Naval Submarine Medical Research Laboratory

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Impulse Assessment of the
PELTOR™ Optime™ 105 H10A Earmuff

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The impulse peak insertion loss (IPIL) is the standard measure of attenuation provided by hearing protection devices (HPDs) in response to an impulsive noise. This technical memorandum describes the IPIL testing conducted on the PELTOR™ Optime™ 105 H10A Earmuff (PELTOR™ Optime™ 105; Model: H10A). Testing was in accordance with the American National Standards Institute (ANSI) standard S12.42-2010. A total of five samples were fitted to an acoustic test fixture two times each for a total of 10 trials per test level. No samples of the HPD were rejected. All samples were tested at the nominal levels of 160 and 170 decibel peak (dBP, re: 20 µPa). As shown in Table 1, the results revealed an overall mean IPIL value of 32.1 dB SPL at 160 dBP and 37.2 dB SPL at the 170 dBP nominal level. These results suggest that when properly fit and functional, the PELTOR™ Optime™ 105 H10A Earmuff will adequately protect (i.e., reduce exposure to less than 140 dBP) for impulses below 177.2 dBP.

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attenuation, impulse peak insertion loss, IPIL, blast, hearing protection device, HPD, passive HPD, earmuff

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CONTENTS

Executive Summary

The impulse peak insertion loss (IPIL) is the standard measure of attenuation provided by hearing protection devices (HPDs) in response to an impulsive noise. This technical memorandum describes the IPIL testing conducted on the PELTOR™ Optime™ 105 H10A Earmuff (PELTOR™ Optime™ 105; Model: H10A). Testing was in accordance with the American National Standards Institute (ANSI) standard S12.42-2010, Methods for the Measurement of Insertion Loss of Hearing Protection Devices in Continuous or Impulsive Noise Using Microphone-in-Real-Ear or Acoustic Test Fixture Procedures. A total of five samples were fitted to an acoustic test fixture two times each for a total of 10 trials per test level. No samples of the HPD were rejected. All samples were tested at the nominal levels of 160 and 170 decibel peak (dBP, re: 20 µPa). As shown in Table 1, the results revealed an overall mean IPIL value of 32.1 dB SPL at 160 dBP and 37.2 dB SPL at the 170 dBP nominal level. These results suggest that when properly fit and functional, the PELTOR™ Optime™ 105 H10A Earmuff will adequately protect (i.e., reduce exposure to less than 140 dBP) for impulses below 177.2 dBP.

Table 1.
PELTOR™ Optime™ 105 mean (SD) IPIL value (in dB) for all test conditions.

160 dBP	**170 dBP**
32.1 (2.7)	37.2 (1.1)

Introduction

The PELTOR™ Optime™ 105 H10A Earmuff (PELTOR™ Optime™ 105; Aearo Technologies, Inc., Indianapolis, IN) is a passive, universal sized over-the-head earmuff built with a double-shell ear cup design and stainless steel headband allowing for a low-pressure fit on the user. Tested earmuff samples were manufactured by Aearo Technologies, Inc. prior to 2008. Since then, Aearo Technologies, Inc. has been acquired by 3M™, and 3M™ has continued to manufacture the PELTOR™ Optime™ 105 Earmuff. Per 3M™ (2021), the PELTOR™ Optime™ 105 is intended to provide adequate hearing protection in environments where continuous noise levels reach up to 105 A-weighted decibels (dBA).

Per the Department of Defense Instruction 6055.12 (2019), the exposure limit for impulse noise is 140 peak decibels (dBP). Therefore, should an impulse noise meet or exceed 140 dBP (e.g., artillery fire, grenade, small arm weapon fire, large caliber weapon fire), hearing conservation efforts must be put into place. One conservation measure used to reduce the noise hazard below the 140 dBP limit at the user level are hearing protection devices (HPDs) like that of an earplug or earmuff.

To determine if the issued HPD will reduce the noise exposure below the 140 dBP limit, the impulse peak insertion loss (IPIL) value of the issued and/or used HPD should be subtracted from the impulse noise level (Department of Defense, 2015). The IPIL value is the standard metric (ANSI/ASA S12.42) used to determine the amount of protection afforded by a HPD in response to impulse noise. At present, the IPIL value of the PELTOR™ Optime™ 105 measured at 160 and 170 dBP is unknown. This current effort determined the IPIL value for the PELTOR™ Optime™ 105 Earmuff. In addition to reporting an overall device IPIL, ear-specific IPILs are reported for the tested nominal levels.

Methods

Facility & Personnel

IPIL testing described herein was completed in the Naval Submarine Medical Research Laboratory (NSMRL) 1000 m^3 anechoic chamber in order to minimize any effects of sound reflections.

Equipment

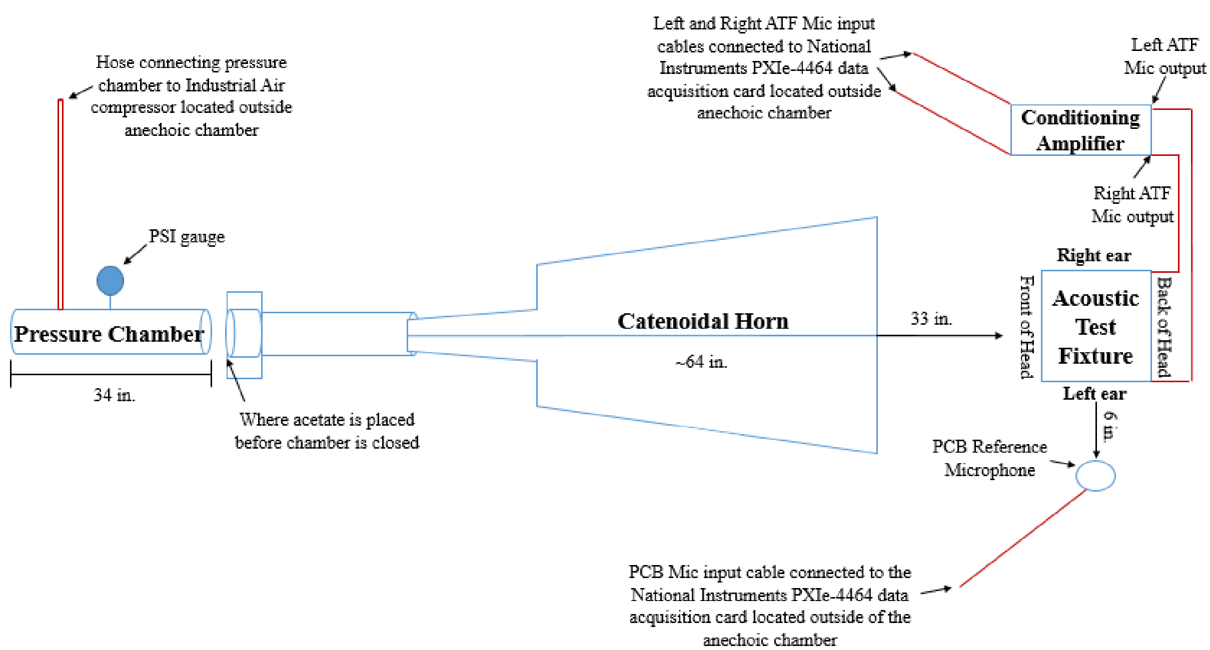
Hardware. Acoustic impulses were generated by NSMRL's 4 inch (in., 10.2 centimeters (cm)) shock tube (B/C Precision, Inc., Greendale, IN). The shock tube pressure chamber is approximately 34 in. (86.4 cm) long, with an inner diameter of 4 in. (10.2 cm). A 64 in. (162.6 cm) long catenoidal tube horn consisting of four welded steel flat-projection sheets forming a square cross section was connected to the shock tube using a PVC 4.5 in. (11.4 cm) coupler. An industrial air compressor (ILA#1883054; Industrial Air Corporation, Memphis, TN) supplied pressurized air (900 kilopascal) to the shock tube. For each trial, a 7 in. (17.8 cm) by 7 in. (17.8 cm), acetate sheet (Grafix Plastic, Maple Heights, OH) was used as a membrane between the pressurized chamber and the catenoidal tube horn to enable pressurization of the air chamber. Each acetate sheet was 0.002 in. (2.0 mil, 50.8 micrometer (µm)) thick.

All waveforms were recorded with the ANSI/ASA S12.42 (2010) compliant GRAS 45CB acoustic test fixture (ATF) along with GRAS RA0045-S7 Ear Simulators (GRAS Sound and Vibration, Twinsburg, OH). The ATF was connected to a conditioning amplifier which served as the power supply (GRAS Type 12AA; GRAS Sound and Vibration, Twinsburg, OH). As required by ANSI/ASA S12.42/2010, the ATF was placed to front-face (i.e., nose facing) the catenoidal tube horn at 0° elevation and 0° azimuth.

A reference microphone (Type 378C20; PCB Piezotronics Inc., Depew, NY) was placed 6 in. (15.2 cm) from the ATF left pinna. The reference microphone, the left ATF microphone, and the right ATF microphone were calibrated each morning prior to data collection at 124 dB sound pressure level (SPL) using a 250 hertz (Hz) tone. A diagram depicting the aerial view of the NSMRL 4 in. (10.2 cm) shock tube and test system can be seen in Figure 1.

Figure 1.

Diagram of the NSMRL Acoustic Shock Tube and ATF.



Data Acquisition System. The data acquisition system (NI chassis PXIe-1071 with NI PXIe-4460 and NI PXIe-4464; National Instruments Corp., Austin, TX) was controlled by a standalone laptop computer running project specific software (LabVIEW; National Instruments Corp., Austin, TX). The data acquisition system was connected to the laptop using an MXI cord and host interface card (NI PXIe-8360). The software controlled the acquisition of waveforms from the three source microphones (left ATF microphone, right ATF microphone, and a reference microphone) at a sampling rate of 204.8 k Samples/second during each impulse recording. Pre-trigger settings were 1024 samples per 0.005 seconds, with a trigger level of 110 dB SPL. Each recording was 0.3 seconds in duration.

Rather than using an ANSI/ASA S12.42-2010 standardized in-line analog external Bessel filter (6th order, corner frequency 20.0 kHz [3 dB down]) to filter impulses during data acquisition, anti-alias filtering was accomplished by an analog filter and a digital filter. First, an electronic analog anti-aliasing filter (corner frequency of 93.0 kHz [3 dB down]) was applied to all waveforms by the National Instruments data acquisition system during data collection. This deviation was made due to equipment and software limitations.

The custom-written software program saved all recorded waveforms as files (.tdms), which were exported and converted to data files using an additional custom software programming script. The script compiled the reference PCB microphone, left ATF microphone, and right ATF microphone channels into a file (.mat) that saved variables for input to analysis script (MATLAB) similar to the script provided in Annex H of the ANSI/ASA S12.42-2010 standard. Minor alterations were made to the analysis script in order to accept 160 decibel peak (dBP) and 170 dBP data (see Data Analysis below).

Hearing Protection Device Samples. Five samples of the PELTOR™ Optime™ 105 H10A Earmuff (Manufacturer Product Number: H10A) with foam ear cushions and headband were tested in accordance with (IAW) ANSI/ASA S12.42-2010. Each sample (i.e., one earmuff) was randomly assigned and labeled with a number 1 through 5.

Figure 2.
PELTOR™ Optime™ 105 Headset.

Procedure

Each sampled HPD was fitted to the ATF twice, resulting in two trials (trials A and B) per sample, and 10 total trials per nominal level test condition (160 and 170 dBP). No samples of the HPD were rejected. To achieve an appropriate fit that would provide maximum attenuation, each sample was expertly fitted to the ATF IAW instructions on the device packaging. The manufacturer fitting guidelines stated that all samples be inspected for any wear, cracks, or damage prior to use. Once inspected, earmuffs were placed over the ears to encompass the pinna and seal tightly against the head, and the headband adjusted to just rest on the head of the ATF.

Testing at the 130 and 150 dBP nominal levels was omitted, and the nominal level of 160 dBP was incorporated. Because of equipment and material limitations, impulses generated with the NSMRL 4 in. (10.2 cm) shock tube at levels below the nominal level of 160 dBP were found to result in waveforms without a shock front. At the measured levels described herein, all generated impulses had a shock front. Inclusion of the 160 dBP nominal level allowed the range of applicability to be extended down to 150 dBP. This in turn allowed for extrapolation of IPIL results down to the 150 dBP level. Due to non-linear effects on IPIL, it is best to use IPIL values measured close to the level of the predicted exposure (Department of Defense, 2015). Although many weapons systems used in the US Navy produce impulses around 170 dBP, there are several that produce impulses between 150 dBP and 165 dBP. Measuring the IPIL at 160 dBP provides IPIL values which are better estimates of the IPIL at those levels of exposure.

Impulse noises were presented to the ATF in the occluded (i.e., HPD donned) and unoccluded (i.e., HPD doffed) test configurations. For all occluded measures, the earmuffs were fitted on the ATF IAW the specifications outlined in ANSI/ASA S12.42-2010. Each HPD sample was exposed to two impulses at each tested nominal level. Adequate pressure for each impulse was determined by increasing pressure (measured in pounds per square inch [psi]) to a point within a pre-specified range necessary for producing either 160 dBP (19.5 to 22.1 psi, 134 to 152 kilopascals (kPa)) or 170 dBP (28.5 to 29.5 psi, 197 to 203 kPa) nominal level impulses using the NSMRL 4 in. (10.2 cm) acoustic shock tube. The acetate was then punctured using a manual trigger, releasing pressurized air into the catenoidal horn, which created an impulse wave through the catenoidal horn to the ATF. The peak decibel level (dBP) emitted was dependent upon the amount of air pressure released.

In place of the ANSI/ASA S12.42-2010 standardized calibration impulses at 130 and 150 dBP, six calibration impulses were generated at the 160 dBP nominal level in the unoccluded (i.e., without HPD) test configuration. Three of these impulses were generated pre-, and three were generated post-testing at 160 dBP. Calibrations were not completed at the 170 dBP nominal level due to exposure limitations of the ATF right and left microphones.

Clamping force of each sample earmuff was measured using a Muff-type HPD Force Measurement System (Michael & Associates, Inc., S/N: 00001). Per ANSI/ASA S12.42-2010, each headset was fit to the measurement device, and left in place for two minutes before clamping force was recorded in pounds force (lbf).

Data Analysis

MATLAB (Natick, MA) was used to calculate the IPIL values at the 160 and 170 dBP nominal levels and to generate all waveform graphs. The mean pressure of each waveform was subtracted from the waveforms to remove any constant offset. The peak levels were then calculated by converting the maximum absolute value of each waveform into dB SPL. The transfer functions of the free-field probe to each ear of the ATF was calculated for the unoccluded waveforms gathered at the 160 dBP nominal level. The mean transfer function for each ear was then calculated, and the first element of the transfer function was set to zero in order to avoid calculations at 0 Hz. The fit of the mean transfer function was tested by applying the mean transfer function for each ear to the free-field probe data gathered in the 160 dBP nominal level. The difference of the maximum absolute values of the calculated values and the measured values was then calculated, converted to dB SPL, and displayed.

The calculated IPIL value (in dB) equaled the mean difference of the maximum absolute value of the waveforms from the ears of the ATF in dB SPL and the maximum absolute value of the estimated values of the unoccluded ears in dB SPL. The estimated values of the unoccluded ears are the waveforms from the free-field probe with the mean transfer function applied to them. These values were calculated for each ear in each trial and condition. The mean values were calculated across both ears and trials, resulting in a displayed mean for each nominal level (i.e., 160 dBP and 170 dBP). Every waveform was plotted with time on the x-axis and pressure on the y-axis. The transfer functions were not plotted.

Deviating from ANSI/ASA S12.42-2010, a second digital Butterworth filter (6^{th} order, low-pass, corner frequency of 20 kHz [3 dB down]) was applied to all recordings by the MATLAB post-processing script. This digital filter was used to mimic the effect of the ANSI/ASA S12.42-2010 standard required anti-aliasing Bessel filter which was omitted due to equipment limitations.

Results

The overall mean IPIL values were found to be 32.1 dB for the 160 dBP test condition and 37.2 dB for the 170 dBP test condition (as shown in Table 2). Calculated IPIL values for all individual sample trials ranged between 26.7 and 35.9 dB at 160 dBP and between 35.2 and 38.8 dB at 170 dBP. Also presented in Table 2 are the individual attenuations for each sample, the ear-specific means and standard deviations (SD) across all samples and trials, and the overall means and SD across all samples, trials, and ears. The waveforms for all trials with the PELTOR™ Optime™ 105 are provided in Appendices A to F.

