Extreme acoustics in the shooting range

Imagine this scene in a Hollywood action movie: Two police officers are chasing the bad guy in an industrial area surrounded by high concrete walls. A wild gunfight ensues for several minutes. In the end, the police capture the bad guy and all walk off unhurt.

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Above: Modern indoor-shooting range with eight lanes at 25m

What's wrong with this scene? In reality, if it had happened that way, all those involved would be temporarily deaf and might even have suffered permanent hearing damage.

As a manufacturer of sound level meters, we asked ourselves how loud gunfire really is and, to find out, we got in touch with the owner of a local indoor shooting range in Schaan, Liechtenstein. In addition to recreational use and competitions, security personnel often use the facility for professional training sessions.

This particular high-tech shooting range is located in the centre of an industrial area surrounded by several businesses, warehouses and manufacturing sites. The excellent sound insulation and the powerful air ventilation as well as state-of-the-art technical equipment are all considered important features of this popular facility. An electronic target system allows for dynamic training sessions on stationary and moving targets.

We had exclusive access to the facility not only to measure the noise from various firearms, but also to assess the room acoustics. A low reverberation time is generally desired for shooting ranges.

Measuring the reverberation time

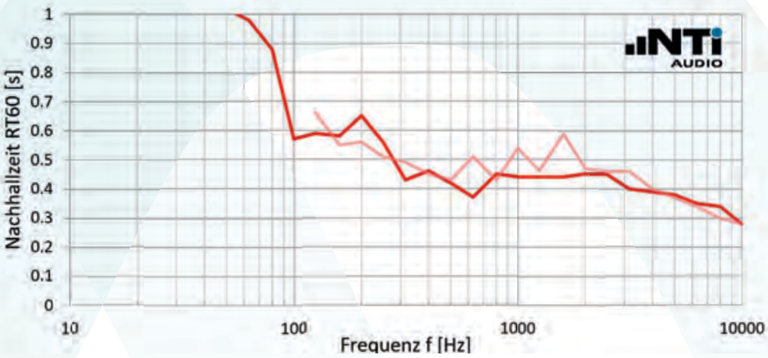
What is the ideal reverberation time in an indoor shooting range? The noise level is high even before the shooting starts, as the powerful air ventilation contributes significantly to the background noise.

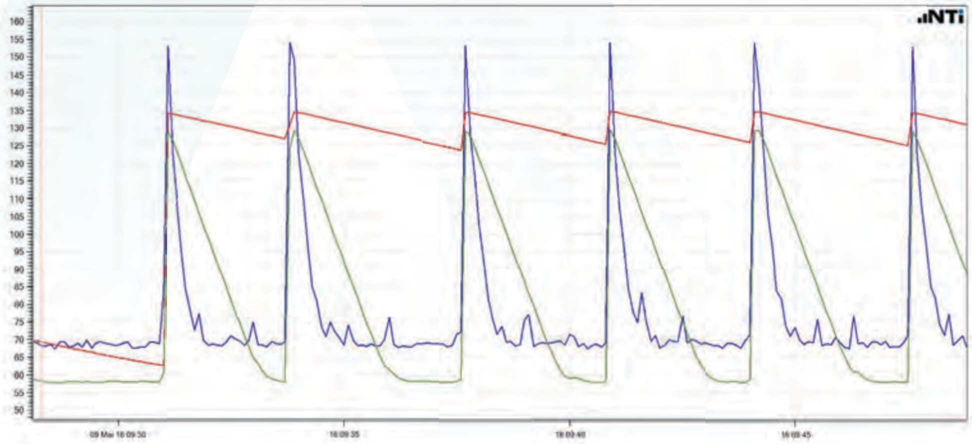
We therefore evaluated the reverberation time with and without active air ventilation. Those measurements were performed with a dodecahedron, omni-directional loudspeaker. For this, the sound source was placed in the centre of the room, between the shooter's position and the target in order to get the full noise distribution throughout the room.

