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Measurement of cantilever vibration using impedance-loaded surface acoustic wave sensor

インピーダンス負荷弾性表面波センサを用いた片持ち梁の振動測定

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1. Introduction

In recent years, a surface acoustic wave (SAW) sensor has become an active area of research. SAW sensors have high sensitivities, do not require a battery to operate, and can be measured wirelessly in harsh environments [1].

Further the development of a sensor for health monitoring of structures such as bridges or tunnels is desired. Typical examples of the sensor for structural health monitoring, include the vibration sensor. But vibration sensor requires a battery. Therefore, the vibration sensor that combines SAW sensor and pressure sensor does not require a power supply. This paper describes cantilever vibration measured by the vibration sensor that combines a 13.5 MHz SAW sensor and a pressure sensor.

2. SAW sensor

The measurement system with the SAW sensor is shown in **Fig. 1**. When an interdigital transducer (IDT) receives an input electrical signal from a reader, the SAW is excited and propagates on a piezoelectric substrate surface and reflected by a reflector on the SAW device. Reflected wave is converted to an electrical signal at the IDT, and the signal is returned to the reader. Here, reflectivity of the reflector depends on the impedance that is connected to the reflector. Thus, if a classical sensor which impedance changes by physical quantity is connected to the reflector, the return signal has information of the classical sensor. We can measure physical quantity without power supply and electric circuit at sensor.

The SAW device used was fabricated on a 128°YX-$LiNbO_3$. Electrode material of the IDT and reflector was an aluminum. Operating frequency was 13.5 MHz.

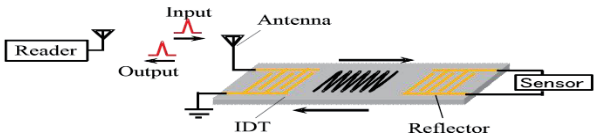

Fig. 1　Measurement of this study.

3. Fundamental characteristics

First, we measured capacitance characteristic of the SAW sensor. An echo amplitude was monitored by using a network analyzer. Capacitor was used to extend the sensing range of the sensor [2]. Relationship of the capacitance and the first echo amplitude is shown in **Fig. 2**.

As a sensor element for measuring the distortion in this study, we used a pressure sensor of FSR 400 series. As we combine the SAW sensor of 13.5 MHz, it is important to know the fundamental characteristics of the pressure sensor in the frequency. Using a weight of 100 g, impedance changes of three kinds of the pressure sensors at the 13.5 MHz was measured by using an impedance analyzer. The results are shown in **Fig. 3**. Comparing the three pressure sensors, only FSR 406 can be seen that the impedance change is dependent on the reactance change. As a result of converting the value of the reactance to the capacitance, when the load is 0 g have a capacitance of 94 pF when a 62 pF, 100 g. From Fig. 2, the first reflection peak at 13.5 MHz SAW sensor is sufficiently changed in this range of the capacitive. Moreover, the peak value and the capacitance are one-to-one correspondence. Therefore, it is considered that FSR 406 is used in combination with a 13.5 MHz SAW sensor.

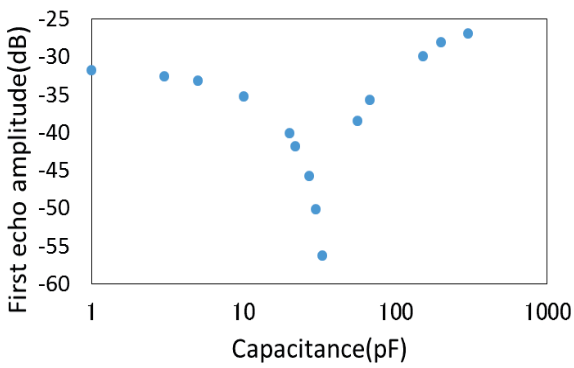

Fig. 2　First echo amplitude as a function of capacitance.

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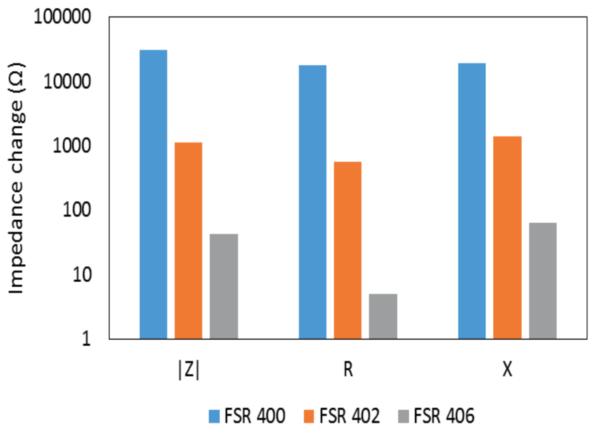

Fig. 3 Impedance variation of each pressure sensor.

