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CURRENT PROGRESS OF DEVELOPMENT OF VIBRATION CALIBRATION SYSTEMS IN NMIJ

Akihiro OTA, Hideaki NOZATO, Wataru KOKUYAMA, and Koichiro HATTORI

AIST/NMIJ, Tsukuba, Japan, a-oota@aist.go.jp

Abstract: AIST/NMIJ has developed, implemented and maintained four vibration calibration systems as primary national metrology standard in the field of vibration acceleration in Japan for more than 10 years. However, due to recent multiple disasters, we address further improvement of these systems to reduce the measurement uncertainty and to streamline the calibration work using them last few years. This paper describes our recent progress of development and future prospects as for these systems in AIST/NMIJ.

Keywords: Vibration, Acceleration standard.

1. INTRODUCTION

AIST/NMIJ has supplied primary national metrology standard in Japan and participated international comparisons to confirm equivalency of our measurement capability. AIST/NMIJ has developed four primary calibration systems in compliance with ISO 16063-11 [1] for national metrology standard in the field of vibration acceleration. They have been classified by their calibration frequency arrange as follows.

System 1: Very low frequency range: 0.1 Hz to 2 Hz
System 2: Low frequency range: 1 Hz to 200 Hz
System 3; Middle frequency range: 20 Hz to 5 kHz
System 4; High frequency range: 5 kHz to 10 kHz

Due to recent multiple disasters, further reliable vibration measurement including metrology standard has been required from across the world. Therefore, we addressed further improvements of these systems last few years.

This paper outlines the current progress of primary national metrology standard in the field of vibration acceleration in AIST/NMIJ. We also conclude the future prospects in Japan.

2. CALIBRATION SYSTEMS FOR VERY LOW AND LOW FREQUENCY RANGE

Both of System 1 and System 2 have been applied to calibrate servo accelerometers and earthquake sensors.

Figure 1 shows a photo of System 1. System1 consists of a combination of modified Michelson type of homodyne laser interferometer for fringe-counting method and sine approximation method in compliance with ISO-16063-11[1] and an electro-dynamic vibration exciter with airborne slider which maximum stroke is 36 cm. The motion of vibration exciter is horizontal direction. Applicable acceleration amplitude range lies from 0.03 m/s^2 to 10 m/s^2.

Figure 2 shows a photo of System 2. System 2 consists of combination of Michelson type of homodyne laser interferometer for fringe-counting method and an electro-dynamic vibration exciter. The moving part of the vibration exciter is supported by pressurized oil. The vibration exciter can generate both motion in vertical and horizontal direction by changing the attitude of vibration exciter. Applicable acceleration amplitude range lies from 0.5 m/s^2 to 10 m/s^2.

System 1 and System 2 had been in operation by using fringe counting method since 2005. NMIJ participated in the international key comparison APMP.AUV.V-K3 using these systems just after the Great East Japan Earthquake. Then, we had found that it is inconvenient to use two systems to

