Differences in Sound Exposure Results From Firearm Discharge Due to Measurement Equipment Selection

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1 Introduction

The high sound levels associated with firearms discharge are of interest to recreational users and police forces. When engaged in training, target practice or competition it is normal to use personal hearing protection to reduce sound exposure from the large numbers of impulses. Hearing protection is also used by high volume shotgun hunters (e.g., for waterfowl) and by those hunting moose or deer with a high-power rifle. However, law enforcement personnel discharging a firearm in the line of duty generally do not have the benefit of hearing protection. Whether there are high sound levels or many impulses, there is interest in knowing the significance of sound exposures for the firearms users.

The sound from a firearm is influenced by several factors. These include the projectile and propellant characteristics, projectile speed, firearm barrel length and gas discharge influences such as a muzzle brake and noise suppression systems. The combination of these factors results in sound that is not evenly distributed around a firearm.

The position of the hearer is also significant to the sound level experienced. People not operating the firearm, such as instructors, safety officers, competitors and observers each have a different and lesser sound exposure based on where they are positioned. The highest sound level generally occurs at the user position.

The relationship of the user's right and left ears to the firearm varies. When a handgun is held in the Isosceles Stance (i.e., with two hands), it is positioned equally in relation to the right and left ears. However, in a Weaver Stance or in single-handed use one ear is closer than the other. Similarly, with a longer firearm, sighting down the barrel brings one ear closer than the other. This paper considers the ear furthest from the gun barrel.

Accurately measuring sound level at the ear position requires consideration of many factors. The US Department of Defense standard MIL-STD-1474E [1] includes guidance for conducting such measurements. Of interest to this paper is the specification of a 192 kHz sampling rate. A 192 kHz sampling rating is intended to capture the very-fast-rising, short duration pulse. The capability of measuring sound at this sampling frequency is not available in a format readily accessible to lay users. Standard sound level meters sample at approximately 50 kHz. Systems at 192 kHz are significantly more expensive, often require knowledge of signal processing and data analysis, lack portability, or operate on batteries for comparatively only periods of time.

Where users are aware of the MIL-STD-1474E standard, equipment selection is still often determined by challenges surrounding 192 kHz measurement systems and convenience of a sound level meter. Without a comparison of measurement results between a sound level meter and a 192 kHz system, the exposure significance is unknown. This paper seeks to inform the equipment selection with a summary of the differences in measured sound levels in proximity to a user's ear over a diversity of firearms.

2 Method

Measurements were conducted using seven different firearms. The following were selected to represent a diversity of what is in use:

Kimber 1911: 45ACP, 5" barrel
FNH FNS40L: 40S&W, 5" barrel
Smith and Wesson M&P Pro: 9x19 mm, 5" barrel
Browning BPS: 12 ga, 26" barrel
Browning X-Bolt: 300 Winchester Magnum, 26" barrel
AR-15 (M4/C8): 5.56x45 mm, 16" barrel
AR15 (M16/C7A2): 5.56x45 mm, 20" barrel

These offered a range of projectile sizes and speeds. Standard issue or common bullets were used for most of the firearms. However, variation due to charge weight and propellant burn rate were also nominally considered.

The measurement program was conducted at an outdoor range. A range was selected that was free of reverberance or reflective surfaces, other than the benches designated for firing. The non-reverberant space was selected to provide the most demanding measurement conditions, where the high sound level is present for the smallest amount of time. A reverberant indoor firing range is understood to be less challenging to measure at slower sampling rates because an elevated sound level is present for a longer duration.

The pistols were fired from a seated position in Isosceles Stance. A standing position was used for the Browning BPS, with the remaining firearms being supported on the bench and fired from a seated position.

Sound levels were measured simultaneously by three measurement systems. The basis for comparison was an LMS system with 204.8 kHz sampling rate. A more portable system, at 102.4 kHz was one alternative. The third system was a sound level meter targeted specifically to firearms noise applications: the Larson Davis LxT1-QPR. The LxT1-QPR has a 51.2 kHz sampling rate. Prior to the measurements each system was field-calibrated.

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Each of the measurement systems was equipped with a blunt cylinder microphone as indicated in the standard. The ¼” microphone size was selected to prevent the overrange that occurs with larger diameter microphones at high sound levels. The microphones were arranged at 5/8” from centre to centre but separated from each other by vibration isolation material. They were positioned in line with a virtual axis through the ears and at approximately 6” to the left side of the head. In all cases where the firearms operator was seated, the microphones were supported on a tripod. They were mounted to the shoulder in the case of the Browning BPS: 12 ga.

