Acoustical periodic test of sound level meter based on smartphone application using free-field method

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Abstract. The number of smartphone-based application software for noise measurement has been increasing recently. Some application software has complete features of the sound level meter such as frequency weighting and time averaging. They have been used for field noise measurement. However, the reliability of the smartphone-based sound level meter as a measurement instrument has not known yet. In this paper, we tested the smartphone-based sound level meter application software according to the international standard for sound level meter calibration IEC 61672. The parameter of self-generating noise, frequency weighting, and long-term stability in a fully anechoic chamber was measured. We evaluated the class of the smartphone-based sound level meter from the deviation of the measured parameter with the tolerance value described in the standard. The practical implementation of the calibration method is also discussed.

Keywords: SLM, smartphone-based application, calibration, free-field method, self-generated noise, frequency weighting, long term stability.

1. Introduction
In the last ten years, the smartphone has become an absolute necessity in a daily life [1]. As the multitasking handheld device, it can be stated that this gadget has the capability to assist most activities for human-being [2]. The most of other electronical devices and instruments can be imitated by this device, or even has a better quality for some aspect. Moreover, without exception for measurement activity, it is featured the supporting hardware and software that make it able to perform a scientific measurement [3].

In the acoustic field, the number of smartphone-based application software for noise measurement has been increasing recently. Some application software has complete features of the sound level meter such as frequency weighting and time averaging. They have been used for field noise measurement. However, the reliability of the smartphone-based sound level meter (SLM) as a measurement instrument has not known yet. Hence, it is recommended strongly to be conducted a test and a calibration periodically to identify the performance and durability of this handheld gadget to be used further [4] [5].

Hereinafter, the purpose of this work is to test the smartphone-based sound level meter application software according to IEC 61672-3. Evaluation of the class of the smartphone-based sound level meter from the deviation of the measured parameter with the tolerance value described in IEC 61672-1 also is conducted.
According to IEC 61672, the SLM testing and calibration parameter is required [6] [7]. This paper will be focused to the parameter related to the performance when it is utilized for noise measurement, and it consists of self-generated noise, long term stability and frequency weighting. For the last parameter, it is considered to be the main parameter that should be applied, either for measurement or calibration. Moreover, it comprises A-frequency weighting, C-frequency weighting, and Z-frequency weighting. The first and second weighting correlates to human hearing response at the low to middle level and high level respectively. Meanwhile, for the last weighting, it is considered as zero or flat weighting without any correction [8]. Because the first weighting is the most weighting that found in smartphone application, it will be discussed further in this paper.

2. Methodology

In this work, the calibration of SLM is conducted for the aforementioned parameters. The method that used to realize the calibration of SLM and the smartphone based on SLM is the free field method that generally has been performed for calibration, testing, and measurement of other acoustical instruments such as a free-field microphone, noise dosimeter, sound calibrator, and loudspeaker [9]. Furthermore, this method is utilized a reference microphone that represent a standard device and full anechoic chamber with the finite volume and installed sound absorber in its surfaces, and moreover, it has a capability to minimize background noise optimally [10]. In addition, when this method is applied, only the sound source, acoustic transducers and unit under test (UUT) are placed inside the chamber, meanwhile for the other apparatus are in its outside as seen in figure 1. The following are the devices and facility used in the free-field method for this work.

2.1. Calibration Standard instrument

As the primary standard of acoustic measurement and calibration, the laboratory standard of microphone (LS) is the common artefact that used by the National Metrology Institution. By having low sensitivity to environment change and well long-term stability, it is appropriate to be used either for pressure or free field conditions. In addition, the response frequency that provided by this transducer is applicable for the wide range of frequency, where it has flat frequency response up to 20 kHz.

2.2. Calibration Medium

As mentioned above, the free field method is conducted by using the full anechoic chamber that has the dimension of (10 x 10 x 10) m³. In addition, it has a capability to reduce noise optimally with the measured background noise is below 15 dB, and the frequency cut off is up to 30 Hz.

2.3. Unit Under Test

The test SLM that used in this work comprise the original SLM that represented by class 2 SLM, and several smartphones that installed software applications based on SLM function. The chosen
smartphones are iPhone 6 with its iOS operating system, and the android smartphones consist of Samsung Galaxy S5, Xiaomi Redmi 5 plus, and Advan G5. Therefore, the software application that used in this calibration are Dbx and SPL meter, where these applications are chosen based on the availability in two platform shop that represented by Appstore for iPhone, and Google Play for the android smartphones. In addition, number of users and the availability of A-frequency weighting are also the main component to be considered on selecting the test smartphones.