The background noise of the room without active air ventilation is 54.1dBA. This was measured with a sound level meter at a distance of four metres from the omni-directional loudspeaker. The dodecahedron used provides 121dB ref 1pW of sound energy and the sound level meter utilised a half-inch, low sensitivity (8mV/Pa) phantom powered microphone.

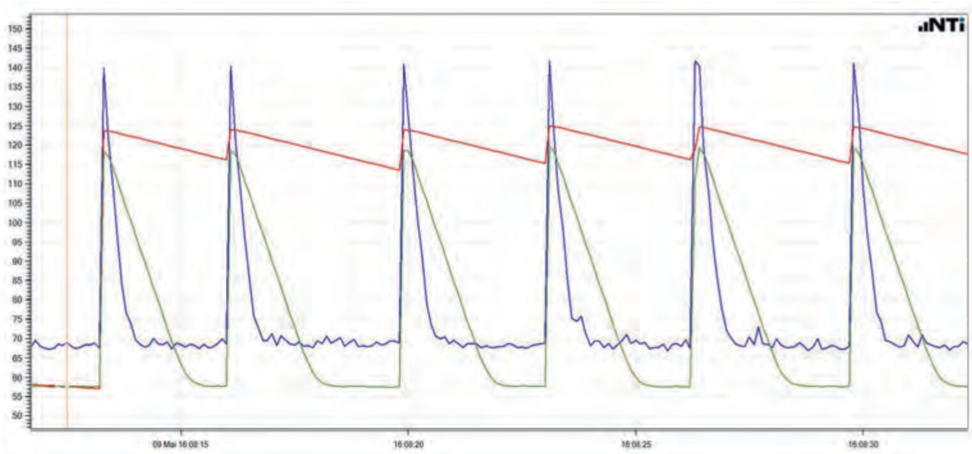
We also wanted to find out whether the laminar airflow of the ventilation system has a significant influence on any of the acoustic parameters. Therefore, we performed all our measurements with and without the active air ventilation system. P42

Right:
Measurements of reverberation time with and without air ventilation





Above:
A series of six shots with LCpkMax (blue) LCIMax(red) and LAFMax (green) at a 2.5m distance



Above:
The same series of six shots at a distance of 8.5m

Measuring the reverberation time with no air ventilation (red curve) was plain sailing. After turning on the air ventilation (pink curve), the reverberation time at low frequencies seems to be lower. However, this is most likely caused by an increased measurement uncertainty, since the laminar airflow significantly increased the low frequency background noise.

How loud is shooting noise?

During initial orientation measurements, we found that a microphone positioned next to the shooter, even a low sensitivity microphone, caused a significant over-range condition on the sound level meter. Therefore, we chose a position at a 30° angle and 2.5m distance from the shooter. This was the closest microphone position that did not lead to an over-range peak level of 154.1dBC or higher.

When projecting that number to a distance of 0.7m (ear to pistol), the peak level at the ear reaches 165.2 dBC. At this level, the unprotected ear would most likely be permanently damaged by a blast trauma.

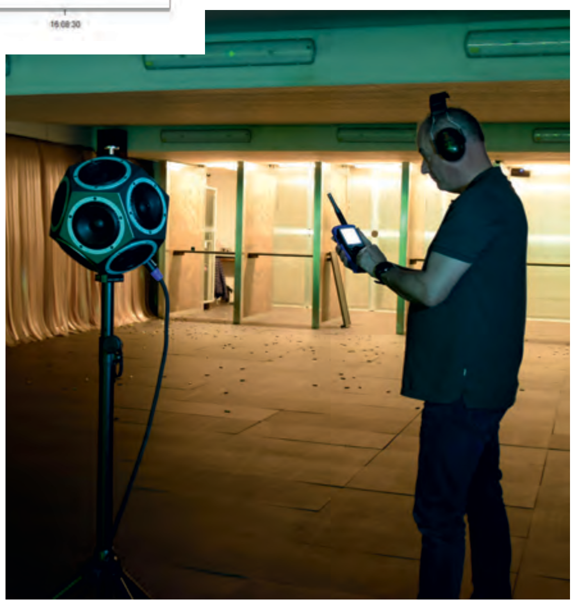
The same series of shots was measured simultaneously with a second device at a distance of 8.5m. At this position, the peak level LCpkMax still reached 143.8dB.