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Table 2.
Mean (SD) IPIL values (in dB) for Tested PELTOR™ Optime™ 105 Samples.

	160 dBP		**170 dBP**	
	Right	*Left*	*Right*	*Left*
HPD 1, Trial A	32.5	27.0	38.8	37.1
HPD 1, Trial B	32.8	31.9	37.8	36.1
HPD 2, Trial A	32.8	28.7	38.0	38.5
HPD 2, Trial B	27.5	26.7	38.0	38.1
HPD 3, Trial A	34.6	33.8	35.7	37.7
HPD 3, Trial B	32.9	29.7	35.3	37.2
HPD 4, Trial A	34.6	32.3	35.2	36.7
HPD 4, Trial B	34.5	31.7	35.9	36.2
HPD 5, Trial A	35.9	34.4	37.9	37.7
HPD 5, Trial B	34.0	33.2	37.6	37.8
Ear Specific Mean (SD)	33.2 (2.3)	30.9 (2.8)	37.0 (1.3)	37.3 (0.8)
Level Overall Mean (SD)	32.1 (2.7)		37.2 (1.1)	

The measured clamping force of the PELTOR™ Optime™ 105 ranged from 1.9 to 2.2 lbf, with a mean (SD) of 2.1 (0.1) lbf (as shown in Table 3).

Table 3.
Mean (SD) Band Force (lbf) for PELTOR™ Optime™ 105 Tested Samples.

	Band Force
HPD 1	2.1
HPD 2	2.1
HPD 3	1.9
HPD 4	2.2
HPD 5	2.0
MEAN (SD)	2.1 (0.1)

Discussion

As anticipated, the calculated mean IPIL value was greater at the 170 dBP nominal level than at the 160 dBP nominal level. The overall mean IPIL value was 32.1 dB at 160 dBP and 37.2 dB at 170 dBP. Across ears, the individual trial mean IPIL values were found to vary as much as 9.2 dB at 160 dBP and 3.6 dB at 170 dBP. This may be due to a combination of inherent variance within the impulse system and/or variability in fit as a result of each HPD sample being fitted twice. Results indicate that a greater variety of attenuation was present in the individual trials at the 160 dBP level compared to 170 dBP. This is noted with a larger SD at the 160 dBP (2.7 dB) nominal level compared to that at the 170 dBP (1.1 dB) nominal level.

It is important to note that these results do not guarantee similar PELTOR™ Optime™ 105 H10A product performance across all users and environments. Product performance may be impacted by factors such as variability in physical fit of the device (i.e., integrity of the ear cup seal) and HPD configuration (e.g., single-, double- or triple- configuration), and/or simultaneous use with other head worn protective devices such as helmets or eye protection.

Conclusions

This report described the determination of the mean impulse peak insertion loss (IPIL) values provided by the PELTOR™ Optime™ 105 H10A Earmuff at 160 dBP and 170 dBP nominal levels. The overall mean (SD) IPIL values for the PELTOR™ Optime™ 105 were found to be 32.1 (2.7) dB at 160 dBP and 37.2 (1.1) dB at 170 dBP. These results imply that when properly fit and functional, the PELTOR™ Optime™ 105 H10A Earmuff will adequately protect (i.e., reduce exposure to less than 140 dBP) the user from impulses below 177.2 dBP.

References

American National Standards Institute, Inc. (2010). *ANSI S12.42-2010: Methods for the Measurement of Insertion Loss of Hearing Protection Devices in Continuous or Impulsive Noise Using Microphone-in-Real-Ear or Acoustic Test Fixture Procedures.* Acoustical Society of America.

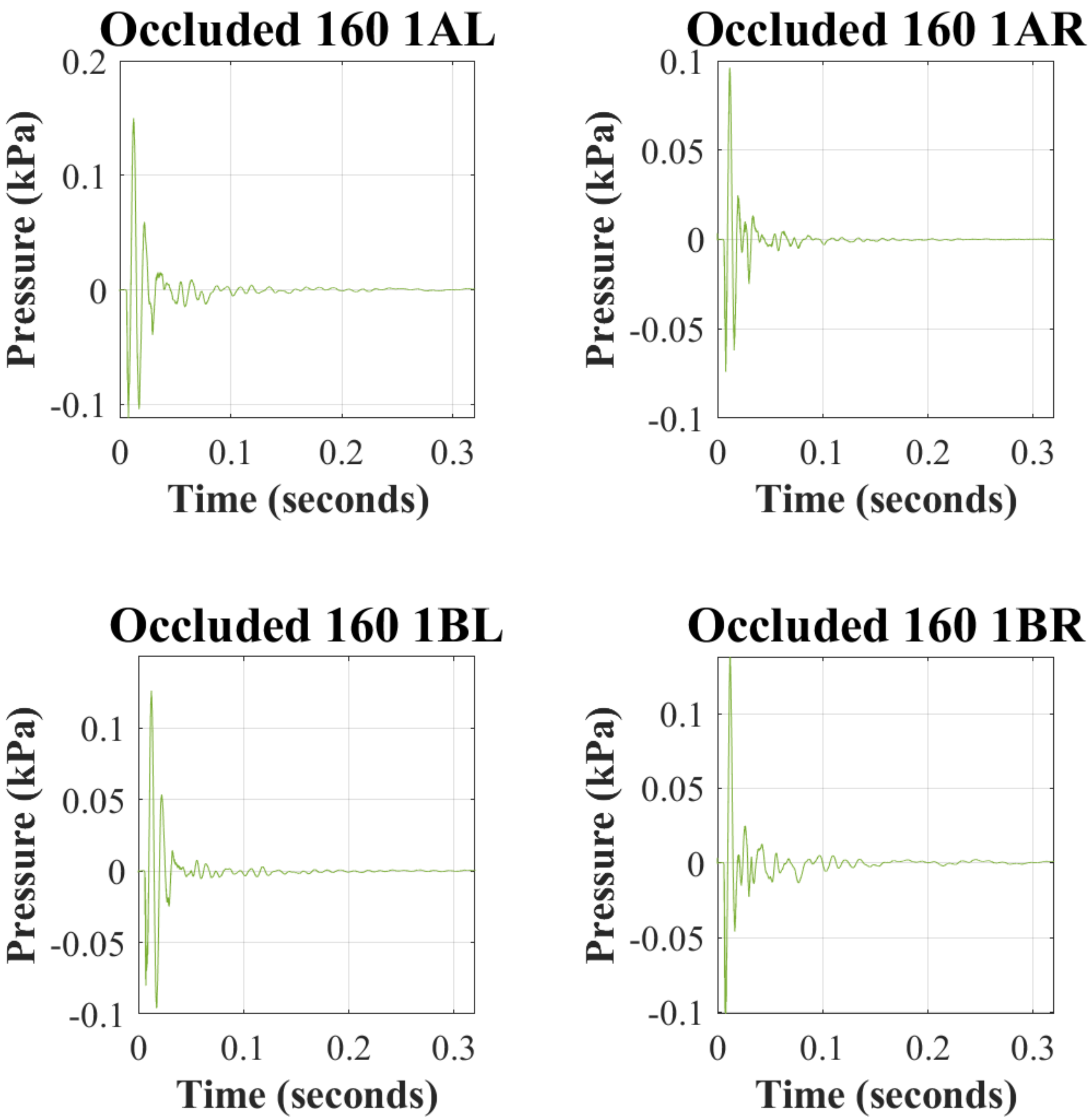
Department of Defense (2015). *MIL-STD-1474E Department of Defense Design Criteria Standard Noise Limits.* Department of Defense.

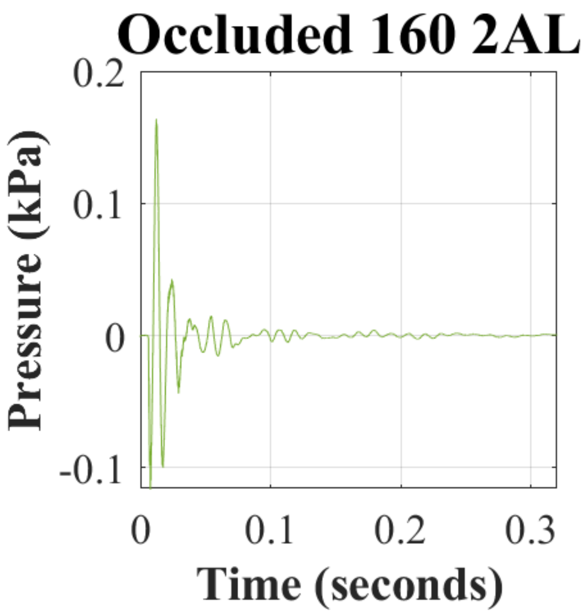
Office of the Under Secretary of Defense for Personnel and Readiness (2019). *DoD Instruction 6055.12 Hearing Conservation Program (HCP).* Department of Defense.

3M (2021). *3M™ PELTOR™ Optime™ 105 Earmuffs H10A, Over-the-Head.* [Webpage] St. Paul, MN: 3M.

3M News Center (2008, April 1). *3M Completes Acquisition of Aearo Technologies Inc.* St. Paul, MN: 3M.

Appendix A. Recorded occluded (earmuff donned) waveforms in response to 160 dBP with the PELTOR™ Optime™ 105.

