



## **CASE STUDIES ADDRESSING PHILOSOPHICAL UNCERTAINTY ISSUES IN VARIOUS ACOUSTICAL SITUATIONS**

Gary W. SIEBEIN<sup>1,2</sup>, Robert M. LILKENDEY<sup>2</sup>, Edwin S. SKORSKI<sup>2</sup>,  
and Hyun PAEK<sup>2</sup>

<sup>1</sup> *University of Florida, Department of Architecture, POB 115702  
Gainesville, FLORIDA 32611-5702*

<sup>2</sup> *Siebein Associates, Inc., 625 NW 60th Street, Suite C,  
Gainesville, FLORIDA 32607*

### **SUMMARY**

One source of uncertainty in interpreting the results of a variety of acoustical measurements is how closely the measurement protocol duplicates the physics and psycho-acoustics of the actual situation that is trying to be understood. This is especially true when the sounds are transient, impact or impulsive in nature. Fine-tuning of the data acquisition and analysis process allows diagnostic insights into the nature of acoustical situations that were only available previously by intuition and experience. Case studies of experimental measurement protocols will be presented to address methods by which basic acoustical phenomena can be explained robustly by attempting to measure the physical acoustic stimulus with greater precision than current standards typically require.

### **INTRODUCTION**

Case study 1 involves the perception of a nuisance by large numbers of people in a community near an amphitheater when amplified music is played during concert events. Leq's taken in the conventional manner showed only minor violations of the existing noise ordinance due to the presence of traffic noise from nearby highways and the averaging times used in the data acquisition. Acquiring the disturbing sounds as .wav files using a digital analysis system allows one to record, listen and measure the background noise and the music to demonstrate the nature of the perceived nuisance and the clear differences between the background noise and the disturbing musical sounds. Case study 2 involves a similar data acquisition system applied to impact insulation class (IIC) measurements of people walking on tile floors in multi-family housing. Comparisons between standard IIC measurements and people actually walking on the floors above highlight the apparent incongruities encountered when residents are disturbed in units below when the IIC indicates acceptable results should have been achieved. Case study 3 involves comparisons and simulations of time average (LDN's) and transient analysis of aircraft flights over a luxury condominium building and the differences in noise mitigation required for occupants determined through the 2 methods. Tests in a full size mock-up of a unit on site verified the analysis results. Case study 4 involved field measurements, computer model studies and aural simulations of sounds from firearms and driver training activities for law enforcement personnel. Time average data for events projected into the community showed compliance with noise ordinance requirements. Peak sound

levels and aural simulations of training events showed clearly discernible noise impacts of 10-20 dB above the ambient sound levels. In all cases significant differences of 10 - 20 dB were found between the results of time average data acquisition and more detailed data recordings. The more detailed data recordings are demonstrated to correlate with the perceptions of people involved in each situation.

### CASE STUDY 1: AMPLIFIED MUSIC

Amplified music played at a large amphitheater in a major city was disturbing residents living near the facility. The municipal noise ordinance had sound level limits of an L max of 60 dBA during daytime hours and 55 dBA during night time hours as well as L max limits of 65 dB in the 63 Hz., 125 Hz., 250 Hz and 500 Hz octave bands. Measurements of noise produced during concerts were recorded using a variety of metrics to understand how the sound levels changed depending upon the metric used. Residents and city staff were perplexed when acoustical measurements made using type 1 sound level meters in accordance with ASTM standards resulted in data that were not distinguishable from or barely above the ambient noise levels while the walls, windows and shelves of their homes were vibrating and words and instrumental components of the music were plainly heard at great distances from the amphitheater.

