2Pa2-5

Oscillation frequencies and Q value of QCM generator by Internet of Things

IoT を用いたＱＣＭ発振器の発振周波数とＱ値について

Yasuaki Watanabe, Yuuta Aoki, Yingbo Sun, and Yuuki Okamoto
(Grad. school of system design, Tokyo Metropolitan Univ.)
渡部　泰明，青木　佑太，孫　英博，岡本　祐希 (東京都立大学 システムデザイン研究科)

1. Introduction

Quartz crystal microbalances (QCMs) are frequently used for measuring mass variations on a nanogram scale and are advantageous because the resonance-frequency variation of quartz crystal resonators is sensitive[1-5]. AT-cut crystal resonators are often used for QCMs because they are precise and the frequency variations in QCMs in AT-cut crystal resonators are small due to temperature changes. When the main thickness-shear mode is used, AT-cut crystal resonators vibrate parallel to the thickness direction of the quartz crystal. The most common application of such resonators is in the vacuum film formation process such as for thin film deposition equipment and sputtering equipment required for manufacturing semiconductors, so-called film thickness monitoring.

We carried out measurement using stress compensate cut (SC-cut) quartz crystal resonators, which are mainly sensitive to flexural vibration because vibration is displaced in-plane as well as the thickness direction. However, a SC-cut quartz crystal resonator has poor temperature characteristics; thus, temperature-control devices are necessary[5].

We used Internet of Things (IoT) technology with an AT-cut crystal unit and obtained effective tactics. As a result of the Q value of AT-cut crystal decreasing by -30 dB/1000 Hz in pure water, and the purpose of this report is whether it can be dealt with by heterodyne detection on the circuits.

2. Measuring system

Acquired QCM data are sent to the cloud and server via a low-power wide-area network, which enables analysis and predictions to be carried out remotely. When large numbers of QCM sensors are used, they must be installed and operated at low costs. Therefore, IoT devices that can function with low operational management are in demand. An effective approach is to use an energy harvester, such as a solar battery.

We measured the Q value of pure water with the QCM method using the frequency of 30.8 MHz, as shown in Fig. 1. This method was carried out using a CMOS crystal oscillator at a supply voltage 5 V to precisely measure the Q value and phase noise by using a signal source analyzer. Figure 2 shows how IoT might be further applied to the QCM method in the future.

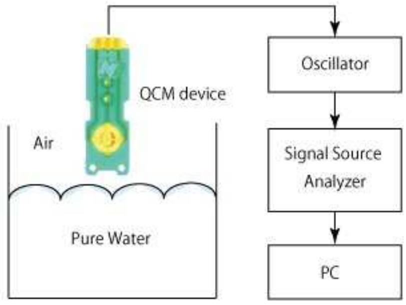

Fig. 1. Method for measuring Q value with QCM in pure water [1].

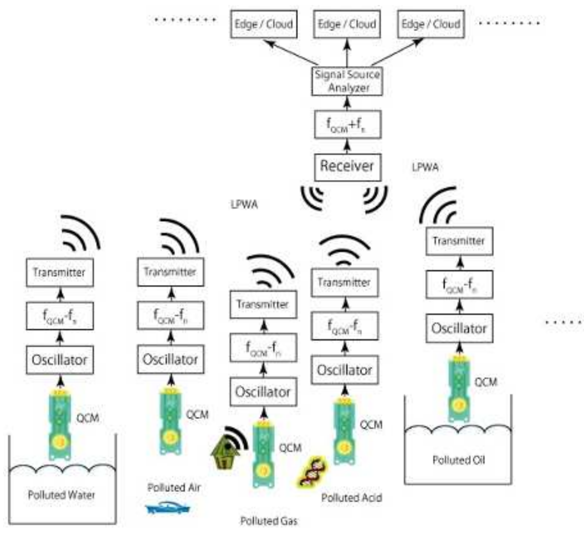

Fig. 2. How IoT might be applied to QCM[1]

3. Measurement results

The temperature of the QCM was maintained at 23.6°C in air, as shown in Fig. 3(a), and the phase noise from the signal-source analyzer was measured under this condition. The orange line in Fig. 3(b) shows QCM in pure water at 23.6°C. At an offset frequency of 1000 Hz, the phase noise in the air was

e-mail: y.watanabe@ieee.org

-120 dBc and -90 dBc in pure water. In pure water, phase noise measurements increase offset frequencies to between 10 and 1000 Hz; thus, the Q value was 1000 in pure water and 72000 in air[1].