The sound from each firearm was measured multiple times, with a total of 92 files being recorded on each measurement system.

3 Results

For each of the 92 files on a system the Z-weighted peak level was recorded and average Z, A and C-weighted sound levels were calculated. The noise floor of the systems and background sound levels in the firing range were determined to be sufficiently low as to not influence the results. The sound level differences between measurement systems were calculated for each file. The 51.2 kHz and 102.4 kHz systems were each compared with the 204.8 kHz system. Results are presented in Table 1 below.

Table 1: Recorded Sound Level Difference When Compared with System Having 204.8 kHz Sample Rate

	102.4 kHz System	**51.2 kHz System**
Peak (dB)	≤ 2.1	≤ 3.4
L_{EQ} (dB)	≤ 1.0	≤ 0.6
L_{EQ} (dBA)	≤ 2.7	≤ 0.5
L_{EQ} (dBC)	≤ 0.7	≤ 0.5

The measurement sets had average projectile speeds between 800 feet per second and 3100 feet per second.

4 Discussion

A clear trend in the peak sound levels has been identified from the measurement data. The faster the sampling rate, the higher the peak level measured. However, the difference in measured peak level between the 51.2 kHz and 102.4 kHz sampling systems is not constant from one firearm measurement set to another. Overall, the 102.4 kHz system provided results up to 2.1 dB quieter than the reference system. The system sampling at 51.2 kHz was up to 3.4 dB quieter than the one sampling at 204.8 kHz.

This trend was expected to continue with the calculated average sound levels. This was generally true for the C-weighted levels. Data sets on the 102.4 kHz system were normally within 0.4 dB, and not more than 0.7 dB of the reference system. The 51.2 kHz sampling rate system was generally close behind, with a difference of 0.5 decibels separating C-weighted levels on the 204.8 kHz and 51.2 kHz systems.

The A and Z-weighted results from the alternate measurement systems are also quieter than the reference system. However, they had an unexpected trend. The calculations show that the 51.2 kHz system produced results closer to the reference system than the 102.4 kHz system in all cases. The difference between 51.2 kHz and 102.4 kHz was generally about 0.2 dB for Z-weighted data sets and 1.7 dB for A-weighted data sets. Maximum A and Z-weighted differences shown in Table 1 were reasonable in the context of the data sets. The trend prompted additional analysis, and consultation with technical staff at the manufacturer of the 102.4 kHz system. The unexpected results suggest that there is more involved than simply sampling rate.

The projectile speed data offered the opportunity to look for trends. The relationships between projectile speed and a system’s ability to capture peak, Z, A and C-weighted average sound levels was considered. No clear correlation was found overall or when the sub-sonic and super-sonic groups were considered separately. Charge weight and propellant burn rate had small influence besides speed.

In general, the differences between measurement systems cannot be ignored. A difference of 3 dB in peak level can make the difference between meeting or exceeding a 140 dB peak-level threshold. For L_{EQ} averaged sound levels, a difference of 3 dB is equivalent to a halving or doubling the allowed time (with a 3-dB exchange rate). If a user is unaware that a system shows A-weighted L_{EQ} results that are 3 dB quieter than actual, the sound exposure may be allowed to continue for twice as long as it should.

Understanding how a measurement system compares with the standard can allow users to compensate. The results of measurements presented here indicate that when measuring a user’s hearing exposure using the Larson Davis LxT1-QPR (i.e., the 51.2 kHz sampling system here), the meter’s peak level (Z-weighted) output would be increased by 3.4 dB. An increase of 0.5 above the meter’s output would apply to A-weighted decibel levels. Measurement using another system, even with a higher sampling rate, does not necessarily produce comparable results. To determine suitable adjustment factors for other sound level meters or sampling systems a similar side-by-side testing program with the diversity of firearms would be needed.

5 Conclusion

Use of a sound level meter to measure user sound exposure when discharging firearms produces quieter results in comparison with systems capable of a 192 kHz sampling specification. The results suggest that data for a Larson Davis LxT1-QPR presented here may not be representative of other systems. Adjustment based on the sampling system should be made for sampling rates less than 192 kHz.

References

[1] MIL-STD-1474E. (2015). U.S. Department of Defense Design Criteria Standard, Noise Limits, AMSC 9542, Washington, DC.