Comparison of sound level meter calibration for frequency weighting parameter using coupler method

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Abstract. A large number of industrial needs to the sound level meter (SLM) calibration has encouraged the laboratory to develop a qualified calibration system. As one of the SLM calibration methods required by the standard, the coupler method is considered as the most convenient to be implemented, especially for the secondary laboratory. Therefore, the aim of this work is to compare the SLM calibration for the frequency weighting parameter by this method using the instrument standards that comprise of a multifunction acoustic calibrator and a working standard of pressure microphone (WS2-P Microphone). Moreover, the result of frequency weighting calibration using these standards, therefore, is compared to the reference value required by IEC 61672-1. From the result, the deviation values of these standards are obtained relative to the reference. At the low to middle frequencies, the deviation values are slight relatively, while at the higher frequency, it tends to bigger. In addition, these methods also support the development system of noise dosimeter and sound level meter calibration that still under research through the scheme of Incentive Research Program for the National Innovation System in 2020.

Keywords: Frequency weighting, Sound level meter, Calibration, Coupler Method, Multifunction Acoustic Calibrator, WS2-P Microphone

1. Introduction

Development of acoustic devices based on smart-audio technologies including wireless networks, storage, data transferring, communication systems, and go green facilities, has shown a rapid acceleration for the last decades significantly [1]. Sound level meter, one of the acoustic instruments that currently manufactured based on this technology, has been applied widely by users. As a handheld gadget that has the main function to monitor loudness in an occupancy area, it has become a primary need not only for manufacturer industries and contractor companies, but also for the research and academic institutions, medical foundation, and private. By the reason of its frequent use, therefore, it is recommended strongly to be conducted a correction check and a calibration for frequency weighting parameter as the major feature of this device [2] [3].

Currently, there are several methods to calibrate the sound level meter, and commonly, it has been implemented either by the government institution or the private calibration laboratory using the free field facilities. However, the realization of calibration with this method is limited in Indonesia due to the complexity issue and business priority, especially for the private calibration laboratory. Furthermore,
to comply with the traceability needs of the stakeholder, and support the secondary calibration laboratories, the development of this instrument calibration has been realized by BSN as the representative of the National Metrology Institute in Indonesia, using a coupler method. Moreover, this method can be implemented by using several instrument standards required by the IEC standard, and it comprises a multifunction acoustic calibrator and working standard of pressure microphone (WS2-P Microphone). The former is the laboratory instrument that provides the reference sound pressure level (SPL) and multi frequencies. While for the latter, it is the secondary standard of pressure type of microphone that utilizes an acoustic comparison coupler as the research prototype that has the role as a mechanical sound source and a portable calibration medium. Therefore, the purpose of this work is to conduct the calibration of SLM for the frequency weighting parameter by the coupler method using the aforementioned standards. Moreover, the result of frequency weighting calibration using these standards, therefore, is compared to the reference value required by IEC 61672-1.

2. Basic theory
In the measurement of sound, frequency weighting is considered as the main parameter that should be applied, either for measurement or calibration. It is defined as an electronic filter that is integrated inside a sound level meter where it correlates the objective measurements with the human subjective response as mentioned in international standards IEC 61672 specifically [4]. Therefore, the human ear is sensitive to sound at frequencies between 500 Hz and 6 kHz effectively compared with the lower and higher frequencies. When applying measurement of sound pressure level, it is important that the acoustic instrument, either sound level meter or noise dosimeter, has the capability to provide an accurate indication of the person of hearing actually. Furthermore, frequency weightings perform this reading by providing more weight to different frequencies over others [5].