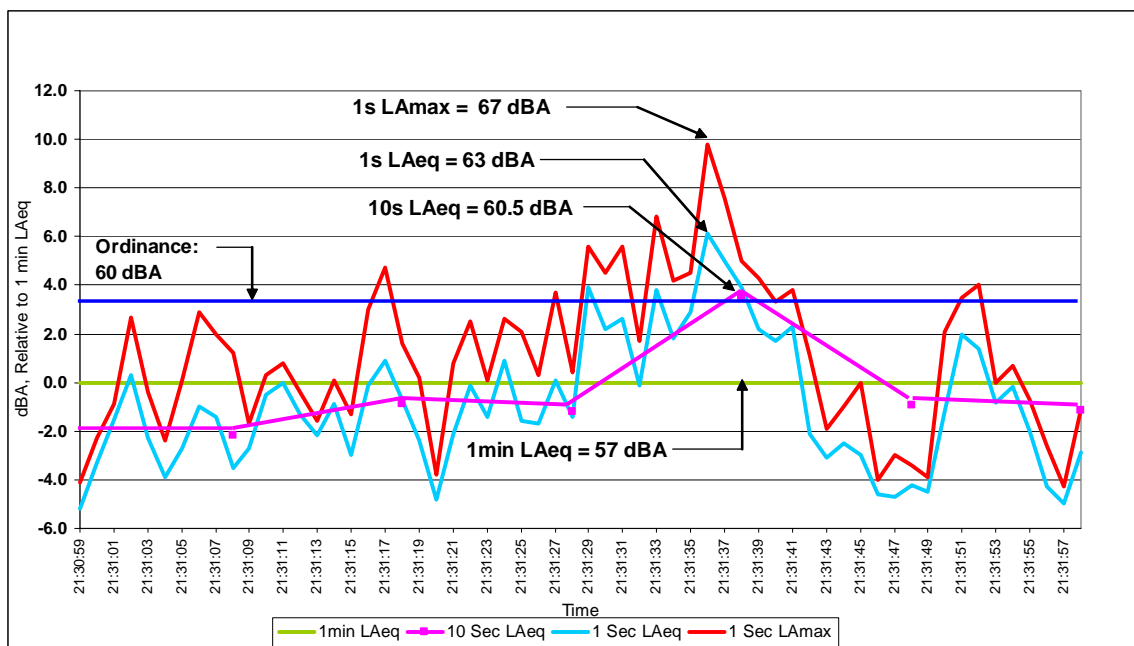


Figure 1. Comparison of sound levels for a segment of music recorded in the neighborhood.

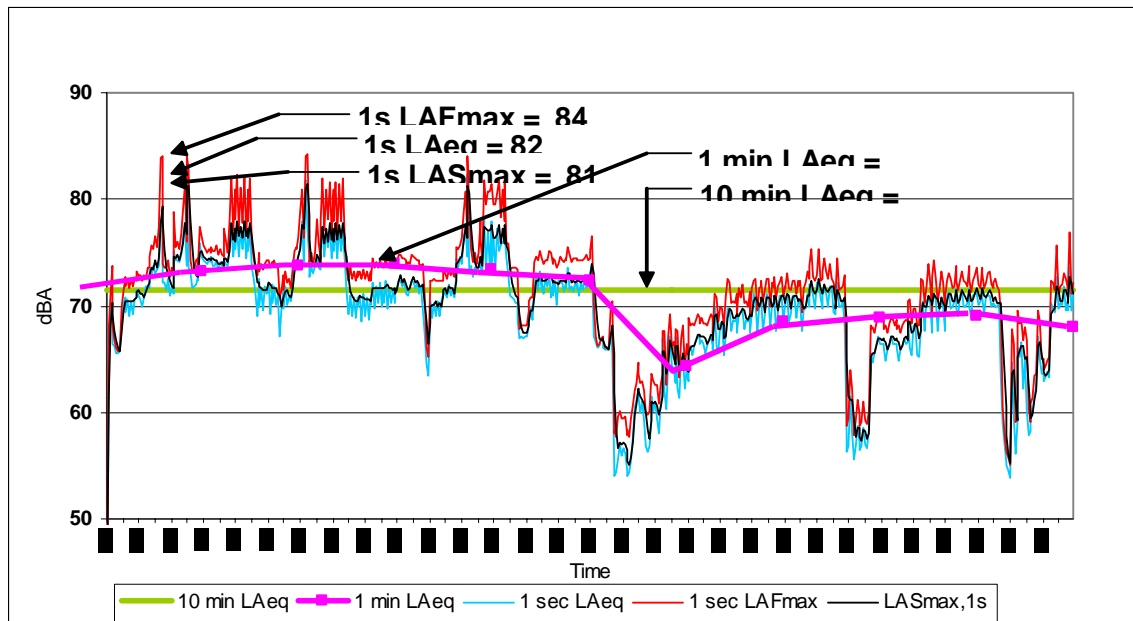


Figure 2. Comparison of various measurement metrics for a recorded segment of music.