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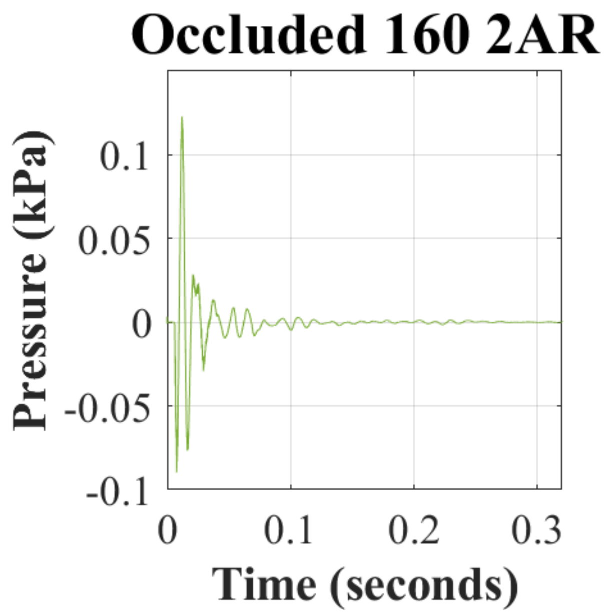
-0.1
0
0.1
0.2
0.3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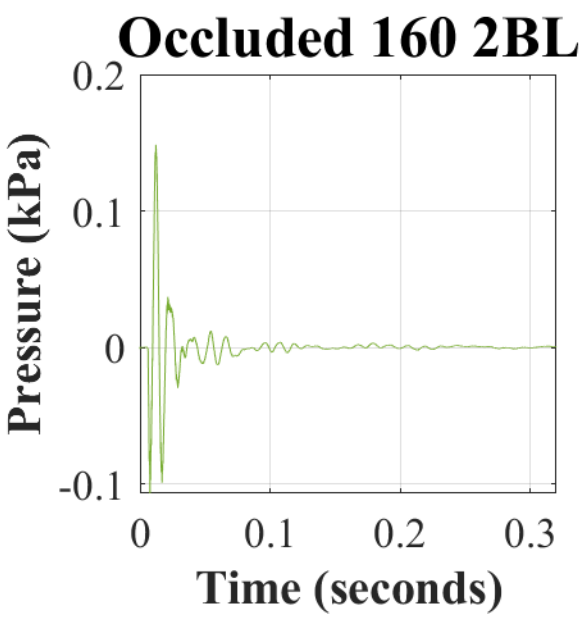
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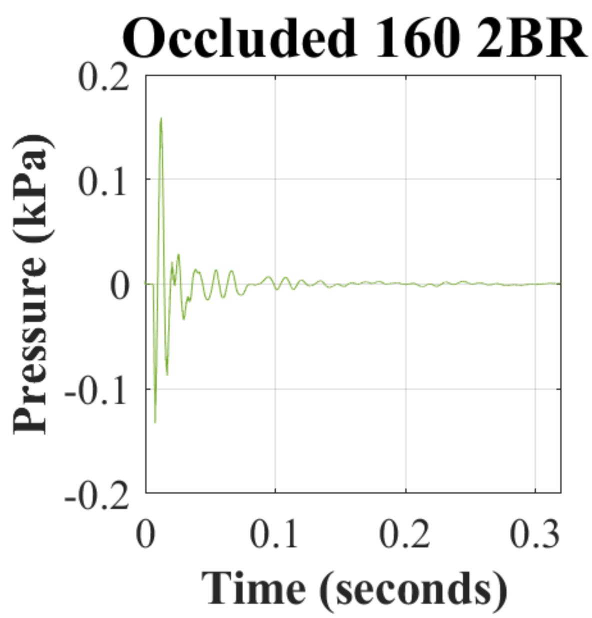
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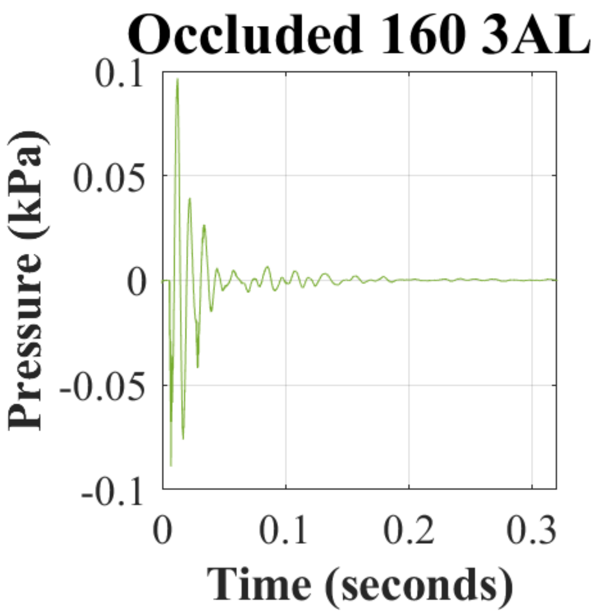
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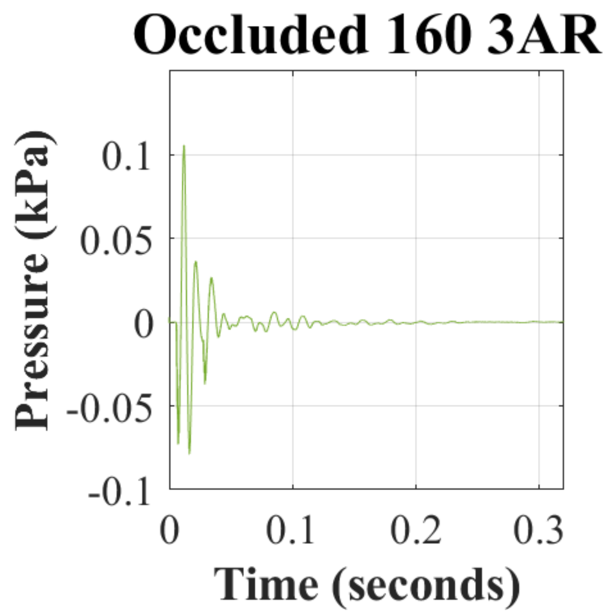
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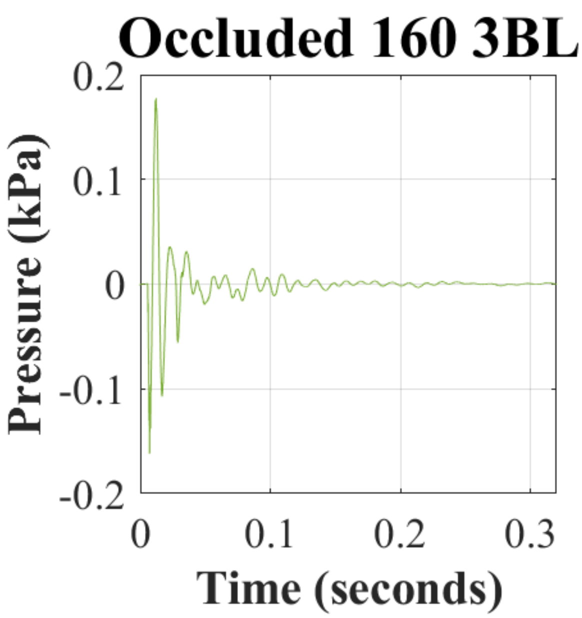
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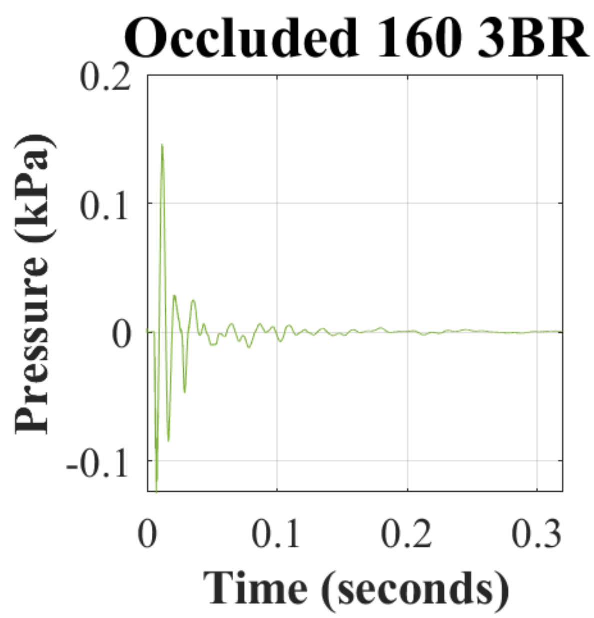
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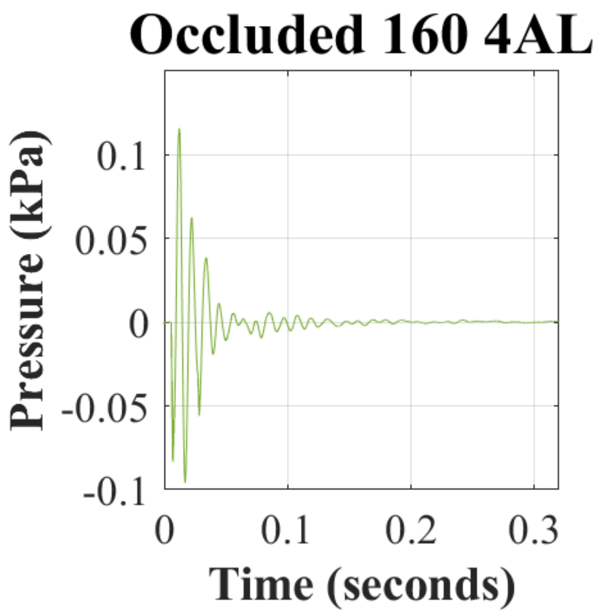
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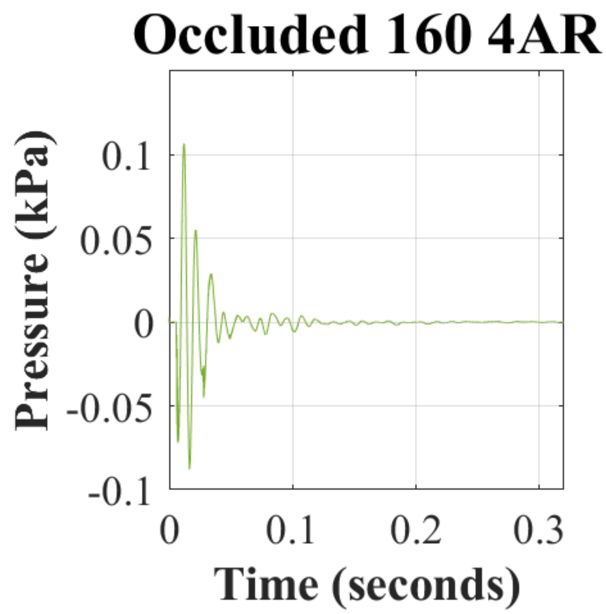
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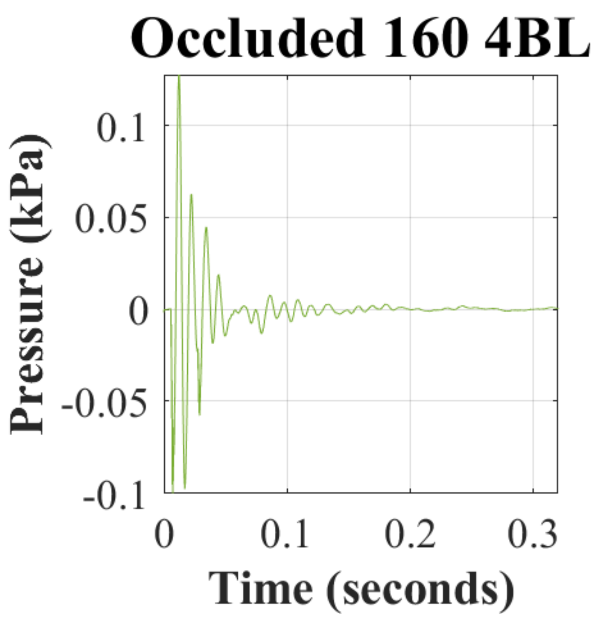
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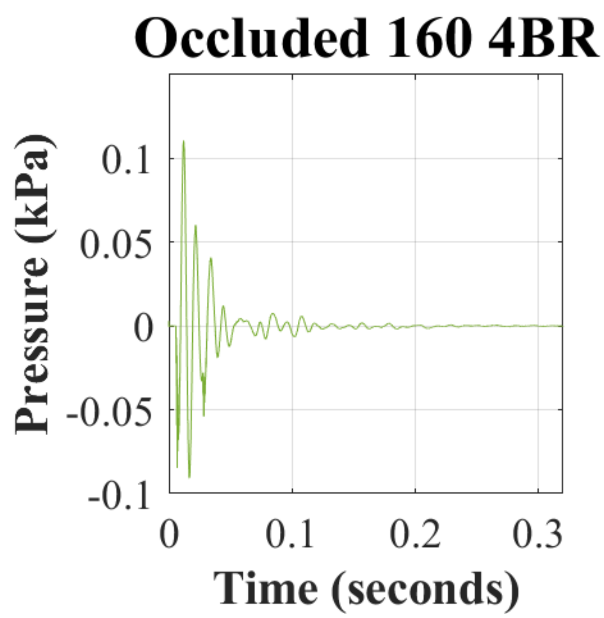
Time (seconds)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Pressure (kPa)
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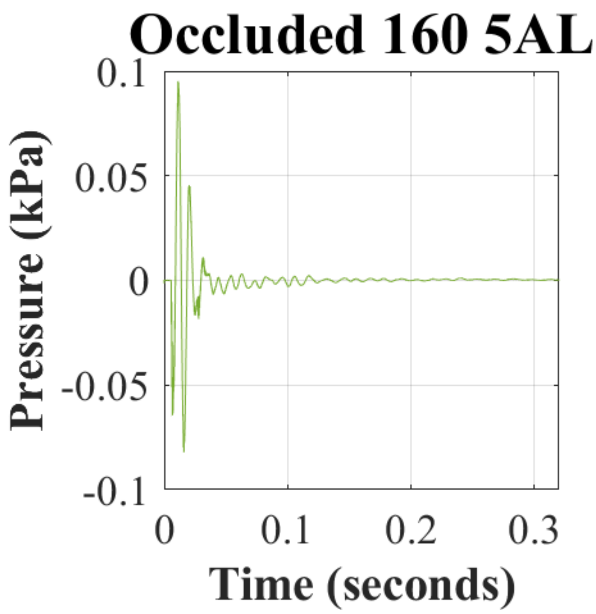
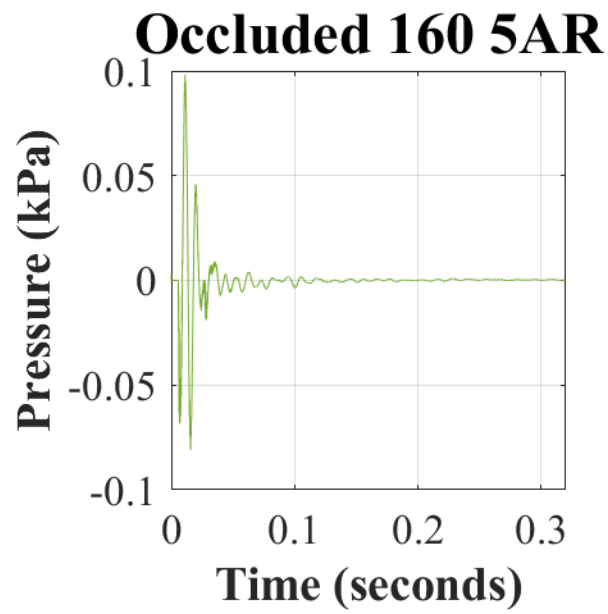
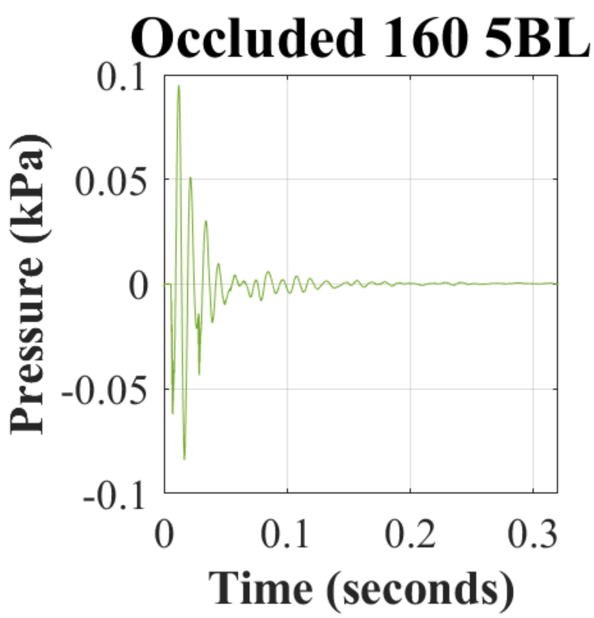
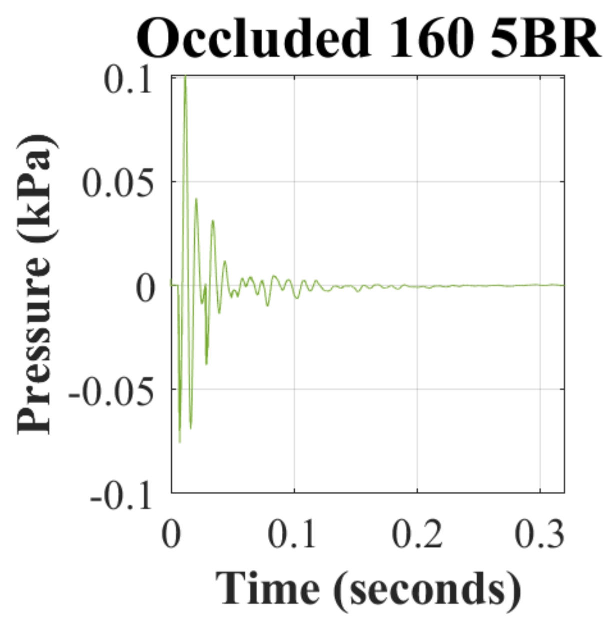
0.05
0
-0.05
-0.1
0
0.1
0.2
0.3
Time (seconds)



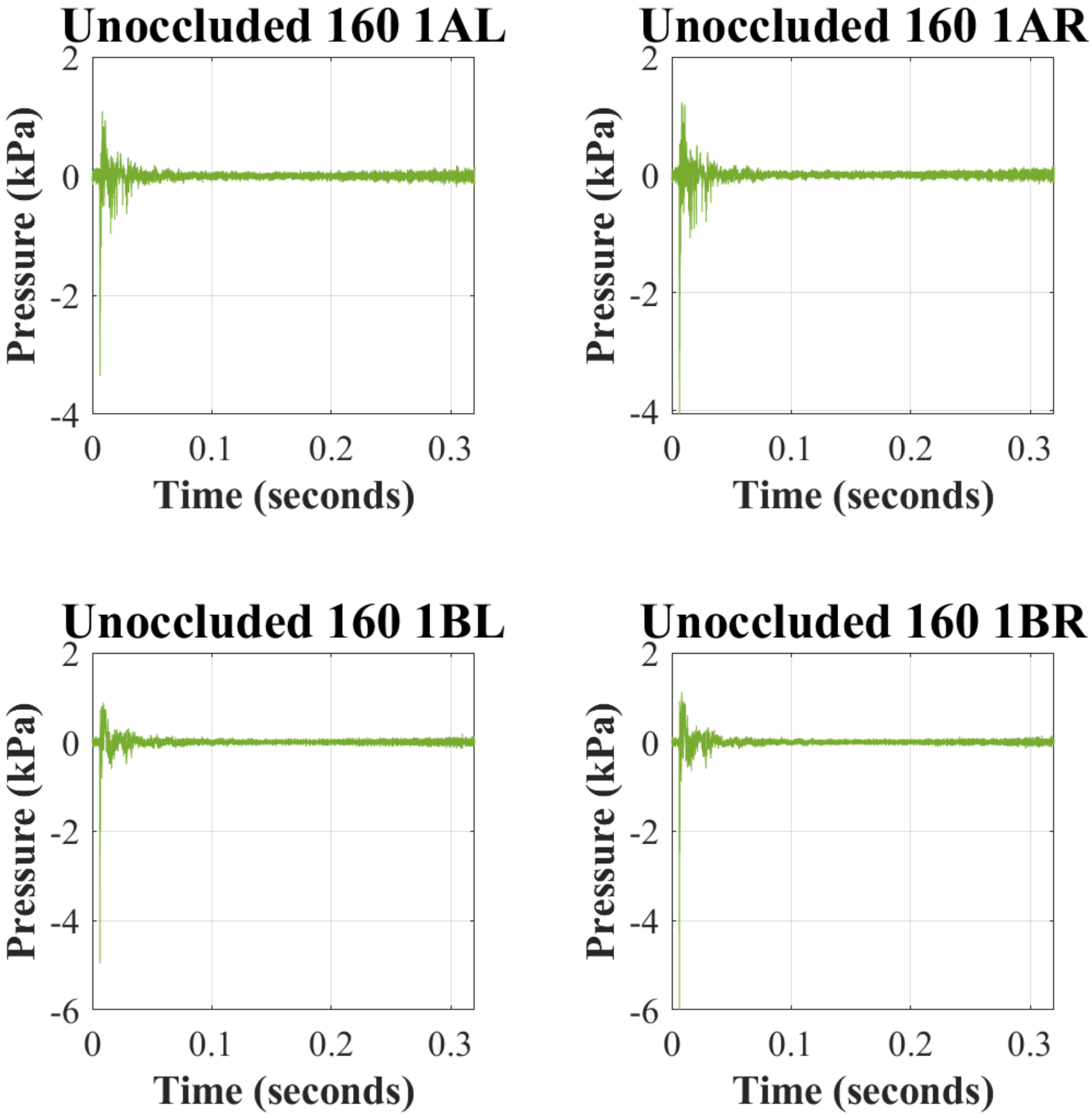


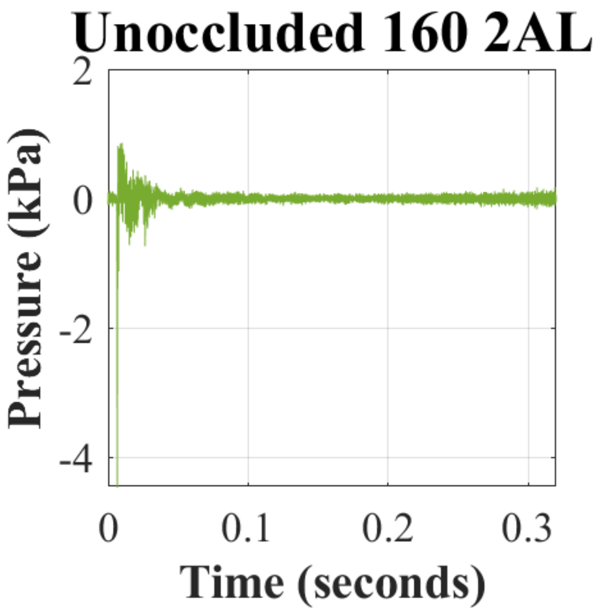


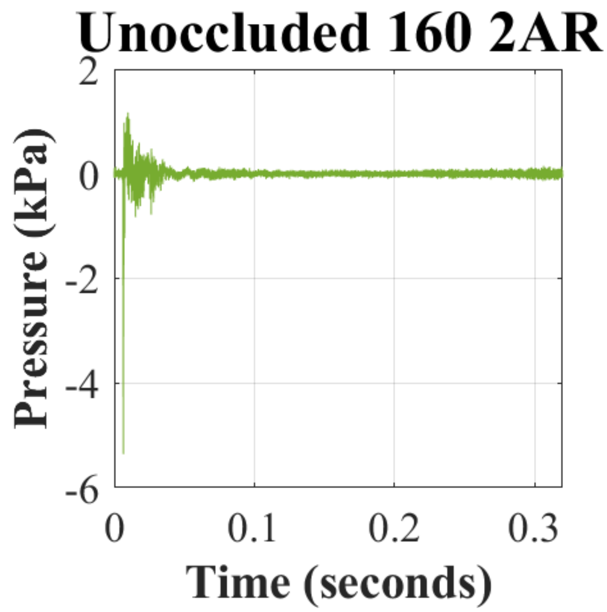


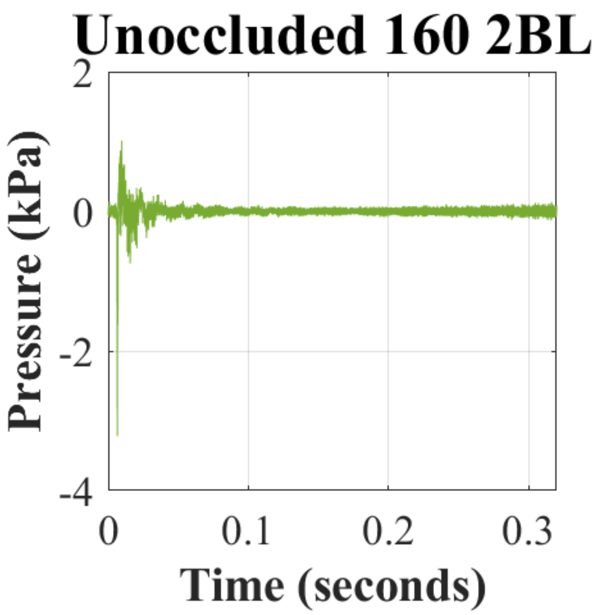
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the earmuff donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating fit (i.e., first or second, respectively), and ‘X’ indicates from what ATF microphone the recording is from (i.e., right (R) or left (L) pinnae).

