3P5-8

Proceedings of Symposium on Ultrasonic Electronics, Vol. 35 (2014) pp. 523-524
3-5 December, 2014

Estimation of scatterer size and density in sound field produced by linear array phased transducers

リニアアレイ探触子からの波動場における散乱体サイズ・密度推定

Takuma Oguri[1†], Kenji Yoshida[2], Mamou Jonathan[3], Hitoshi Maruyama[4], Hiroyuki Hachiya[5] and Tadashi Yamaguchi[2] ([1]Graduate School of Engineering, Chiba Univ.; [2]Center for Frontier Medical, Chiba Univ.; [3]Lizzi Center for Biomedical Engineering, Riverside Research; [4]Gradutae School of Medical, Chiba Univ.; [5]Graduate School of Science of engineering, Tokyo Institute of Technology)

大栗　拓真 [1†]，吉田　憲司 [2]，Mamou Jonathan[3]，丸山　紀史 [4]，蜂屋　弘之 [5]，山口　匡 [2]
([1] 千葉大院　工学研究科, [2] 千葉大　CFME, [3]Riverside Research Lizzi Center for Biomedical Engineering，[4] 千葉大院　医学研究院，[5] 東工大院　理工学研究科)

1. Introduction

There are several reports on the estimation of scatterer size and density based on the analysis RF signal, e.g. The progress degree judgments of the cancer metastasis to lymph node using a high frequency around 15 MHz [1] and the fat of the liver of the rabbit [2]. In these reports, single-element transducer was served as the ultrasound probe. The ultrasonic diagnosis equipment was not used often because of the complicated calculation of the sound fields. In this study, we tried estimating the scatterer size and density of glass beads phantoms by using the ultrasonic diagnosis equipment and the linear array phased transducers.

2. Theory

The scatterer size and density can be made by comparing the backscattered power spectrum of the RF signal gated from each region of interest (ROI) with a theoretical backscattered power spectrum. [3]

By considering the three-dimensional expanse and frequency dependence of the backscattered signal affected by size and shape of scatterers, a theoretical backscattered power spectrum is given by

$$W_{theor}(f) = \frac{185Lq^2 a_{eff}^6 n_z f^4}{1+2.66(fqa_{eff})^2} e^{-12.159f^2 a_{eff}^2} \quad (1)$$

where L is the length of the ROI, q is the ratio of aperture radius to distance from the ROI, a_{eff} is the scatterer size, n_z is the scatterer density and f is frequency.

The backscattered power spectrum from the ROI is given by

$$W_{ROI}(f) = A(f,L)\frac{R^2}{4N}\sum_{n=1}^{N}\frac{w_n(f)}{w_{ref}(f)} \quad (2)$$

where R is the reflection coefficient of the known planar reflector, $W_n(f)$ is the Fourier transform of the RF signal from the ROI and $W_{ref}(f)$ is the calibration power spectrum. $A(f,L)$, which is a attenuation compensation function, is calculated by considering the effect of acoustic attenuations in distance from the transducer to the ROI and in the ROI, and the effect of a window function. In this study, Hanning window is used. $A(f,L)$ is given by [4]

$$A(f,L) = e^{4\alpha_0(f)x_0}\left\{\frac{2\alpha(f)L}{1-e^{-2\alpha(f)L}}\right\}^2\left[1+\left\{\frac{2\alpha(f)L}{2\pi}\right\}^2\right]^2 \quad (3)$$

where $\alpha_0(f)$ and x_0 are the attenuation coefficient and propagation distance, and $\alpha(f)$ is the attenuation coefficient in the ROI.

The scatterer size and density can be made by the f^2 function calculated by comparing the logarithm of the compensated backscattered power spectrum (Eq. 2) with the logarithm of the theoretical power spectrum (Eq. 1). The f^2 function is given by

$$10\log_{10} W_{ROI}(f) - 10\log_{10} f^4 \approx m(a_{eff})f^2 + b(n_z, a_{eff}) \quad (4)$$

where the slope, m, is a function of the scatterer size, and the intercept, b, is a function of both the scatterer size and density. To obtain the parameter estimates, the least square method is used to find the best fit slope and intercept to the linearized, backscattered power spectrum.

3. Data acquisition

The ultrasonic diagnosis equipment (AplioXG; TOSHIBA MEDICAL SYSTEMS Co.) and the leaner phased array transducers (PLT-704AT; TOSHIBA MEDICAL SYSTEMS Co.) were used. The center frequency of the transducers is 5 MHz. The depth was set 40 mm, and the focus depth was set 30 mm.

For comparing with the result estimated from the RF signal acquired by the ultrasonic diagnosis equipment, the single-element transducer (PT5-25-75; Toray Engineering Co.) was employed in the acquisition of the RF signals. It had an aperture diameter of 25 mm and a focal length of 75 mm. The center frequency of the transducer was around 5 MHz. The transducer was operated in pulse-echo mode through a pulser/receiver (5800; Panametrics). The signals were recorded and digitized on an oscilloscope (6030-I; LeCroy). The sampling rate was 250 MHz.

