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Tips for making standardized measurements with a sound level meter

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ABSTRACT
Many measurement standards can be executed using sound level meters. This tutorial session will focus on tips and tricks for using handheld sound level meters to conduct standardized measurements. Because handheld sound level meters are different in form and function than multi-channel data acquisition systems, particular care must be taken in using them for some measurements. Measurements in reverberant and anechoic rooms will be discussed as well as field measurements in buildings and outdoors.

1 INTRODUCTION
Sound level meters (SLM) are convenient and portable measurement equipment for acousticians and noise and vibration engineers. Previous papers in this tutorial series have discussed the basics of using a sound level meter. In this tutorial, we will discuss things to consider when making standardized measurements using a sound level meter.

Many acoustical engineers are required to follow standardized measurement methods when making reportable measurements. Based on geographic region, different standards organizations may govern the work. Organizations like the International Standards Organization (ISO), the American National Standards Institute (ANSI), the Society for Automotive Engineering International (SAE), or the American Society for Testing and Measurement (ASTM), among others, govern regional and global standards for acoustical testing. Industries such as aerospace, building and construction, consumer appliances, automotive, and consumer electronics require specific measurement standards to certify products.

Many standards allow for the use of either an SLM or a data system with cabled microphones. It is important to understand the differences and how these differences can affect your data. In this tutorial, several standardized measurements will be discussed and tips for using a sound level meter for these measurements will be given.

2 MEASUREMENT SPECIFIC GUIDANCE
Before starting any standardized measurement, verify whether the standard requires a Type I or Type II SLM. This is important for accuracy claims on the data in reporting; a Type I sound level meter will have a better response and must meet tighter tolerances. The difference between these SLMs, discussed in an earlier tutorial, are the error bounds around the frequency dependent data

collected. For more information, see ANSI S1.4 / IEC 61672-1[1].

Users should also be very familiar with calibration techniques[5]. While sound level meters should be calibrated in a laboratory at least once every 2 years, users should also have a portable calibrator. This will emit a known sound level at a known frequency and thus allow the user to determine if the meter is working correctly). This should be used before (to calibrate) and after (to check calibration) each sound measurement to ensure validity. Portable calibrators must also be calibrated in a laboratory on a regular basis. Some standards will require traceable calibration of the instrument. In general, SLMs are sent back to the manufacturer and returned with a traceable calibration certificate.

2.1 Outdoor measurements

Sound level meters are particularly convenient for outdoor measurements because they are self-contained and self-powered[2]. In addition, data can be stored locally and basic analysis can be carried out on the SLM, allowing for near real time data quality assurance. When measuring outdoor sound, the most important consideration is wind noise. Many SLMs come with wind screens and may have built-in compensation for the wind screens. You should always use a windscreen when taking measurements outdoors. However, windscreens are not acoustically transparent. They can have insertion loss in the range of 1-3 dB, depending on frequency. In SLMs that automatically compensate for this, the compensation should be verified before conducting a test. This can be done in a laboratory setting using a fixed sound source and measuring the sound pressure levels (SPL) at a fixed location with and without the windscreen present[3]. If using automatic compensation, one should measure the same SPL for both conditions. If automatic compensation is not available on the SLM, care should be taken to correct the SPL measured by the SLM in post processing, using the measured insertion loss. This will lead to the best quality data. There are also standard methods for measuring windscreen effectiveness in the presences of flow[4] which should be used for long term outdoor measurements.

Mounting for the SLM is another primary consideration for outdoor measurements[2,6,9]. Mounting location is often specified in a particular standard. In general, if the SLM is representing a human ear receiver, the SLM should be placed in the same location as a human ear would be. In outdoor measurements, the SPL can vary with height based on outdoor sound propagation effects. This makes it imperative that the correct height is chosen for the measurement. It is also recommended that a tripod be used for the SLM, rather than holding it in your hand. Tripods allow the sound waves to seamlessly propagate over the SLM. In contrast, a human body behind the SLM can cause reflections which will alter the measured SPL. If handheld operation is the only option, the microphone should be held at least at head height and as far away from the body as possible to minimize the reflection effect. When using a tripod, it is best to try to stand several wavelengths (6-10 if possible) away from the microphone in order to minimize the effects of reflections from your body.