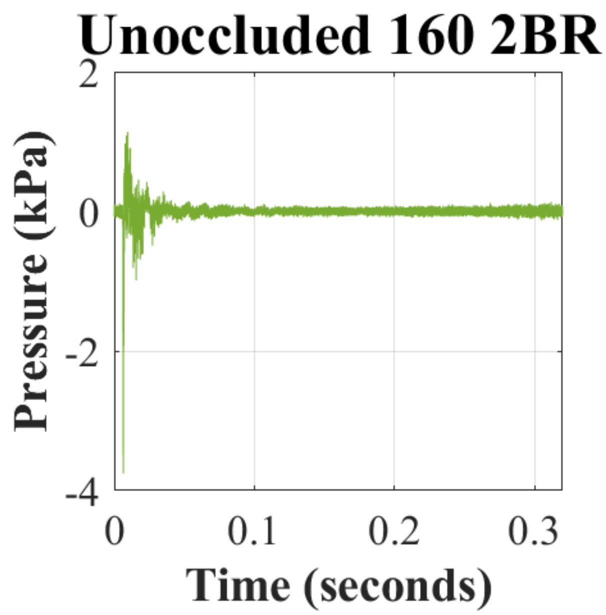
Appendix B. Estimated unoccluded (earmuff doffed) waveforms in response to 160 dBP with the PELTOR™ Optime™ 105.

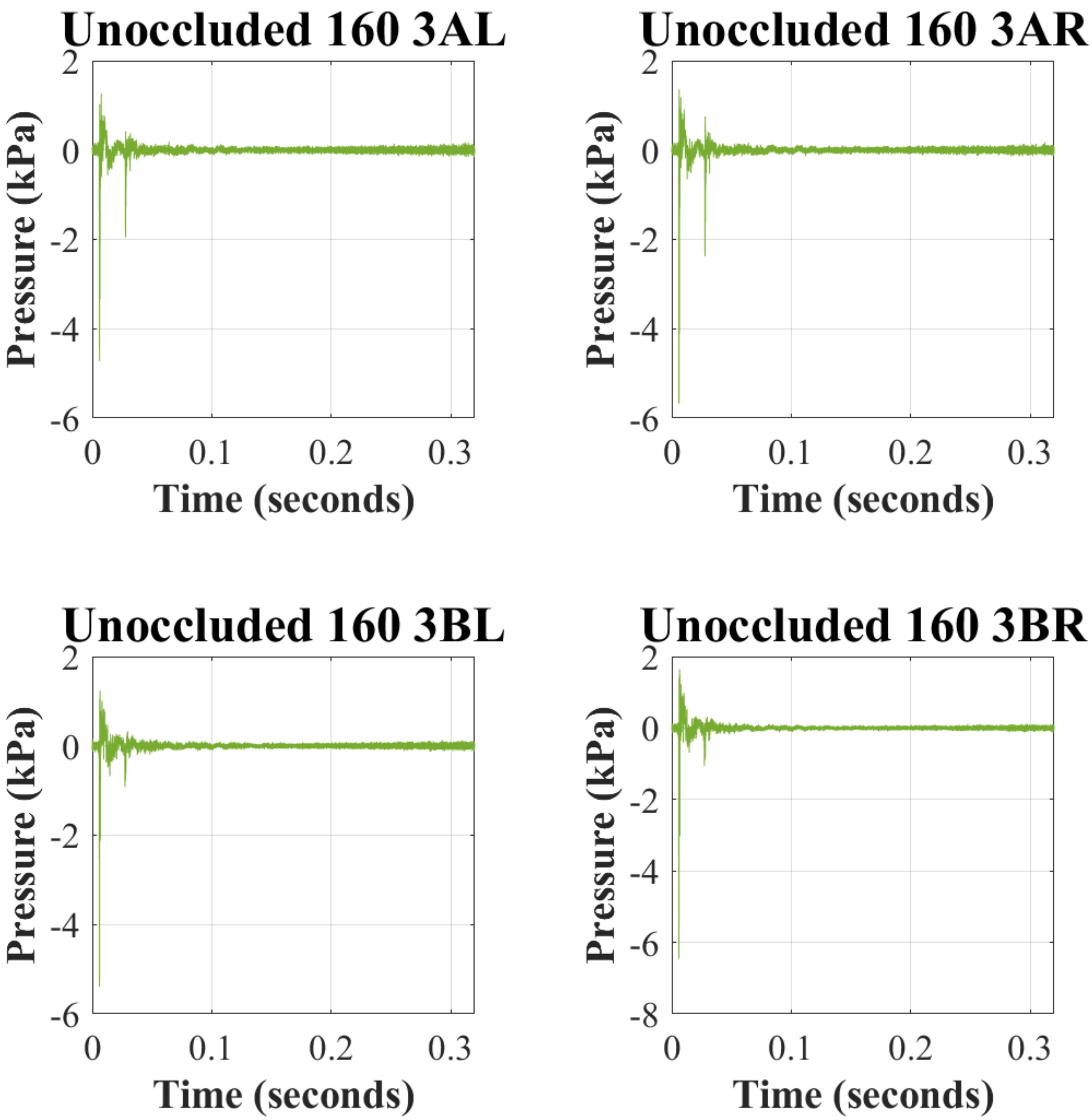


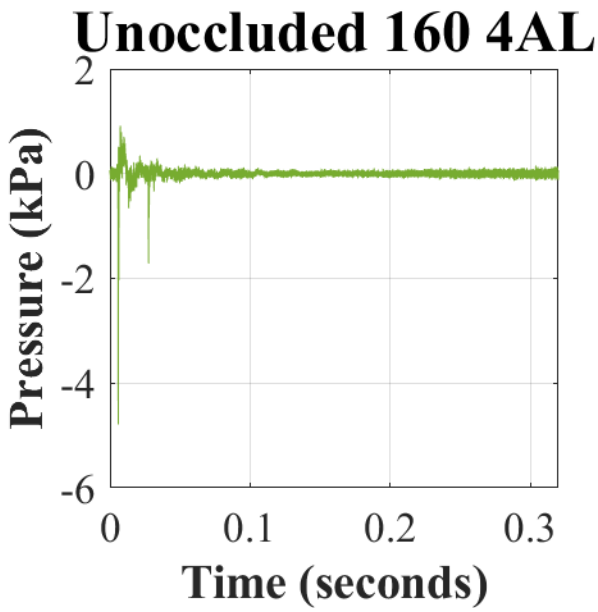

Unoccluded 160 2AL
Pressure (kPa)
Time (seconds)
2
0
-2
-4
0
0.1
0.2
0.3

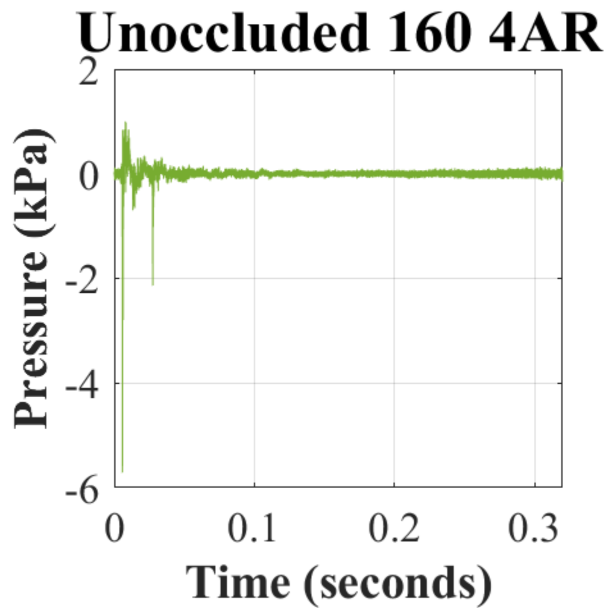

Unoccluded 160 2AR
Pressure (kPa)
Time (seconds)
2
0
-2
-4
-6
0
0.1
0.2
0.3

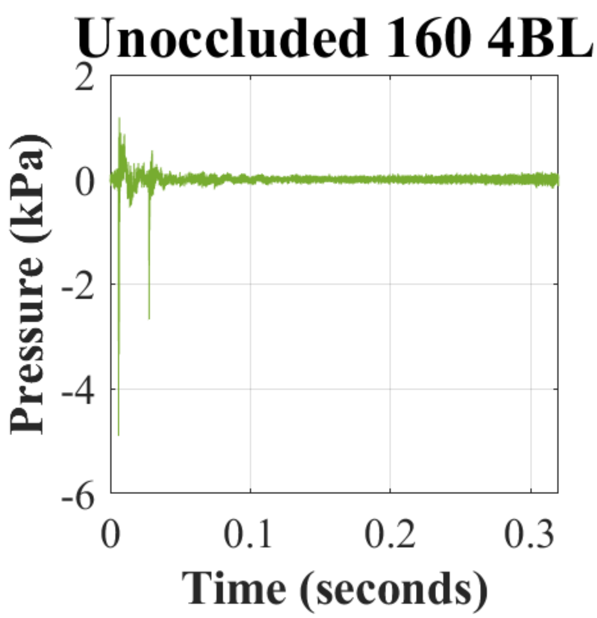

Unoccluded 160 2BL
Pressure (kPa)
Time (seconds)
2
0
-2
-4
0
0.1
0.2
0.3

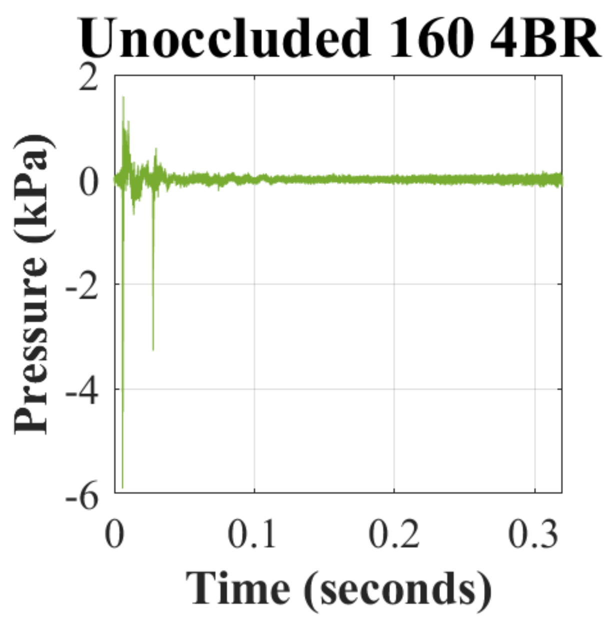

Unoccluded 160 2BR
Pressure (kPa)
Time (seconds)
2
0
-2
-4
0
0.1
0.2
0.3

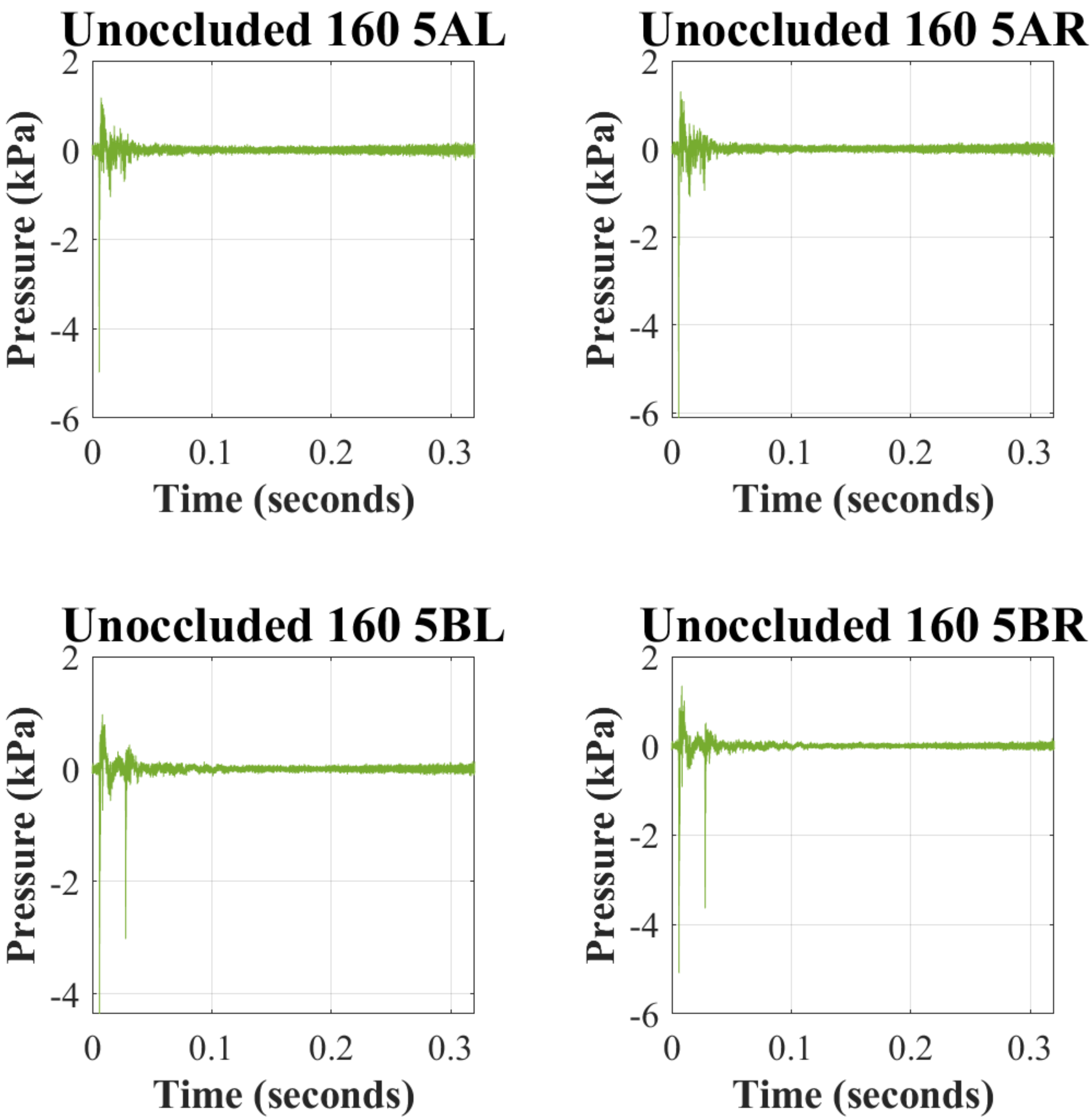

Unoccluded 160 3AL
Pressure (kPa)
Time (seconds)
Unoccluded 160 3AR
Pressure (kPa)
Time (seconds)
Unoccluded 160 3BL
Pressure (kPa)
Time (seconds)
Unoccluded 160 3BR
Pressure (kPa)
Time (seconds)