There are three types of frequency weightings, and it consists of A-weighting, C-weighting, and Z-weighting. The first weighting is found commonly in sound level meter that its readings conform to a human hearing response [6]. Moreover, it is the most common used in sound measurement and it also covers the full frequency range of 20 Hz to 20 kHz, and therefore, it works with adjusting the indication of sound pressure level (SPL) that refer to the sensitivity of the human ear [7]. Besides, this weighting is a mandatory parameter for measurements of hearing damage risk. The result of sound measurements based on A-weighting are commonly stated as dB(A) or dBA [8]. Meanwhile, for the second weighting, it is found in the sound level meter that conform to a human hearing response at the high sound pressure level. The C-weighting has more effect at the low-frequency sounds on the human ear compared with the A-weighting, and it is essentially flat or linear between 31.5 Hz and 8 kHz. Commonly, it is used for peak sound pressure level and an impulse noise measurement. The indication using this weighting are typically displayed as dB(C) or dBC [5] [9]. The last is Z-weighting which has a flat frequency response of 8 Hz to 20 kHz, and this is the actual noise that is determined without weighting calculation for the human ear (Z for zero). Moreover, it is often used in octave band analysis and determining environmental noise. Measurements unit of this weighting are shown as dB(Z) or dBZ [5] [9]. The correction value curve of the frequency weighting is shown in figure 1.
Figure 1. Frequency weighting curves (one third octave bands)

The first of two aforementioned weighting will be discussed further in this work for the reason that most of the SLM has these weightings parameter, meanwhile for the last weighting, it is an optional parameter and additional feature for the specific sound level meter that found for class 1 ordinarily.

3. Methodology

In this work, the calibration of SLM is conducted for A-frequency weighting and C-frequency weighting at the frequency range of 63 Hz ~ 16 kHz [10]. As mentioned above, the used method is the coupler method that utilized two standards consist of the Multifunction Acoustic Calibrator, later is written as coupler method-1, and WS2-P Microphone as another method (coupler method-2). The explanation of the coupler method using the aforementioned standards will be discussed in this work singly.

3.1. Coupler Method-1

Implementation of this method is quite simple. As mentioned above, this method uses the multifunction acoustic calibrator that is the laboratory precision instrument, and, therefore, it is capable to deliver a stable SPL with a frequency varying from 31.5 Hz to 16 kHz in octave steps. Moreover, it comprises a signal controller, a control unit, a loudspeaker, a reference microphone, a temperature sensor, a pressure sensor, a user interface, and a communication interface for receiving from a PC connection (5).

Additionally, to optimize the calibration process, it is necessary to use an insulation box as the calibration medium, where it is made from a wood with a thickness is 10 cm, and inside this chamber is installed acoustic foam as the absorber. In the calibration process, SLM is put into this box, and its SPL indication is compared directly to the SPL generated by the calibrator.

3.2. Coupler Method-2

For this method, it is conducted using the pressure working standard microphone as the reference that is designed for high-precision coupler measurements. It is optimized to have a flat frequency response in a pressure field, and appropriate to be used for conducting measurements in small, closed couplers, and reflective surfaces. Afterward, it also has a stainless-steel diaphragm to ensure long-term stability and mechanical robustness, as well as to maintain their inherent low noise floor and high stability even when used in environments with a combination of high humidity and temperature.

In addition, the calibration using this method is performed by utilizing the acoustic comparison coupler as the research prototype that has the role as a mechanical sound source and a portable calibration medium as shown in figure 2. Subsequently, it is manufactured using a solid aluminum with a density of 2700 kg.m⁻³. Moreover, inside this prototype is installed a stabilized loudspeaker, a glass wool with the density of 100 kg.m⁻³, a super low noise connector, a concave space that has the form of half-round, and an additional adaptor made from a solid foam black material that has a dual coupler on its surfaces. The diameter size of its coupler is a half-inch or about 1.33 cm, and has a depth of 1.50 cm.
In contrast to the multifunction acoustic calibrator that has a built-in equipment system, the signal controller is not a part of the design of this prototype. Nevertheless, an external generator can be used as the supporting device optionally, and, therefore, its performance is reasonable because it has a wide range of frequencies and levels that is capable to be applied to the calibration system.

Therefore, there are some steps to calibrate SLM using this second method. The first step is initiated by determining a reference sound pressure level using the stable sound generator use an acoustic calibrator at SPL of 94 dB and the frequency of 1000 Hz. Subsequently, this reference SPL is re-generated by the stabilized loudspeaker inside the acoustic comparison coupler to the microphone and sound level meter test simultaneously. Moreover, because this prototype is designed to be a calibration medium concurrently, the anechoic chamber is not necessary to be used in this method. In addition, the comparison value of SPL between standard and SLM is applied at the same time, so this method is also known as the comparison method.