2.4. The Apparatus and Other Facilities
The supporting devices also utilized to assist SLM calibration process. To ensure their indication correctness and level of confidence in accordance with calibration result, the devices has been calibrated and traceable to the National Metrology Institute (SNSU BSN). Moreover, The equipment and facilities used in this calibration work are as follow:

| Equipment/Facilities                      | General Specification                                                                 |
|------------------------------------------|----------------------------------------------------------------------------------------|
| Function generator (sine generator)      | Fluke 282 Arbitrary Waveform Generator: Double channel, frequency range 0.1 mHz – 16 MHz, resolution 7 digits, frequency accuracy 10 ppm/year |
| Power amplifier                          | Brüel & Kjær type 2716: Maximum voltage gain 30 dB, range of frequency response 20 Hz - 20 kHz, output impedance 0.03 Ω |
| Reference microphone LS2                 | Brüel & Kjær type 4180, Primary standard/working standard of acoustic measurement     |
| Acoustic calibrator                      | Brüel & Kjær type 4231                                                                |
| Measuring amplifier                      | Brüel & Kjær type 2610                                                                |
| Pulse analyzer (Sound analyzer)          | Brüel & Kjær type 3650-C: PC with LAN interface, PULSE software, and IDAe-based data acquisition front-end |
| Digital voltmeter                        | Resolution 6 ½ digits                                                                |
| Single directional loudspeaker (loudspeaker) | Frequency range of 20 Hz – 20 kHz, the flat response between 63 Hz – 16 kHz.           |
| Full anechoic chamber                    | Dimension 10 m x 10 m x 10 m, rock wool absorber, 0.1 dB deviation due to characterization and positioning of unit under test at 1 meter in front of a sound source. |
| Class 2 SLM                              | Smartphone based on SLM                                                               |

3. Experiment
3.1. Self-Generated Noise Measurement
Hereafter, the experiment for self-noise measurement was conducted by setting up the apparatus as shown in figure 2.
From this figure, SLM or smartphone was placed inside the anechoic chamber. It was set to the lowest range of SPL and A-frequency weighting. After that, SPL was recorded after 30 second.

3.2. Long Term Stability Measurement
The experiment set up of the long-term stability measurement using the free-field method is shown in figure 3.

From the figure, SLM was placed inside the chamber and the weighting was set to A-frequency weighting. After that, by applying the apparatus that set so as seen on this figure, the SPL of 94 dB at the frequency of 1000 Hz was generated by the sine generator, was read by SLM. After the duration time of 30 minutes, the SPL was recorded.

3.3. A-Frequency Weighting Calibration
The last parameter that represented by A-frequency weighting calibration was conducted by setting up the system equipments that shown in figure 4, figure 5, and figure 6.
From this figure, a reference microphone was placed inside the full anechoic chamber and was connected to an acoustic calibrator. This calibrator was set to the nominal SPL of 94 dB and frequency of 1000 Hz. After that, by activating the calibrator, the reference value in voltage unit was indicated by the digital voltmeter. The second step of this section is shown in figure 5. The reference microphone was installed at the distance of 1 meter from the loudspeaker that was connected to the power amplifier and the sine generator. After that, by selecting the measurement frequency and adjusting an input level of the generator, the digital voltmeter was arranged so to make the display indicated the same value as the previous step.

Finally, by replacing the reference microphone with the UUT at the same position inside the full anechoic chamber and generating the same frequency and level of acoustic signal through the calibration system, the SPL was recorded by the UUT. After that, these SPL values was compared and evaluated according to IEC standard that discussed in the next section.