Unoccluded 160 4AL
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)


Unoccluded 160 4AR
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

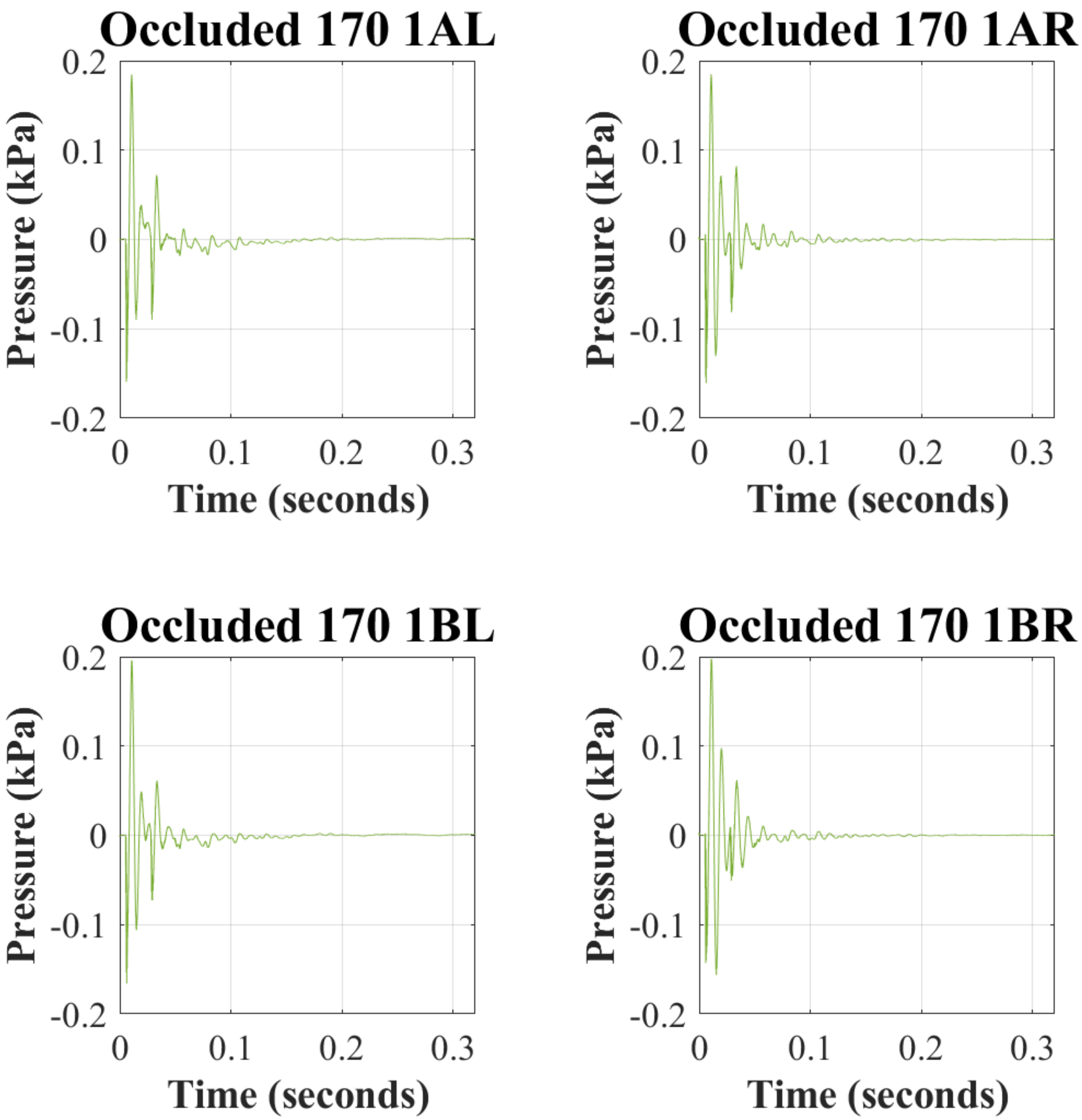

Unoccluded 160 4BL
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

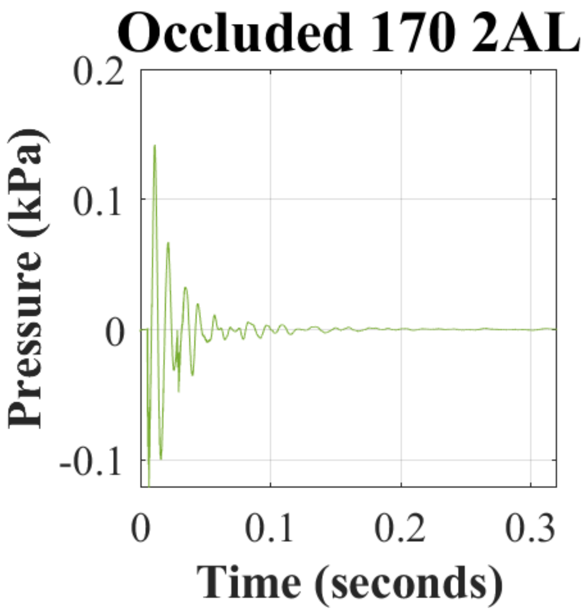

Unoccluded 160 4BR
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

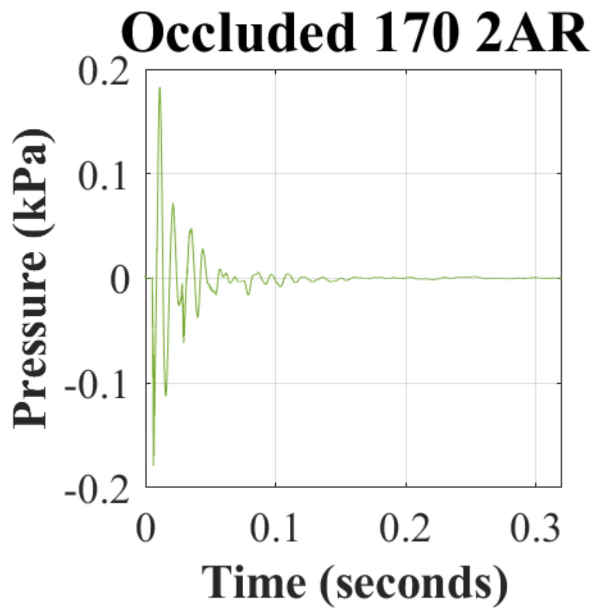


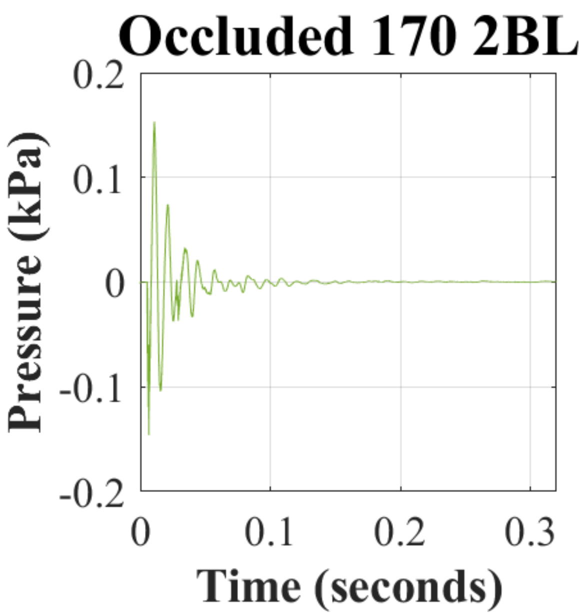
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the earmuff doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating fit (i.e., first or second, respectively), and ‘X’ indicates from what ATF microphone the recording is from (i.e., right (R) or left (L) pinnae).

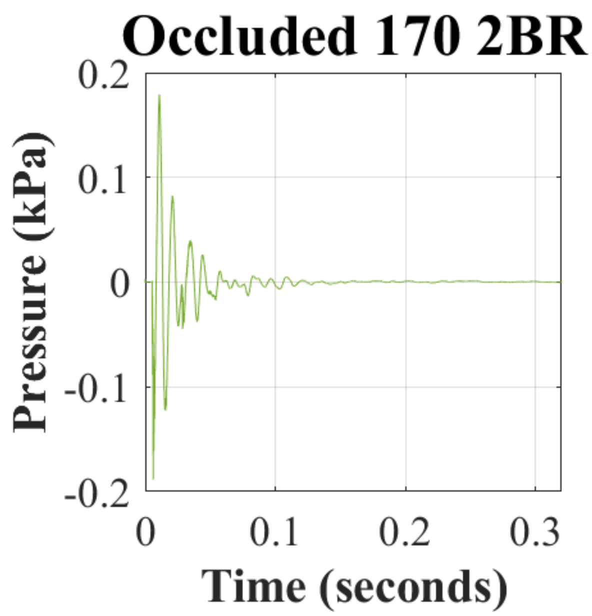
Appendix C. Recorded occluded (earmuff donned) waveforms in response to 170 dBP with the PELTOR™ Optime™ 105.

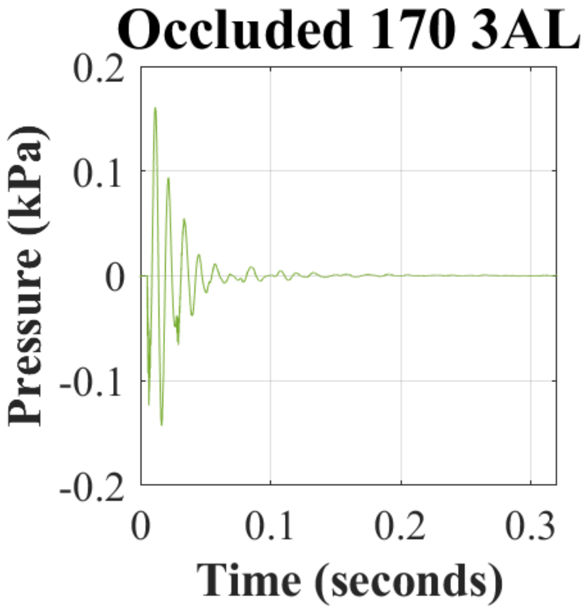


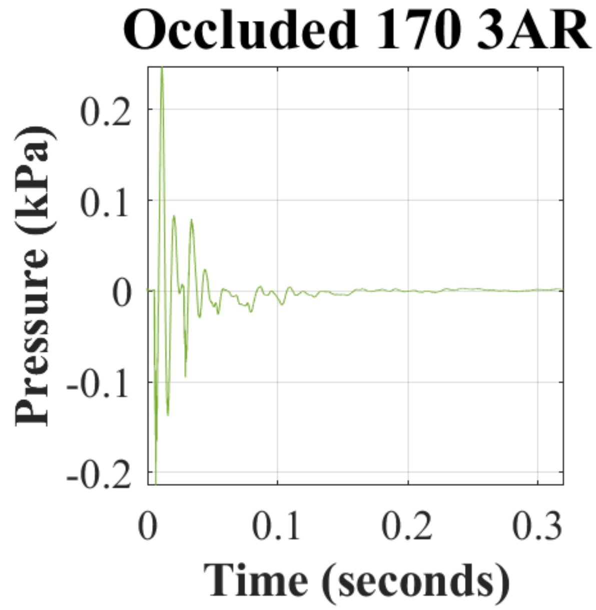

Occluded 170 2AL
Pressure (kPa)
0.2
0.1
0
-0.1
0
0.1
0.2
0.3
Time (seconds)

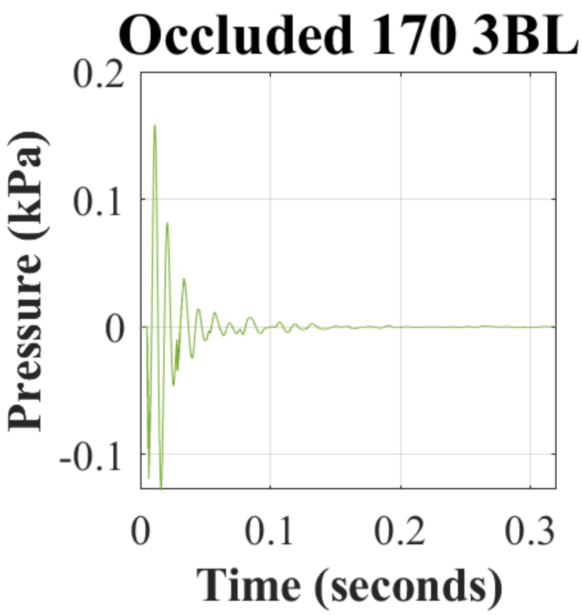

Occluded 170 2AR
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)

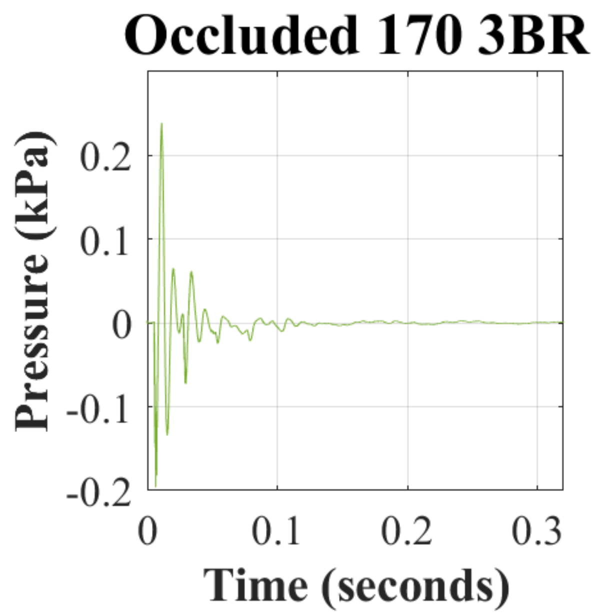

Occluded 170 2BL
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)

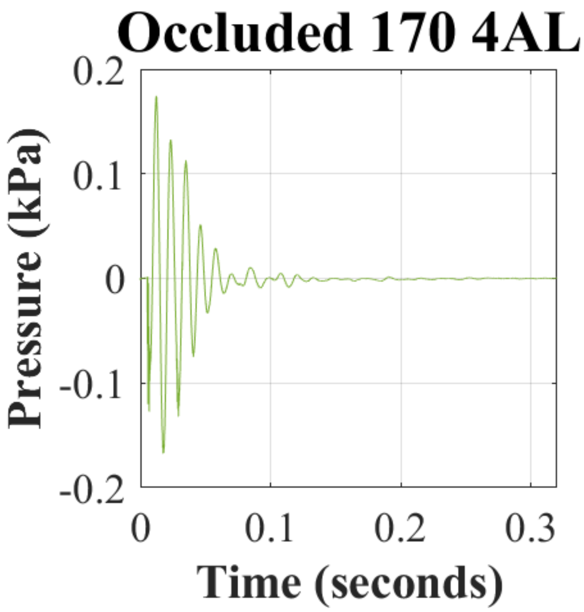

Occluded 170 2BR
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)

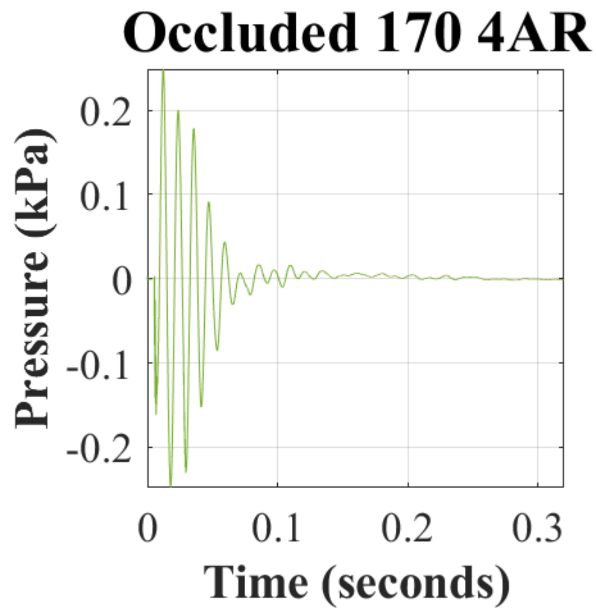

Occluded 170 3AL
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)