Figure 1 Photo of System 1

Figure 2 Photo of System 2

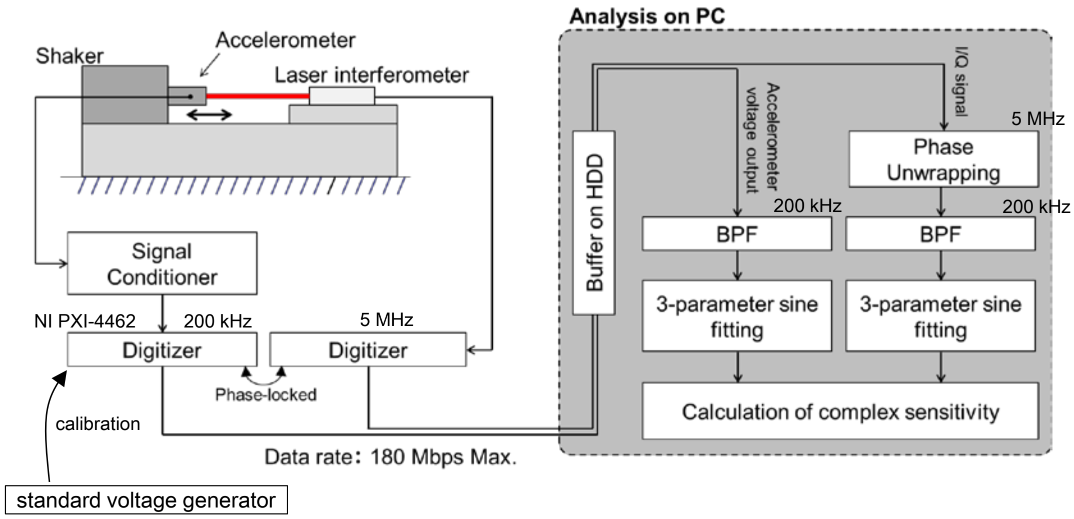

Figure 3 Overview of the improved System 1

cover the calibration frequency series of 0.1 Hz to 20 Hz using two systems and our systems do not always have calibration capability enough to respond to the expectations of domestic industry in some frequency series. Therefore, three years ago, System 1 was improved by installing new signal processing instruments and software specially designed to apply sine approximation method as shown in previous report [2], then the stable calibration with smaller amount of uncertainty was implemented and the upper limit of calibration frequency range extended to 10 Hz.

However, the applicable frequency range had been still restricted due to some reasons such as a mechanical resonance. We have continuously made further improvement and the improved System 1 was completed as shown in figure 3. As a result, the calibration frequency range of System 1 lies from 0.1 Hz to 200 Hz, and smaller amount of uncertainty was achieved. Figure 4 shows typical comparison results between System 1, System 2, and improved System 1 by calibrating a reference accelerometer. The results of improved System 1 are in good agreement with both results of the System 1 and System 2. Although terrible fluctuation of the measurement results is observed in low frequency range of 0.1 Hz to 0.5 Hz in System 1, the results is stable in improved System 1 and the smaller amount of uncertainty is achieved in the calibration frequency range of 0.1 Hz to 100 Hz. We participated CCAUV.V-K3 by using this improved System 1. The improved System 1 would have enough calibration capability as shown in final report of CCAUV.V-K3 [3].

As future prospect, we will apply only System 1 as a

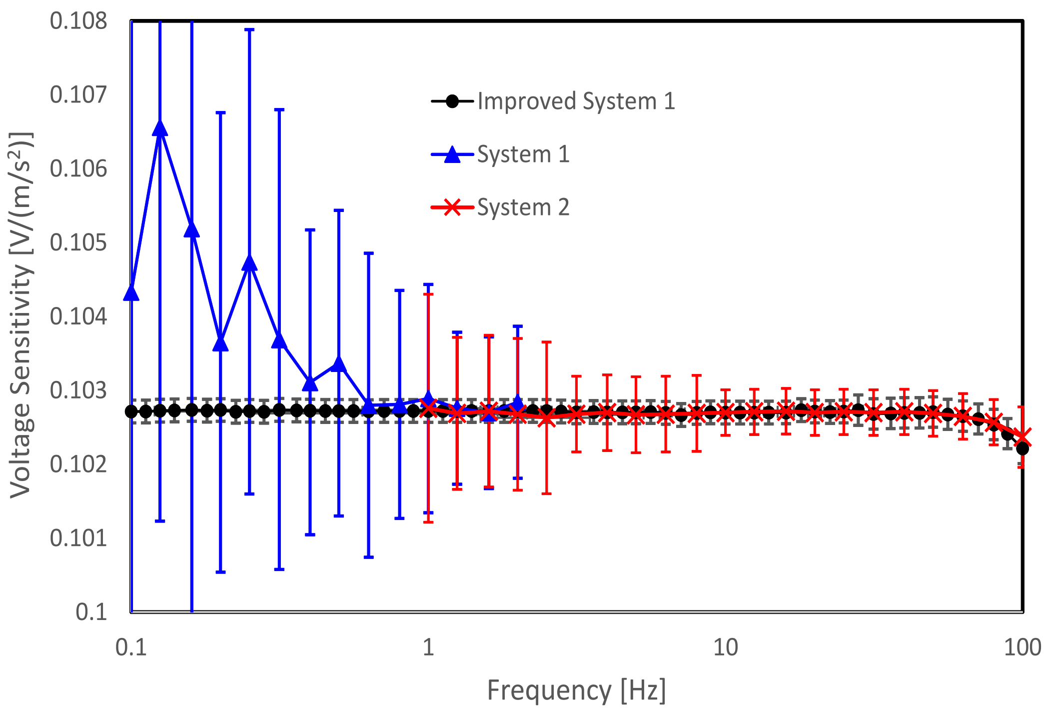

Figure 4. Comparison results between System 1, System 2, and improved System 1.

