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Noise near the shooter's ear using plastic short range training ammunition and plastic blank ammunition

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Approved by

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Jon E. Skjervold	Director

English summary

This report is a delivery to Nammo Bakelittfabrikken AS. It documents that NM250 plastic short range training ammunition and NM226F1 plastic blank ammunition make less noise at the shooter's ear than ball ammunition in caliber 5.56x45 mm NATO (NM255). We have also measured NM126 and NM134 plastic blank ammunition (7.62x51 mm NATO) relative to NM231, with the same result.

We use methods defined in MIL-STD-1474D. When comparing training and blank ammunition with standard ammunition, we see that the peak pressure and the C-weighted sound exposure level is smaller for training and blank ammunition. This means that the use of such ammunition reduces the possible risk of hearing damage for the shooter.

Sammendrag

Denne rapporten er laget for Nammo Bakelittfabrikken AS. Det dokumenteres at NM250 treningsammunisjon og NM226F1 løsammunisjon lager mindre støy ved skytterens øre enn skarp ammunisjon i kaliber 5.56x45 mm NATO (NM255). Vi har også undersøkt løsammunisjon i kaliber 7.62x51 mm (mot NM231), med samme resultat.

Vi bruker metoder definert i MIL-STD-1474D. Når vi sammenligner treningsammunisjon og løsammunisjon med standardammunisjon, ser vi at makstrykk og C-veid sound exposure level er mindre for treningsammunisjon og løsammunisjon. Det betyr at mulig fare for hørselsskader reduseres ved bruk av slik ammunisjon.

Contents

1 Introduction

This report is made for Nammo Bakelittfabrikken AS. It documents that 5.56x45 mm plastic short range training ammunition (P-SRTA) NM250 and 5.56x45 mm plastic blank ammunition (PB) NM226F1 make less noise at the shooters ear than ball ammunition (NM255). We have also measured 7.62x51 mm plastic blank ammunition (NM126 and NM134) relative to ball ammunition (NM231), with the same result.

The measurements were made June 4-5, 2015, at the FFI noise measurements cite for small arms (Figure 1.1). The cite and the measure equipment is described in [1]. Weapons and ammunition were handled by our research technicians Andreas Haugland and Lasse Sundem-Eriksen.

Noise measurements relevant for estimating shooting noise in the far field, e.g. outside a training range, is documented in [2].

Figure 1.1 Measurement site at FFI.

It is difficult to establish the risk of hearing damage from firing a weapon, for several reasons. The mechanisms that lead to hearing loss seems to not be completely understood, especially for impulsive noise. The noise close to the ear when shooting is difficult to measure without altering the sound field. The noise will change with measurement position, but standardized positions are difficult to agree on since they depend on the geometry of both shooter and weapons, and possibly surrounding objects. Propagation of the noise into the ear depend on the geometry of the individual ear. The inner ear that might be damaged may also be different from person to person.

MIL-STD-1474D [3] sets limits for shooting noise. First the time series of the pressure is measured where the shooter would have his head. Following MIL-STD-1474D we have low-pass filtered the data using a 12-order Bessel filter with 40 kHz cut of frequency. Then the filtered time series of the pressure is analyzed with an algorithm resulting in a peak pressure and a B-duration. Because of the low-pass filter the resulting peak will be lower than the actual peak. This is a feature that makes

the peak measurement less dependent on the measurement system. The B-duration is roughly the time window the signal is louder than 20 dB below the peak. The peak and the B-duration is then plotted together with four limiting curves, the W-curve, the X-curve, the Y-curve and the Z-curve (Figure 4.1). These curves define the allowed number of shots with specified hearing protection (Table 1.1). No shooting is allowed if the peak pressure is above the Z-curve. If the peak pressure is below the W-curve (140 dB) unlimited exposure is allowed without hearing protection (but not recommended).

Limit	No protection	Either plugs of muffs	both plugs and muffs
W	Unlimited	Unlimited	Unlimited
X	0	2000	40000
Y	0	100	2000
Z	0	5	100

Table 1.1 Exposure limits (number of shots) per day, according to MIL-STD-1474D.

MIL-STD-1474D has not been updated for several years. Currently MIL-STD-1474E is under development. Other groups in NATO also work on establishing new criteria that more accurately allow us to estimate the danger of hearing damage. This report only serves to document that the specified P-SRTA and PB makes less noise than ball ammunition, using the criteria specified in MIL-STD-1474D. This makes it very probable that this ammunition provide less risk of hearing damage than standard ammunition.

2 Measurement setup

Figure 2.1 Placement of the sensors. The reflectors seen on the sensors are removed before measurement, and is used for measurement of sensor positions with Topcon GPT 3107NW.

The time series of the pressure is measured at a position close to where the shooter would have his head (Figure 2.1). In the current investigation, this is 20 cm horizontally to the right of the barrel, in a plane 90 degrees to the barrel which also includes the shooters ears. The idea is that the measured noise at this sensor position will be the same as the noise at the left ear of an average shooter. Normally there is less noise closer to the barrel, so that the left ear will be the most critical.

The time series analyzed will include some reflections from the floor of the shooting platform (about 6 ms later than the direct sound). This will not affect the peak pressure, but might lead to somewhat larger B-duration. The increase is so small that it does not affect the conclusions of this report.

We used pressure field microphones from Brüel & Kjær of type 4938-A-001. The sampling rate was 204.8 kHz. Further description of the measurements equipment can be found in [1].

We also measured 1 m to the left of the muzzle. This is not relevant for hearing damage to the shooter, but is included in Appendix A for possible future interest. E.g. it might be relevant for hearing damage of a soldier advancing past another soldier firing his weapon.

3 Weapons and ammunition

The main task of this report is to measure P-SRTA and PB ammunition from Nammo Bakelitt-fabrikken used with HK 416N and HK 416K. We have also included other weapons and ammunition to give a somewhat broader view.

NM250 is a P-SRTA in caliber 5.56x45 mm NATO. We have used lot 02-BF-15. NM250 has a plastic projectile with high muzzle velocity. The velocity of the projectile decreases very fast, so that the safety template at the shooting range is much smaller than with ball ammunition.

PB ammunition is without a projectile, but still has shooting noise and recoil. A blank firing attachment (BFA) is attached to the flash hider at the muzzle, restricting the gas flow (Figure 3.3 and Figure 3.4). This is necessary to make the weapon function properly. The design of the BFA's directs the gun powder gas in different directions, highly influencing the directivity of the noise. This seems to be more important to the noise level at the shooters ear than the ammunition. Some of the BFA's are not symmetric around the barrel axis. This could possibly lead to different results if the BFA's are mounted another way (rotated differently). The weapons was fired with the BFA's mounted as shown in the pictures.

In caliber 5.56 mm PB NM226F1, lot 17-BF-14 were used. In caliber 7.62 mm we use two types of PB (Figure 3.2), identified by Nammo as NM134 (lot 03-BF-93) and NM126 (lot 43411001).

The ball ammunition in caliber 5.56 mm is NM255 of lot 14-CG-12. The ball ammunition in caliber 7.62 mm is NM231 of lot lot 04-CG-07.

The weapons used were HK 416N (weapon number 88-006854), HK 416K (weapon number 88-048211). HK 416 is the standard weapon of the Norwegian defence (Figure 3.1). We also used AG3 (Figure 3.1), MG3 and FN Minimi Para 5.56 mm (Figure 3.1).

Figure 3.1 Left: HK 416N. Right HK 416K

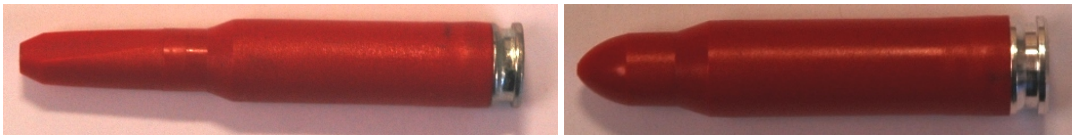


Figure 3.2 PB in caliber 7.62x51 mm. Left: NM134. Right: NM126.

Figure 3.3 BFA's. Left: HK 416N. Right: HK 416K.

Figure 3.4 BFA's. Left Minimi 5.56 mm Para. Right AG3.

4 Results and summary

For each combination of weapon and ammunition we present a figure with three plots (Figure 4.1–4.13):

1. Time series of the pressure
2. 1/3-octave, C-weighted sound exposure level
3. Weapon noise relative to MIL-STD-1474D noise limits

The time series of the pressure in the plots are unfiltered. The red squares and triangles are sub results from the MIL-STD-1474D algorithm, i.e. they are based on the filtered time series. E.g the red square represents the filtered peak and is smaller than the unfiltered peak. Other red symbols relate to the B-duration. The green lines represent the level that is 20 dB smaller than the filtered peak.

The C-weighted sound exposure level [1] says something about how loud the shooting noise sound to the shooter. It is believed that peak pressure is very important for hearing damage. However, energy based indicators, such as sound exposure level, could also be relevant. This is in some way reflected in the B-duration, since the B-duration will most often increase when the sound exposure level increase (and peak pressure remain constant).

Weapon	Ammunition	Type	max peak (MIL-STD-1474D)	$L_{\mathrm{CE}}[dB]$
HK 416N	NM226F	PB	153	111
HK 416N	NM250	P-SRTA	153	114
HK 416N	NM255	Ball	159	121
HK 416K	NM226F1	PB	162	120
HK 416K	NM250	P-SRTA	159	119
HK 416K	NM255	Ball	164	126
FN Minimi Para	NM226F1	PB	153	116
FN Minimi Para	NM255	Ball	162	123
AG3	NM126	PB	149	108
AG3	NM134	PB	157	112
AG3	NM231	Ball	160	123
MG3	NM134	PB	147	105
MG3	NM231	Ball	155	118

Table 4.1 Max peak pressure over all 10 shots for each weapon, according to MIL-STD-1474D.

The main result of this report is given in the plots of the MIL-STD-1474D noise limits relative to the noise of the different weapons. We have measured and plotted 10 shots for each combination of weapon and ammunition. As we see, all the results lie between the W-curve and the X-curve. This means that (according to MIL-STD-1474D) you need to wear hearing protection, but that you

can shoot 2000 shots with either ear plugs or muffs, or 40000 shots with both plugs and muffs protection. However, this does not change the fact that more hearing protection is always better for your hearing.

More importantly, we compare P-SRTA and PB ammunition with ball ammunition. In Table 4.1 we see that the peak pressure and the C-weighted sound exposure level is smaller for P-SRTA and PB ammunition than for ball ammunition. This means that the use of such ammunition reduce the risk of hearing damage for the shooter.

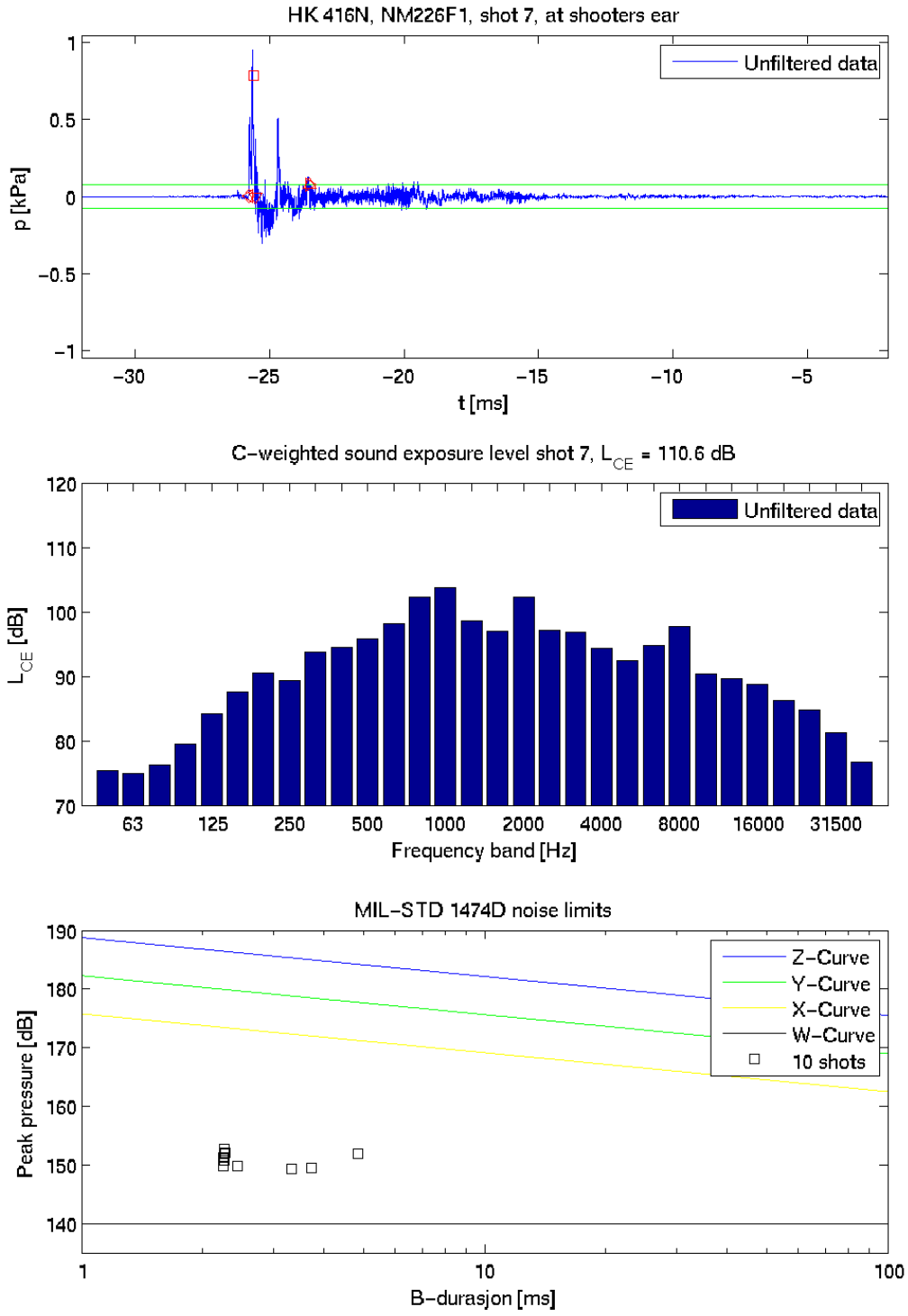


Figure 4.1 HK 416N with NM226F1.