The device under test that is used in this work is the class-1 of sound level meter that has range SPL and frequency of 30 dB – 120 dB and 31.5 Hz – 20 kHz respectively.

4. Experiment

4.1. Coupler Method-1
Hereafter, the experiment set up of sound level meter calibration for frequency weighting parameter use the second method is shown in figure 3.
From this figure, a coupler system as the part of multifunction acoustic calibrator was installed in the insulation box, while the calibrator itself was located outside of this chamber. After that, SLM was put into the coupler inside the box. Afterwards, by controlling the frequency and the SPL are 63 Hz and 94 dB respectively, and generating an acoustic signal through the calibrator, the SPL was read by this instrument after selecting the parameter to A-weighting. All the above same steps are also applied for the C-weighting parameter.

4.2. Coupler Method-2

The experiment set up of sound level meter calibration for frequency weighting parameter using the last method is shown in figure 4, figure 5, and figure 6.

![Figure 4](image1.png)

**Figure 4.** Determining of sound pressure level using acoustic calibrator

From the figure, the working standard microphone was put into an acoustic calibrator. The SPL of 94 dB at the frequency of 1000 Hz was generated by the calibrator and read by the sound analyzer in the DC voltage unit as the reference value. After that, the microphone was entered into the acoustic comparison coupler, and the system was set so to make it as the figure 5.

![Figure 5](image2.png)

**Figure 5.** Providing of reference SPL through the sound source in a pressure condition

Subsequently, by applying some steps include selecting the frequency at 63 Hz, organizing the input level, and generating the signal through the generator, the value of the sound analyzer was configured so to make the display indicated the same value as the reference. For the frequency of 125 Hz to 16 kHz, the same step was also conducted.

Hereinafter, a dual coupler was installed into the acoustic coupler. After that, the microphone and SLM were put into a pair of coupler holes on this converter. Afterward, the apparatus was set as seen in figure 6.

![Figure 6](image3.png)

**Figure 6.** Calibration SLM using a reference value of the working standard microphone
5. Result and Discussion

The measurement results of the sound level meter calibration for frequency weighting parameter using the three methods are shown in the figure below, where the A-weighting result is indicated in figure 7, while figure 8 describes the result of C-weighting.

![A-weighting curve](image)

**Figure 7.** The measurement curve of A-weighting

From this figure, the standard of A-weighting values is taken from IEC 61672-1: 2002. For the calibration of the sound level meter using the aforementioned methods, the obtained A-weighting curves tend to be similar of its trend to the standard curve from the frequency of 63 Hz to 4000 Hz. After this frequency, it tends to diverge to the reference curve where it is found that the second method has a bigger value at the frequency of 8000 Hz, and therefore, it decreases to the last frequency. Meanwhile, the difference curve trend also is obtained for the first method, where it decreases at the frequency of 4000 Hz to 16000 Hz.

![C-weighting curve](image)

**Figure 8.** The measurement curve of C-weighting

Subsequently, the calibration result of C-weighting is shown in figure 8, and the standard of this weighting value is also taken as same as the A-weighting. For the result calibration of sound level meter using the two standards, the obtained C-weighting curves have a similar trend with the A-weighting curves, where the trend to be identical to the standard curve that starts at the frequency of 63 Hz to 4000 Hz.
Hz. After this frequency, the difference of curve trend is found among these standards. For the former, it decreases to the frequency of 16000 Hz. Meanwhile, the latter has the similarity of the curve trend to its A-weighting curve, where the deviation value has the tendency to go up at the frequency of 8000 Hz. After that, it leans to 16000 Hz. Furthermore, the deviations of weighting values relative to the acceptance limit taken from IEC 61672-1:2002 also is explained in the results, where it is shown in table 1 and table 2.

