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Modification of Adaptive Beamformer for Improvement of Spatial Resolution in High Frame Rate Ultrasonography

高速超音波イメージングにおける空間分解能向上のための適応ビームフォーマの改良

Hideyuki Hasegawa[1,2†] and Hiroshi Kanai[2,1]
([1]Graduate School of Biomed. Eng.; [2]Graduate School of Eng., Tohoku Univ.)
長谷川英之 [1,2†]，金井　浩 [2,1]　（[1] 東北大院　医工; [2] 東北大院　工）

1. Introduction

High frame rate ultrasonography is a promising method for noninvasive measurement of tissue dynamics. In general, this method is based on transmission of unfocused beams and creation of multiple focused receiving beams in each unfocused transmit beam [1]. Based on this technique, the number of transmissions, which is required to obtain the number of scan lines (focused receiving beams) consisting of one image frame, can be reduced significantly and, as a result, the imaging frame rate can be significantly increased. Recently, high frame rate ultrasonography has been used in various applications, such as shear wave elastography [2], pulse wave imaging [3,4], blood flow imaging [5-7], and so on. One of the problems of high frame rate ultrasonography is the degradation of the spatial resolution and contrast. Therefore, we are trying to develop methods for improvement of the spatial resolution and contrast in high frame rate ultrasonography.

Recently, minimum variance beamformer has been introduced in medical ultrasound imaging for improvement of the spatial resolution [8]. This method suppresses the signal from undesired directions by determining the optimum weights (corresponding to receive apodization) using the spatial covariance matrix of echo signals received by individual transducer elements in an ultrasonic probe. In the present study, the minimum variance beamformer was modified, and it was shown that the image contrast was also improved by the modified minimum variance beamformer, in addition to the spatial resolution.

2. Materials and Methods

In receive beamforming, the minimum variance beamformer determines the weights (corresponding to receive apodization) to echo signals received by individual transducer elements.

This optimization is performed by minimizing the power (variance) of the echo signal received by individual elements. The estimated power includes the spatial covariance matrix of the echo signal received by individual elements. The desired signal (echo from the focal point) is also suppressed when there is a correlation between the spatial covariance matrix and the desired signal. Therefore, in conventional adaptive beamforming based on the minimum variance beamformer, subarray averaging [9] or removal of the desired signal from the spatial covariance matrix (called APES (amplitude and phase estimation) beamformer) [10] is applied before minimizing the power of the echo signal.

In the present study, the method of removing the desired signal from the spatial covariance matrix was improved. In the conventional APES beamformer, the desired signal was estimated by assuming that the echo signals received by individual elements become plane wave after the compensation of the propagation time delay based on conventional delay and sum beamforming. In the present study, a more realistic wave front (not a plane wave) was used for better estimation of the desired signal.

3. Basic Experiment Using Phantom

An ultrasound imaging phantom (model 54GS, CIRS) was used for evaluation of the improvement of the imaging spatial resolution. A linear array ultrasonic probe at a nominal center frequency of 10 MHz (UST-5412, Aloka) was used, and ultrasonic echo signals received by individual transducer elements were acquired by modified ultrasound scanner (α-10, Aloka) at a sampling frequency of 40 MHz. The beamforming procedure was performed off-line on the ultrasound echo signals received by the individual elements.

The transmit-receive sequence is described in [5]. In the present study, the number of emissions of plane waves for creation of one image frame was set at 4, and each plane wave was emitted using 96

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†hasegawa@ecei.tohoku.ac.jp

transducer element. In each transmission, 24 focused receiving beams were created at intervals of 0.2 mm, and the aperture used to create one focused receiving beam consisted of M = 72 elements. Consequently, one image frame consisted of 24 × 4 = 96 focused receiving beams was obtained by four times emissions of plane waves.