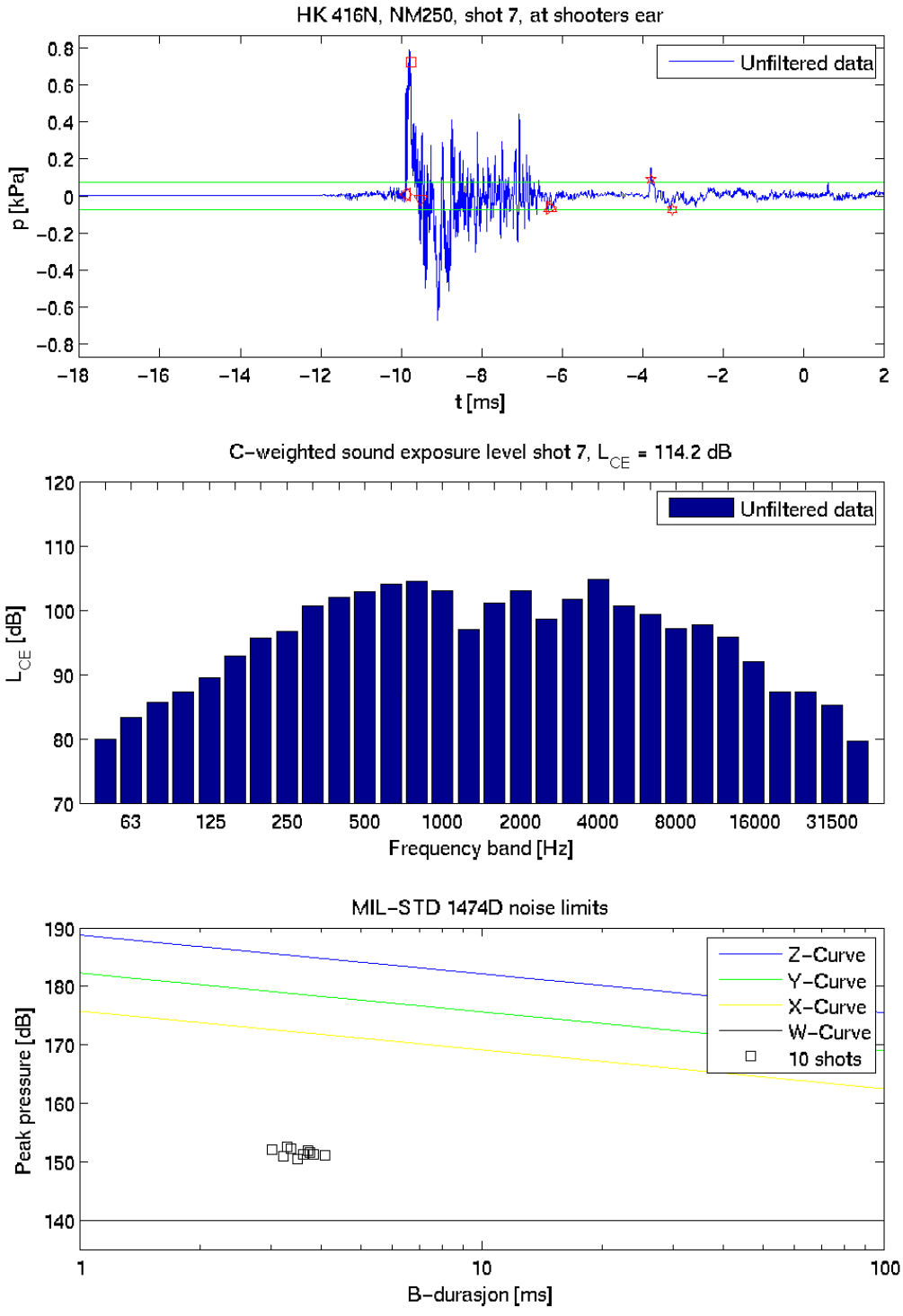


Figure 4.2 HK 416N with NM250.

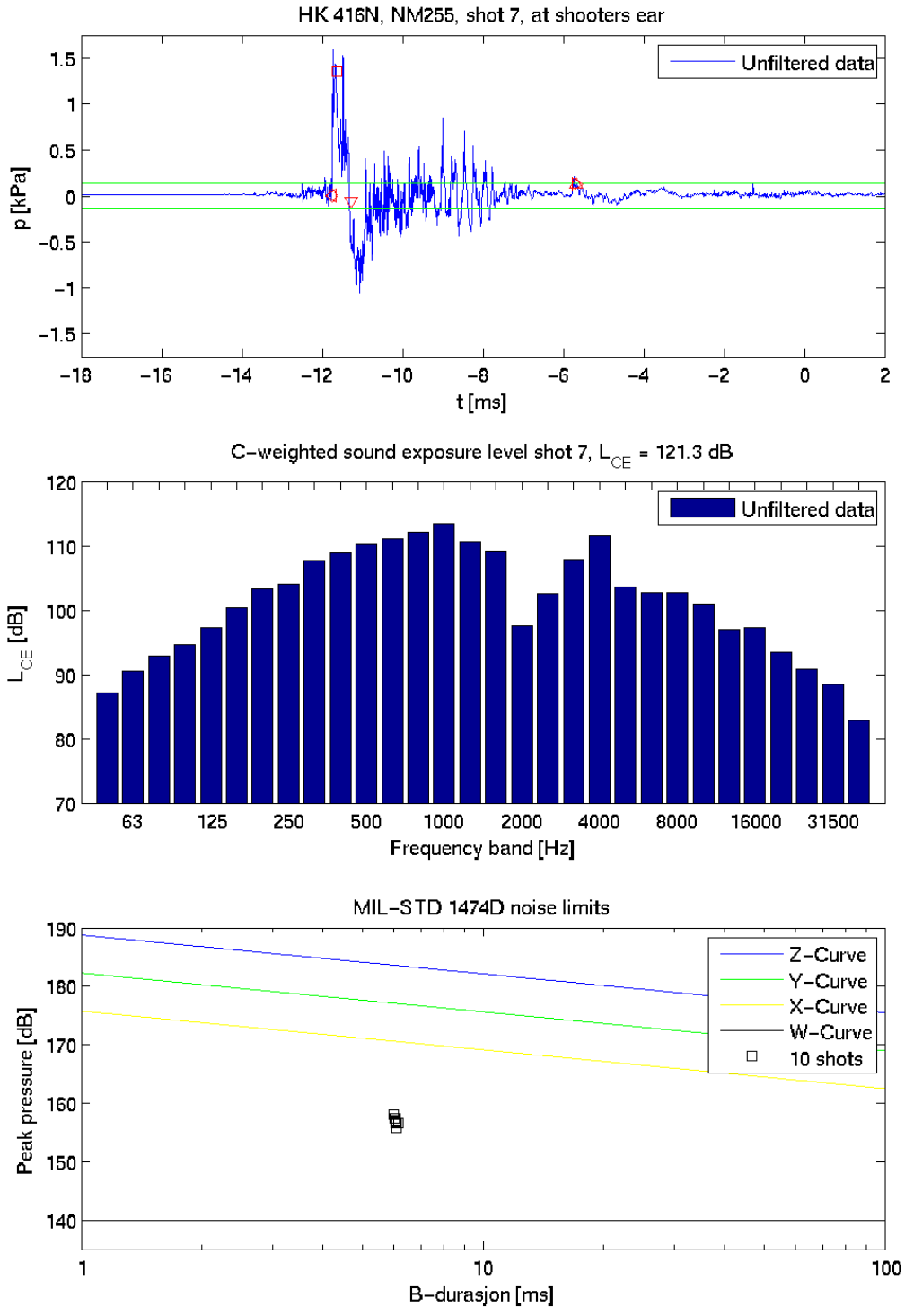


Figure 4.3 HK 416N with NM255.

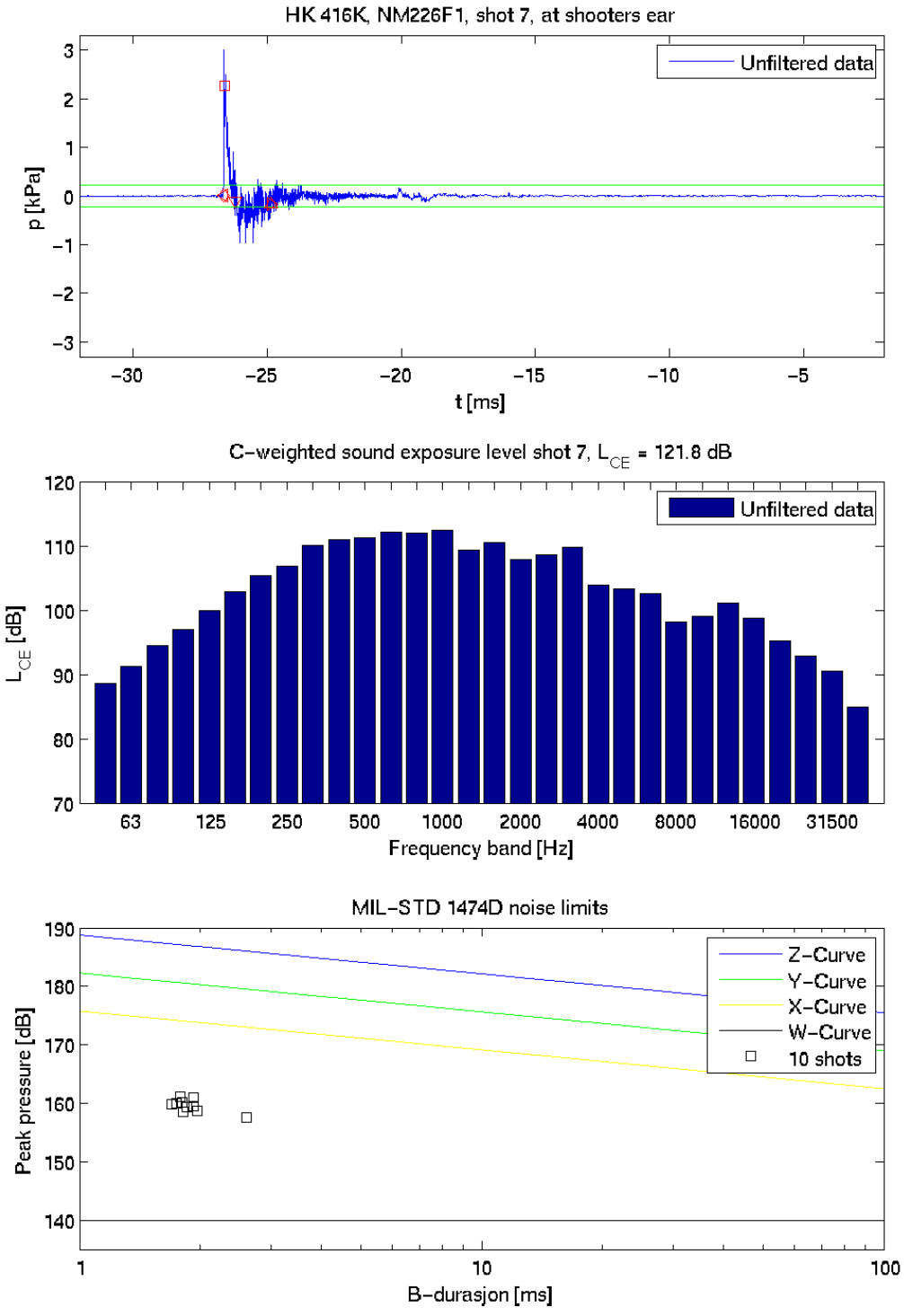


Figure 4.4 HK 416K with NM226F1.

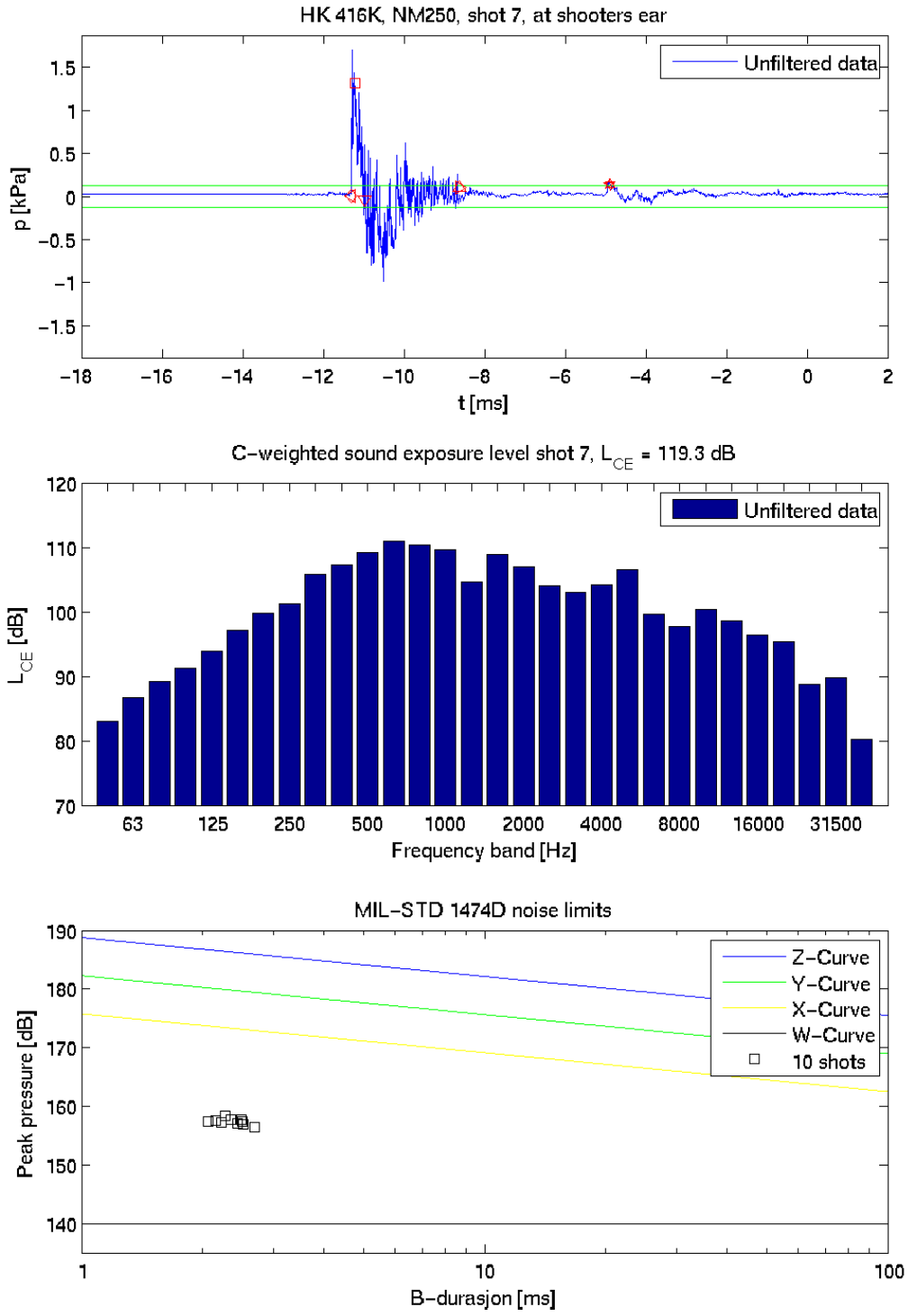


Figure 4.5 HK 416K with NM250.