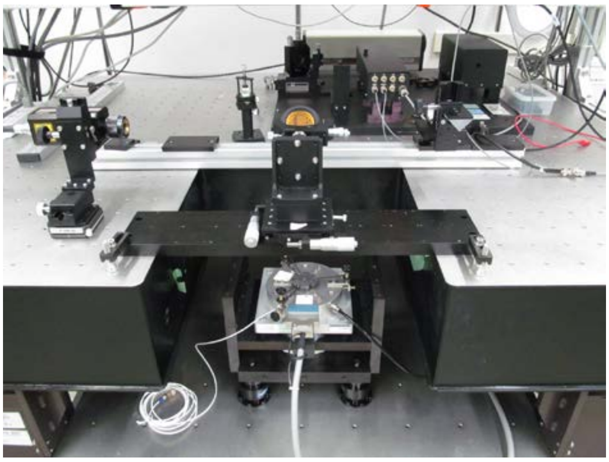

Figure 5. Photo of System 3

Figure 6. Photo of System 4

national metrology standard for low frequency range from 0.1 Hz to 200 Hz, continue to expand the lower limit calibration frequency below 0.1 Hz and hope to promote collaboration research work in seismology.

3. CALIBRATION SYSTEMS FOR MIDDLE AND HIGH FREQUENCY RANGE

System3 and System 4 have been applied to calibrate piezoelectric and piezoresistive types of accelerometers within the frequency range of 20 Hz to 10 kHz. Firgure 5 and figure 6 shows photos of System 3 and System 4, respecitvely. Both systems consist of several similar components; electro-dynamic vibration exciter with airborne armature, modified Michelson type of homodyne laser interferometer, and signal processing software specially designed to apply sine approximation method [4], [5]. These systems are quite different in laser interferometer part. System 3 has the laser interferometer with single optical path and System 4 has the laser interferometer with double optical path. Their calibration capabilities were validated by participation to international key comparisons CCAUV.V-K2 [6].

Wide variety of demands for our calibration service and collaborated/contracted research have been given from many customers in Japan since Great East Japan Earthquake. Therefore, the improved efficiency both in our calibration work and collaborated/contracted research work should be strongly quested. As one of solutions, we address to develop one unified calibration system for whole frequency range from 20 Hz to 10 kHz by improvement of System 4.

The applicable lower limit calibration frequency on this unified system can expand by improving anti-vibration table and installing signal processing instruments synchronized with common high accuracy clock and original signal processing software. The calibration capability of the improved System 4 is validated by making a comparison between the calibration results from improved System 4 and current System 3. Figure 7 shows a typical comparison results. As a result, a good agreement with the calibration