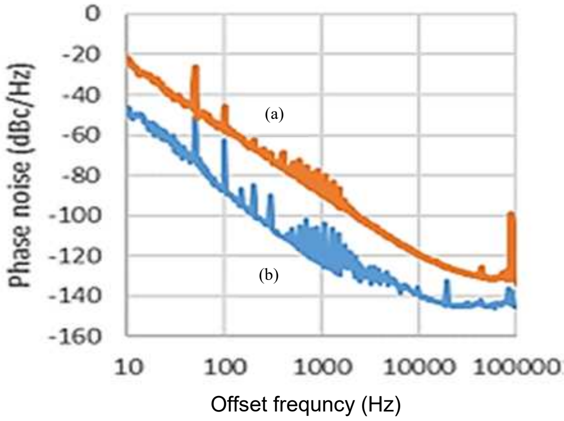

Fig. 3. Phase noise measured with QCM in pure water (a) and air (b) [(1)].

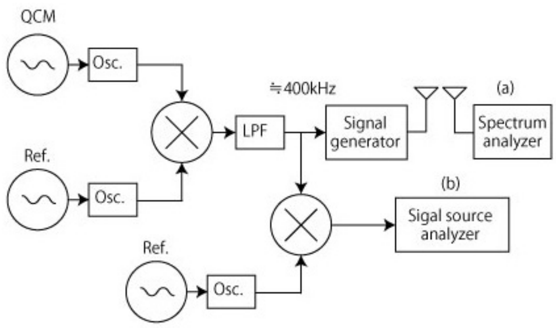

Fig. 4. Outline of phase noise measuring system of QCM and oscillators.

Figure 4 shows the phase-noise measurement system of the oscillators included in a QCM with reference frequencies of about 30.4 MHz. The measurement system includes Keysight N5181A with an amplifier modulated (AM) signal generator (output level = 10 dBm) and GWinstek GSP730 with a spectrum analyzer. The antennas showed impedances at 50 Ω and tuned to a frequency of about 800 MHz.

Figure 5 shows the spectral analysis results (a) of 800 MHz with a span of 1 MHz using the system in Fig. 4. The spectrum results are the AM signal pulses (heterodyne detection) at a position about ±400 kHz from the reference of 800 MHz. This shows that AM modulation was done correctly.

Figure 6(a) shows the QCM included in the measurement system in Fig. 4 in pure water, and Fig. 6 (b) shows it in air. At an offset frequency of 1000 Hz, the phase noise in the air was -110 dBc and -90 dBc in pure water. As results in Figs. 3 and 6 is – 10 dBc lower than Fig. 3 at in the air. This reason is influenced by the mixer.

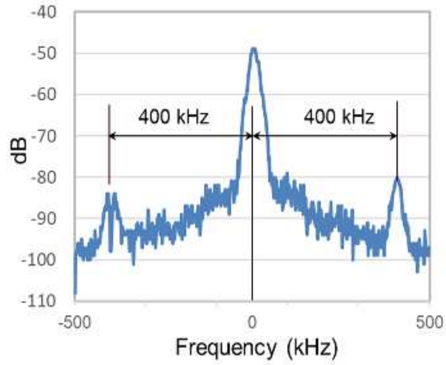

Fig. 5. Results of spectrum analyzer of 800 MHz.

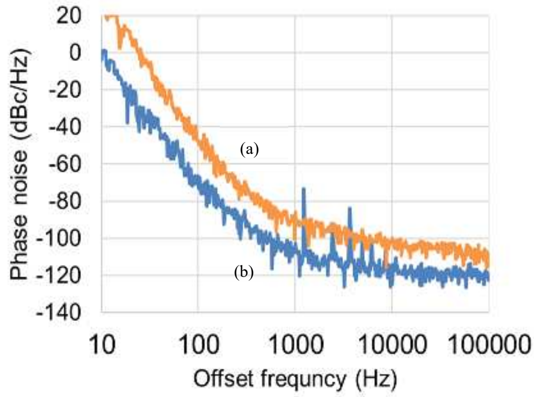

Fig. 6. Phase noise measured with QCM in pure water (a) and air (b).

4. Conclusion

By improving the QCM, a more specific numerical value (≃ 20 dB) was determined. By using the frequency spectrum, the band limitation of phase noise was eliminated, and the Q value of the QCM can be between air and pure water. However, further analysis is necessary.

Acknowledgement

This work was supported by JSPS Grants-in-Aid for Scientific Research Grant Number 17K06466.

References

1. Y. Watanabe, et. al., USE2019 Symp. (2019)
2. Y. Okahata, Quarts-crystal microbalance for bio-sensing, Koudansya (in Japanese, 2013)
3. L. R. Pardo, et. al., IEEE Trans on UFFC, Vol. 54, No. 10, (2007)
4. J. Auge, et. al., Sensor and Actuators B, 2425 (1995)
5. S. Watanabe, et. al., USE2017 (2017)