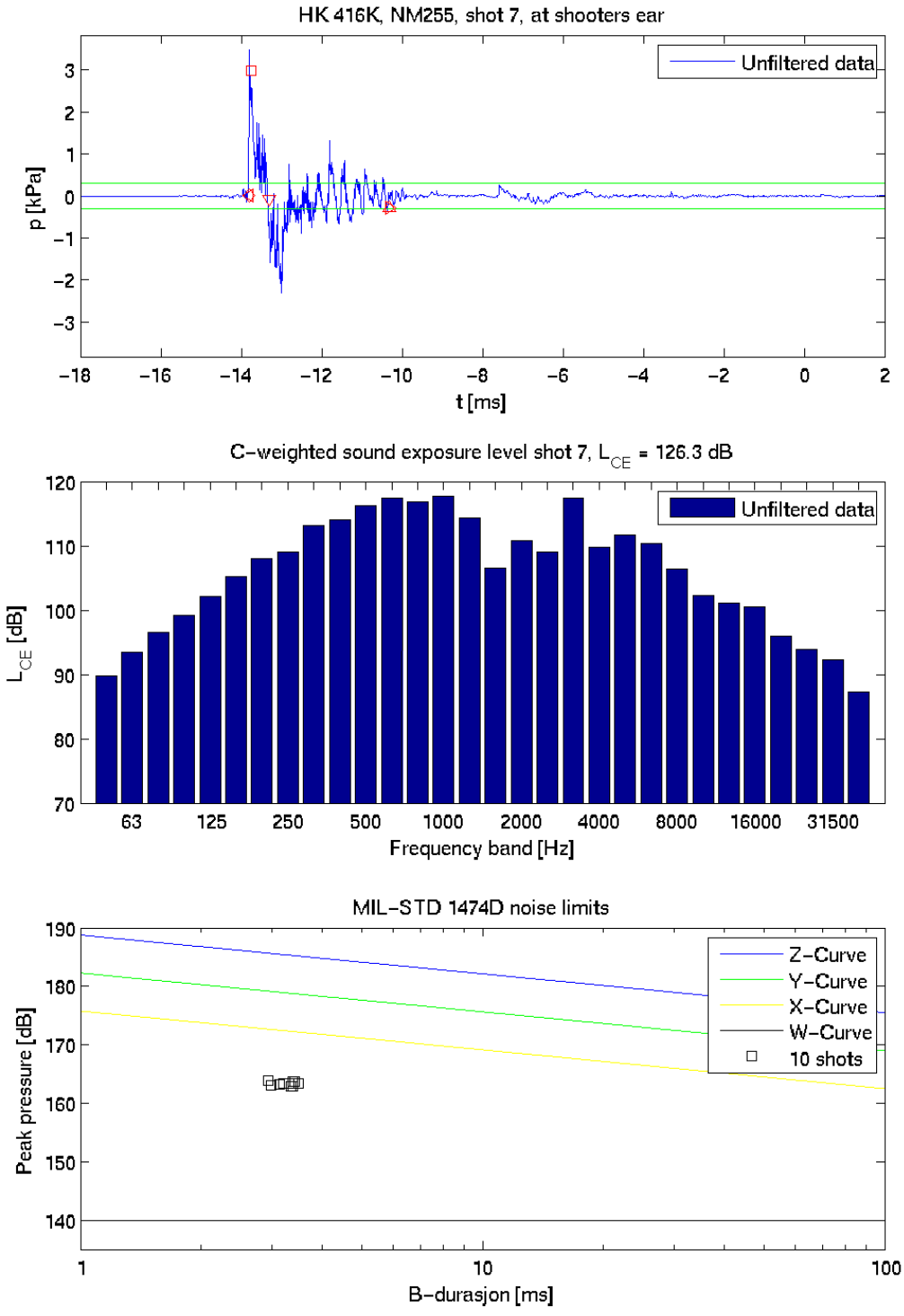


Figure 4.6 HK 416K with NM255.

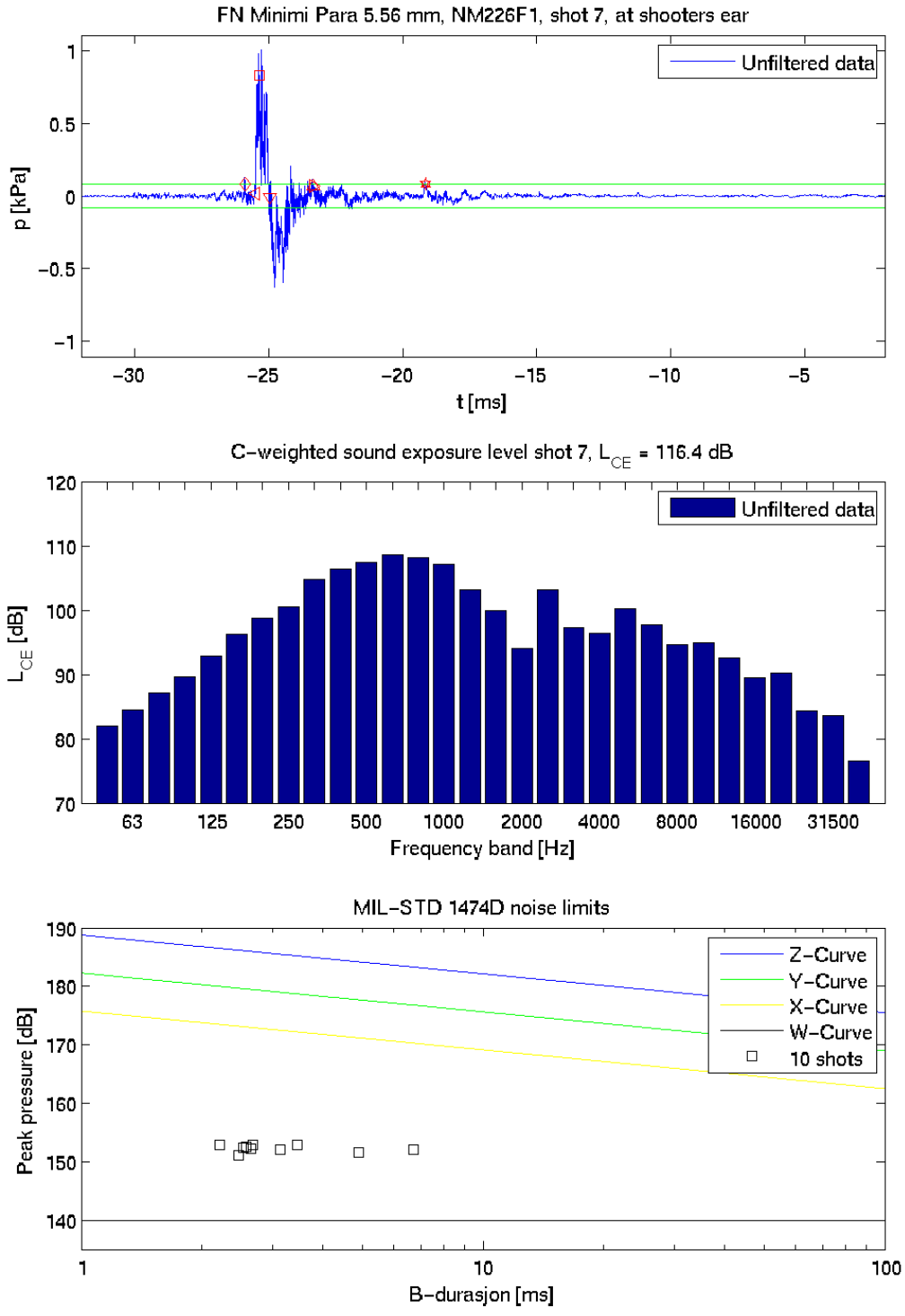


Figure 4.7 FN Minimi Para 5.56 mm with NM226F1.

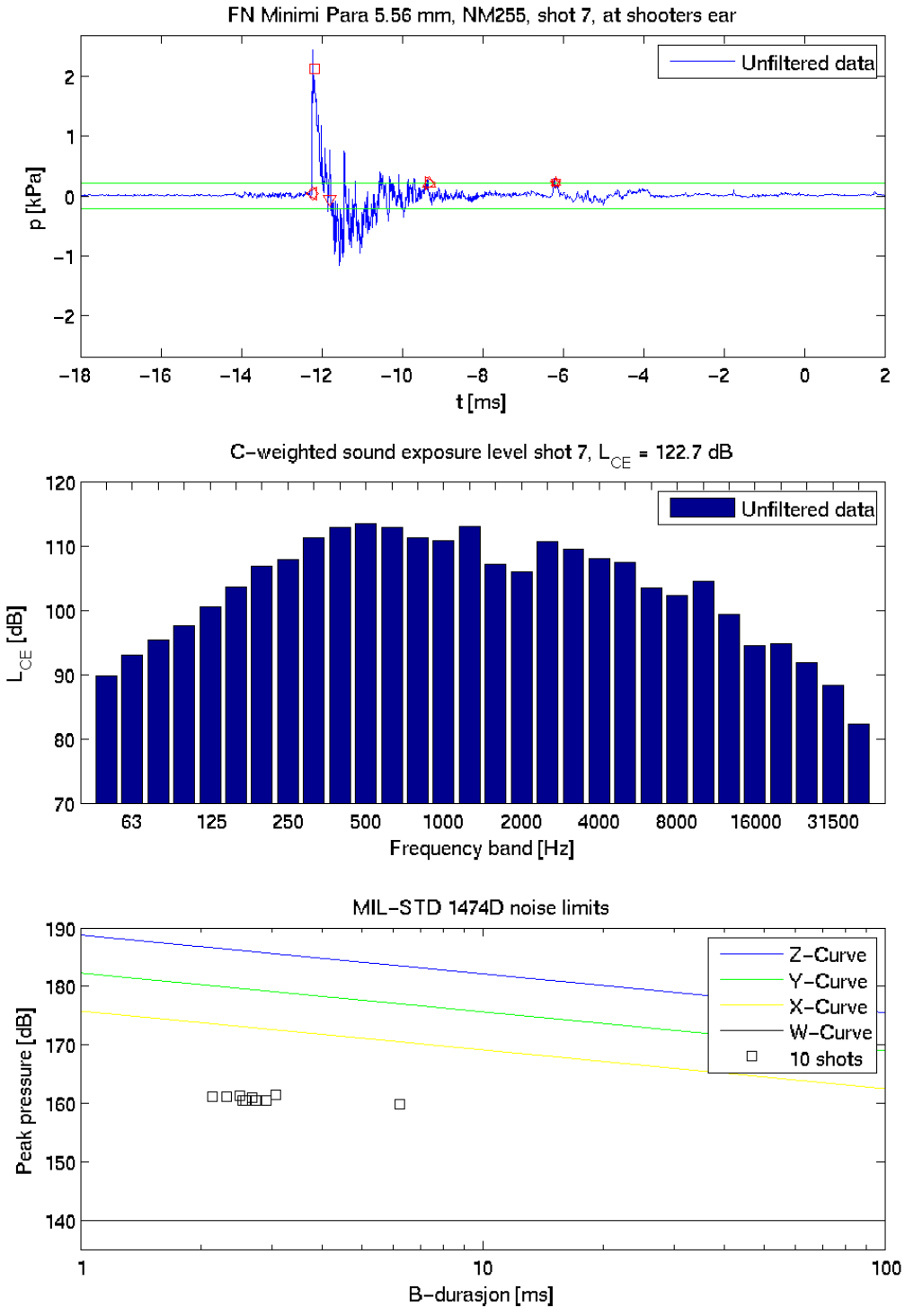


Figure 4.8 FN Minimi Para 5.56 mm with NM255.

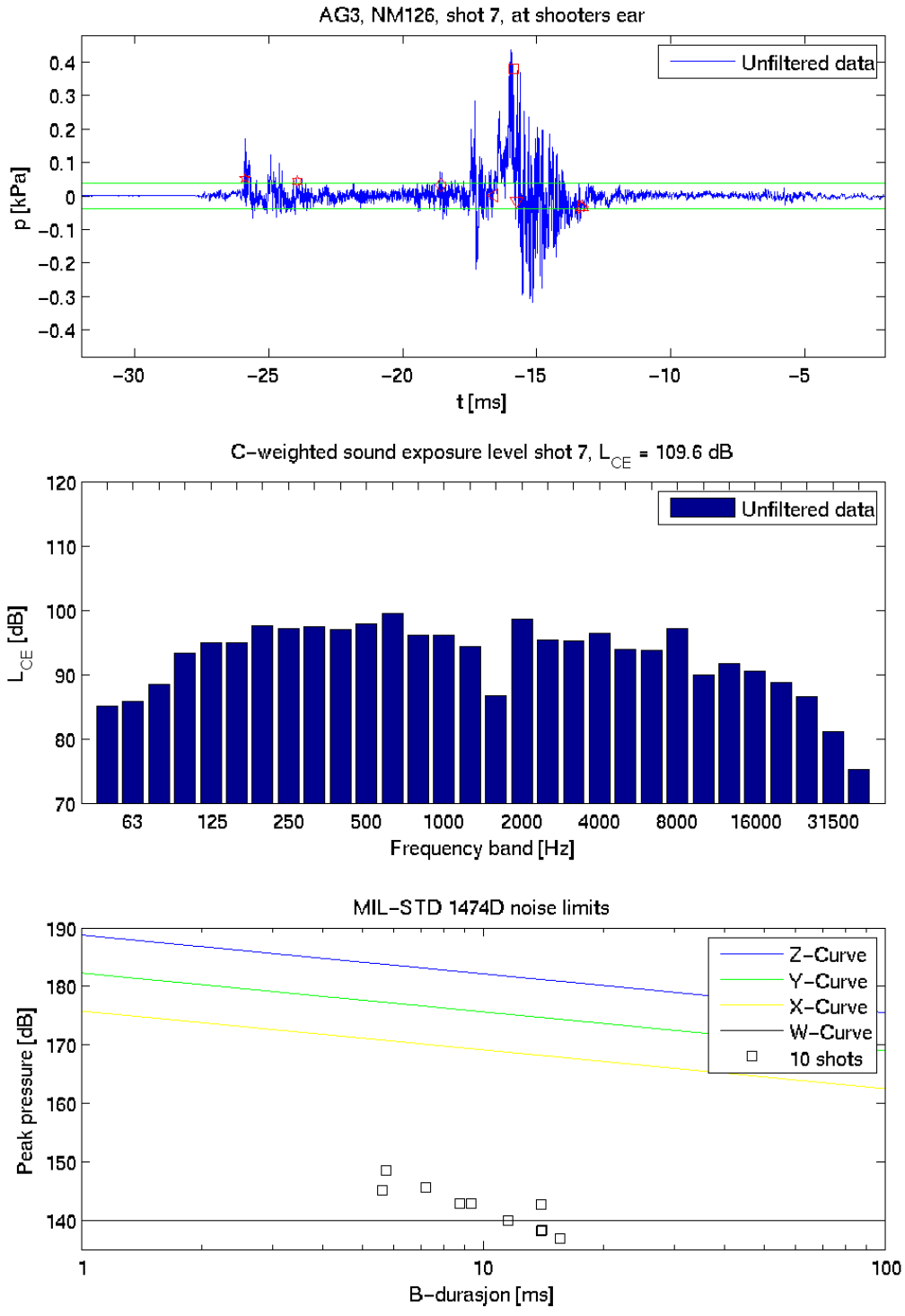


Figure 4.9 AG3 with NM126.