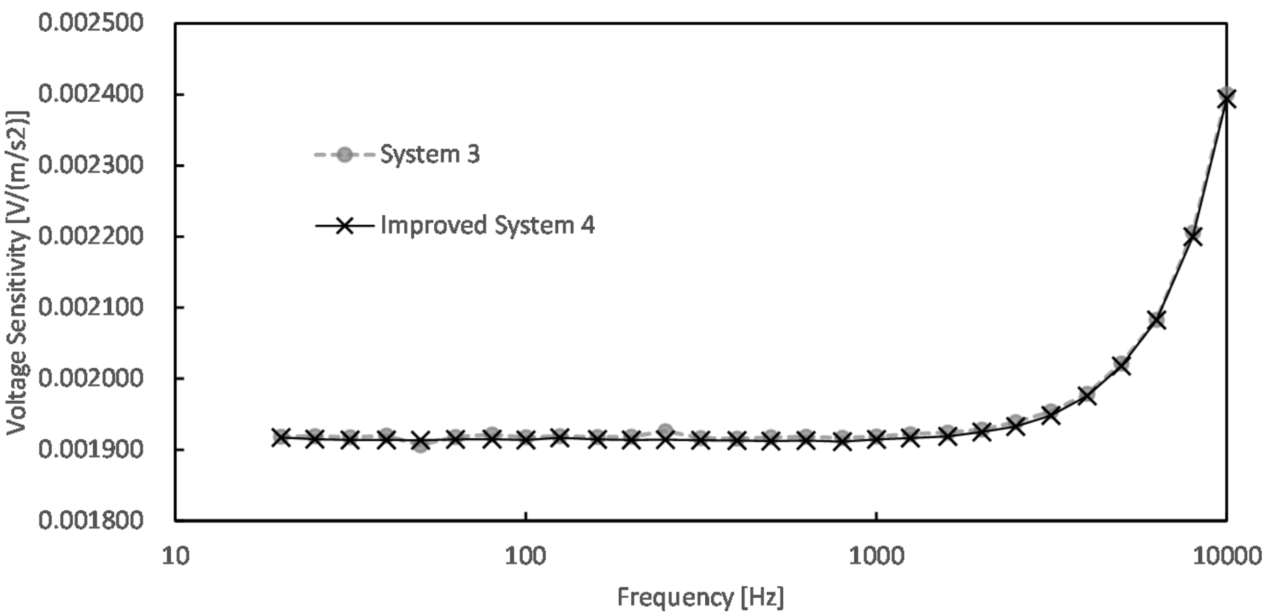

Figure 7. Consistency between improved System 4 and current System 3

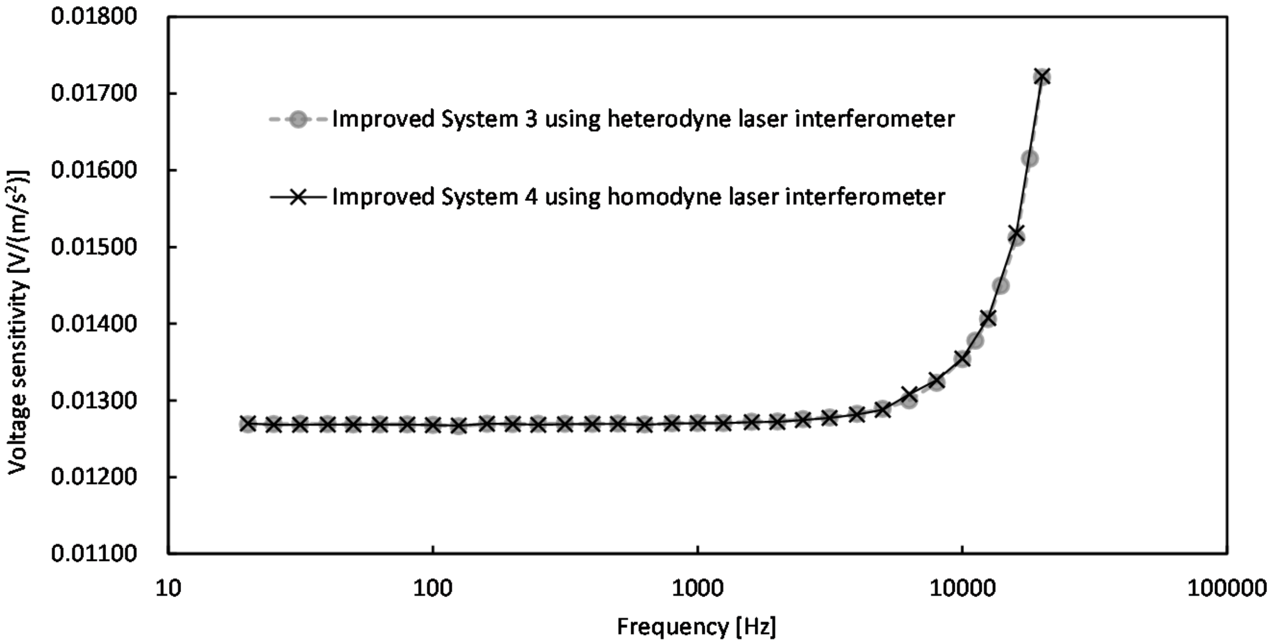

Figure 8. Approach of expansion in the frequency range up to 40 kHz

results from them is observed and the improved System 4 would have enough calibration capability in the calibration frequency range of 20 Hz to 10 kHz. Furthermore, in order to contribute to the measurement technology dissemination to private enterprises through collaborative/contracted research work, we are planning to develop vibration measurement technology to achieve upper limit calibration frequency to 20 kHz or beyond by using heterodyne laser interferometer. Figure 8 shows preliminary experimental results both of improved System 4 using current homodyne laser interferometer with double optical path and improved System 3 using heterodyne laser interferometer. The both results are in good agreement with each other and these interferometers would be available for the calibration up to 20 kHz with no consideration for uncertainty estimation.

The use of homodyne laser interferometer would become more difficult in higher frequency range more than 20 kHz even if the current laser interferometer with double optical path is applied, because the displacement amplitude extremely becomes small. We will develop the calibration system suitable for higher frequency range with consideration for use of heterodyne laser interferometer.

4. SUMMARY

The current progress of vibration calibration system in NMIJ was introduced in this paper. We will continue to improve these systems to participate next international key comparison and then, will contribute global economic activity from a viewpoint of metrology. Additionally we will also continue to develop novel vibration measurement technology and then, will respond social demands from a viewpoint of academic base such as seismology.

5. REFERENCES

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