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Application of annular array in biostructure evaluation by amplitude envelope analysis
振幅包絡特性解析による生体構造評価におけるアニュラアレイの適用

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1. Introduction

Many of quantitative ultrasound（QUS）based on statistical analysis of ultrasound echo signal amplitude envelope are proposed as one of the tissue characterization tequnique, and some methods are already using in clinical study and diagnosis.

Generally, high frequency ultrasound（>15 MHz） transducers provide to realize the high resolution ultrasound images. In the case of single element transducer, a spatial resolution is decided by center frequency and transducer geometry, therefore a depth of field (DOF) of single element transducers is limited. On the other hand, multi-element array transducer (e.g, annular array transducer) can improve the DOF and the spatial resolution by using a synthetic aperture technique, compared with a single element concave transducer with similar geometry.

In order to confirm the sensitivity of the imaging and the statistical analysis on an annular array transducer, RF echo signal were acquired with a 5-channels annular array transducer and a concaved single element transducer. In addition, two beam forming algorithms were compared on the annular array transducer. Envelope amplitude distribution of measured RF signal were analyzed with Rayleigh distribution and Nakagami distribution models.

2. Theory

2.1 Synthetic focusing technique

Synthetic focusing technique (STF) for digitized echo signal data was accomplished by applying an appropriate round trip delay to each transmit-receive (TR) pair for a given focal depth, and then summing the data to create a locally focused region[1)]. These processes are repeated to create an arbitrary number of focal zone. To focus the array at the depth f, the one-way delay t_n of each element is

$$t_n = \frac{a_n^2(\frac{1}{R}-\frac{1}{f})}{2c} \tag{1}$$

where a_n is the average radius of the n^{th} array element, R is geometric focal length, and c is the speed of sound.

2.2 Statistical analysis models

In a homogeneous medium with high scatters density, it is known that the probability density function (PDF) of echo amplitude envelope can be approximated by the Rayleigh distribution. On the other hands, a PDF of the echo envelope amplitude shows non-Rayleigh distribution with heteroginious media, and normalized echo amplitude distribution is apploximated with the Nakagami distribution for charactrizing. Nakagami distibution is equal to Rayleigh distribution when scale parameter is $\mu = 1$.

3. Experiments

An agar graphite phantom was measured with a 5-channels annular array transducer. A graphite concentration of the phantom was 3 % which is high density for the PDF of the transducer. Total aperture and geometrical focal length were 6.2 mm and 31 mm, respectively. The center frequency of each element was 20 MHz. The element diameter were 2.6 to 6.2 mm and defined as ch. 1 to ch. 5. The echo signal were digitized with 250 MHz for 12 bit digitizer. RF echo signal were measured every 30 µm for lateral direction. The region of interest (ROI) in the range of 250 µm * 540 µm (depth * lateral) was set at 31 mm from the transducer. The Rayleigh distribution and the Nakagami distribution were fitted for envelope data inside the ROI. For comparison, a data of a single element concave transducer whose aperture size and center frequency are equivalent to annular arrays were also analyzed with the two distribution models.

4. Result and Discussion

Figure 1 shows the B-mode images and the corresponding amplitude PDFs. Ultrasound wave was transmitted from each cannel, and RF echo signal were received by ch. 1 (smallest element) (a) and by ch. 5 (largest element) (b). All B-mode images were normalized with the maximum amplitude in 25 TR pairs (transmit: chs. 1–5, receive: chs. 1–5). In Fig. 1 (a), since the smallest element was used for receiving, spatial resolution is low. In the case of transmit with large element such as ch. 4 and ch. 5, the apparent resolution was improved but the receive sensitivity was low. Therefore, even though the phantom was a homogeneous medium, PDF had low approximation accuracy with respect to two distribution models. In Fig. 1(b), B-mode images had high spatial resolution because it was received by the largest element. But due to the difference in the transmit and receive sound field characteristics, PDFs were not general characteristics. However, in either case, two distributions were approximated in the particular TR pairs, and highly sensitive measurement can be performed in near the focus.