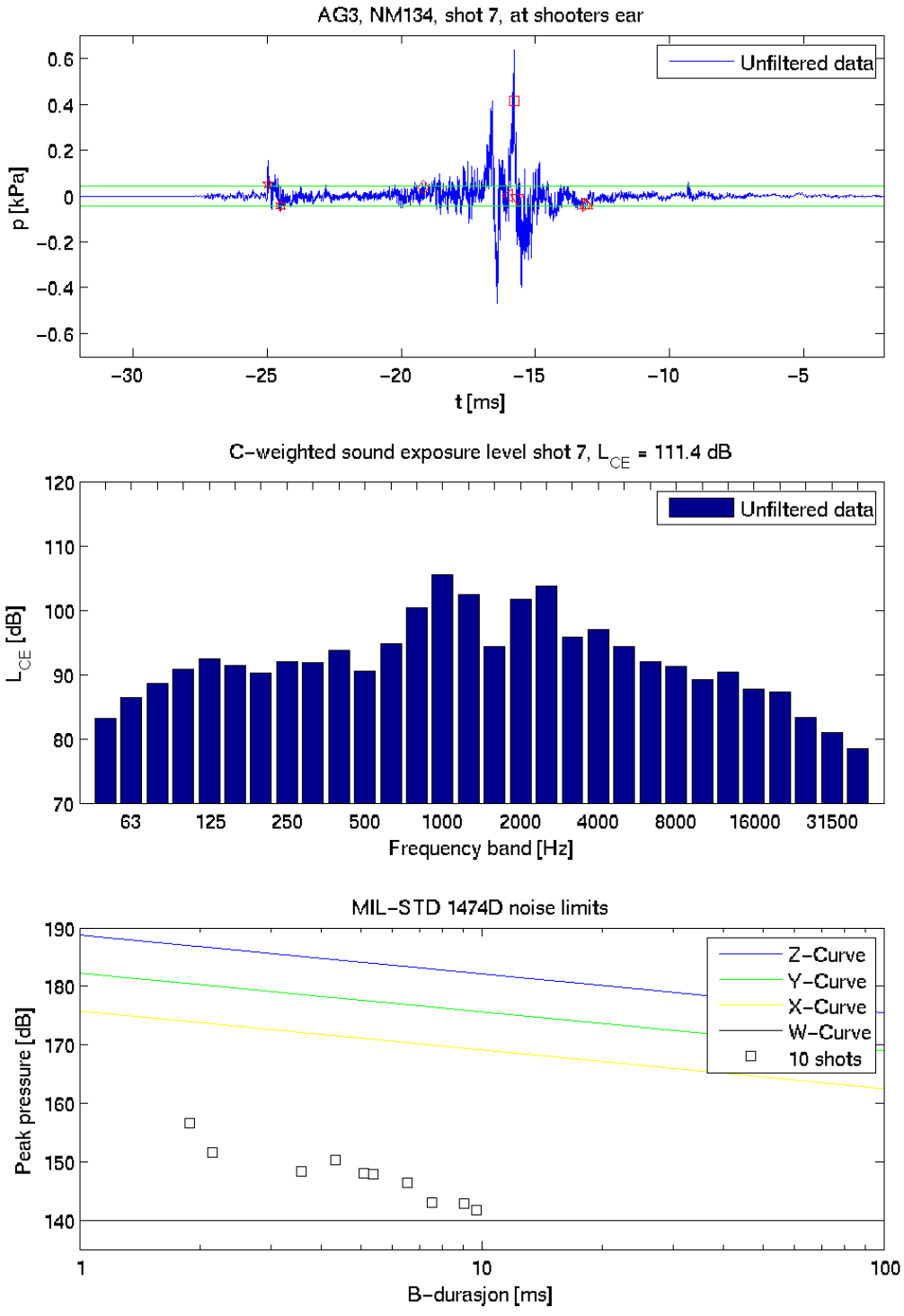


Figure 4.10 AG3 with NM134.

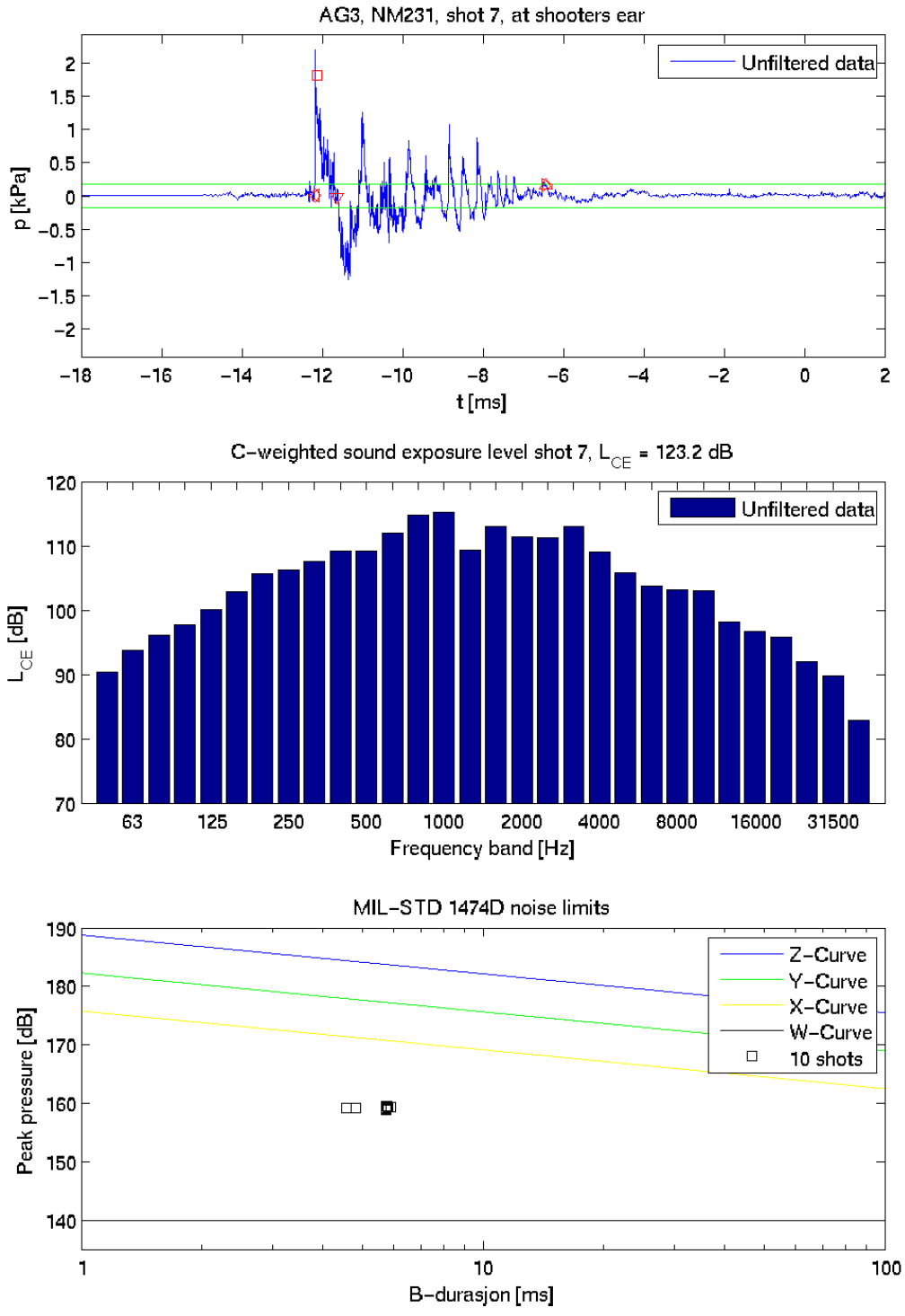


Figure 4.11 AG3 with NM231.

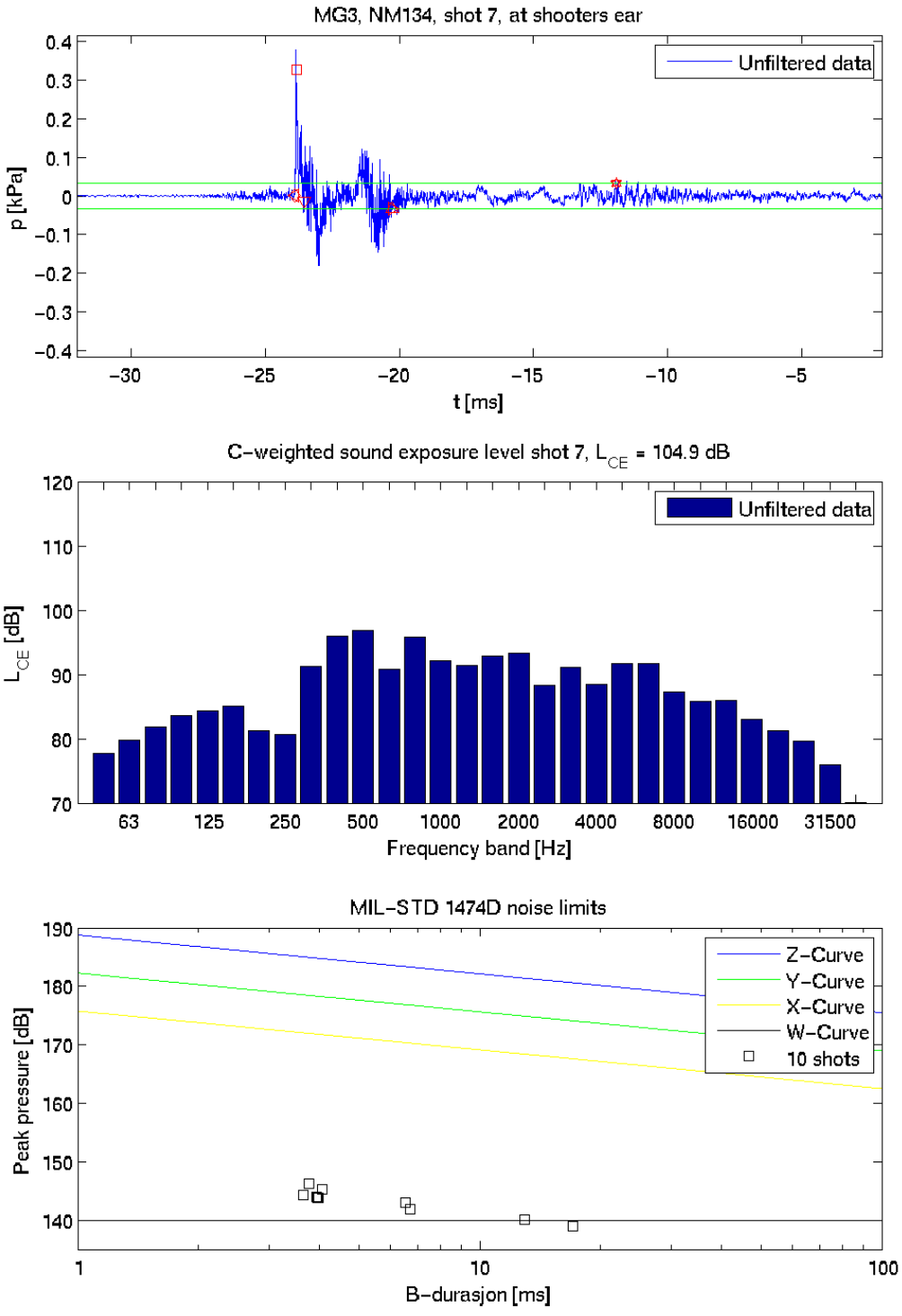


Figure 4.12 MG3 with NM134.

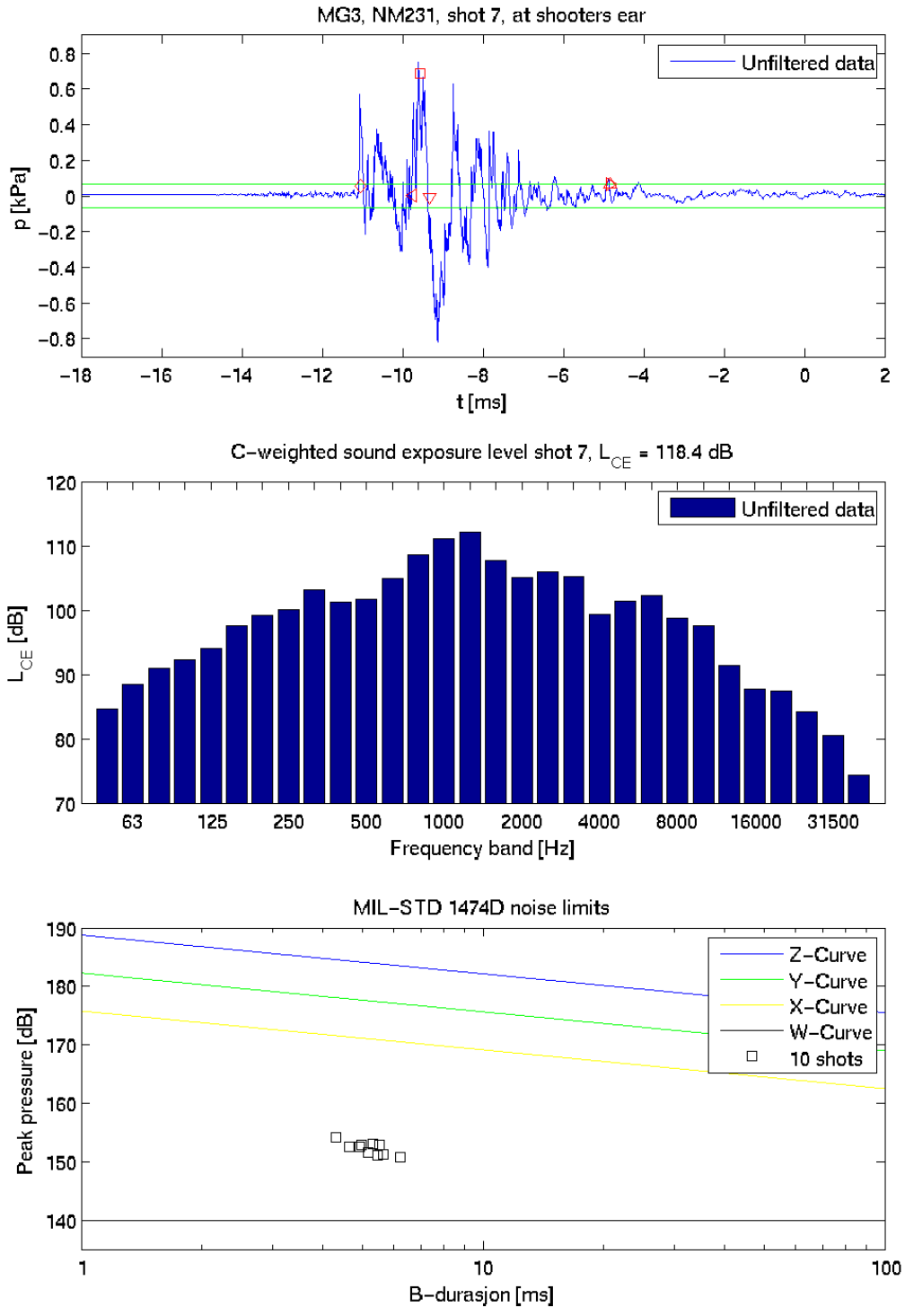
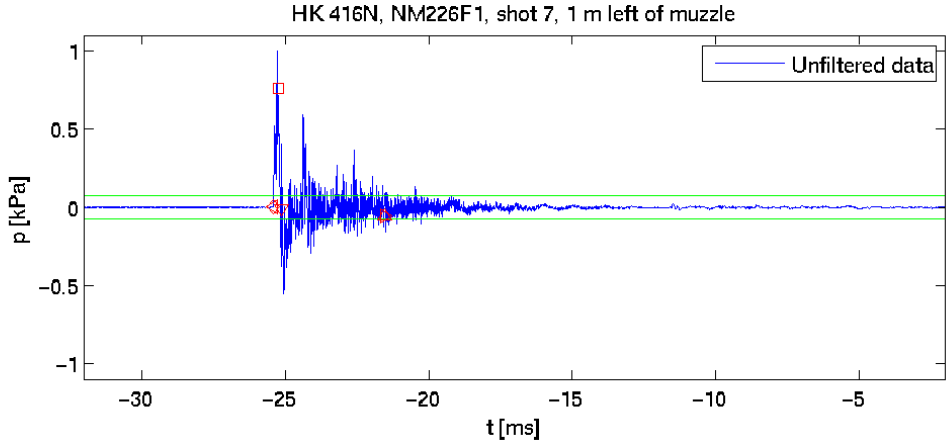
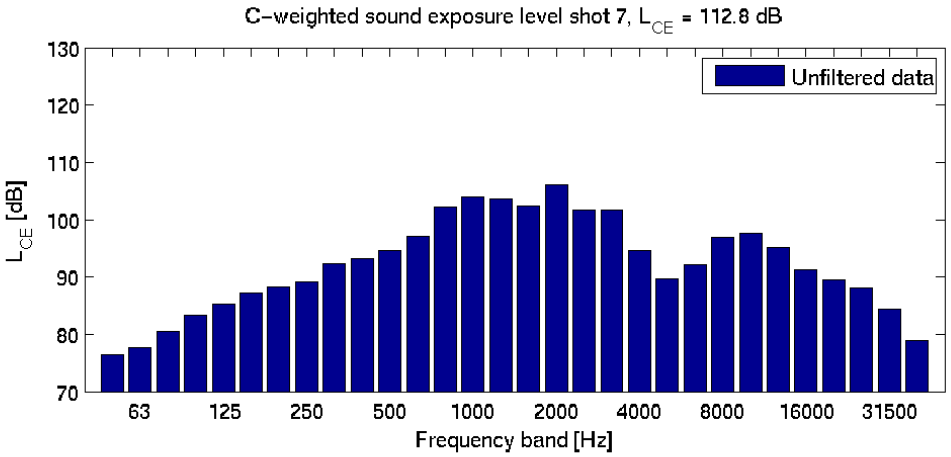
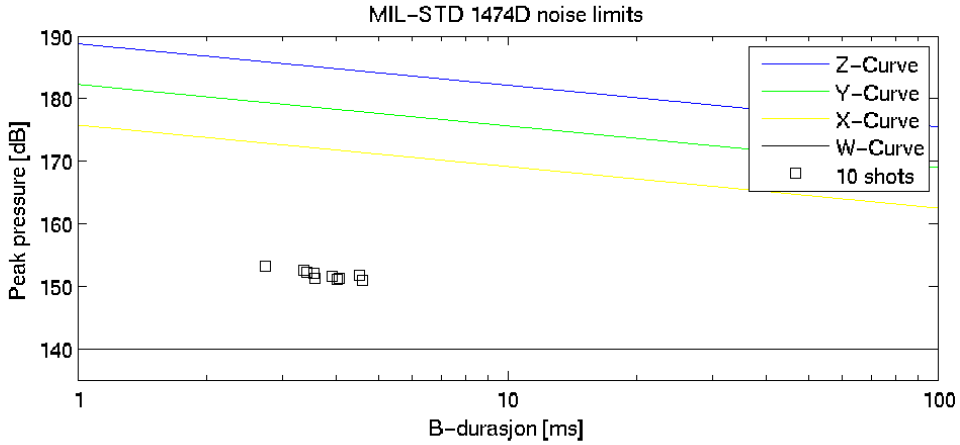


