3P5-10

Measurement of Bioacoustic Properties by Ultrasonic Interference Method Using Frequency Sweep

周波数掃引を用いた超音波干渉法による生体音響特性の測定

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1. Introduction

To enable tissue diagnosis by endoscopic ultrasonography, we have been developing puncture needle-type ultrasonography.[1–6] We previously demonstrated an imaging method for determining the phase difference of the acoustic complex impedance. This imaging method makes it possible to observe cells without staining like optical microscopy. In this imaging method used for pathological diagnosis, it is necessary to display more information in the image to make it possible to distinguish cancer tissue from normal tissue. As is well known, the frequency dependence of the scattering depends on the shape of the scattering body and distribution. In addition, the frequency dependence of the attenuation due to viscosity and elasticity depends on the type of elastic body and the amount of oil contained therein.

In the past, multispectral phase-contrast imaging of acoustic impedance was used to measure the physical properties of the sample. This time, we investigate the possibility to realize the same measurement by using an FM chirp signal.

2. Principle

2.1 Ultrasonic interference method

Complex acoustic impedance can be measured using a fixed length transmission line (thin rod sensor) and a variable length transmission line (water) as shown in **Fig. 1**. An ultrasonic burst pulse propagates through the former and is reflected at the boundary between them. Furthermore, the propagating wave is reflected at the interface between the water and a sample. Both reflected waves interfere. When the distance of the variable length transmission line is changed, the amplitude of the interference wave changes. The ratio between the maximum amplitude V_{max} and the minimum amplitude V_{min} at this time is expressed by the following equation.

$$\frac{V_{max}}{V_{min}} = \left|\frac{1-K_0 \cdot r_0}{1+K_0 \cdot r_0} \cdot \frac{K_0+r_0}{K_0-r_0}\right|, \qquad (1)$$

where K_0 represents the reflection coefficient at the boundary between the fixed length transmission line and the variable length transmission line, and r_0 represents the reflection coefficient at the boundary between the variable length transmission line and the sample. Assuming that the acoustic impedance of the variable length transmission line is Z_V and the acoustic impedance of the fixed length transmission line is Z_A, K_0 can be expressed as follows.

$$K_0 = \left|\frac{Z_V-Z_A}{Z_V-Z_A}\right|. \qquad (2)$$

Since Z_V, Z_A and K_0 are known, if V_{max} and V_{min} are measured, r_0 can be determined from Eq. 1. Therefore, the acoustic impedance of the sample can be obtained from the following equation.

$$Z_R = Z_V \cdot \left|\frac{1+r_0}{1-r_0}\right|. \qquad (3)$$

2.2 Ultrasonic interference method using frequency sweep

Changing the distance as described in Section 2.1 is difficult for application of in vivo microscopy. Instead, we can change the frequency of the burst pulse in order to realize the same measurement with fixing the distance between the sample and the tip of the rod sensor.[7] In this method, burst waves with different frequencies are transmitted, and each interference wave is measured. It has been confirmed that information on the absolute value and the phase of the complex acoustic impedance of the sample can be obtained.

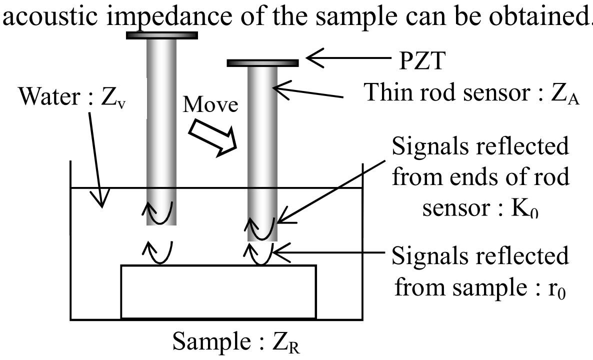

Fig. 1 Ultrasonic interference method procedure.

3. Method

In the conventional method, burst pulses are transmitted for each frequency to generate interference waves. For efficient measurement, one FM chirp wave can be used instead of multiple burst waves. Discrete Fourier transform can be applied to the measured interference wave to investigate the interference information for each frequency.

4. Simulation

We conducted an FEM simulation. We modeled the tissue simulation sample and simulated the above interference waves by transmitting an FM chirp wave which frequency is swept from 40MHz to 50MHz. We tried to determine the amount related to complex acoustic impedance by simulating the wave received by the transducer. **Figure 2** shows the simulation model and **Table 1** and **Table 2** shows the used parameters. For the simulation, two samples with different parameters related to elasticity were used.

5. Simulation result

Figure 3 is the simulation result using an FM chirp wave and **Fig. 4** shows the result using a burst wave for each frequency. Since the chirp wave is used, the reflected wave on the end face of the quartz rod differs somewhat from the reflection from the sample surface. Therefore, the interference patterns shown in Fig 3 and Fig 4 are different.

However, it can be confirmed that the interference wave of Sample 2 is larger in both results. This is because the reflectance changes due to the difference in elasticity. From this, the overall trend is considered to be the same. From this, it is considered that the overall fluctuation will be the same even if an FM chirp wave is used.

6. Conclusion

We examined the ultrasound interference method using an FM chirp wave. By performing simulation using samples with different elasticity, it was found that the same result as the conventional method can be obtained by this method. This makes it possible to investigate with finer frequency increments and to shorten calculation time.

In the future, it is necessary to evaluate the effectiveness of the method by the simulation and experiment for viscoelastic materials.

References

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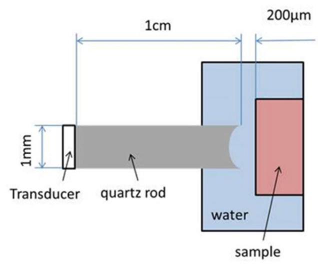

Fig.2 Simulation model

Table 1. Parameter of piezoelectric element

Name	Density(kg/m^2)	dB/unit length(dB/m)	Q Value
PZT5h	7500	4.637×10^3	65

Table2. Parameter of material

Name	Density(kg/m^2)	Sound velocity(m/s)
Water	1000	1496
Quartz	2650	5750
Sample1	1030	1579
Sample2	1050	1600

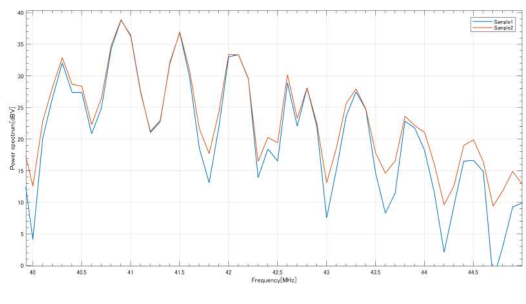

Fig. 3 Result using FM chirp signal

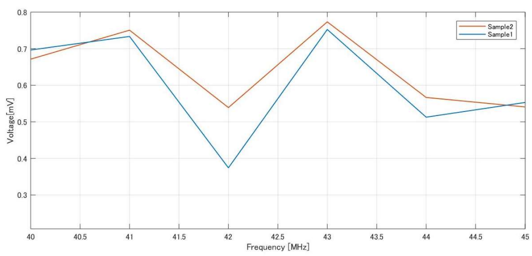

Fig. 4 Result using burst waves