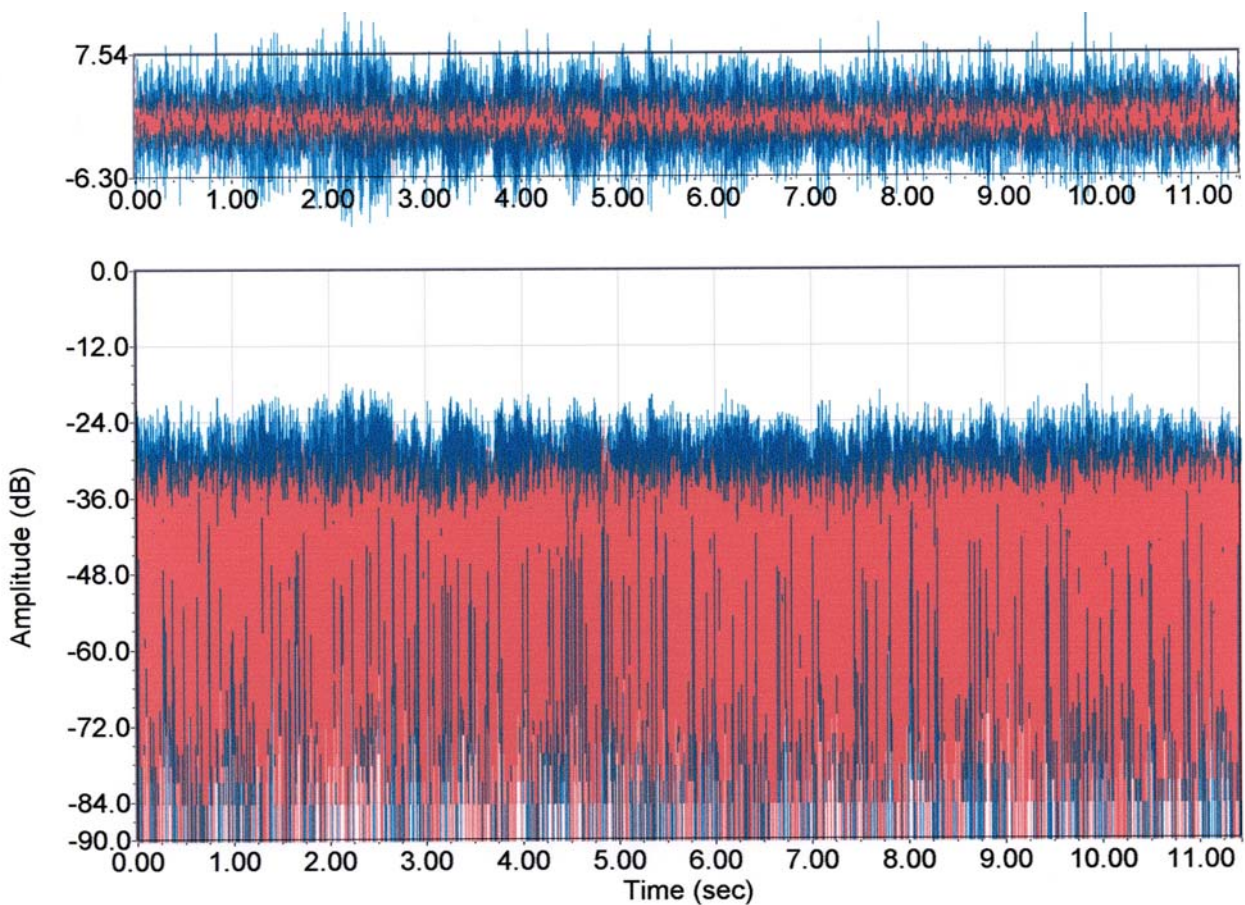


Figure 3. Calibrated wave file of music recorded in the neighborhood compared to ambient noise immediately after the song was played. The relative amplitude of the sounds at -24 dB is 90 dB.