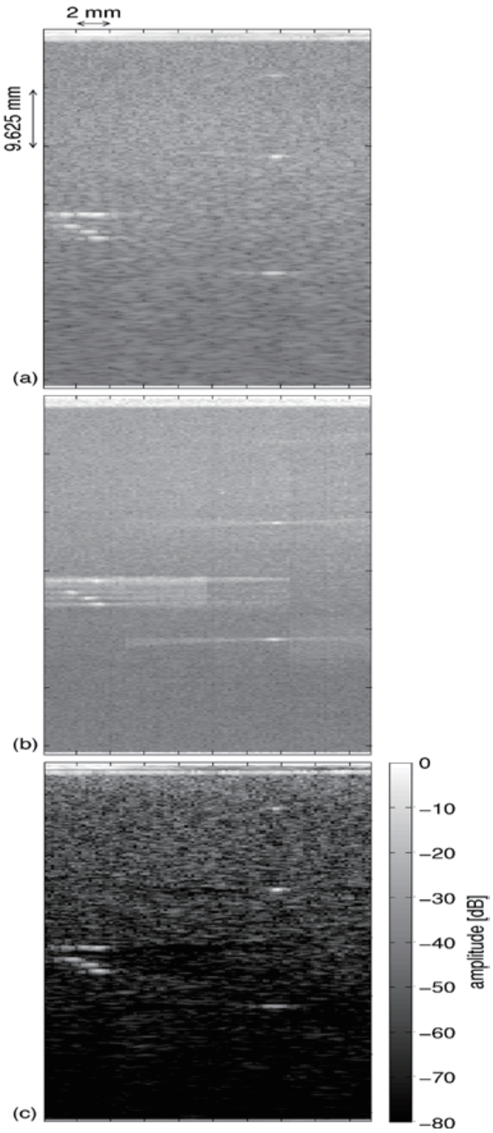

Fig. 1 B-mode images obtained by parallel beamforming with plane wave transmission. (a) No additional processing. (b) APES beamforming. (c) modified APES beamforming.

Figure 1 shows B-mode images of the phantom obtained by plane wave transmission and parallel receive beamforming. Figures 1(a), 1(b), and 1(c) show B-mode images obtained with no additional processing, conventional APES beamforming, and modified APES beamforming proposed in the present study, respectively. In conventional APES beamforming, we can see artifacts due to inaccurate estimation of the desired signals. Using the proposed method, as can be seen in Fig. 1(c), both the spatial resolution and contrast are significantly improved compared with the B-mode image obtained with no additional processing shown in Fig. 1(a).

Figure 2 shows lateral amplitude profiles at 21 mm in range distance obtained by the respective method. The improvements in the spatial resolution and contrast are also shown quantitatively in Fig. 2.

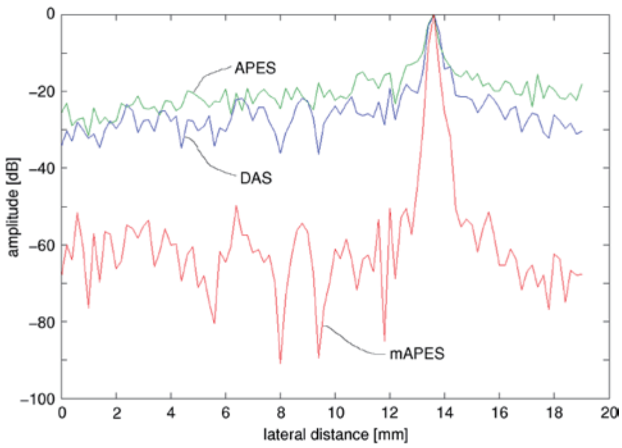

Fig. 2 Lateral amplitude profiles at a range distance of 21 mm obtained by (a) delay and sum beamforming (DAS), (b) amplitude and phase estimation beamforming (APES), and (c) modified amplitude and phase estimation beamforming (mAPES).

6. Conclusion

In the present study, the minimum variance beamformer was modified for improvement of the spatial resolution and contrast in high frame rate ultrasonography.

References

1. D. P. Shattuck, et al.: *J. Acoust. Soc. Amer.* **75** (1984) 1273.
2. M. Tanter, et al.: *IEEE Trans. Ultrason. Ferroelectr. Freq. Contr.* **49** (2002) 1363.
3. D. Shahmirzadi, et al.: *J Biomechan. Eng.* **134** (2012) 114502.
4. H. Hasegawa, et al.: *J. Med. Ultrason.* **40** (2013) 91.
5. H. Hasegawa and H. Kanai: *IEEE Trans. UFFC* **55** (2008) 2626.
6. B. Y. Yiu and A. C. Yu: *Ultrasound Med. Biol.* **39** (2013) 1015.
7. H. Takahashi, et al.: *Jpn. J. Appl. Phys.* **53** (2014) 07KF08.
8. J. F. Synnevåg, et al.: *IEEE Trans. UFFC* **54** (2007) 1606.
9. I. K. Holfort, et al.: *IEEE Trans. UFFC* **56** (2009) 314.
10. A. E. A. Blomberg, et al.: *2009 IEEE Ultrason. Symp. Proc.* (2009) 2347.