Figure 2 shows the imaging results of simple synthesis with no time delay, synthesis with SFT, and signal acquired by single concave transducer. Compared with the results of simple synthesis and SFT, there is no big difference in the PDF at near the focus, however in the B-mode image of the SFT, the deep part was clearly imaged, since the intensity of echo in SFT case was about 3 dB higher than the simple synthesis case. Besides, The PDF characteristic was stable in the part that was deeper than the focus. Also, the same advantages were confirmed as a comparison with the single element concave transducer case.

5. Conclusion

It is confirmed that complication of the transmit and receive sound field affects the PDF analysis. In the annular array, imaging sensitivity was improved by SFT, however, the sensitivity of PDF analysis near the focus was not higher than supposition. In order to carry out the PDF analysis efficiently with annular array transducer, it is necessary to consider methods such as weighting between TR pairs at applying SFT.

Acknowledgment

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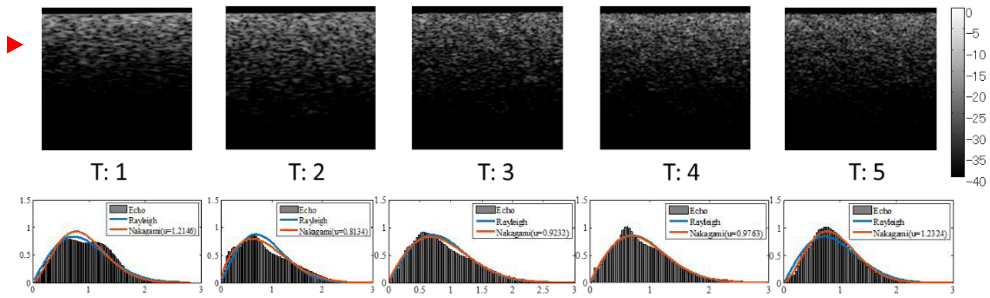
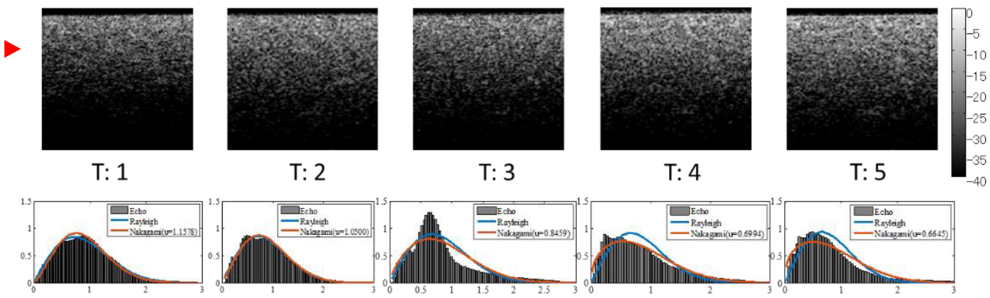
Reference

1. M. Arditi et al.: *Ultrason. Imaging*, (1982), **3**, 37.



(a) received by ch. 1



(b) received by ch. 5

Fig.1 B-mode images and amplitude PDF computed from single element signal.

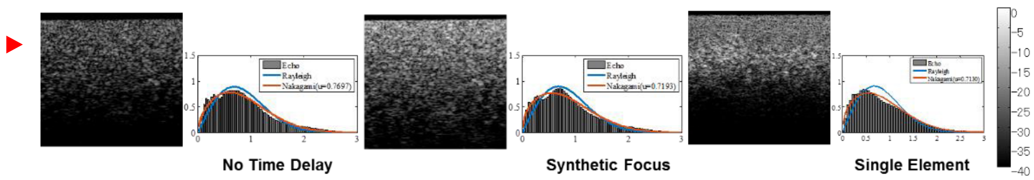


Fig. 2 B-mode images and PDFs of synthetic signal from 25 data and single element concave transducer.