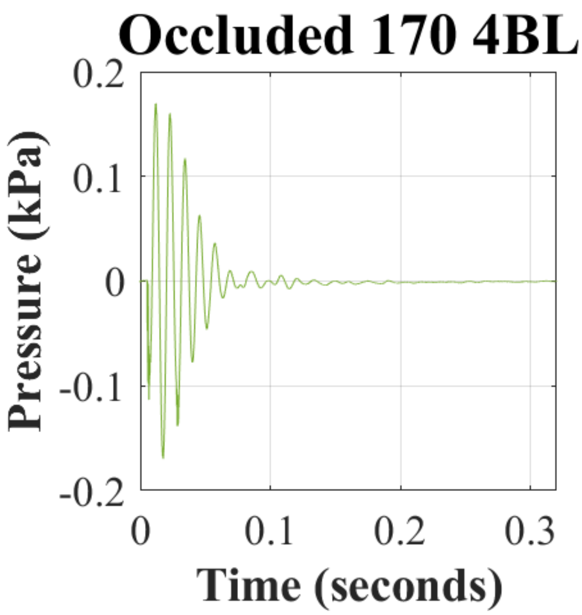

Occluded 170 3AR
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)

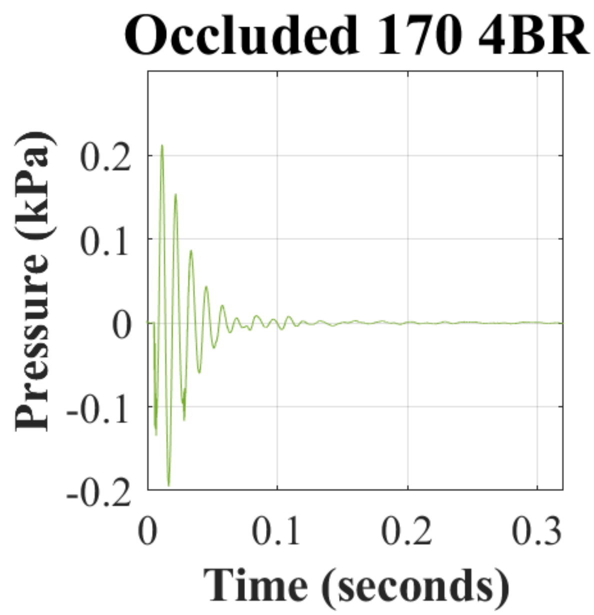

Occluded 170 3BL
Pressure (kPa)
0.2
0.1
0
-0.1
0
0.1
0.2
0.3
Time (seconds)

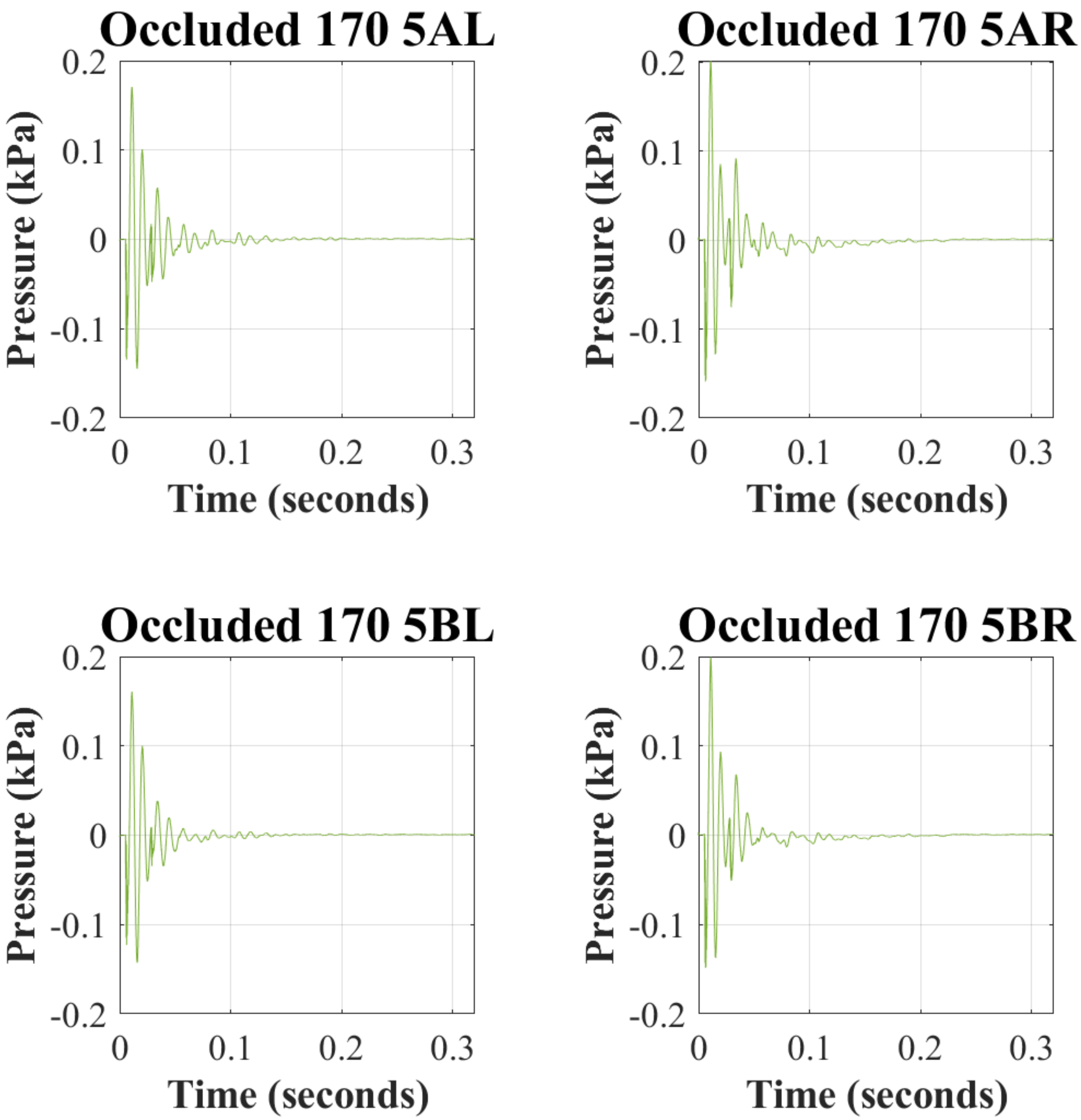

Occluded 170 3BR
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)


Occluded 170 4AL
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)


Occluded 170 4AR
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)

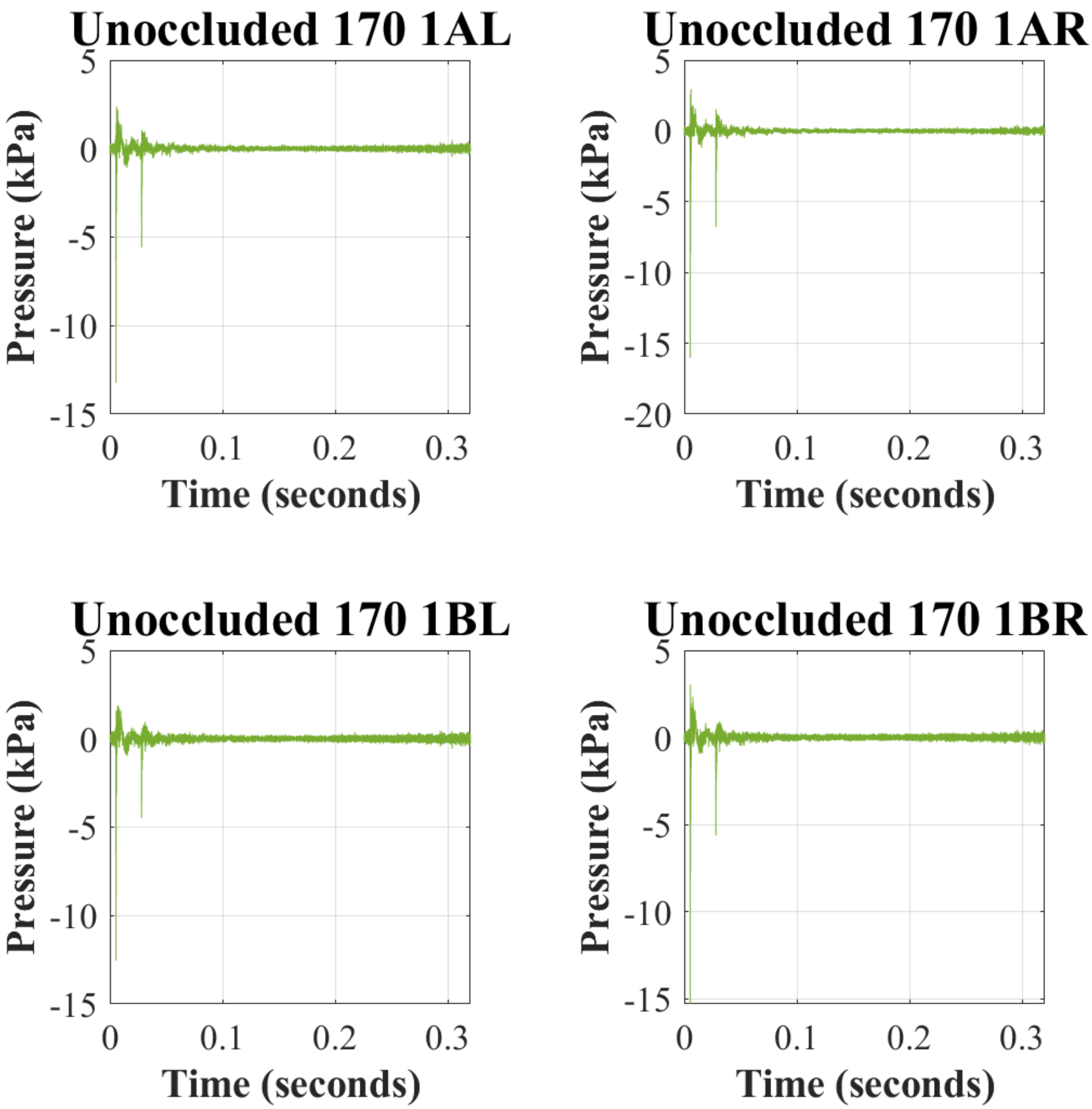

Occluded 170 4BL
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)

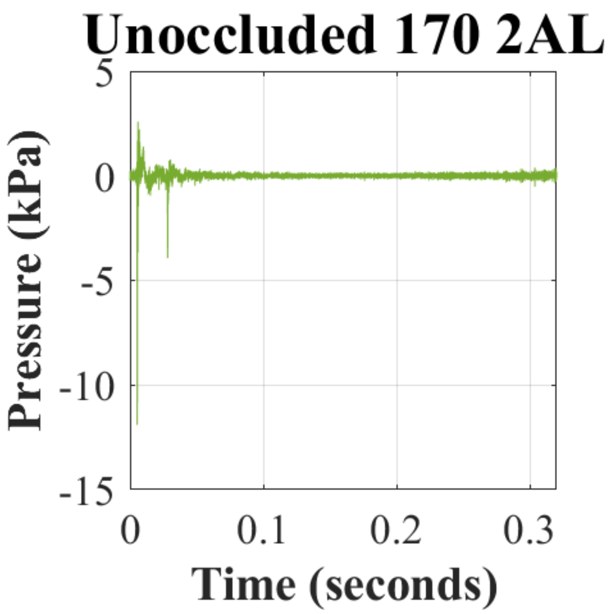

Occluded 170 4BR
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)

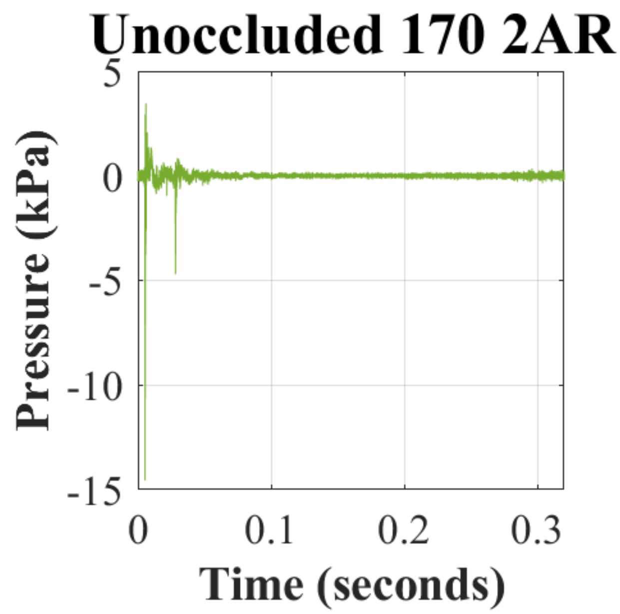


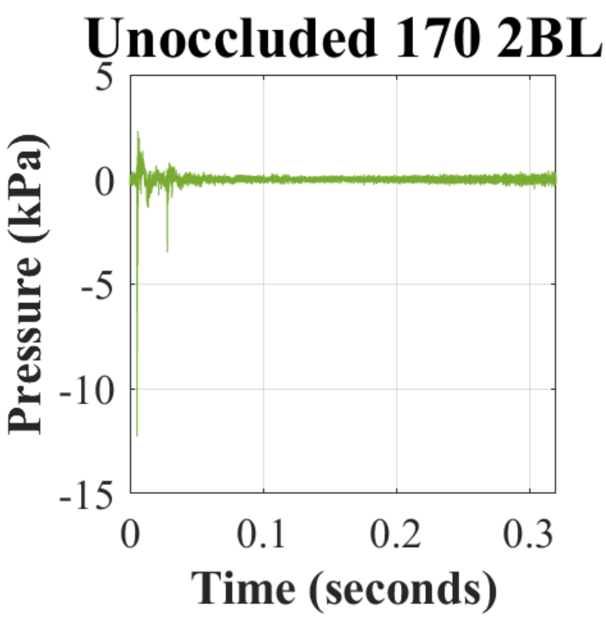
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the earmuff donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating fit (i.e., first or second, respectively), and ‘X’ indicates from what ATF microphone the recording is from (i.e., right (R) or left (L) pinnae).

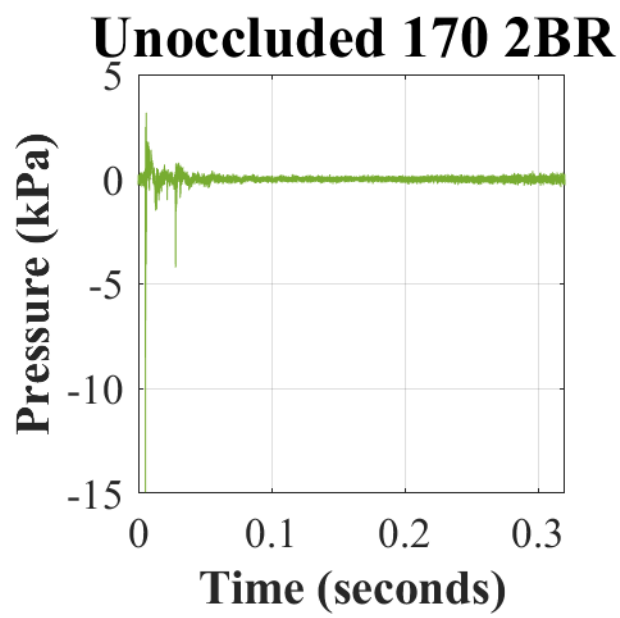
Appendix D. Estimated unoccluded (earmuff doffed) waveforms in response to 170 dBP with the PELTOR™ Optime™ 105.