Figure 1: *Sound Level Meter placed on tripod measuring noise outdoors*

Users should take great care in the positioning of the microphone relative to walls or other reflecting structures/objects. In general, the microphone on the sound level meter should generally be positioned at least 3 m away from hard surfaces to minimize the effect of reflections. Alternatively, ISO 1996-2[9] suggests flush mounting the microphone on a reflecting surface (the backing board method). In this case a correction of -6 dB is applied to represent the incident sound field, i.e., to eliminate the impact of reflections. Another option is to position the microphones 0.5–2 m in front of a reflecting facade. In this case a correction of -3 dB must be applied to determine the incident sound field.

Finally, the effect of weather should be considered. One great feature of SLMs is that they can be made weatherproof with cases, which provides for easy long-term outdoor measurements. However, the microphone must be exposed to the atmosphere to make accurate measurements. Weather resistant wind screens are often used for this purpose. The operator should note that a water saturated wind screen will not have the same insertion loss as a dry wind screen and care should be taken to understand this effect in your measurements. For long term outdoor measurements, it would be considered best practice to log weather conditions simultaneously, with some SLMs having the capability to do this. In general, measurement should not be made during rain or high wind speeds (> 5 m/s). The noise from the wind may impact on the diaphragm of the microphone and often the noise from the wind itself may ‘drown out’ the noise you are trying to measure. Wind speed, wind direction, temperature and precipitation should all be logged and reported.

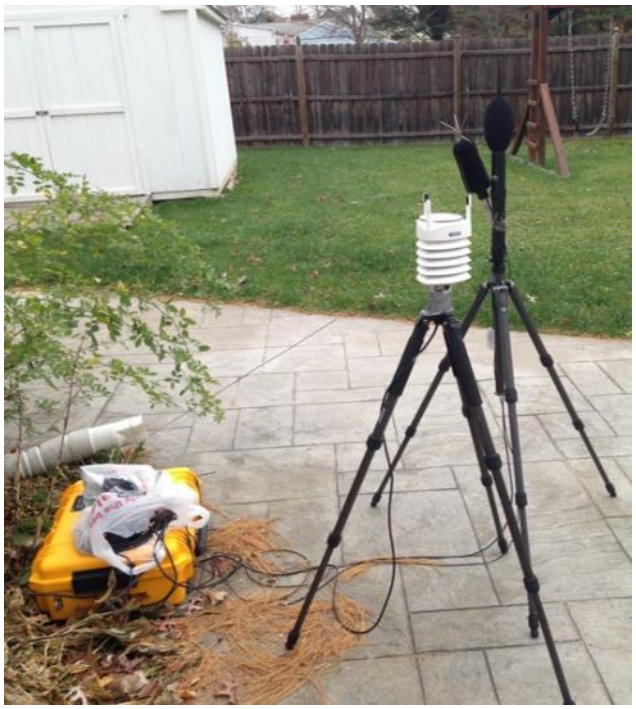

Figure 2: *Sound Level meter (unit in yellow case) with external microphone and separate weather station*

2.2 Acoustical Laboratory Measurements

Acoustical laboratory measurements are ideal for standalone and multi-channel data acquisition systems cabled to microphones. However, many standardized measurements conducted in acoustical laboratories can also be done with SLMs. Two main types of acoustical laboratories will be discussed here, anechoic and reverberant. In anechoic spaces, similar recommendations apply to outdoor measurements in terms of mounting the SLM. The best scenario is to cable the microphone inside the anechoic chamber to the SLM outside of the chamber for easy operation. Some SLMs have a time delay function that may allow you to exit the room if the SLM body is not separated from the microphone using a cable.