Figures 1 and 2 show sound levels that result when these sounds are measured by a traditional sound level meter. When one compares the relative sound levels between the measurement metrics shown in figures 1 and 2 and the .wav file recording sampled at 44, 100 Hz the reasons for the discrepancy between the perception of the sounds by residents and the measured sound levels are readily apparent. The .wav file in figure 3 shows maximum sound levels of music at approximately 90 dB. These peaks are what allows one to discern the lyrics and the individual notes of the guitars clearly above the ambient noise in the vicinity (shown as the lower line in figure 3). The .wav file also clearly shows the transient nature of the music which consists of a series of rapidly ascending and descending short duration sounds.

There is a 15-20 dB difference between the maximum levels recorded in the wav file and the Lmax recorded in fast mode with a sound level meter. There is another 10-12 dB difference between the Lmax and the 1-minute Leq. A 5 or 10 minute Leq is slightly less than the 1-minute Leq value. This means that the actual amplitudes of the musical sounds shown at 80-90 dB in figure 3 that are clearly discernible from the ambient sounds are reduced to Lmax values of 60-70 dB and longer term average sound levels of 55-60 dB. The ambient noise levels from traffic and insects are in the 50-58 dBA range. Therefore, when one takes longer-term Leq measurements of transient events, corrections for background noise levels are required. The measurements are barely distinguishable from the ambient noise and enforcement of the noise ordinance is difficult at best. On the other hand, the wav files show musical sounds with clearly discernible words and individual notes of music that are not mixed within the ambient noise levels. The Lmax metric and short term Leq's demonstrate some of the transient behavior of the actual sounds and do not require corrections for background noise. Questions are asked as to whether more elaborate correction methods for noise sources in the presence of background noise are required; more precise sound level meters, windscreen corrections, and other technical details of the measurement process are required or whether simply recording and measuring the musical events and the background noise as they are heard, listening to the wav files and measuring the resulting sound levels with calibrated equipment at high resolution provides a more suitable method.

Table 1 contains a summary of the number of exceedences logged by 2 different operators for the recorded music samples shown in figure 2 using the different metrics. There would be significant differences in enforcement actions taken depending upon the measurement method used. An arbitrary enforcement level of 84 and 81 dBA were used for the study because the levels were measured indoors using an amplified sound source.

Table 1. Summary of exceedences of the noise ordinance depending upon the measurement metric used assuming an arbitrary reference of 84 and 81 dBA.

	Song 1		Song 2	
	Lp Range	# of 84 dBA Exceedences*	Lp Range	# of 81 dBA Exceedences**
Enforcement Method 1	72 to 89 dBA	16	80 to 85 dBA	11
Enforcement Method 2	73 to 88 dBA	8	77 to 83 dBA	5
1s L <sub>Amax</sub> , Fast	66 to 89 dBA	55	73 to 85 dBA	61
1s L <sub>Amax</sub> , Slow	63 to 85 dBA	15	70to 83 dBA	20

		Song 1		Song 2
	Lp Range	# of 84 dBA Exceedences*	Lp Range	# of 81 dBA Exceedences**
L5	84 dBA	0	82 dBA	1
L10	83 dBA	0	81 dBA	0
L50	78 dBA	0	79 dBA	0
Full Song Overall LAeq	80 dBA	0	79 dBA	0

\* Only used values that exceeded 84.4 dBA

\*\* Only used values that exceeded 81.4 dBA

Song 1: 5 minutes, 48 seconds long = 24 total 15 second periods

Song 2: 3 minutes, 23 seconds long = 13 total 15 second periods (last 8 seconds was quiet ending)

