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Echo Imaging and Displacement Measurement Using New Virtual Sources

新しい virtual source を用いた新しいエコーイメージングおよび変位計測

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1. Introduction

Originally, a US virtual source was applied for increasing a lateral resolution and a transmission US intensity in a conventional B-mode imaging [1], in which the first application is also referred to. That is, the virtual source is set at a focus position of a physically large aperture, a synthesized aperture or individual element aperture. However, the virtual source must remove its neighborhood from a region of interest (ROI). However, in our newly developed virtual source [2,3], because a virtual source is set backward to the US transducer, such a shallow region to be removed is not generated. Then, superficial tissues such as skin will also be dealt with.

Recently, we also propose another virtual source that is realized by a random scatters [4]. Because a summation of random scattering echo is performed, a virtual source may not always be set at the focus positions as in the original virtual source, i.e., an arbitrary position regardless the focus positions. This will increase the applications of a virtual source as discussed later.

Thus, in this report, after reviewing the new virtual sources, on an agar phantom experiment, the feasibilities of a lateral modulation B-mode imaging, displacement vector/strain tensor measurements and a shear modulus reconstruction were confirmed.

2. New virtual sources

As shown in **Fig. 1a**, the setting of a virtual source backward to the transducer array [2,3] yields a larger transmitted ultrasound intensity by firing plural elements than a physical source used in the classical SA. This virtual source is refereed to as VS1. When using an array aperture, although the original virtual source [1] set in the focus position also gains the transmitted US intensity using plural transmission elements than a physical source (i.e., one element of array) for a classical SA, VS1 gains more effectively the transmission intensity than the original virtual source. Then a larger echo SNR can be obtained. In addition, VS1 does not decrease the axial length of ROI but increases the range of an ROI.

In this report, new virtual sources are dealt with as point acoustical sources. Then, a spherical wave is considered as a generated wave. Thus, in this case, the transmitted US from the respective elements is weighted by decay weights that are determined by the reciprocal of the distance from the virtual source and the respective transmission elements. Other types of virtual sources from the point acoustical source are discussed later.

Otherwise, our previously proposed another virtual source (VS2) is realized by a random scatter in a random scattering medium (material), i.e., that can be realized regardless the focus position of a physical aperture but in the neighborhood of the physical aperture, i.e., those (**Fig. 1b**) realized by installing the medium in the transducer, putting it between the transducer and the target body, or in a target medium [4].

VS2 as well as VS1 will increase the applications of a virtual source. For instance, virtual sources (or receivers) will be realized in null spaces aside the short physical array aperture by searching for the corresponding echo data in acquired echo data set (**Fig. 1c**). Then, a lateral width as well as an axial length of a vision of field (VOF) will also increase. Because when a transducer has a small physical array aperture, LM cannot deal with deeply situated tissues [4], new virtual sources will be used for mitigating such a limitation. Alternatively, an arbitrary shape of a VOF will be obtained regardless the physical aperture geometry (see **Fig. 1c** again, convex, linear etc).

3. Experiments

Experiments are performed using the same agar phantom as that used in [4]. The target agar phantom [40 (axial, x) x 96 (lateral, y) x 40 (elavational) mm^3] had a central circular cylindrical inclusion (dia., 10mm; depth, 19 mm) with a shear modulus different from that of the surrounding region, and shear moduli of 2.63 and 0.80 x 10^6 N/m^2 in the inclusion and surrounding regions, respectively (i.e., relative shear modulus, 3.29).

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Manually, the phantom was compressed by 2.0 mm in the lateral direction. The contact surfaces of the linear array type transducer (7.5 MHz, 0.2 mm US element pitch, 2.4 mm depth for acoustic lens involving matching layers) and phantom were separated by less than 0.3 mm by immersing them in water in a tank. A rectangular ROI 13.7 (axial, x) x 13.2 (lateral, y) mm^2 was centered on the inclusion (depths from 12.2 to 25.9 mm).

The depth of a lateral line in which point virtual sources were set was changed from –19.0 mm to 9.0 mm with respect to the linear array surface (0.0 mm). The minus and plus positions respectively correspond to the backward and forward positions from the array surface (i.e., VS1 and VS2). For LM, the same parabolic modulation was performed as that described in [4]. An achieved lateral modulation frequency was 3.75 MHz.