In reverberant spaces, several different types of standardized measurements can be made. Measurements such as reverberation time, volume averaged SPL, and sound power are required for several standards. When using an SLM, the main concern is whether to use a fixed location or a roving SLM. Both have advantages and disadvantages. Fixed location measurements are easy to repeat; however, they require more time to complete because the microphone needs to be moved throughout the chamber to collect a volume average. The volume average also must be done in post processing with single point measurements. Some measurements, like T60 reverberation time, must use fixed locations. If a standard calls for a volume averaged SPL, often denoted with a bar over the symbol, such as $\overline{L_P}$, the measurement can be taken using a roving SLM set to a long averaging time. In this situation, the averaging time for the equivalent SPL can be set to several minutes and a SLM can be moved slowly around a room. Sometimes this can happen using a rotating boom, and other times it can be done by a person in the reverberation room. It should be noted that if a person in roving the SLM, they should keep the microphone away from the surfaces of the room and away from their body. In addition, the same person and clothing types should be used throughout the entire test so that the room absorption remains unchanged. Finally, care should be taken to ensure the person roving the SLM does not create any unwanted noises in the room

that could affect the measurements, such as audible footsteps, keys jingling, coughing, or other noises not intended to be measured.

When using a SLM in a laboratory environment, the effect of moving the SLM should always be considered. Usually, a standard, such as measurement of sound power, will require multiple microphone positions. Using one (or a few) sound level meters is common which requires taking many measurements consecutively over time when physically moving the SLM. In this case, the operator should take care to methodically measure the source sound output level to ensure that the source level is not changing over the course of the test, since data are not collected in a time synchronous fashion. It is recommended to use two SLMs and leave one in a fixed location during the test. This way, the operator can validate the source levels were unchanged throughout the test when the roving SLM was moved to different locations. It is important to separate the change in SPL that is due to a directivity difference, which we want to measure, versus a source level change, which we want to avoid.

2.3 Indoor field measurements

Many standards deal with making indoor measurements at a field location[7-8]. These are predominantly in the building and construction industry, but could be in other industries like automotive. Field measurements bring a different set of concerns due to the more uncontrolled environment compared to a laboratory setting. One thing a user should note is the field type of microphone that is in use on the SLM. At high frequencies (>4 kHz) in rooms it is important to select the right type of microphone. Most often this will be a random incidence microphone as most standard measurements in rooms are measuring a room averaged SPL and all reflection paths and directions should be equally weighted by the microphone. At frequencies below about 4 kHz (for ½" diameter microphones) random incidence, free field, and pressure microphones have similar directivity characteristics and can be used interchangeably.

Similar precautions should be taken for SLM mounting or handheld roving as described in the previous section. In field measurements, background noise is a bigger concern than in laboratory measurements. It is important to take many background noise measurements throughout a test day. The standards may only require one background measurement. However, having many throughout the day will provide insurance that the ambient noise has not changed appreciably throughout the course of the test, which is common in the field.

When conducting standard measurements that require reverberation time measurements, make sure that the SLM is stationary during the individual decays, you are using a random incidence microphone, and that sufficient spatial and temporal averaging is used. Most SLMs equipped with reverberation time modules have user control for setting exit and entry time to the rooms, automatic measurement of background noise, and automatic calculation of reverberation times using T20 or T30 methods. Understand what your standard requires and what features are available on your SLM prior to making the measurements to save time in post processing and avoid rework.

3 CONCLUSIONS AND FINAL THOUGHTS

In conclusion, this tutorial provided insights on how to use a sound level meter to make standardized measurements outdoors, in labs, and in field environments. In general, SLMs are very useful for standardized measurements, but users should train properly to avoid mistakenly collecting bad data. Several tips and tricks were presented here to avoid common mistakes when making SLM measurement for standardized methods.

4 ACKNOWLEDGEMENTS

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