## CASE STUDY 2: IMPACT NOISE FROM FOOTSTEPS ON FLOOR ASSEMBLIES IN MULTI-FAMILY HOUSING

The Impact Insulation Class (IIC) rating and its various derivatives are used to characterize the transmission of sound from impact sources such as footsteps on the floor above into a housing unit below. The IIC scale varies from a low of 25-30 for bare concrete floor systems with no suspended ceiling below to highs of 65-80 or higher for floor/ceiling assemblies with carpet on heavy pads. Building codes in the US require minimum IIC ratings of 50 in most locales. Federal Housing and Urban Development (HUD) and the National Association of Homebuilders (NAHB) recommend IIC ratings of 48-over 60 depending upon the ambient noise environment and adjacent room use. There are many instances of multi-family homes built with field measured IIC ratings of 45-52 where complaints from residents regarding disturbances from impact sounds of normal occupancy in units above them are considered serious and in need of modification. This is likely attributable to several factors. First, impact noises are sharp short duration transients that are clearly distinguishable from the ambient noise, especially in relatively quiet indoor environments. Second, the spatial, time and frequency averaging of the IIC rating system and its derivatives “smooth” out these abrupt intrusions. Third, the frequency limitations of the IIC metric also eliminate from consideration the “thuds” that often occur in the lower frequencies that contribute to the disturbance noted by residents. The difference of the loudness of the footsteps compared to the ambient sounds in 2 housing units with IIC ratings of 43-45 (upper curve) and 52-55 (lower curve) for the floor/ceiling systems are shown in figure 4. The paths of people walking on the floors above are clearly identifiable. Numerous complaints from residents have been recorded in both situations. . The sounds are 10-20 dB above the ambient and are clearly heard by occupants. The data were taken in representative units in large developments so the complaints are not the result of one person’s sensitivity to acoustical issues.

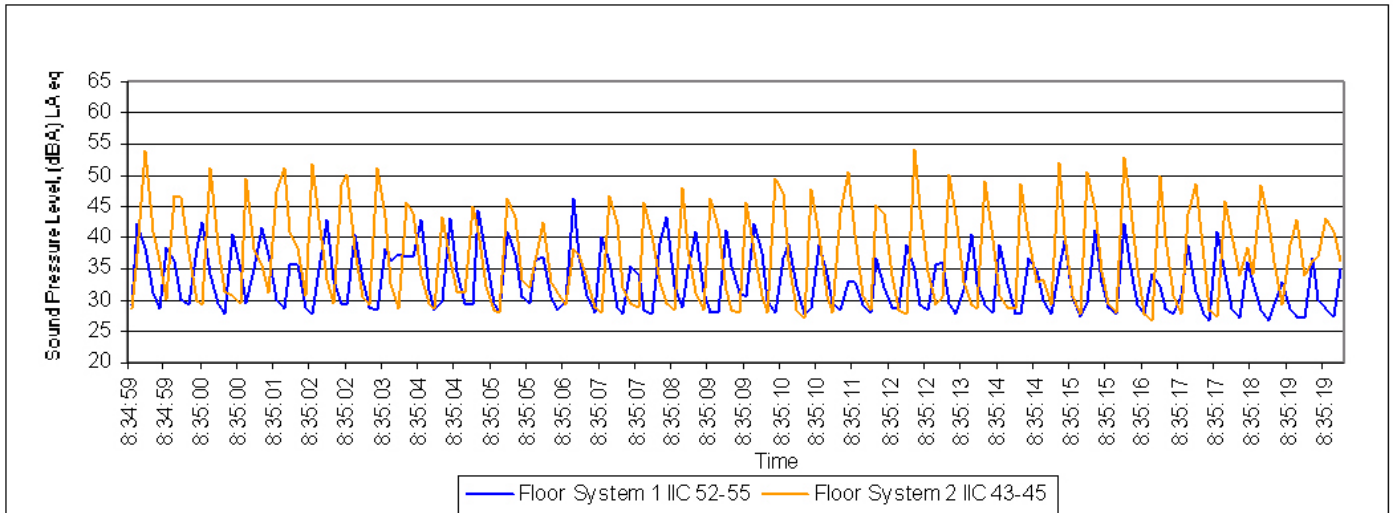


Figure 4. Amplitude vs. time graph of impacts from a 150-pound person with normal gait of 1 step per second walking on a floor ceiling system with an IIC rating of 52-55 and on a ceiling with an IIC rating of 43-45.