The transducer was scanned laterally by a motor stage (UTM100CC1HL; New-port) with a step size of 300 μm between each A line scan.

4. Materials

Two glass beads phantoms with different weight concentration of 1 % and 2 % were made from agar, glass beads (EMB-10; Potters-Ballotini Co.) and water. The radius of the glass beads was 2~10 μm. Table I shows the speed of sound and the attenuation coefficient of these phantoms. These parameters were measured by time of flight and insertion loss method [5].

Table I Speed of sound and attenuation coefficient of glass beads phantom

Weight concentration [%]	Speed of sound [m/s]	Attenuation coefficient [dB/cm/MHz]
1	1538±4.9	0.2±0.02
2	1551±5.7	0.3±0.03

5. Result

In both cases of the linear phased array transducers and the single-element transducer, the ROI with a square of 3×3 mm was positioned and scanned on the focus point of ultrasonic beam for lateral direction. The scan interval was a 33 % of ultrasonic beam width. The acoustic impedance of acryl used as the planar reflector, and the acoustic impedance and the speed of sound of water in Refs. [6] and [7] were referred.

Figure.1 and 2 show the estimated scatterer size and density, respectively. The logarithmic value of scatterer density was normalized by the maximum value in all cases. Welch's T test was conducted focusing on the difference of ultrasonic probe. As a result, in case of the phantom with weight concentration of 1 %, the scatterer size and density estimated by using the linear array transducers were significantly different from the values estimated by using the single-element transducer. In case of other phantom with weight concentration of 2 %, there was a significant difference between the value of scatterer density.

6. Conclusion

The scatterer size and density of glass beads phantoms with different beads concentration were estimated from the RF signals acquired by using the linear phased array transducers and the single-element transducer. As a result, there were significant differences between the results of the linear phased array transducers and the single-element transducer.

In the future work, we plan to discuss the effect of beam shape of the linear phased array transducers on the estimated values for scatterer size and density.

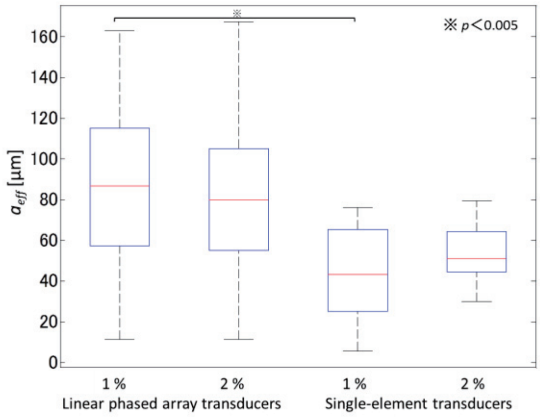

Fig. 1 Scatterer size estimated in RF signals acquired by linear phased array transducers and single-element transducer.

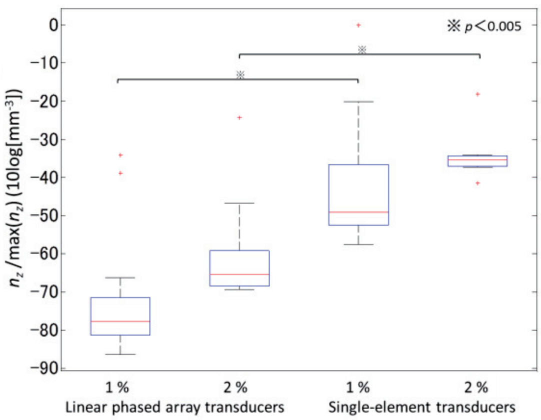

Fig. 2 Scatterer density estimated in RF signals acquired by linear phased array transducers and single-element transducer.

Reference

1. J.Mamou, E.Feleppa et al.: Ultrasound in Med. & Biol.(2010), Vol. 36, No. 3, pp. 361-375.
2. G.Ghoshal, M.Oleze et al.: Ultrasound in Med. & Biol.(2012), pp. 1-11.
3. M.Insana, T.Hall et al.: J.Acoust. Soc. Am.(1990), 87(1).
4. M.Oleze, W.O'Brien et al.: J.Acoust. Soc. Am.(2002), Pt. 1, 112(3).
5. E.Madsen, G.Miller et al.: J Ultrasound Med, American Institute of Ultrasound in Medicine(1990), 18:615-631.
6. M.Ueda, Y.Watanabe et al.: Tyouonpa Binran (Handbook of ultrasonic) (Maruzen, Tokyo, 1978) pp. 1352-1354 [in Japanese].
7. M.Greenspan, C.Tschiegg: Journal of Research of the National Bureau of Standard(1957), Vol. 59, No. 4.