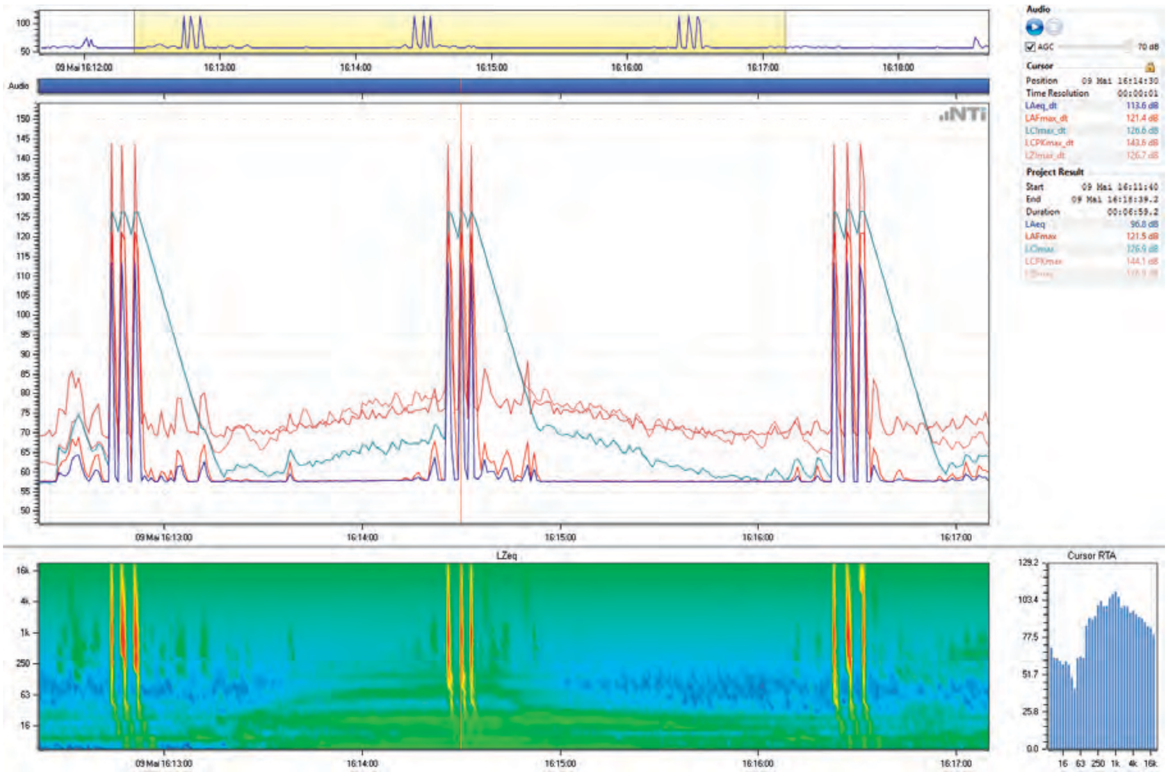
We knew that for a standard-compliant measurement of very short-term impulses, one should ideally measure with higher sampling rates of 192kHz as specified in the US MIL-STD 1474E standard, which specifies the maximum permissible noise levels produced by military systems and the test requirements for measuring these levels. In this measurement application the existing sampling rate of 48kHz for the sound level meter used allowed for a sufficient measurement and repeatable accuracy due to the spectral energy distribution of our measured shots. If the sampling of the meter was not sufficient, we would have seen large variations of the LCpkMax. We could then only conclude that the actual value was at least as high as our highest measurement with the sound level meter.

When projecting these measurement results to our initial action movie scene, it becomes highly likely that all participants would suffer from hearing damage after the first shot, no matter who fired first.

We also investigated whether the peak level changes with active air ventilation. The graph below shows that the background noise between the shots did indeed rise. The peak level however was not affected.