### CASE STUDY 3: AIRCRAFT NOISE HEARD INSIDE A BUILDING

A condominium building with all glass walls was proposed to be built in the flight path of a major urban airport between the LDN 65-70 noise contours determined in accordance with US FAA 150 procedures. Figure 4 shows a graph of sound pressure level vs. time for XX hours on grade at the site. Computer model studies of outside to inside noise transmitted through the façade of the building showed that a double pane acoustical window with a large air space was required to reduce the sound levels to normal interior levels of NC 25-35 when the sound source used was the amplitude of sounds during the actual aircraft over flights. A previous analysis had shown that when time average data (L DN) were used as the sound source level that the 13 mm (½”) thick single pane of laminated glass provided adequate protection for residents. As a result, the building as designed only included the single pane glass in the project budget. A mock-up chamber was constructed on site at grade level to verify the computer model results. The clients and consultants had the opportunity to sleep inside the chamber and work over a period of time to determine the adequacy of the design solution.

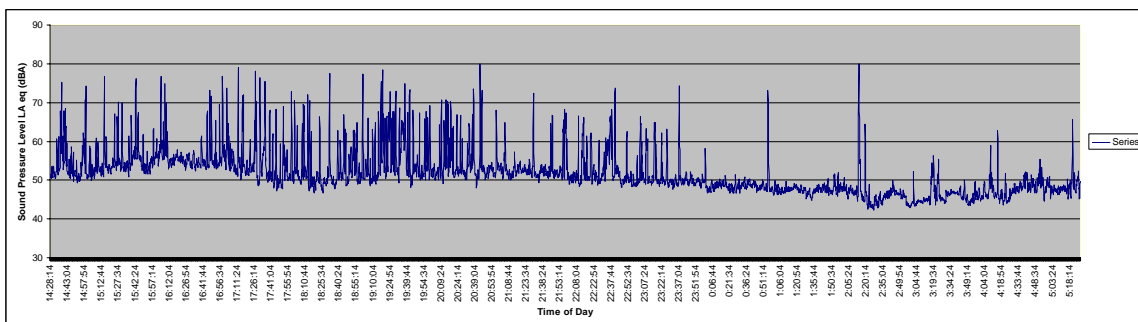


Figure 5. Sound pressure level (dBA) vs. time at grade level on the condominium site showing the amplitude and number of occurrences of aircraft over flights.

## CASE STUDY 4: DRIVER TRAINING AND FIREARMS TRAINING NOISE IMPACTS

Acoustical measurements of peak and average sound levels from firearms training and driver training events were taken at a law enforcement training center. These sound levels were used as sound source data in a computer model to estimate noise impacts in a residential neighborhood surrounding a potential new facility. The computer model was developed to account for distance, topographic, vegetation, atmospheric, barriers, and other constructed items effects. Acoustical measurements were also made at multiple locations in the neighborhoods of existing noise levels. The proposed site was near a large existing airport so there are many flights by jets during daytime hours. A comparison of projected peak and average sound levels from the firearms and driver-training events with the ambient noise levels is shown in figure 6. The average sound levels are well below both the noise ordinance requirements and the existing ambient sound levels. However peak sound levels from firearms training which occurs for long portions of the day and evening as well as tire squeals, rapid acceleration and deceleration of cars in training events are above the ambient noise levels except for the brief times when planes were flying directly overhead. The noise ordinance only had requirements to meet time average sound levels taken over 10 minutes. Therefore the project complied with the ordinance. Simulations of the resulting sound levels showed clearly identifiable events from training heard above ambient levels by 10-20 dB. The higher ambient sound levels during the nighttime hours are from crickets and other insects.