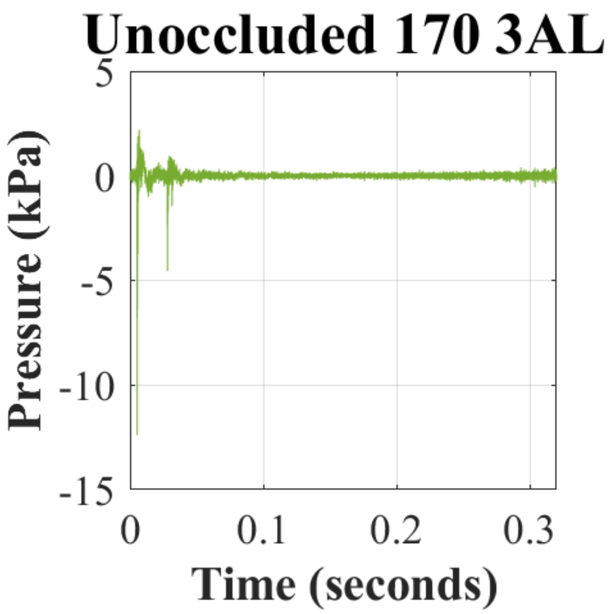


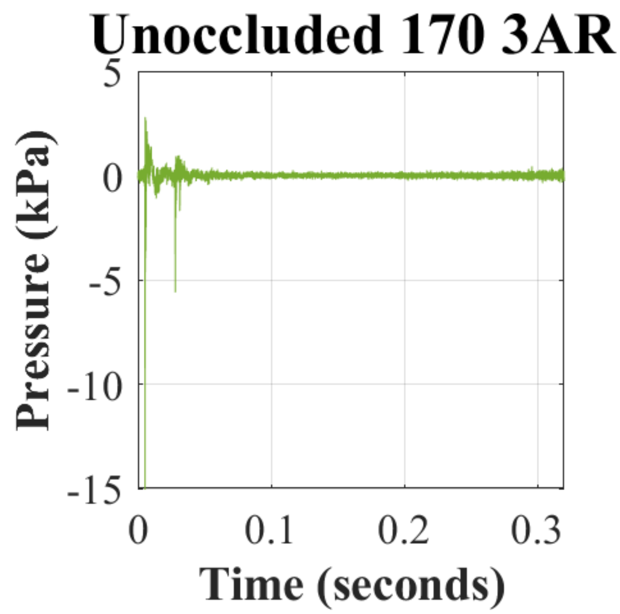

Unoccluded 170 2AL
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

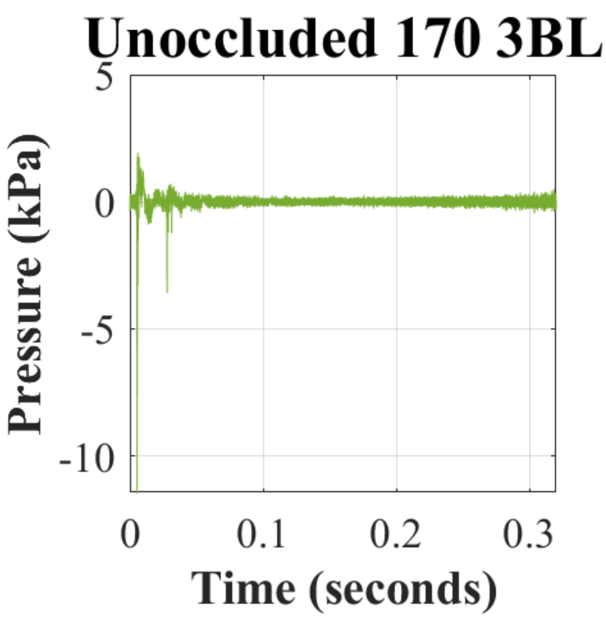

Unoccluded 170 2AR
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

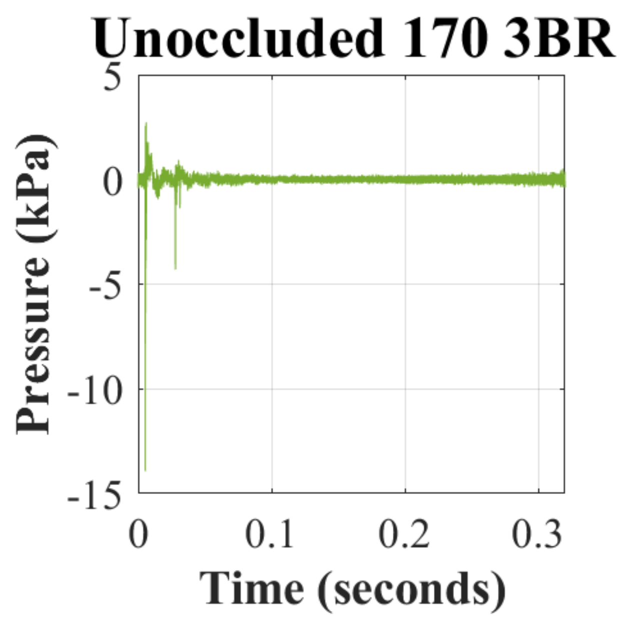

Unoccluded 170 2BL
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

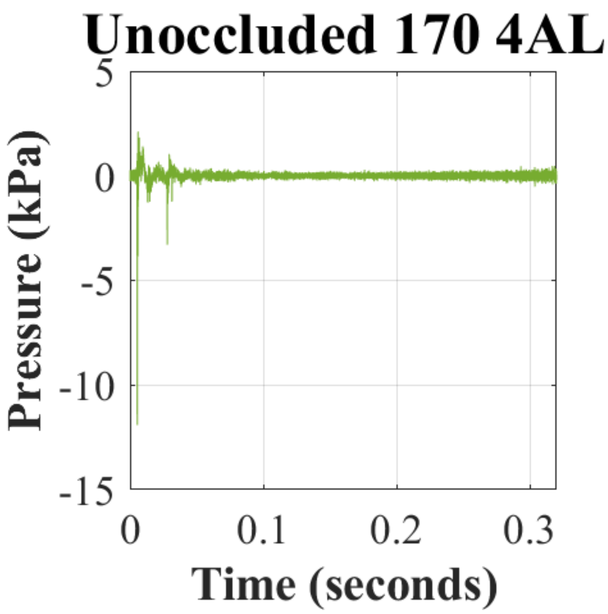

Unoccluded 170 2BR
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

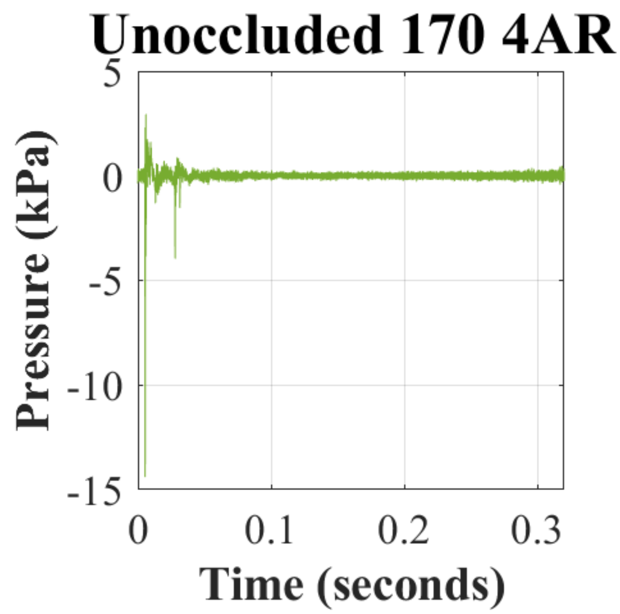

Unoccluded 170 3AL
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

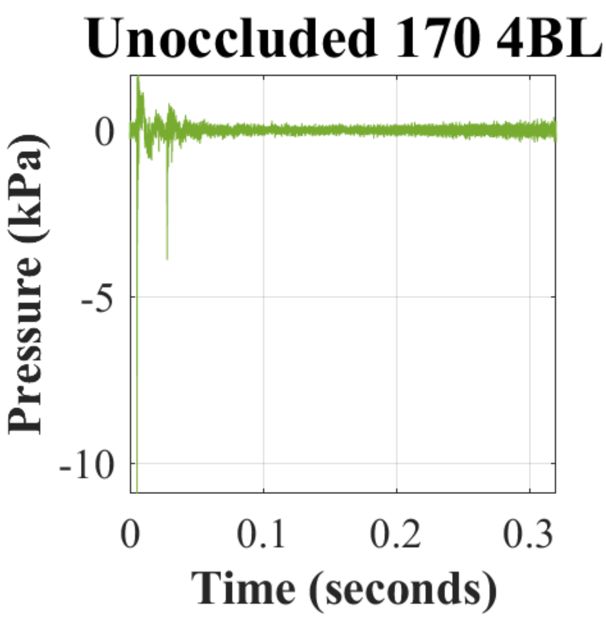

Unoccluded 170 3AR
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

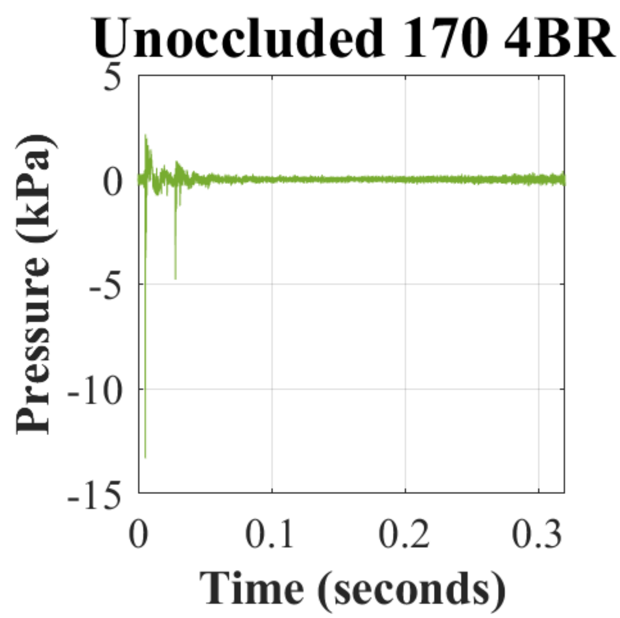

Unoccluded 170 3BL
Pressure (kPa)
5
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

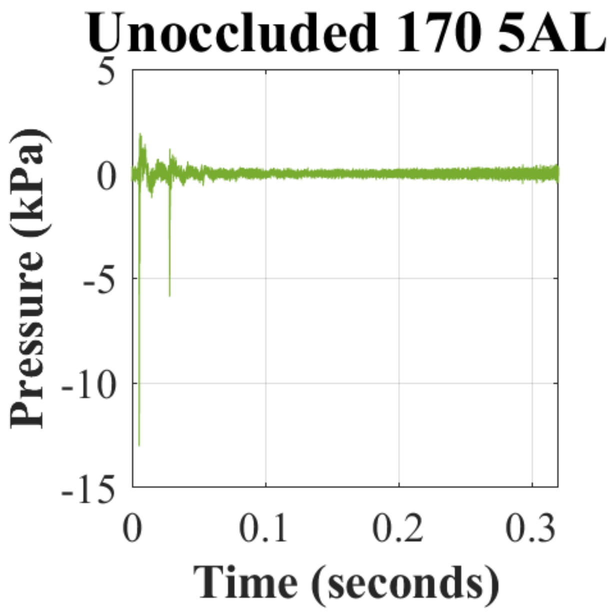

Unoccluded 170 3BR
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

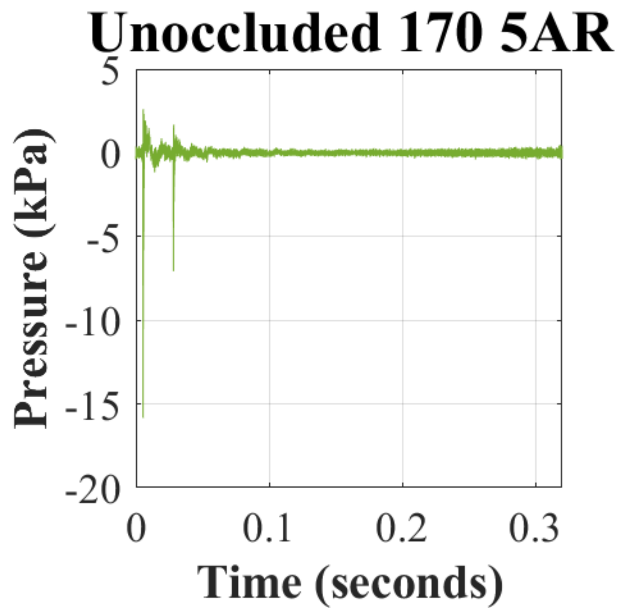

Unoccluded 170 4AL
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

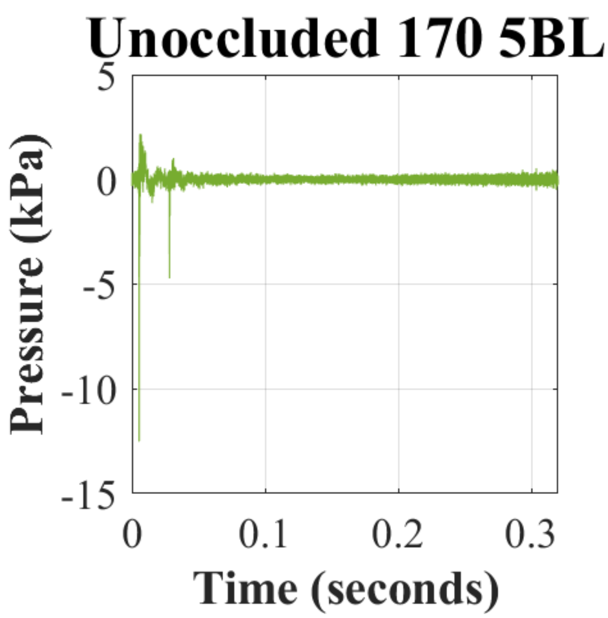

Unoccluded 170 4AR
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

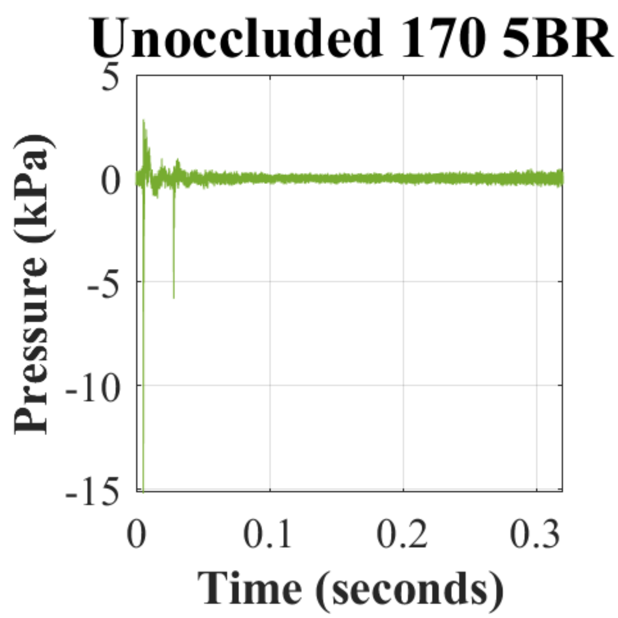

Unoccluded 170 4BL
Pressure (kPa)
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)


Unoccluded 170 4BR
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)