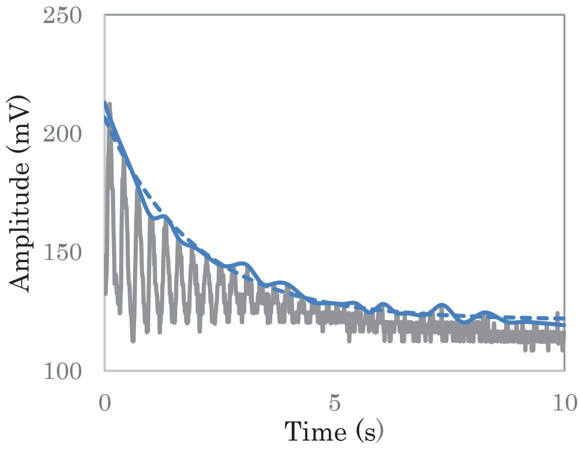

Fig. 4 Time response.

4. Vibration measurement

Pressure sensor was affixed to a cantilever and connected to the reflector. When cantilever was vibrated, the changes in the peak value of the reflected wave was measured with wired by a oscilloscope. Material and size of the cantilever used was Polyvinyl chloride, a length of 22.6 cm, width 18 cm, and thickness 0.7 mm respectively. It was carried out data logging of the sampling interval 10 ms by using the segment memory function. A time response of the peak value of the reflected wave is shown in **Fig. 4**. It shows the upper envelope of the time response with a blue solid line. It also shows the result of exponential approximation of the envelope with a blue dashed line. Exponential function used in the approximation is the following equation.

$$y = a + b \times \exp(cx) \qquad (1)$$

Large distortion occurs out of the beginning of the vibration, the change in the peak value is also large. Changes in the peak value is reduced gradually, we see that the distortion is smaller. Exponential function performed approximation is the following equation.

$$y = 121.53 + 85.10 \times \exp(-0.51x) \qquad (2)$$

From the above equation, attenuation coefficient is -0.51. The result of the first Fourier transform (FFT) from Fig. 4 is shown in **Fig. 5**. The figure shows that the peak frequency of the cantilever used is 3.32 Hz. This value corresponds to the natural frequency of the cantilever. Measurement result showed that can detect the vibration from the change the first echo amplitude. Moreover, it was possible to obtain the attenuation coefficient and natural frequency from the time responses.

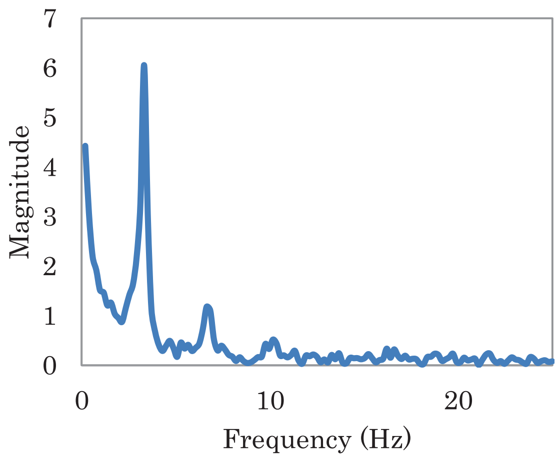

Fig. 5 The result of FFT.

5. Conclusion

In this paper, we described the results of measurement of cantilever vibration due to the vibration sensor that combines a 13.5 MHz SAW sensor and a pressure sensor. By changes of attenuation coefficient and natural frequency, it showed the possibility that can detect the deterioration of the structure. In future work, measurement of changes of attenuation coefficient and natural frequency due to deterioration of the cantilever will be occurred. Measurement of cantilever vibration will be occurred in wireless.

References

1. Haekwan Oh, et al; Jpn. J. Appl. Phys. **48** (2009) 066505
2. A. Narushima, et al; Acoustic Society of Japan., pp. 1239-1240 (2014) [In Japanese]