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Measurement on Ultrasonic Attenuation Coefficient of Tissue Mimicking Materials

生体擬似物質の減衰定数の測定

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1. Introduction

There is a need for testing the performance of the ultrasound diagnostic equipment in hospitals and manufacturing works. There have been developed various ultrasound phantoms, which are essential to quality control of the equipment. Acoustic velocity, attenuation, characteristic acoustic impedance, and backscatter coefficient of tissue mimicking materials used in a phantom should be in agree with the parameters of living organs. Parameters of tissue-mimicking material for phantoms defined in IEC standard are shown in **Table I**.[1)]

In conventional method[2)], precise measurement of attenuation is taken in a lot of time for the need of experimental diffraction corrections of transducer diffraction fields and the associated transducer characteristic. The approaches proposed by Terence. P. Lerch et.al. achieves attenuation coefficient estimation without the diffraction corrections[3)]. However, the approach has the disadvantage of weak sensitivity in the measurement of materials with acoustic impedances close to the acoustic impedance of water. We have examined optimum acoustic impedance of liquid in acoustic path, for intense reflections from a specimen with tissue-like acoustic impedance are attained .

In this paper, we describe new techniques on accurate attenuation measurement of the materials with acoustic impedance near 1.5 (MRayl).

2. The principle of Measurement

The specimen for measurement is placed in liquid as shown in **Fig.1**. Solution for attenuation constant α_s by taking the ratio of any pair of reflections (F/B_1, B_1/B_2, or F/B_2) as follows:

$$\alpha_s = \frac{1}{2z_s}\ln\frac{F^*}{B_1^* \Big/ (1-R^2)e^{2\Delta z_w^* \alpha_w}} = \frac{1}{2z_s}\ln\frac{B_1^* \Big/ e^{2\Delta z_w^* \alpha_w}}{B_2^* \Big/ R^2 e^{4\Delta z_w^* \alpha_w}} \tag{1}$$

where first defining as the water path change is:

$$\Delta_w^* = \frac{c_s}{c_w} z_s = z_{wf}^* - z_{wb1}^* = z_{wb2}^* - z_{wb2}^* \tag{2}$$

c_s and c_w are the acoustic speed in the solid and liquid, respectively. z_s is the thickness of the specimen, R is the reflection coefficient at the front surface between the liquid and the solid, α_w is the attenuation coefficient in the liquid. Some variables are indicated in Fig.1.

Table I Parameters of tissue-mimicking material (TMM)

Sound velocity	(1540 ± 15) m s^{-1}
Attenuation (one-way passage)	(0.5 ±0.05) × 10^{-4} × f dB m^{-1} Hz^{-1}
Attenuation	(0.75 ±0.05) × 10^{-4} × f dB m^{-1} Hz^{-1}
Characteristic acoustic impedance	(1.60 ±0.16) × 10^{6} kg m^{-2} s^{-1}
Backscatter coefficient	(1 to 4) × 10^{-28} × f^4 m^{-1} Hz^{-4} sr^{-1}

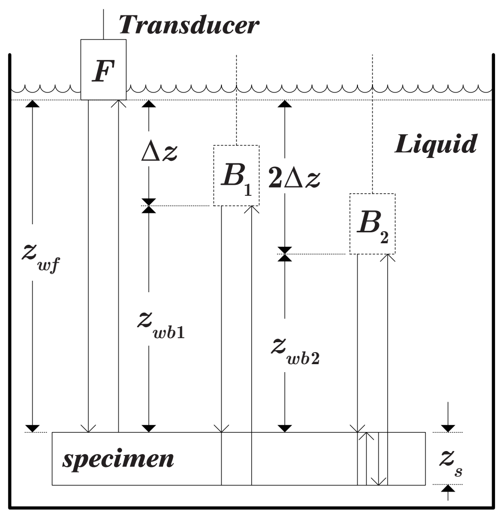

Fig.1 Typical pulse-echo attenuation measurement technique utilizing multi reflections.
Note that the transducer is shifted axially to equal diffraction points for the first and second surface reflections.

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The relation between acoustic impedance of the specimen and reflections F, B_1 and B_2 is calculate on the transmission line model. Reflection waves in specimen surfaces are given by equations of reflection and transmission coefficients on a transmission line with impedance mismatching.

The lower acoustic impedance of liquid become, the more intense reflections become in **Fig.2.**

The optimum value of acoustic impedance of the liquid is ～0.5 MRayl.

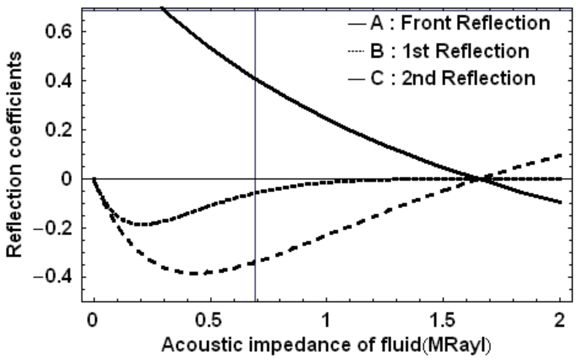

Fig.2 . The relation between acoustic impedance of the specimen and reflections F, B_1 and B_2.

