# Prediction of the Difference between CSEL and ASEL of Blast Sounds for Purposes of Predicting Annoyance

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**Abstract:** For impulse noise, decibel-adjustments are applied to yield rating levels that correlate with annoyance. Constant adjustments with respect to source type categories do not take into account the change of 'impulsiveness' due to sound propagation effects. The difference between CSEL and ASEL at the receiver may yield a more appropriate adjustments to the assessment of shooting sounds (muzzle blasts and explosions). This paper presents a method to predict the difference between CSEL and ASEL from a physical point of view.

## INTRODUCTION

ISO-TC43/SC1/WG45 plans to have three categories of impulsive sound sources for purposes of noise ratings. Each category, "ordinary impulsive" (adjustment 5 dB), "highly impulsive" (12 dB) and "high-energy impulsive" (significantly more than 12 dB to ASEL) sound, will receive the indicated adjustment to its measured SEL. An enumerated list will assign the sources to the categories. Small arms firing, for example, will be "highly impulsive", firing noise from heavy weapons will be "high-energy impulsive".

But these adjustments based on source categories do not take into account the change of "impulsiveness" with propagation. The omission of propagation effects raises uncertainties - especially for firing sounds that are audible over far distances and sound different close to or far away from the source.

For firing sounds, Buchta [1] and Vos [2] recently used the difference between C- and A-weighted levels at the receiver to determine adjustments P to the ASEL in order to correlate better with annoyance. They introduce:

$$P = 0.4C + 0.08\left(C - A\right) - 21.9\,dB \qquad \text{Buchta [1]} \qquad (1)$$

$$P = 0.017\left(C - A\right)\left(A - 45\right) + 12\,dB \qquad \text{Vos [2]} \qquad (2)$$

Formula 1 is recast herein for comparison purposes. Originally, /1/ gives the adjustment to a CSEL level, based on the difference of CF-AF. Assuming that CF-AF is close to CSEL-ASEL for audible firing sounds, all levels are substituted by their exposure level equivalent. In both formulas C denotes CSEL and A denotes ASEL.

## PREDICTION OF THE DIFFERENCE BETWEEN CSEL AND ASEL

The advantage of this idea is that the adjustment is objective, measurable and sensitive to the propagated signal at the receiver. From a physical point of view, there are two problems with this method, a theoretical one and a practical one.

- 'Impulsiveness' is not very evident in the frequency spectrum; mainly it is evident in the time domain of the pressure signal. Therefore, in general the difference of two frequency weighted levels should not provide a reliable descriptor for 'impulsiveness.'
- For low-frequency high-energy blasts, the level difference is often not reliably measurable. The spectrum is influenced by the local properties of the ground due to superposition and the A-weighted levels are close to the background noise level at typical receiver distances.

For firing sounds there are solutions for both problems. Firing sounds are generated by explosions in air. Explosions in air produce a blast wave that always exhibits a typical spectrum. The one-third-octave spectrum increases at 30 dB/decade up to the maximum frequency and then decays at 10 dB/decade for frequencies above the maximum frequency. Only the maximum frequency and the overall level of the spectrum scale with the mass of explosives. Also the phase of the spectrum scales in a direct way relative to the amplitude of the spectrum. Therefore, there is an underlying correlation between the spectrum (one-third-octave spectrum) and the waveform of the pressure signal. Hence, C-A can be a measure of the 'impulsiveness' for this type of impulsive sound.

Every measurement of a blast signal at a receiver at least involves ground reflections. Therefore, the measured one-third-octave spectrum always will be disturbed by the superposition effects of pressure doubling and pressure release [3]. As a consequence, measured C-A values for the same source at the same distance show large variations. For purposes of predicting annoyance, it is sufficient and more reliable to predict the C-A difference using just the scaling laws described above. This prediction will yield an expected value for C-A that does not depend on the local ground impedance at the receiver or weather effects.

The simple scaling of the one-third-octave spectra of blast signals is the result of a very simple linear acoustical model. This model was first published by Weber [4] in1939 to describe pressure impulses generated by the release of electrical energy by discharge across a spark gap. The only parameter in this model is the radius of an equivalent sphere, the so-called Weber-radius. This radius strongly correlates with the mass of explosives. Validation of this model shows that the spectra of blasts are reliably (in terms of spectral acoustical energy ) predicted over a wide range of Weber-radii and masses of explosives [5]. At the present stage of this investigation, the validation includes the sound radiated perpendicularly to the line of fire for muzzle blasts from small arms and heavy weapons.

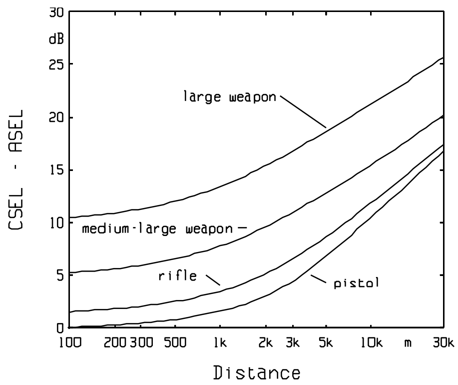


**FIGURE 1**. CSEL-ASEL versus distance

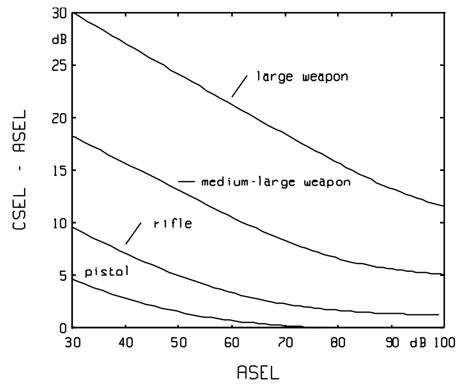


**FIGURE 2**. CSEL-ASEL versus ASEL

This model is used to determine source spectra. Applying propagation effects, geometrical spreading and absorption in air yield one-third-octave spectra at given receiver distances. Figures 1 and 2 present results for predicted C-A from the predicted spectra versus distance and versus ASEL, respectively. The figures include four typical types of weapons: pistols (e.g., 357 Magnum—about 0.8 g of explosives), rifles (e.g., G3--4 g), medium-large weapons (e.g., 30 mm gun--50 g) and large weapons (e.g., 120 mm gun or howitzers--10 kg). The figures show that the difference between CSEL and ASEL increases with distance and decreases with receiver level.

## RESULTS FOR IMPULSE ADJUSTMENTS

Assume that a received ASEL of 70 dB is measured for all four selected types of weapons. (Of course, this will occur at different distances.) The predicted differences are 0 dB for pistols, 3 dB for rifles, 8 dB for medium-large weapons and 18 dB for large weapons. (Note, measured values will typically be greater due to the ground effect which is neglected here. The influence of the ground on receiver levels for blast at large distances is discussed in [3].) Equation 1(2) yields the following decibel-adjustments to be added to the measured ASEL: pistols--6 dB (12 dB), rifles--8 dB (13 dB), medium-large weapons--10 dB (16 dB), large weapons--15 dB (20 dB).

The two formulae yield very different results. Clearly, there is more work to be done in this field. However, for firing sounds, the basic idea of determining the adjustments by a physical measure at the receiver is promising and is a step forward from constant adjustments by categories.

## REFERENCES

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