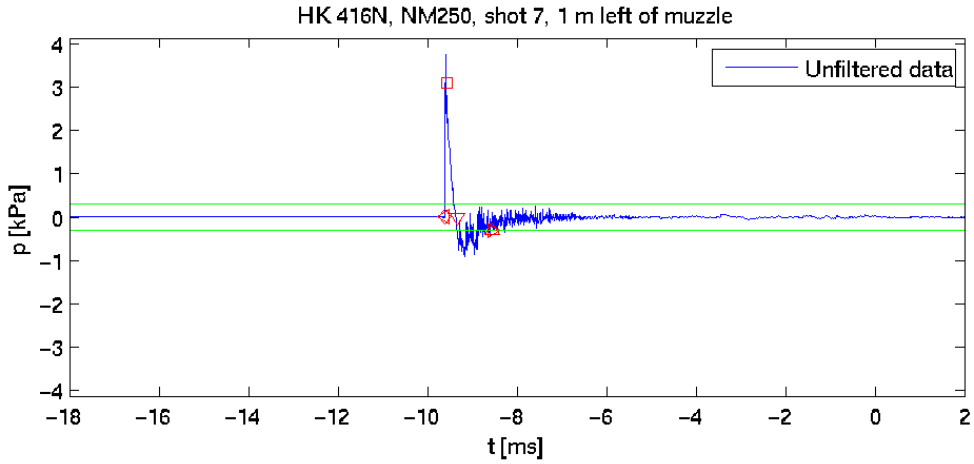
Figure 4.13 MG3 with NM231.

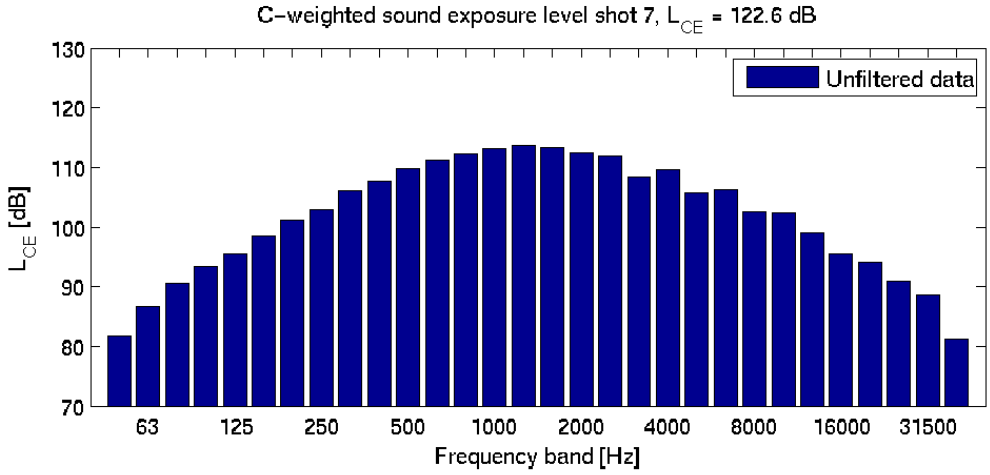
Appendix A Measurements 1 m to the left of the muzzle

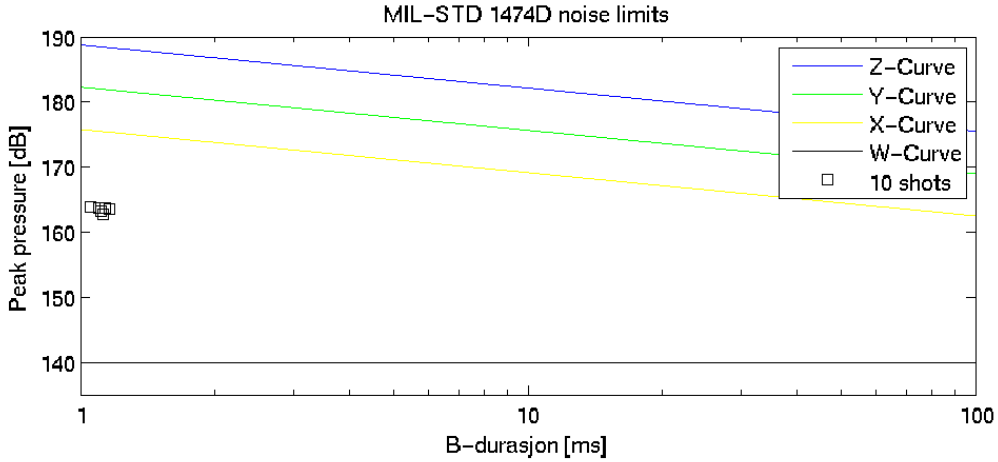


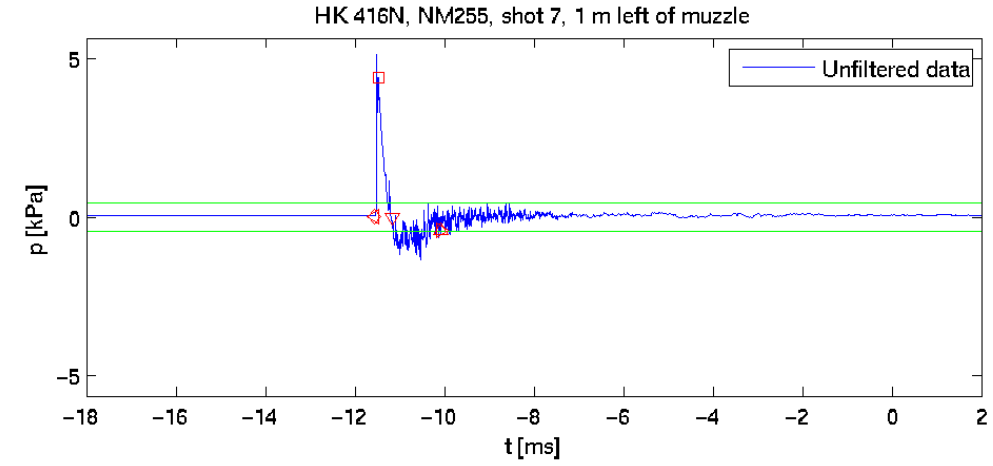





HK 416N, NM250, shot 7, 1 m left of muzzle
Unfiltered data
p [kPa]
t [ms]


C-weighted sound exposure level shot 7, L_CE = 122.6 dB
Unfiltered data
L_CE [dB]
Frequency band [Hz]


MIL-STD 1474D noise limits
Z-Curve
Y-Curve
X-Curve
W-Curve
10 shots
Peak pressure [dB]
B-durasjon [ms]


HK 416N, NM255, shot 7, 1 m left of muzzle
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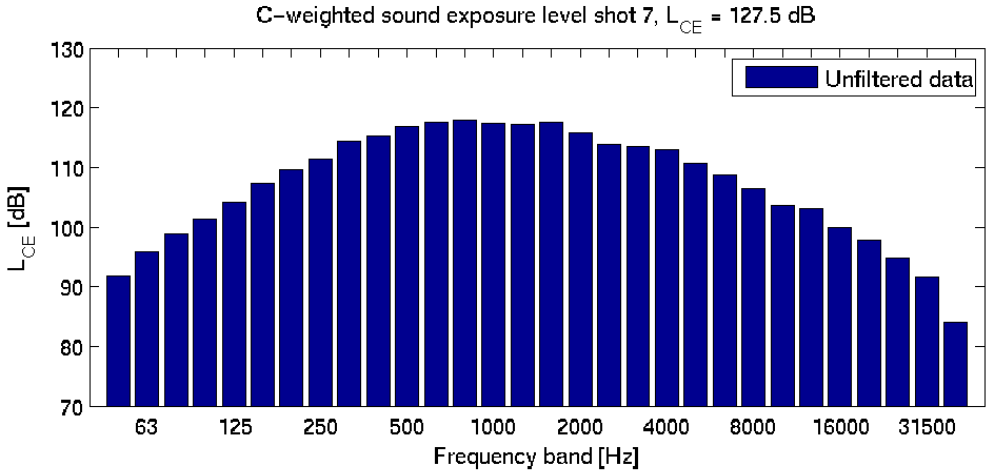
p [kPa]
t [ms]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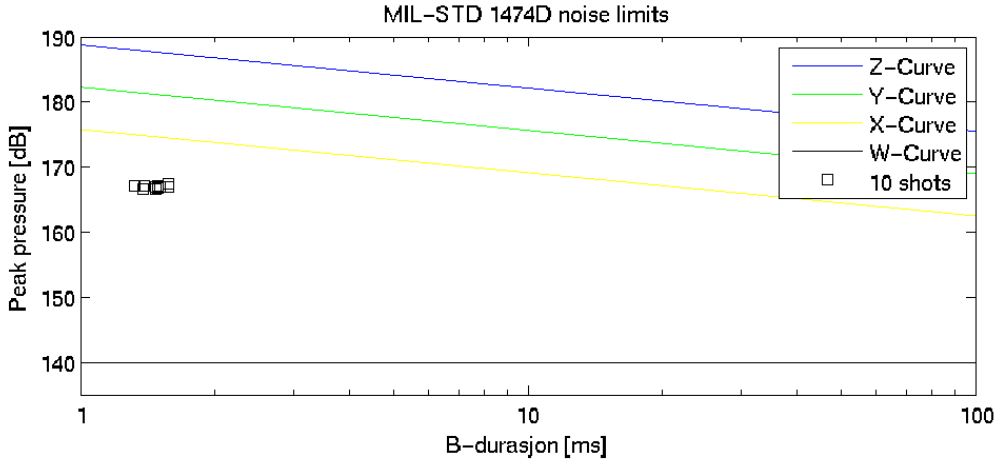
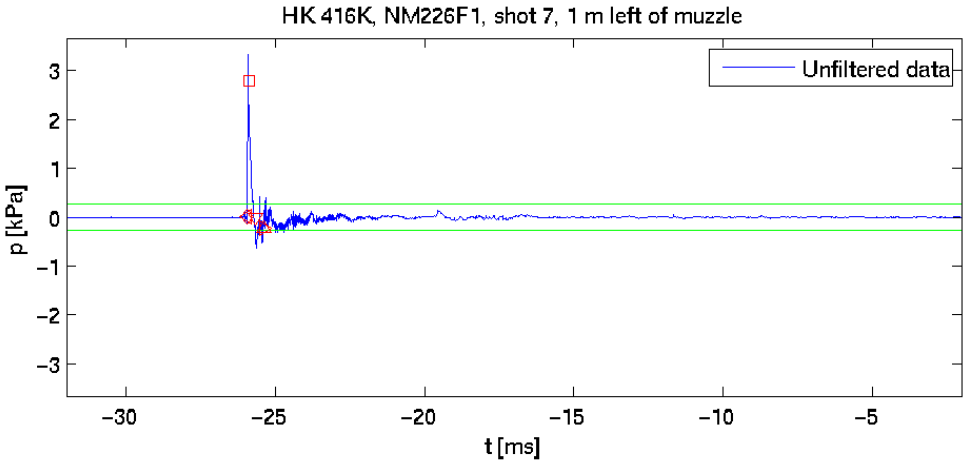
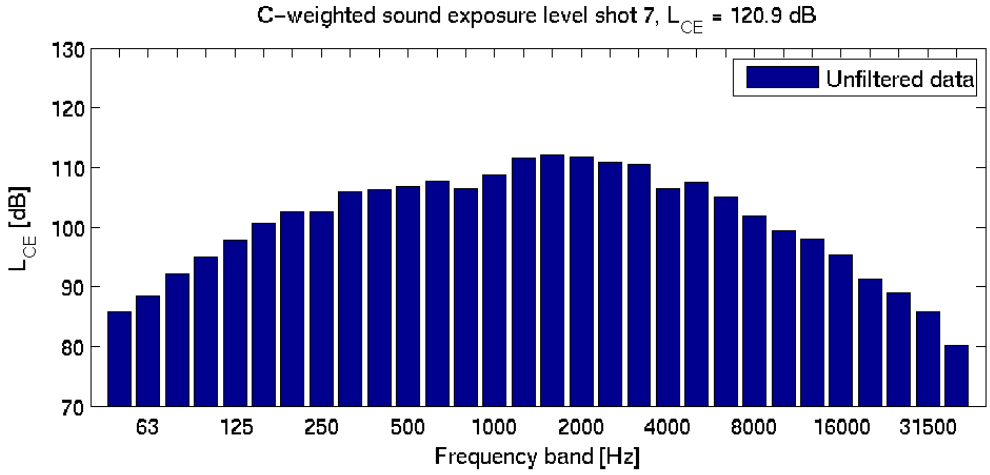
L_CE [dB]
Frequency band [Hz]


MIL-STD 1474D noise limits
Z-Curve
Y-Curve
X-Curve
W-Curve
10 shots
Peak pressure [dB]
B-durasjon [ms]