4. Result and Discussion
The calibration result of the SLM and smartphone based on SLM for the aforementioned parameters is described in this section. The first parameter that represented by the self-generated noise measurement is shown in table 2.
Table 2. the self-generated noise measurement result

| Instrument/Software       | SPL (dBA) |
|---------------------------|-----------|
| Class 2 SLM               | 31.7      |
| dBX (iPhone6)            | 35.4      |
| dBX (Galaxy S5)          | 35.8      |
| dBX (Xiaomi Redmi 5 Plus) | 36.4      |
| dBX (Advan G5)           | 36.7      |
| SPL meter (iPhone6)      | 37.9      |
| SPL meter (Galaxy S5)    | 37.8      |
| SPL meter (Xiaomi Redmi 5 Plus) | 37.4  |
| SPL meter (Advan G5)     | 38.2      |

This table describes that the smartphones based on SLM have bigger self-noise for all platform compared to the original sound level meter (SLM) that provide the internal noise is 31.7 dBA. For the used smartphones, the maximum internal noise is found in Advan G5 for SPL meter application that its value is 38.2 dBA. Meanwhile, dBX software that installed in iPhone 6 has the minimum self-noise that contribute the value is 35.4 dBA. Moreover, the dBX application has tendency to be smaller self-noise compared to the other application, where the obtained deviation among the software is about 2 dBA. Subsequently, the result measurement for the second parameter is shown in table 3 related to the stability when it used for long duration time.

Table 3. The long-term stability measurement result

| Instrument/Software       | Deviation of SPL (dBA) | Acceptance limit of deviation |
|---------------------------|------------------------|-----------------------------|
| Class 2 SLM               | 0.1                    | 0.3                         |
| dBX (iPhone6)            | 0.2                    |                             |
| dBX (Galaxy S5)          | 0.1                    |                             |
| dBX (Xiaomi Redmi 5 Plus) | 0.2                    |                             |
| dBX (Advan G5)           | 0.3                    |                             |
| SPL meter (iPhone6)      | 0.3                    |                             |
| SPL meter (Galaxy S5)    | 0.3                    |                             |
| SPL meter (Xiaomi Redmi 5 Plus) | 0.3  |
| SPL meter (Advan G5)     | 0.3                    |                             |

Similar with the previous measurement section, the smartphones based on SLM have bigger deviation of SPL for all platform compared to the sound level meter (SLM) exclude for the dBX application installed in Galaxy S5 that has equal deviation value. For the SPL meter application, the obtained deviation is same among these smartphones, where they provide value is 0.3 dBA. In addition, the recorded environment condition when take the measurement data for these instruments is difference but
not significant, where it is about 1 °C. Even though this alteration is slight relatively, the effect to the measurement result should be considered into the uncertainty budget that will be explained in the next paper. However, these deviations value were still in the tolerance limit that required by IEC standard. For the last parameter that represented by the A-frequency weighting calibration, the result is shown in figure 6 and figure 7.

**Figure 6. Curve of A-frequency weighting deviation for dBX software**

![Deviation of A-Frequency Weighting for dBX Software](image1)

**Figure 7. Curve of A-frequency weighting deviation for SPL meter software**

![Deviation of A-Frequency Weighting for SPL meter Software](image2)

From this figure, the blue dash line represents the acceptance test limit value of deviation provided by IEC standard. For the original SLM, the measured deviation value is acceptable for whole frequencies as seen in the figures 6 and figure 7, where it denoted by the yellow solid line. While for smartphones using both of application software, iPhone 6 and Galaxy S5 provide the inlayer deviation value at frequency of 63 Hz to 2000 Hz. After that, it tends to deviate to exceed the limit value at the frequency of 4000 Hz to 8000 Hz. Meanwhile, the appropriate deviation value also found for Redmi 5 plus from the initial frequency to 2000 Hz. After that, the same condition also found as the previous smartphones. Therefore, Advan G5 has the acceptable value at frequency of 63 Hz to 1000 Hz. Afterwards, it tends to be outlayer for the next frequency.
From whole result, the test smartphones have the admissible value of their stability because the used signal in this experiment is the stabilized pure tone signal. Moreover, the difference type of the signal will provide the difference result. Other result was reported when using a broadband signal such as the pink noise or white noise, where the result shown that a bigger deviation was obtained between SLM and the used smartphones. In addition, the integrated microphone for these smartphones are vary of their front depth, that have a possibility have a difference correction for all smartphones. Therefore, this result does not cover the acoustic quality for the used smartphone completely because they have been tested with the difference of usage level.

5. Conclusion
In this work, implementation of test the smartphone-based sound level meter application software according to IEC 61672-3 has carried out at The Deputy of National Measurement Standard BSN by Research Group for Acoustics and Vibration. From the results, all platform software has bigger value of self-noise and long-term stability compared to the class 2 sound level meter (SLM). Meanwhile, at the frequency of 2000 Hz – 8000 Hz, the deviations tend to be outlayer for all platform for the A-frequency weighting calibration.

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