Table 1. Deviation of A-weighting relative to the acceptance limit

| Frequency (Hz) | Deviation of A-weighting (dBA) | Acceptance limit (dBA) |
|---------------|-------------------------------|-----------------------|
|               | Multifunction Acoustic Calibrator | WS2-P Microphone | IEC 61672-1:2002 |
| 63            | 0.0                           | 0.2                  | ± 1.5               |
| 125           | 0.0                           | 0.1                  | ± 1.5               |
| 250           | 0.0                           | -0.2                 | ± 1.4               |
| 500           | 0.0                           | -0.2                 | ± 1.4               |
| 1000          | 0.3                           | 0.1                  | ± 1.1               |
| 2000          | -0.1                          | 0.2                  | ± 1.6               |
| 4000          | -0.7                          | 1.0                  | ± 1.6               |
| 8000          | -2.7                          | 0.8                  | + 2.1 ; - 3.1       |
| 12500         | -5.4                          | -5.5                 | + 2.6 ; - 6.0       |
| 16000         | -7.1                          | -9.2                 | + 3.5 ; - 16.0      |

From table 1, it is indicated that the obtained deviation of A-weighting using the two standards is still in the permissible limit value of the aforementioned frequencies. Therefore, for the low to middle frequencies, the first standard provides finer deviation values than the other. Meanwhile, the second standard has the tendency to has the bigger deviation values relative to others, where it is found at the range of -0.2 dB to 0.2 dB beyond these frequencies. Whilst, in contrast to the low-mid frequencies, deviation values that given by the first standard lean to increase at the high frequencies, where the maximum deviation is found at the frequency of 16000 Hz. Therefore, the second standard has a similarity at these frequencies, where the maximum deviation also is found at the frequency of 16000 Hz.

Table 2. Deviation of C-weighting relative to the acceptance limit

| Frequency (Hz) | Deviation of C-weighting (dBC) | Acceptance limit (dBC) |
|---------------|-------------------------------|-----------------------|
|               | Multifunction Acoustic Calibrator | WS2-P Microphone | IEC 61672-1:2002 |
| 63            | 0.0                           | 0.2                  | ± 1.5               |
| 125           | 0.0                           | 0.1                  | ± 1.5               |
| 250           | 0.0                           | -0.2                 | ± 1.4               |
| 500           | 0.0                           | -0.2                 | ± 1.4               |
| 1000          | 0.3                           | 0.1                  | ± 1.1               |
| 2000          | -0.1                          | 0.2                  | ± 1.6               |
| 4000          | -0.7                          | 1.0                  | ± 1.6               |
| 8000          | -2.7                          | 0.8                  | + 2.1 ; - 3.1       |
| 12500         | -5.4                          | -5.5                 | + 2.6 ; - 6.0       |
| 16000         | -7.1                          | -9.2                 | + 3.5 ; - 16.0      |

Meanwhile, the same conditions were also found in table 2, where it is shown that the obtained deviation of C-weighting using the two standards is still in the tolerance limit of the whole frequencies. Therefore, from the frequencies of 63 Hz to 2000 Hz, the former has smoother its deviation values than the others, where it has a slight difference at the frequency of 63 Hz and 125 Hz, and no correction at the remaining frequencies. Meantime, the latter tend to have the bigger deviation value relative to others, where it has the deviation values at the range of -0.6 dB to 0.1 dB beyond these frequencies. Whilst, in contrast of the low-mid frequencies, deviation values supplied by the former at the high frequencies have similar
values with the A-weighting. Passingly, the latter has smaller to others, where the maximum deviation also is found at the frequency of 16000 Hz. From the whole result, the two obtained weightings have slight deviation values at the low to middle frequency to the reference when using the coupler method exclude at the high frequency that has the deviation values are large relatively. However, it still within a tolerance limit required by IEC 61672-1.

6. Conclusion
In this work, the calibration of sound level meter based on frequency weighting parameter at the frequency of 63 Hz to 16000 Hz in an octave band using the methods that consist of absolute method, coupler method, and dual coupler method was carried out at The Deputy of National Measurement Standard BSN by Research Group for Acoustics and Vibration. From the results, the obtained deviation values of the two weightings are still in the tolerance limit required by IEC 61672-1: 2002. Moreover, the two obtained weightings have slight deviation values at the low to middle frequency to the reference when using the coupler method. Contrarily, it tends to increase at the higher frequencies. In addition, these methods support the development of system of noise dosimeter and sound level meter calibration that still under research through the scheme of Incentive Research Program for the National Innovation System in 2020.

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