HK 416K, NM226F1, shot 7, 1 m left of muzzle
Unfiltered data
p [kPa]
t [ms]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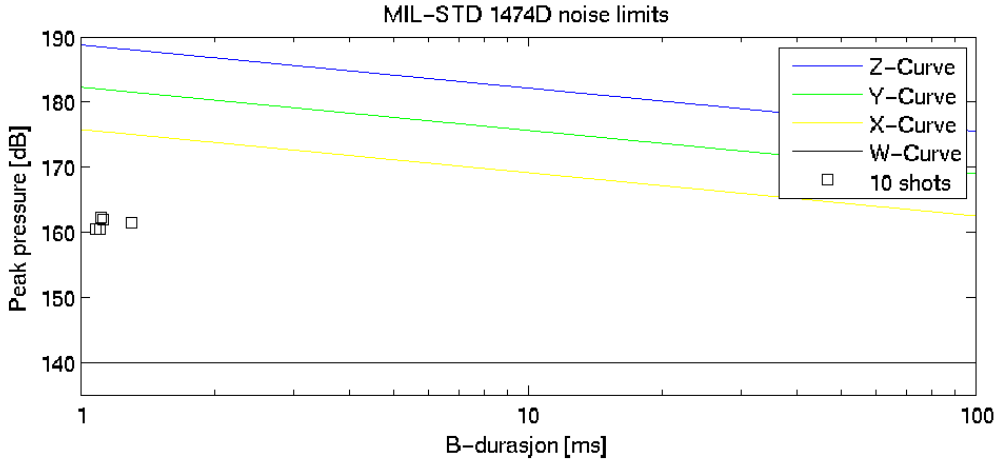
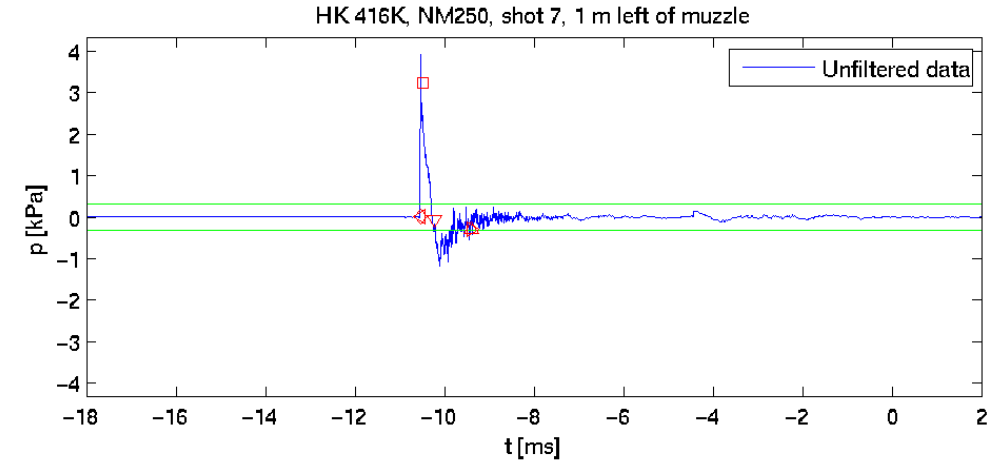
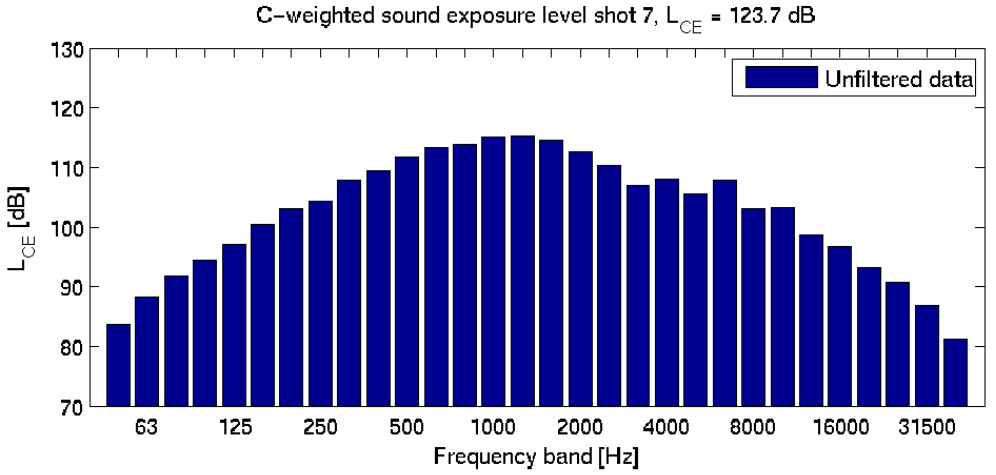
Unfiltered data
L_CE [dB]
Frequency band [Hz]


MIL-STD 1474D noise limits
Z-Curve
Y-Curve
X-Curve
W-Curve
10 shots
Peak pressure [dB]
B-durasjon [ms]


HK 416K, NM250, shot 7, 1 m left of muzzle
Unfiltered data
p [kPa]
t [ms]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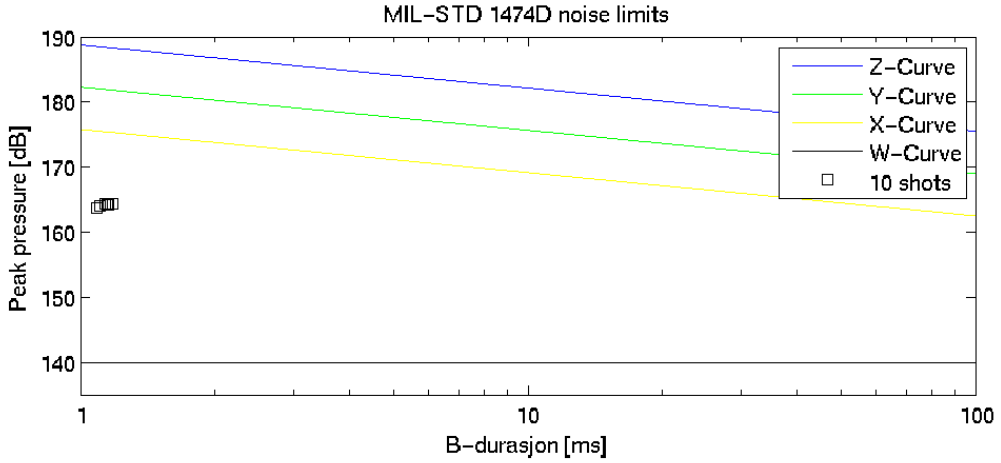
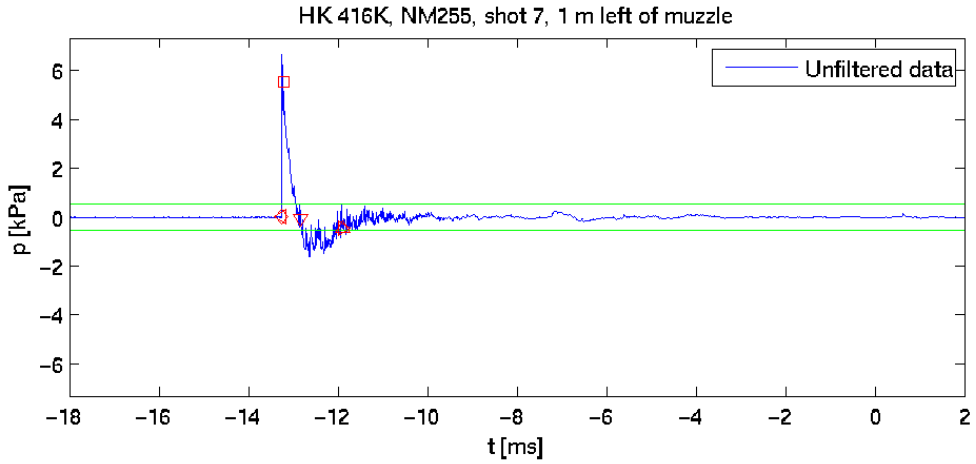
L_CE [dB]
Frequency band [Hz]


MIL-STD 1474D noise limits
Z-Curve
Y-Curve
X-Curve
W-Curve
10 shots
Peak pressure [dB]
B-durasjon [ms]


HK 416K, NM255, shot 7, 1 m left of muzzle
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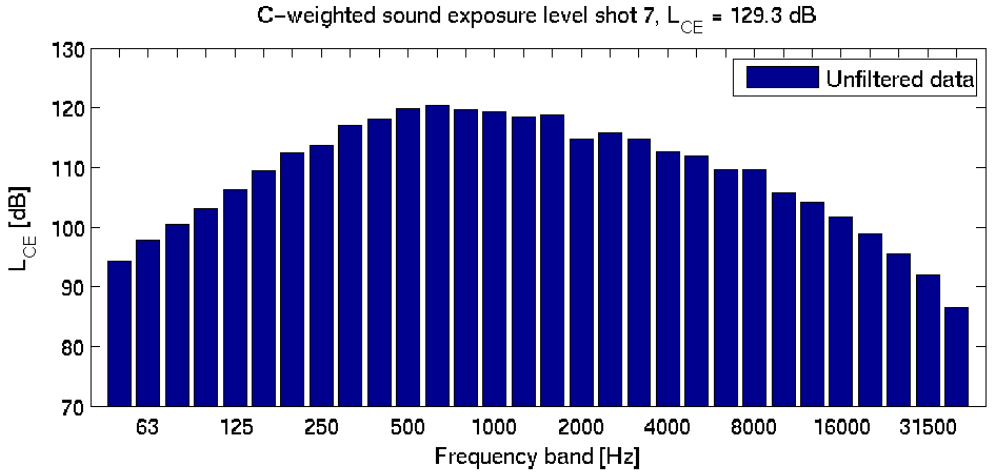
t [ms]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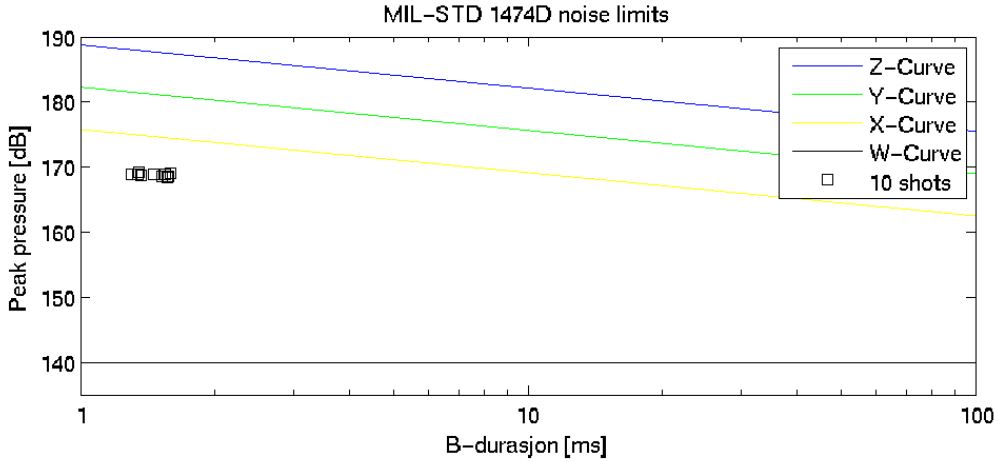
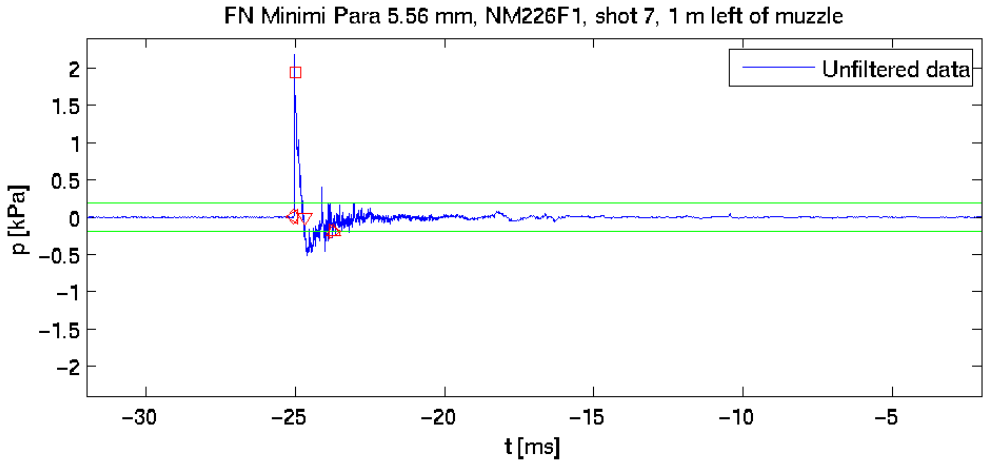
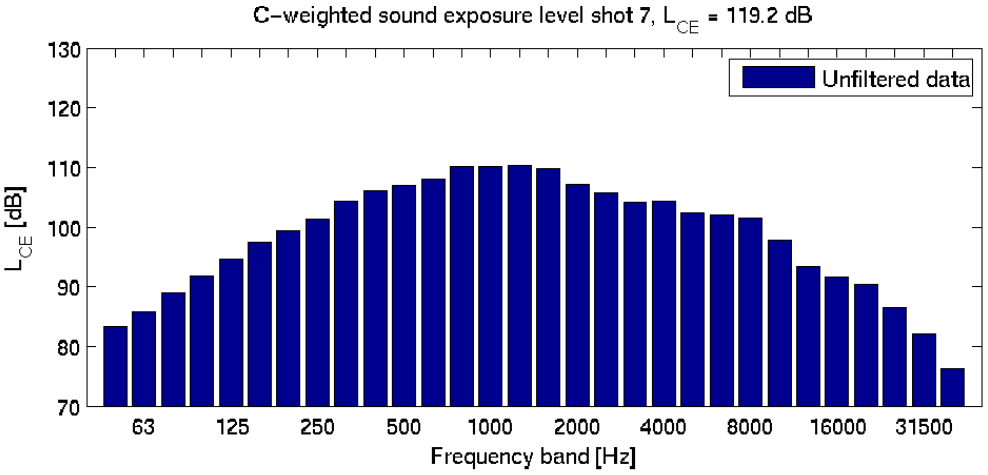
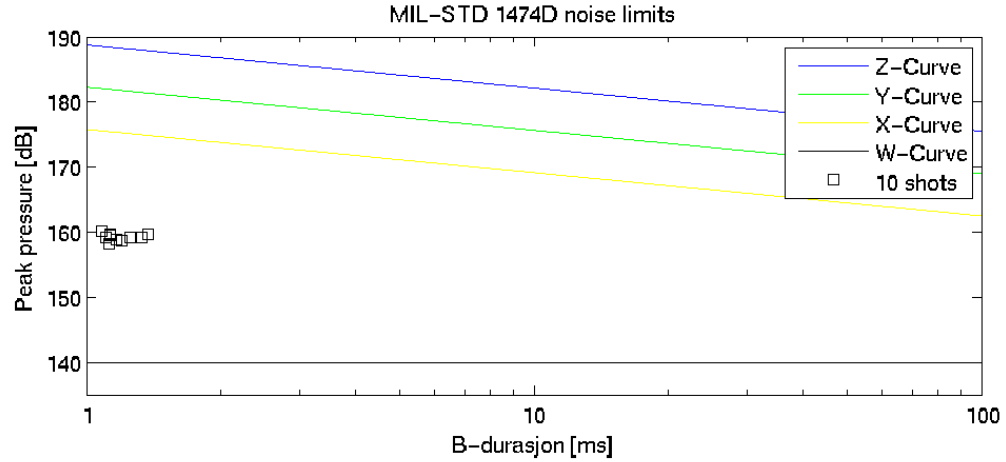
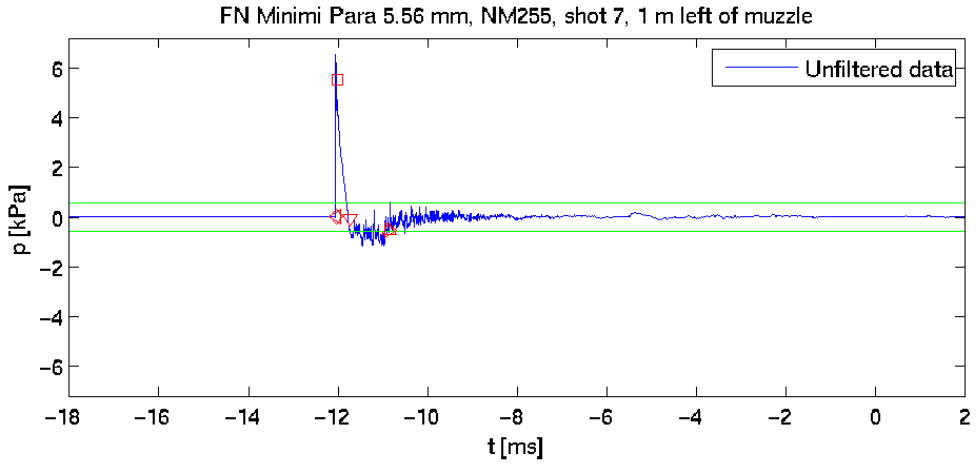
Frequency band [Hz]