Below:
Dodecahedron loudspeaker in the shooting range





Left:
Shooting sequence without / with / without air ventilation

Trained shooters know that hearing protection at a shooting range is mandatory. The attenuation of good hearing protection reaches 35-40 dB at mid and high frequencies, whereas lower frequencies below 500 Hz are only attenuated by 15-20 dB.

The main energy of a shot exists at frequencies above 1kHz. Assuming a realistic attenuation of 35 dB, the peak level at the shooter's ears will still reach 130 dBC. For extra sensitive people or those who shoot frequently, it is recommended to combine the hearing protection with an extra earplug or earmold.

A public restaurant is located in the space next to the shooting range. Therefore, it was interesting to investigate the sound insulation of the shooting noise.

Based on the short-term Leq, the door to the foyer attenuates the sound by 44 dB, and in the restaurant area, the noise is attenuated by 80 dB. At an attenuated level of 65 dB, the shots are barely audible when the air-conditioning and background music are off. The sound insulation measures are therefore highly effective.

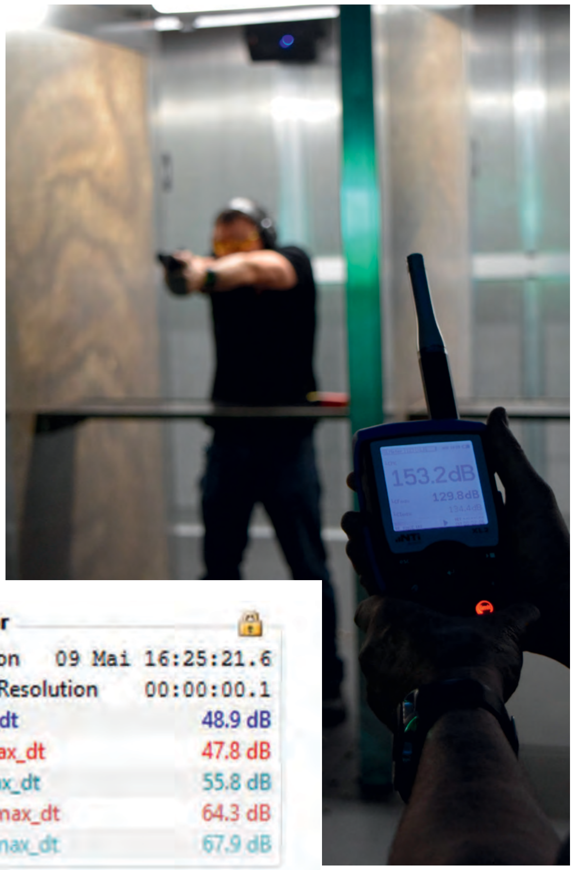
Perfect ambience

The measured reverberation time and sound insulation values confirmed the subjective look and feel of the shooting range. The acoustic conditions were as pleasant and functional in the reception area as they were throughout the rest of the range. Generally, there are no reference values for shooting ranges.

The director of the shooting range and the person responsible for safety said: "We took great care of the acoustics in the planning phase. The interior and materials were selected to get not only perfect functional conditions, but also to provide a comfortable ambience for our shooters.

"It is my top priority that our customers get the best possible and individually arranged training at our facilities and that is only possible when everyone feels safe and comfortable." ◎

Below:
Sound level measurements at a distance of 2.5m



Below:
Shot noise measured at shooting range (left), foyer (centre) and restaurant (right)

Cursor			
Position	09 Mai 16:15:46.2	09 Mai 16:24:29.6	09 Mai 16:25:21.6
Time Resolution	00:00:00.1	00:00:00.1	00:00:00.1
LAeq_dt	129.5 dB	85.3 dB	48.9 dB
LAFmax_dt	127.7 dB	82.9 dB	47.8 dB
LCImax_dt	133.1 dB	86.2 dB	55.8 dB
LCPKmax_dt	152.2 dB	96.8 dB	64.3 dB
LZPKmax_dt	152.5 dB	96.6 dB	67.9 dB