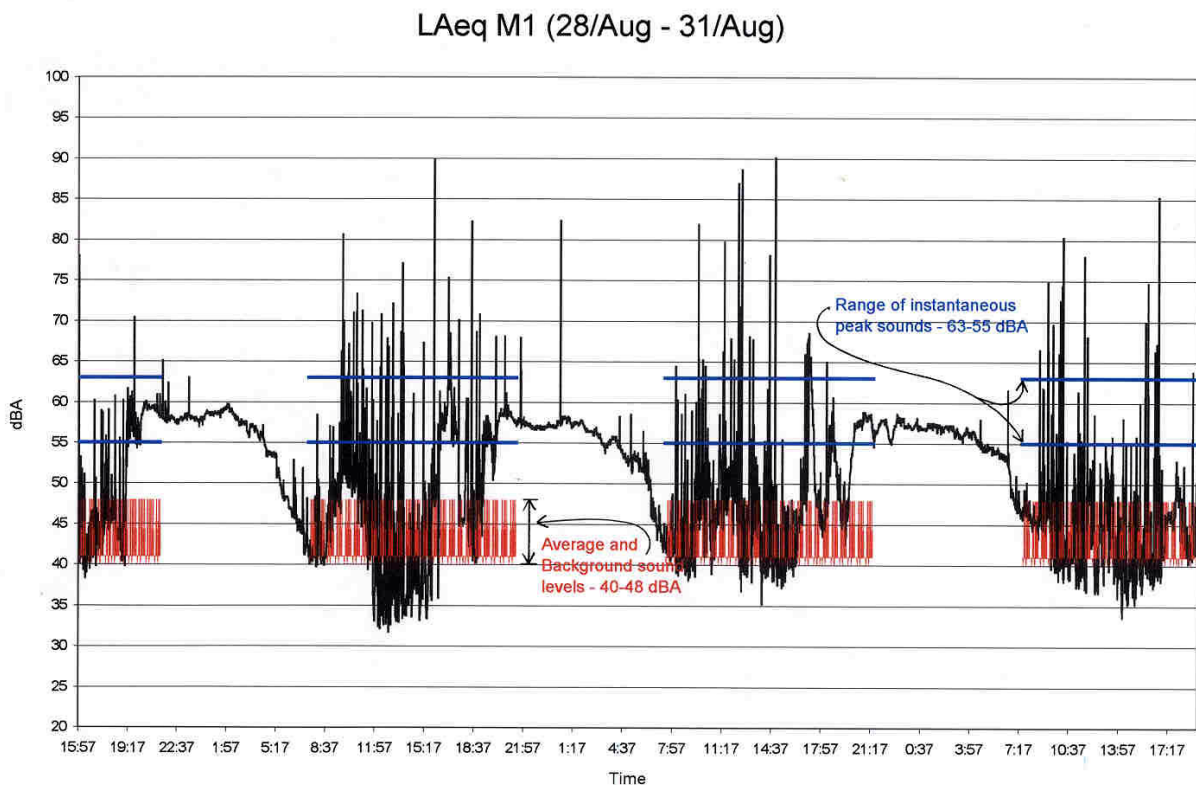


Figure 6. Comparison of projected average and peak sound levels from firearms and driver training events with ambient noise levels at one location in the community.

## **CONCLUSIONS**

These case studies are presented to raise issues about the use of time, frequency and spatial averaging of sound levels in design, analysis and legislation of the sonic environment. The philosophical issues of oversimplifying the acoustical metrics used for community noise assessment, interior noise control, impulse and impact noise create difficulties when one attempts to diagnose, explain and correct acoustical problems perceived by people. The advances in digital data acquisition, recording of sounds, computer and physical modeling, aural simulations and measurement technology allow one to measure, model, predict and simulate specific acoustical events and account for them in planning and design of communities and buildings. Acoustical standards and legislation should evolve in this direction as well to improve the quality of the sonic environment for all.