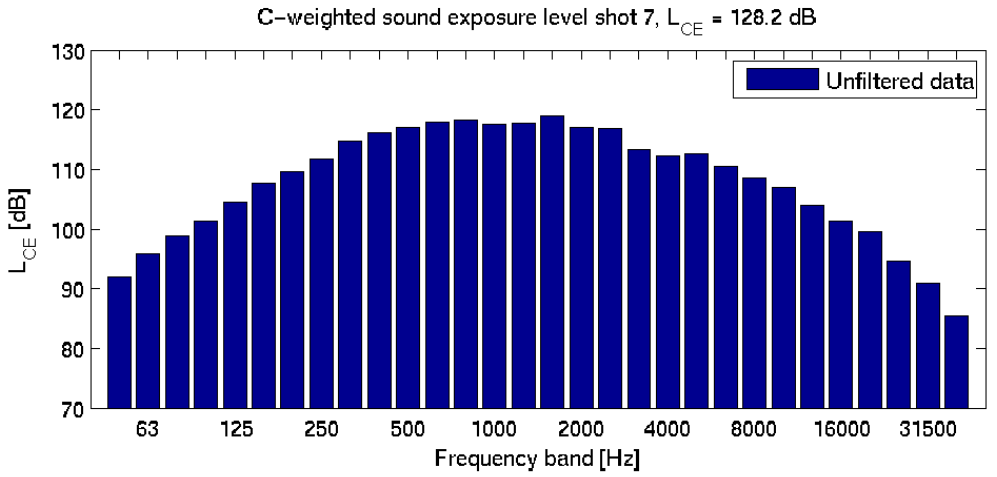

MIL-STD 1474D noise limits
Z-Curve
Y-Curve
X-Curve
W-Curve
10 shots
Peak pressure [dB]
B-durasjon [ms]

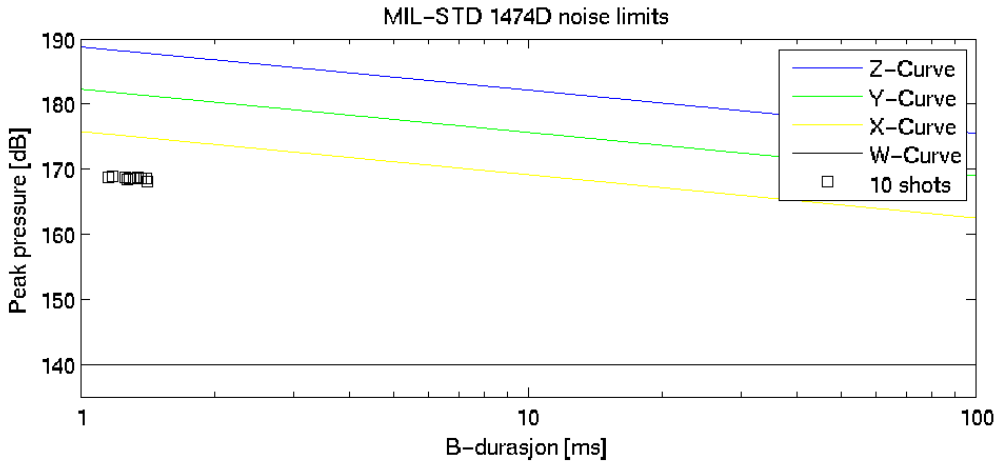

FN Minimi Para 5.56 mm, NM226F1, shot 7, 1 m left of muzzle
Unfiltered data
p [kPa]
t [ms]

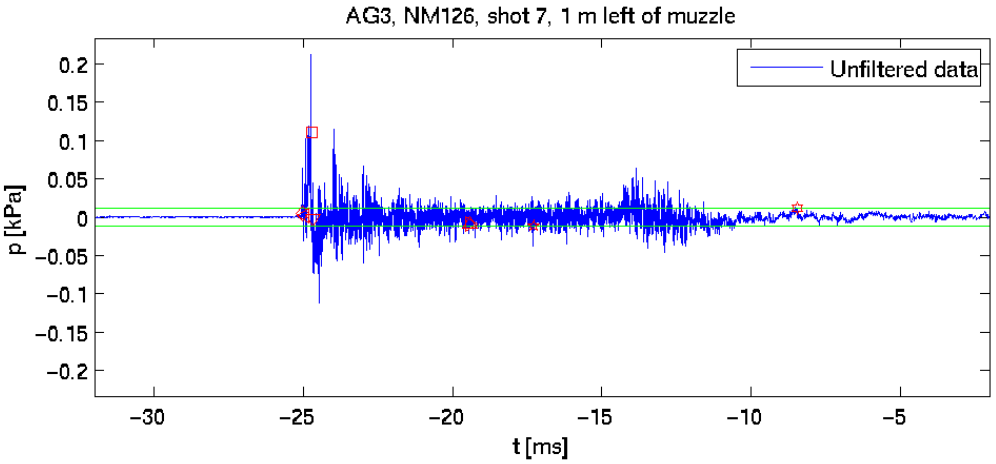

C-weighted sound exposure level shot 7, L_CE = 119.2 dB
Unfiltered data
L_CE [dB]
Frequency band [Hz]

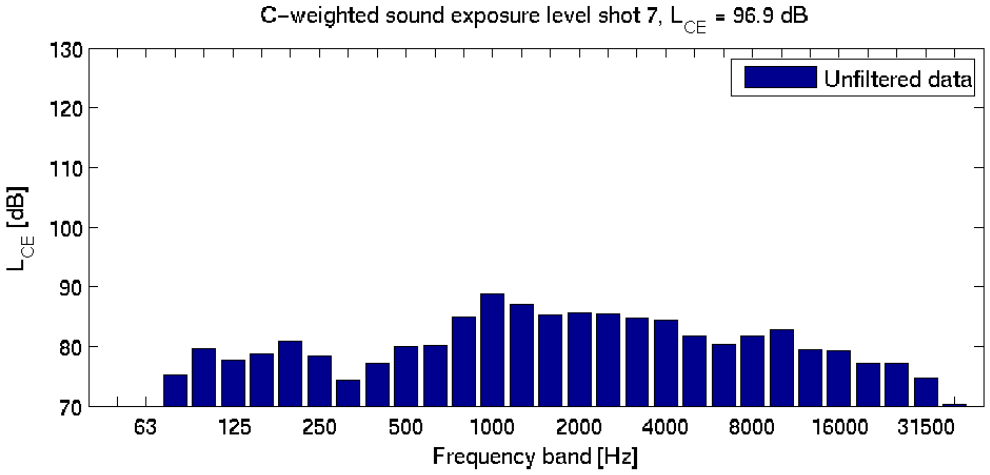

MIL-STD 1474D noise limits
Z-Curve
Y-Curve
X-Curve
W-Curve
10 shots
Peak pressure [dB]
B-durasjon [ms]

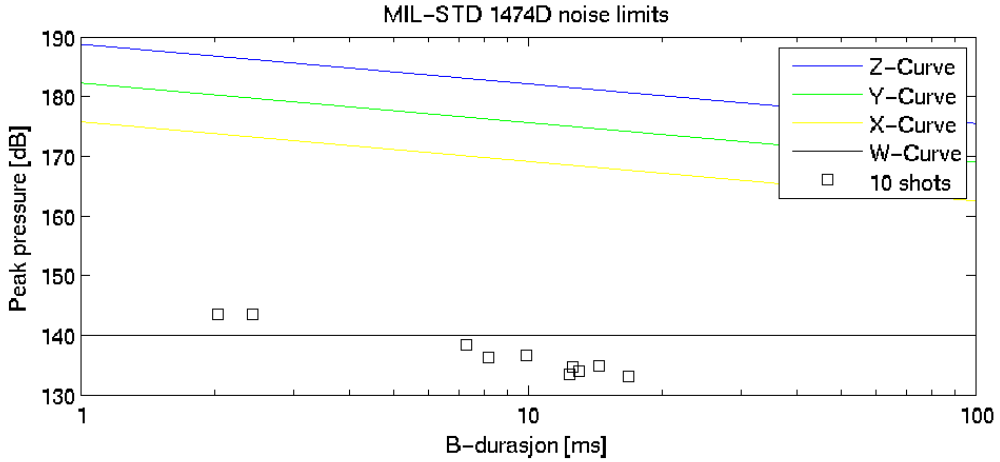

FN Minimi Para 5.56 mm, NM255, shot 7, 1 m left of muzzle
Unfiltered data
p [kPa]
t [ms]

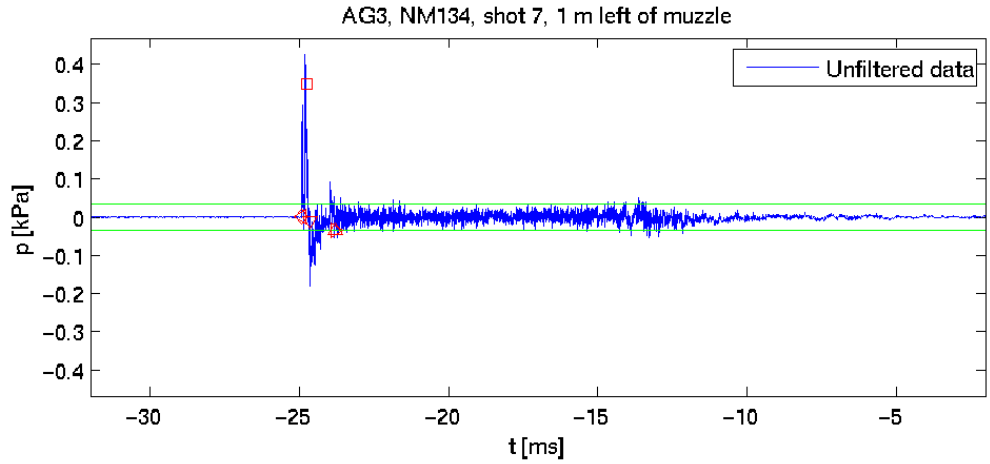

C-weighted sound exposure level shot 7, L_CE = 128.2 dB
Unfiltered data
L_CE [dB]
Frequency band [Hz]

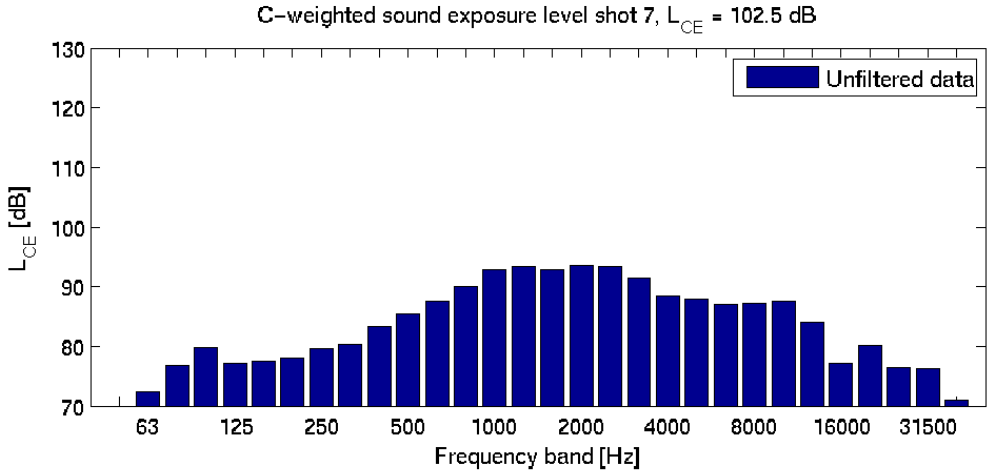

MIL-STD 1474D noise limits
Z-Curve
Y-Curve
X-Curve
W-Curve
10 shots
Peak pressure [dB]
B-durasjon [ms]

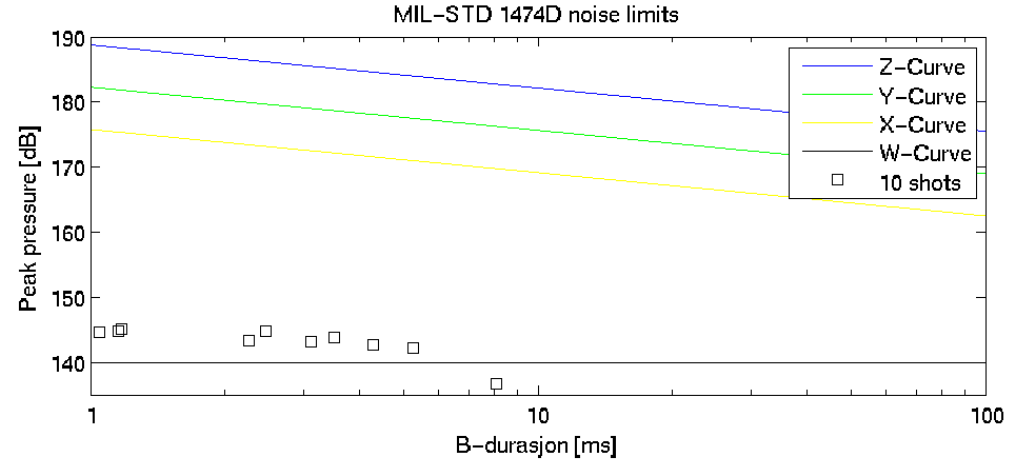

AG3, NM126, shot 7, 1 m left of muzzle
Unfiltered data
p [kPa]
t [ms]