3. Measurement apparatus

Measurement apparatus based on technique utilizing multi reflections is shown in **Fig.3**. Silicon oil with the acoustic impedance of 0.69 (MRayl) is used for the liquid, and high sensitivity measurement has been obtained. Therefore, F=0.41, B=-0.34 and B_2=-0.06 respectively are attained. A vessel filled with silicon oil is placed in a constant temperature bath (22 ± 0.1℃) and a specimen is held in the same temperature. Reflections are recorded by a digital oscilloscope and integrated data are analyzed with a PC.

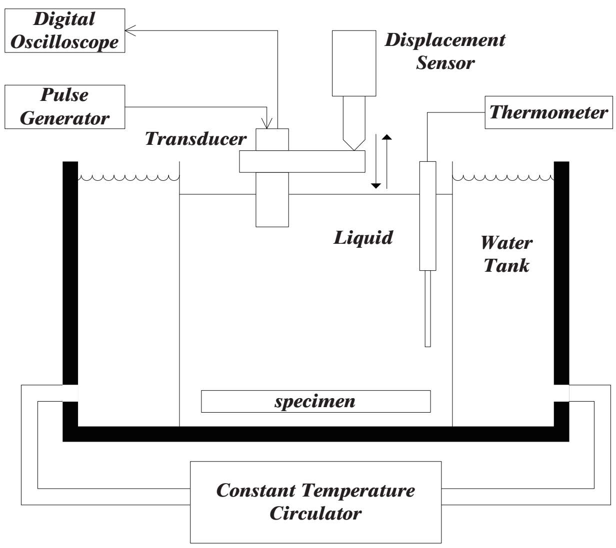

Fig.3 Configuration of measurement apparatus.

4. Results

Reflection waves from the specimen (pure water) in a silicon oil (ShinEtu KF-96-0.65cs: acoustic velocity: 903 m/s, density: 0.76 g/cm^3, acoustic impedance:0.69 MRayl) vessel are shown in **Fig.4**.

Reflection waves from the specimen made from SPUG; Segmented Polyurethane Gel in the silicon oil vessel are shown in **Fig.5.**

The gel is dispersed with PMMA powder and have attenuation of 0.5 dB/cm・MHz.

Reflection waves from the specimen (gel with PMMA powder) in a silicon oil vessel are shown in **Fig.4**.

In the specimen with attenuation of 0.5 dB/ cm MHz, 1st reflection is lower than front reflection as shown in Fig.5.

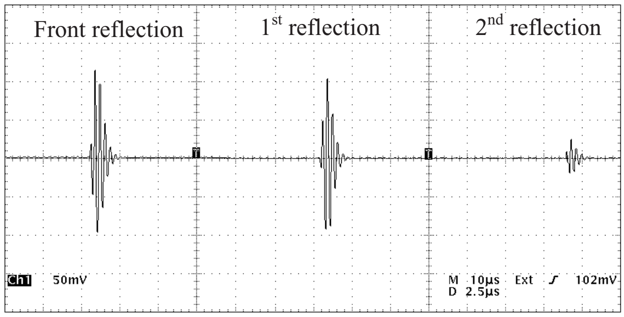

Fig.4 Wave trains of the front surface, first back surface, and second back surface reflections on a water specimen.

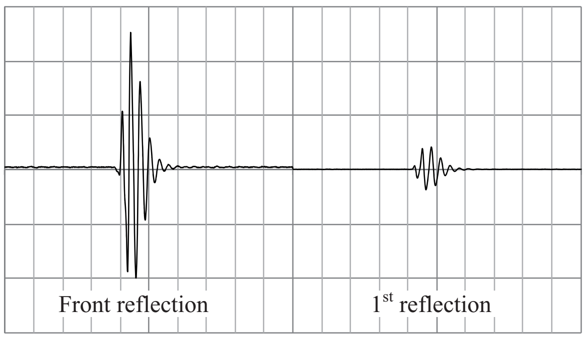

Fig.5 Wave trains of the front surface and first back surface reflections on a specimen with attenuation of 0.5 dB / cm MHZ.

References

1. IEC: International Standard, IEC1685(2001)
2. AIUM Technical Standards Committee: "Methods for Specifying Acoustic Properties of Tissue Mimicking Phantoms and Objects, AIUM, Maryland,1995
3. T. P. Lerch, R. Cepel, and S. P. Neal: "Attenuation coefficient estimation using experimental diffraction corrections with multiple interface reflections", Ultrasonics, **44**, pp83-92(2006)