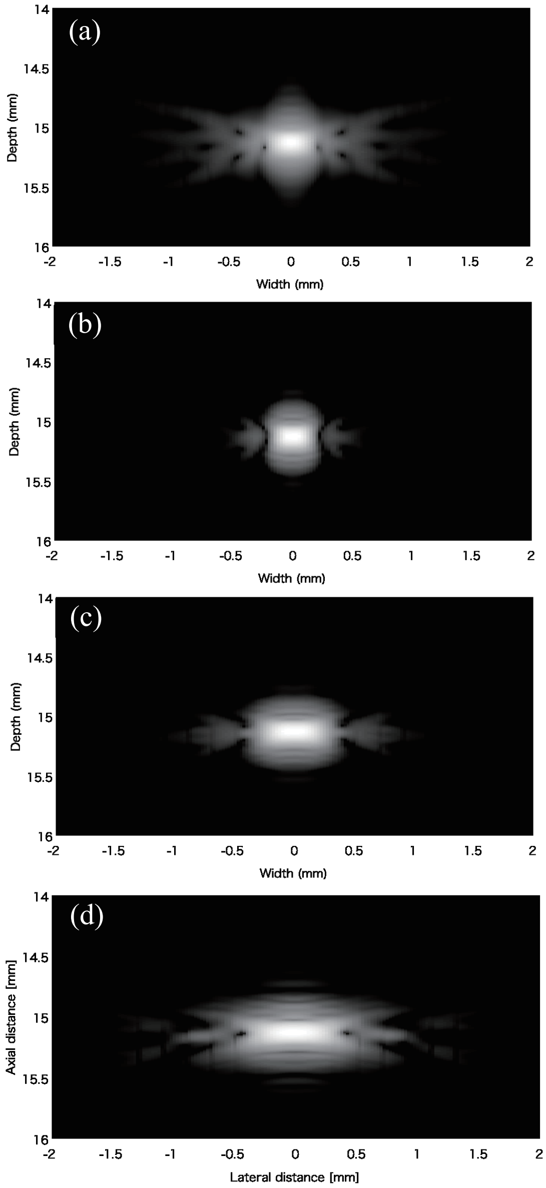

Fig. 2. PSFs at the transmission focal depth, obtained by employing (a)DAS with full aperture and FDMAS with aperture sizes of (b)64, (c)32, and (d)16.

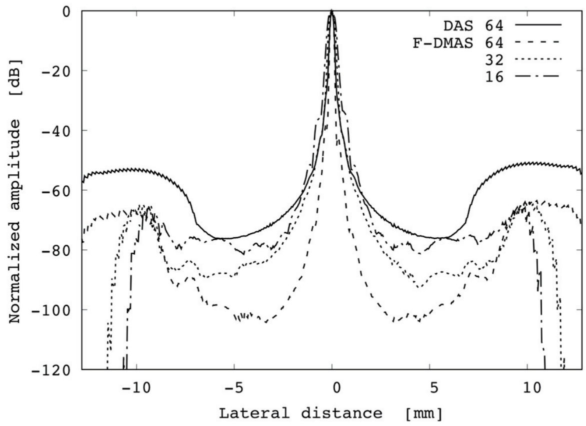

Fig.3. Two-way normalized beampatterns at z = 15 mm for DAS with full aperture size and F-DMAS with various receive aperture sizes.

4. Conclusion

In this study, the FDMAS with various receive aperture size was evaluated. In future work, further investigations will be carried out.

References

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