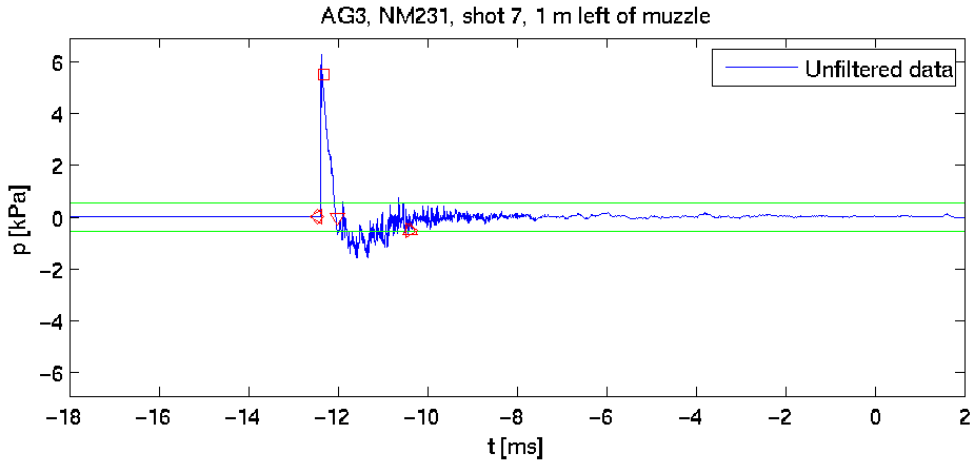

C-weighted sound exposure level shot 7, L_CE = 96.9 dB
Unfiltered data
L_CE [dB]
Frequency band [Hz]

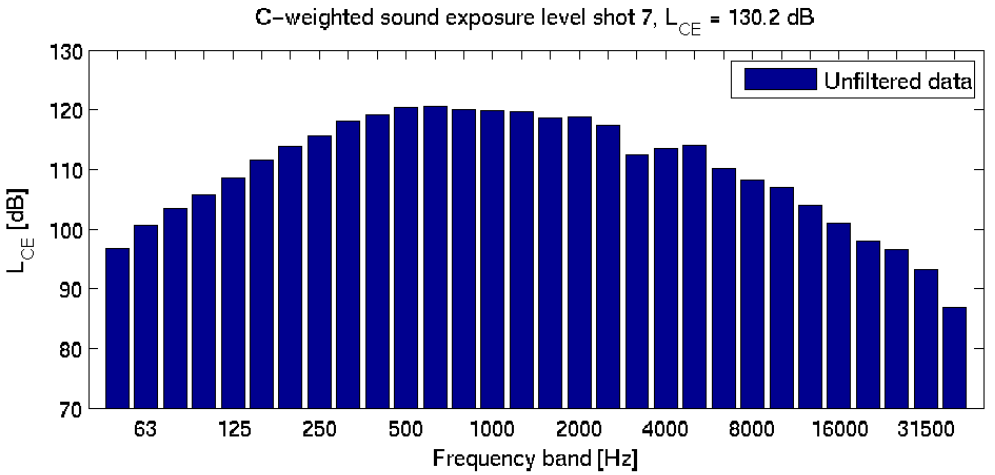

MIL-STD 1474D noise limits
Z-Curve
Y-Curve
X-Curve
W-Curve
10 shots
Peak pressure [dB]
B-durasjon [ms]

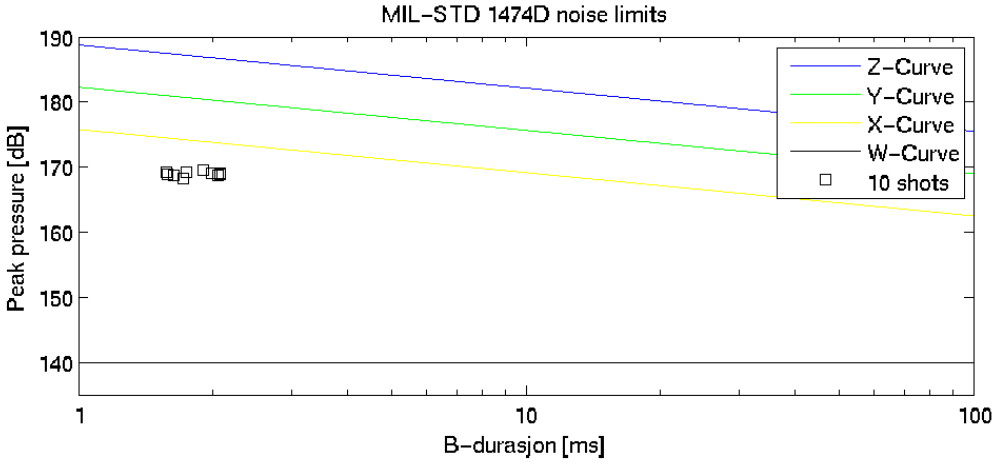

AG3, NM134, shot 7, 1 m left of muzzle
Unfiltered data
p [kPa]
t [ms]

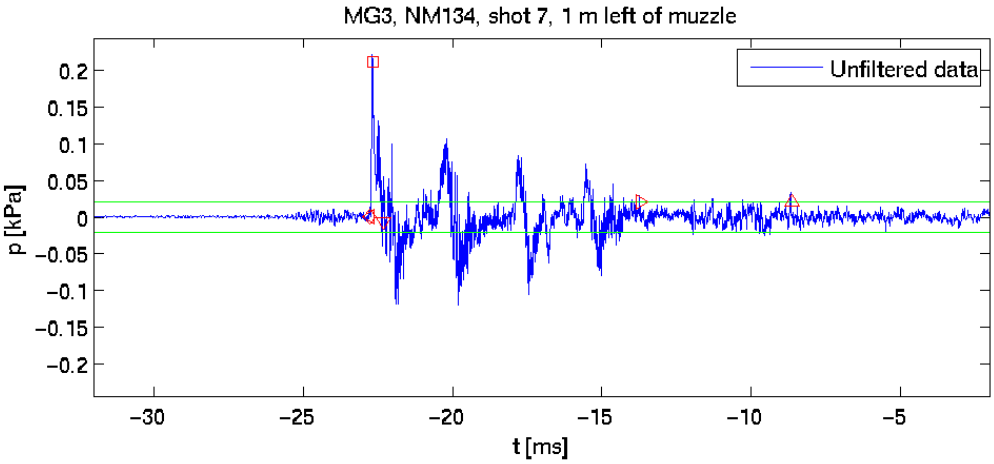

C-weighted sound exposure level shot 7, L_CE = 102.5 dB
Unfiltered data
L_CE [dB]
Frequency band [Hz]

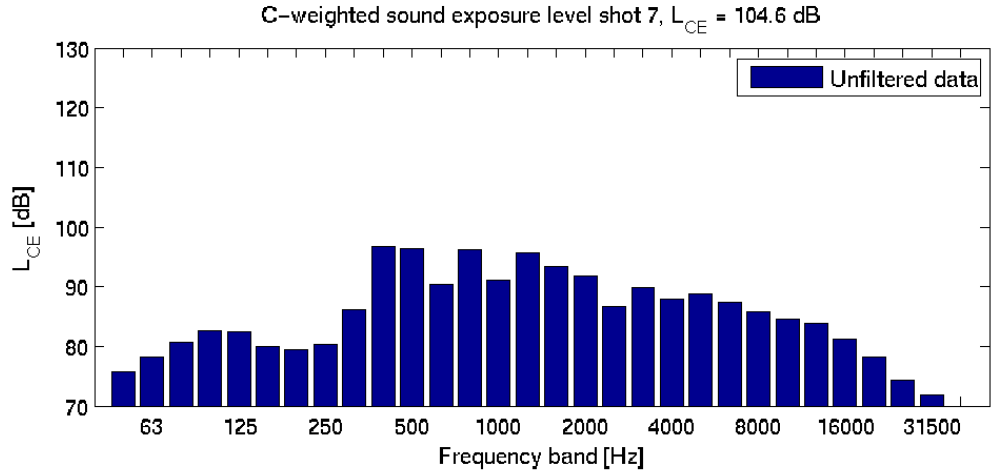

MIL-STD 1474D noise limits
Z-Curve
Y-Curve
X-Curve
W-Curve
10 shots
Peak pressure [dB]
B-durasjon [ms]

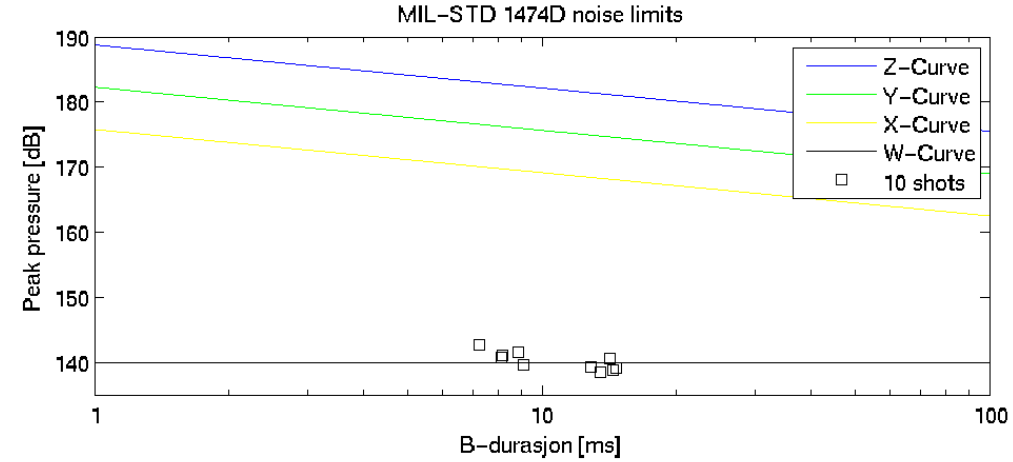

AG3, NM231, shot 7, 1 m left of muzzle
Unfiltered data
p [kPa]
t [ms]

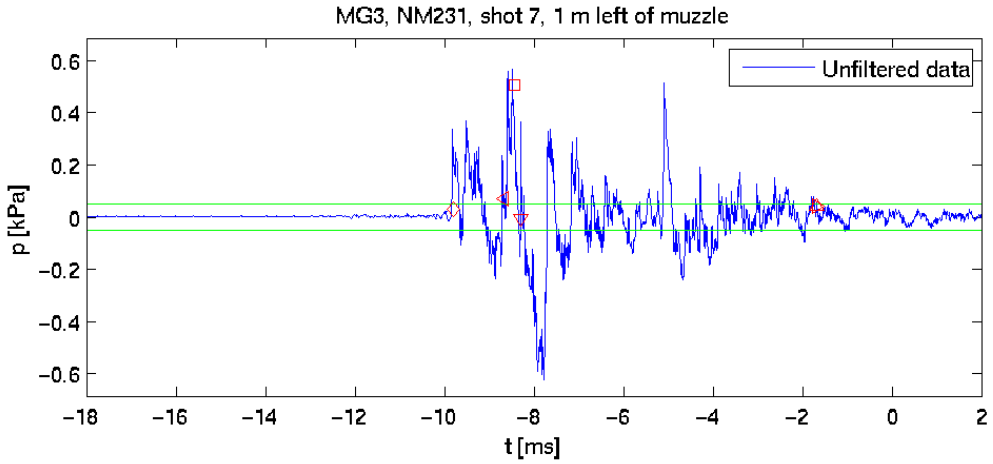

C-weighted sound exposure level shot 7, L_CE = 130.2 dB
Unfiltered data
L_CE [dB]
Frequency band [Hz]

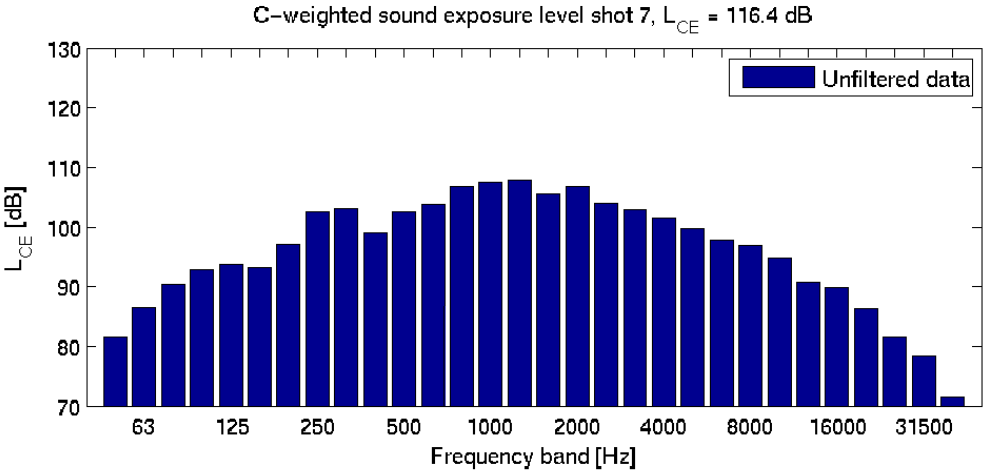

MIL-STD 1474D noise limits
Z-Curve
Y-Curve
X-Curve
W-Curve
10 shots
Peak pressure [dB]
B-durasjon [ms]

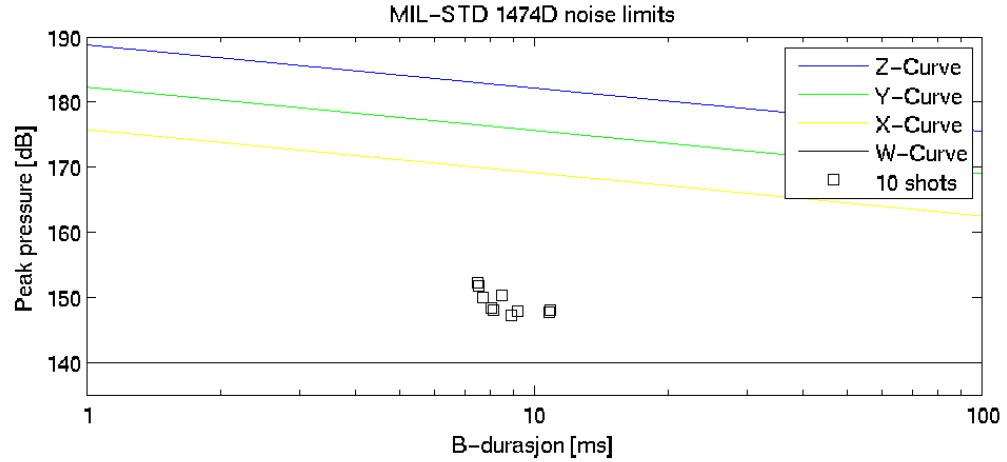

MG3, NM134, shot 7, 1 m left of muzzle
Unfiltered data
p [kPa]
t [ms]


C-weighted sound exposure level shot 7, L_CE = 104.6 dB
Unfiltered data
L_CE [dB]
Frequency band [Hz]


MIL-STD 1474D noise limits
Z-Curve
Y-Curve
X-Curve
W-Curve
10 shots
Peak pressure [dB]
B-durasjon [ms]


MG3, NM231, shot 7, 1 m left of muzzle
Unfiltered data
p [kPa]
t [ms]


C-weighted sound exposure level shot 7, L_CE = 116.4 dB
Unfiltered data
L_CE [dB]
Frequency band [Hz]


MIL-STD 1474D noise limits
Z-Curve
Y-Curve
X-Curve
W-Curve
10 shots
Peak pressure [dB]
B-durasjon [ms]

References

[1] M. Huseby. Evaluering av støy fra håndvåpen ved måleanlegget på FFI. FFI-rapport 2015/01416, Norwegian Defence Research Establishment, 2015.

[2] M. Huseby. Kildedata for støy fra NM218, MØR, HK 417S, MG3, treningsammunisjon og løsammunisjon. FFI-rapport 2015/01748, Norwegian Defence Research Establishment, 2015.

[3] MIL-STD-1474D, Department of Defense . Design criteria standard - Noise limits, 12 February 1997.