Fig. 2 shows the B-mode image and the images of lateral and axial displacements (i.e., dy, dx), a relative 2D shear modulus reconstruction, and lateral, axial and shear strains obtained for (upper) physical sources (i.e., 0.0 mm depth), (middle) -3.0 mm (VS1), and (lower) 3.0 mm (VS2) that a specular can be seen at the same circled position. For the range, a relative shear modulus could be estimated with a high accuracy ($\approx$ 3.3).

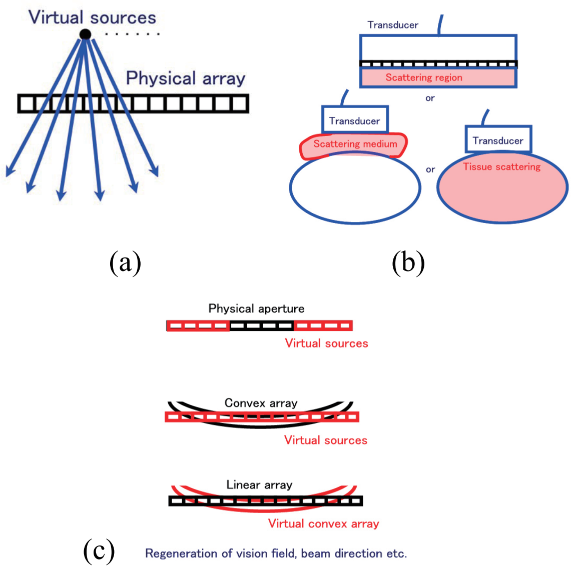

Fig. 1. New VS's. (a) VS1, and (b) and (c) VS2.

4. Discussions and conclusions

In this report, on our newly developed virtual sources VS1 and VS2, preliminary experimental results were presented for a lateral modulation (LM). However, no long range of a virtual source depth could not be obtained for the used ultrasound transducer.

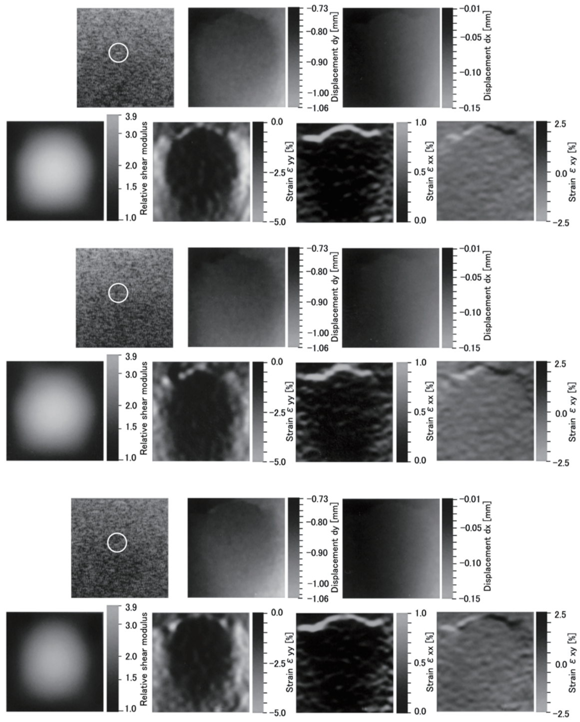

Fig. 2. Agar phantom experiments (0, -3, and 3mm).

However, in this study, the noises filled in the acquired echo data for SA were also weighted together with original echo signals by the decay weights. That is, the improvement in an echo SNR achievable by SA is not shown yet. In the near future, the smaller pitch of US elements will be used. Such an improvement will increase the range of a virtual source depth. Because our newly developed virtual sources will also mitigate the problem of a rapid motion, dynamic experiments will also be conducted. Aforementioned other applications will also be achieved with a consideration of the results obtained.

In addition, for VS1 and VS2, we'll also conduct the use of another virtual source that is not a point source, for instance, one having a finite aperture. That is, decay weights will be calculated analytically or numerically. Moreover, our developed optimization method for determining the beamforming parameters such as an apodization function involving delays will also be used to determine the position of virtual sources.

References

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