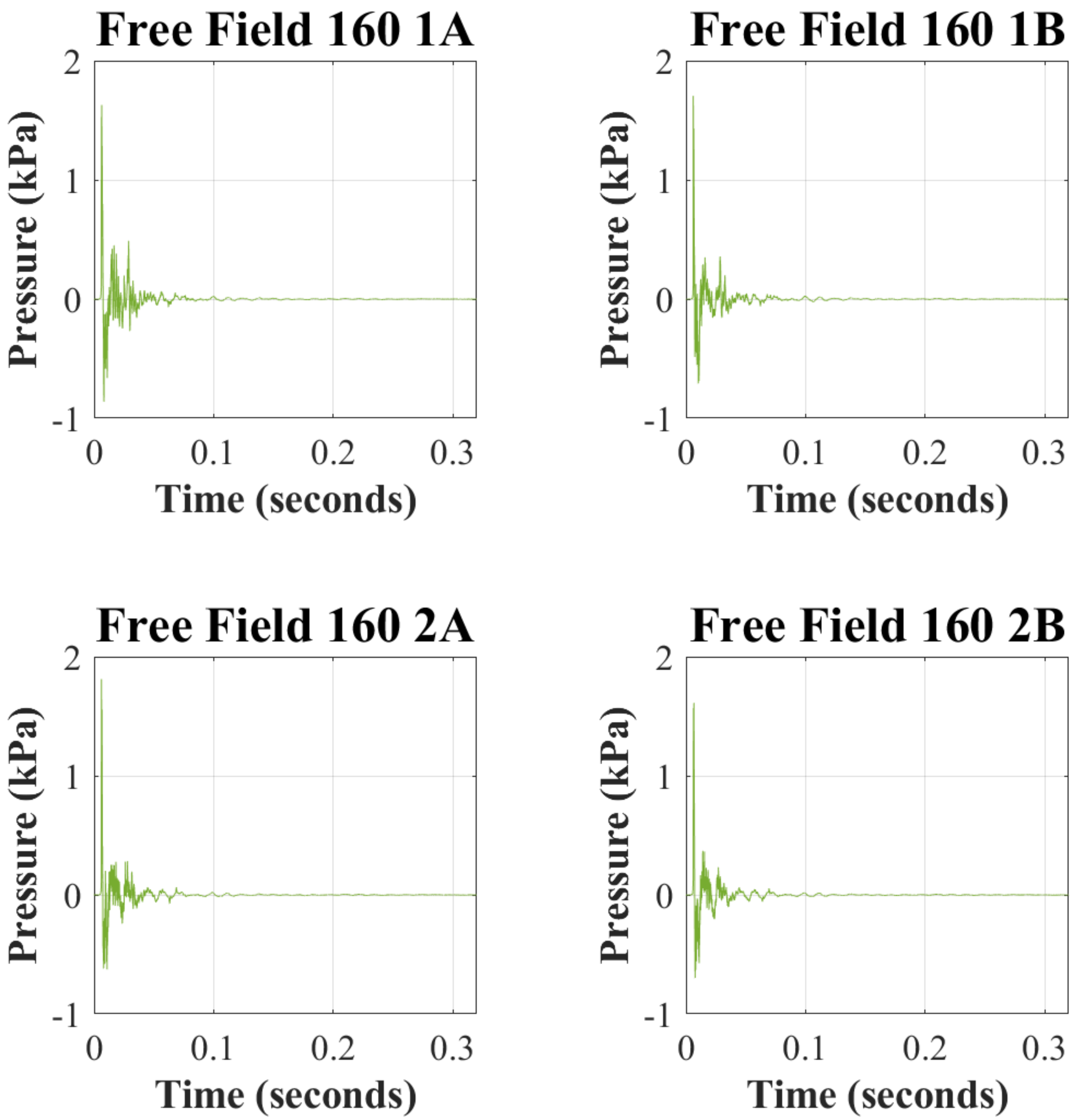


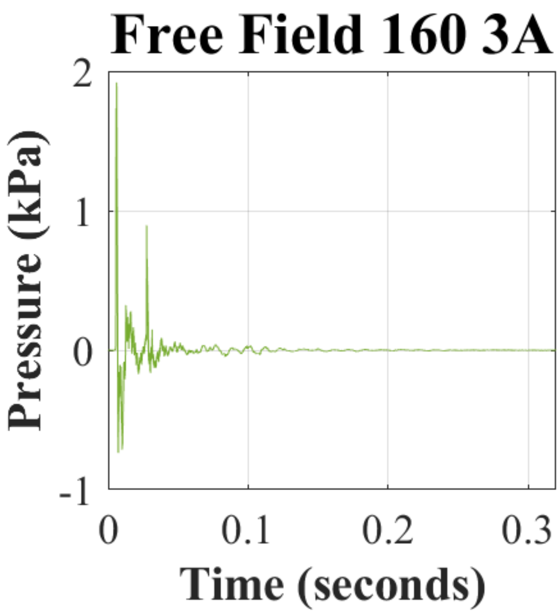


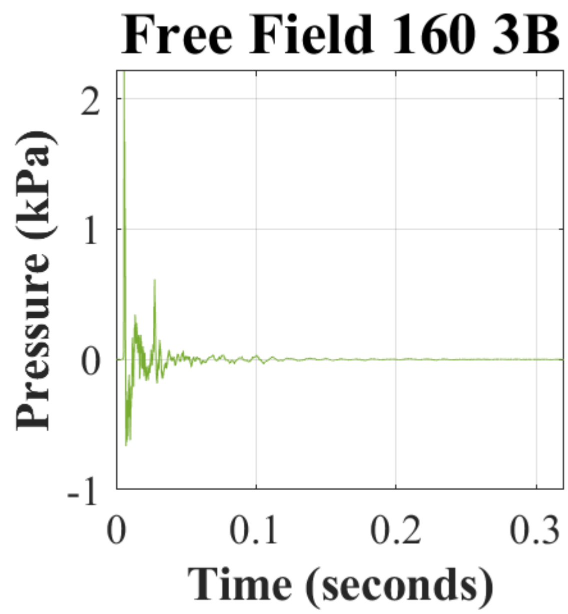


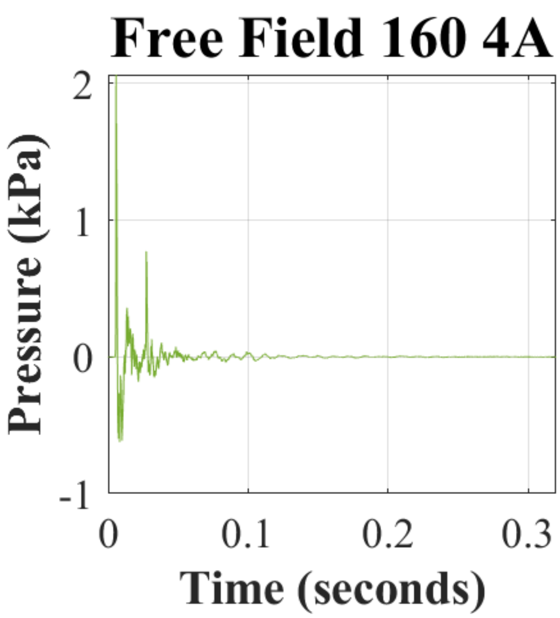
Note. The naming convention for all occluded waveforms is "Occluded LvL NnX", where 'Unoccluded' is the test condition (i.e., ATF has the earmuff doffed), 'LvL' is the nominal test level (i.e., 160 or 170 dBP), 'N' is the sample number (i.e., 1 to 5) of the device tested, 'n' is the trial (i.e., A or B) indicating fit (i.e., first or second, respectively), and 'X' indicates from what ATF microphone the recording is from (i.e., right (R) or left (L) pinnae).

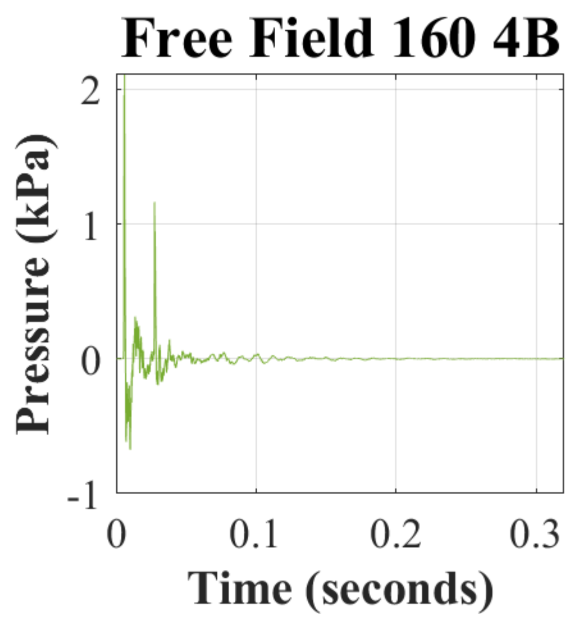
Appendix E. Recorded waveform of the impulse measured with the free-field probe at 160 dBP and the PELTOR™ Optime™ 105 donned.

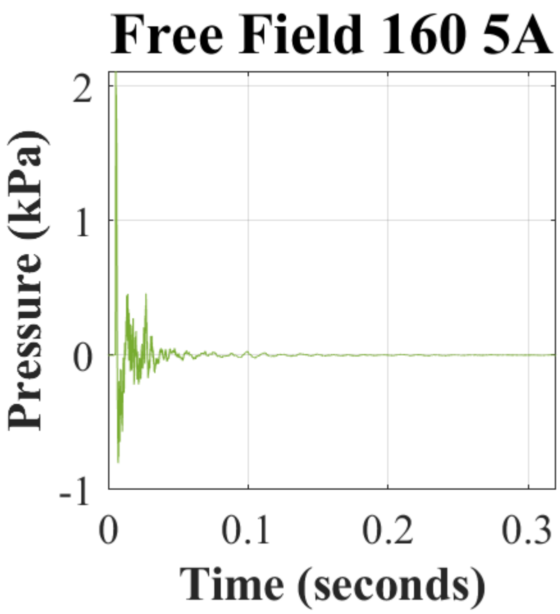


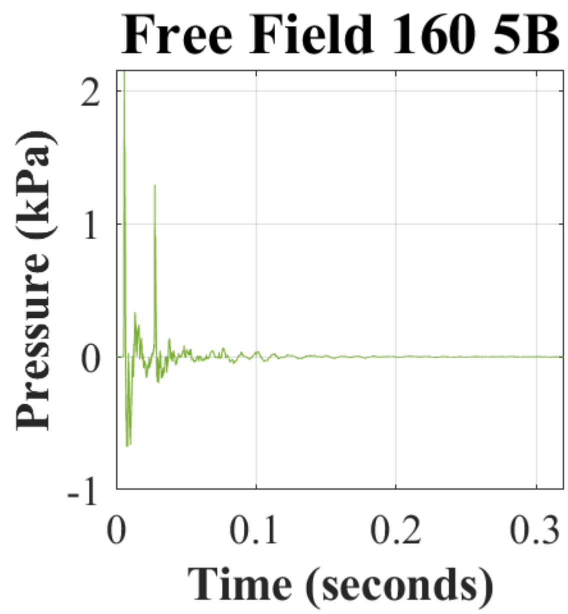

Free Field 160 3A
Pressure (kPa)
Time (seconds)
2
1
0
-1
0
0.1
0.2
0.3


Free Field 160 3B
Pressure (kPa)
Time (seconds)
2
1
0
-1
0
0.1
0.2
0.3


Free Field 160 4A
Pressure (kPa)
Time (seconds)
2
1
0
-1
0
0.1
0.2
0.3

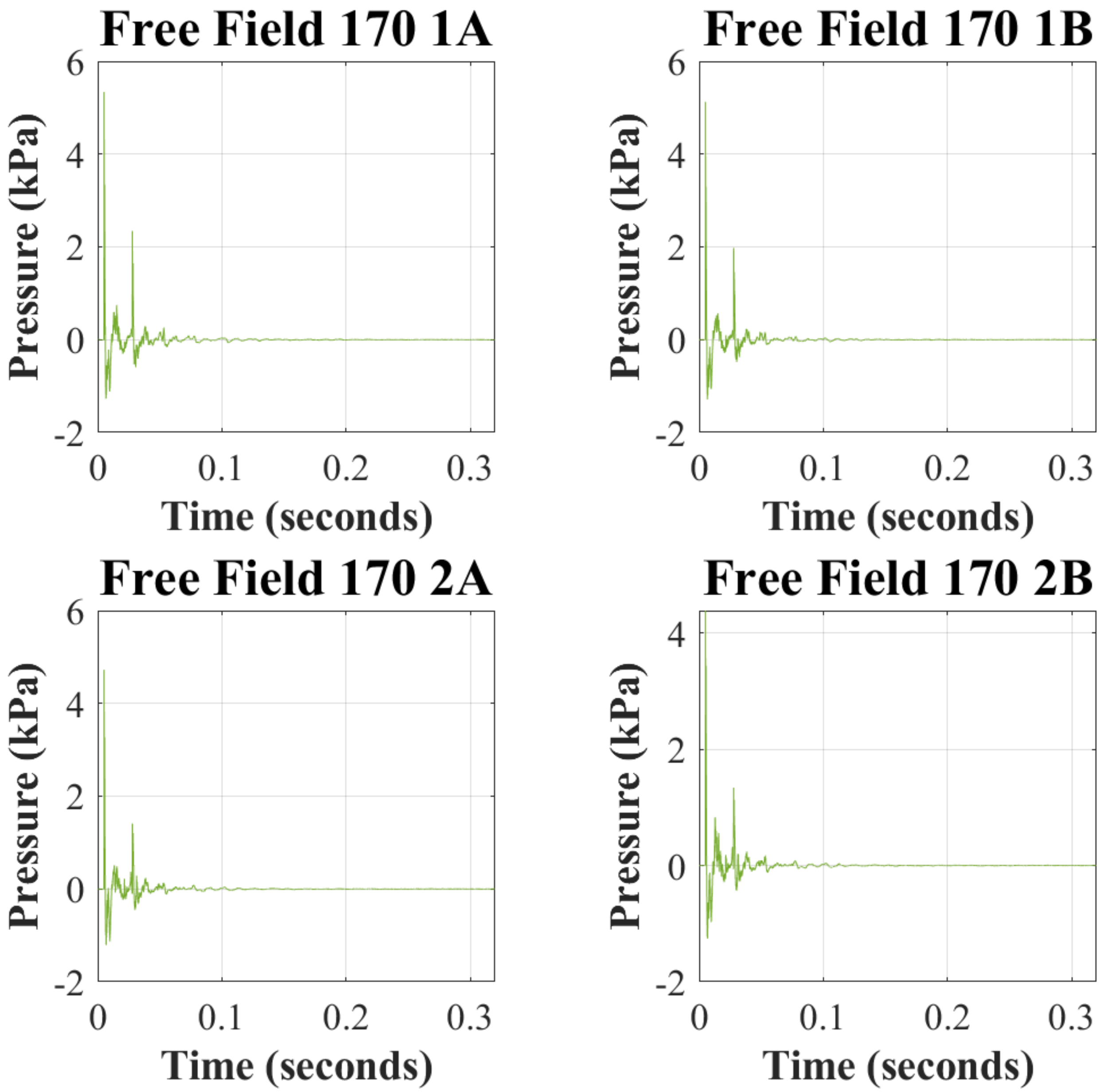

Free Field 160 4B
Pressure (kPa)
Time (seconds)
2
1
0
-1
0
0.1
0.2
0.3

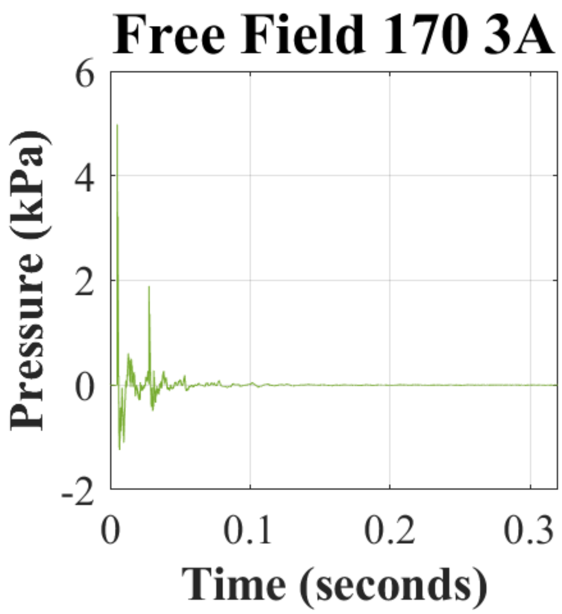


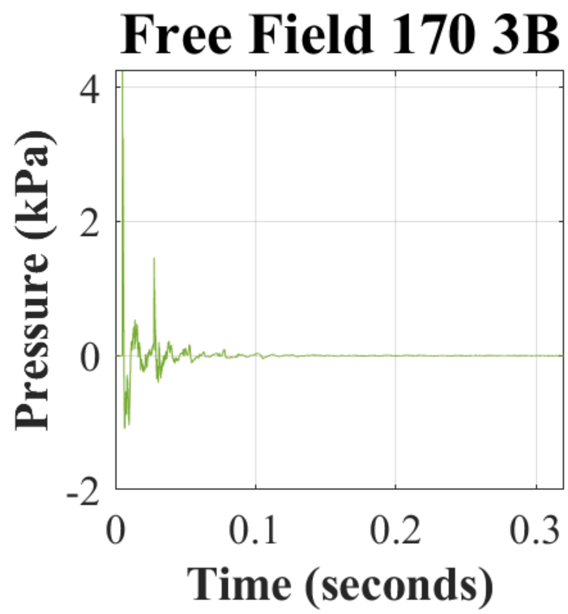


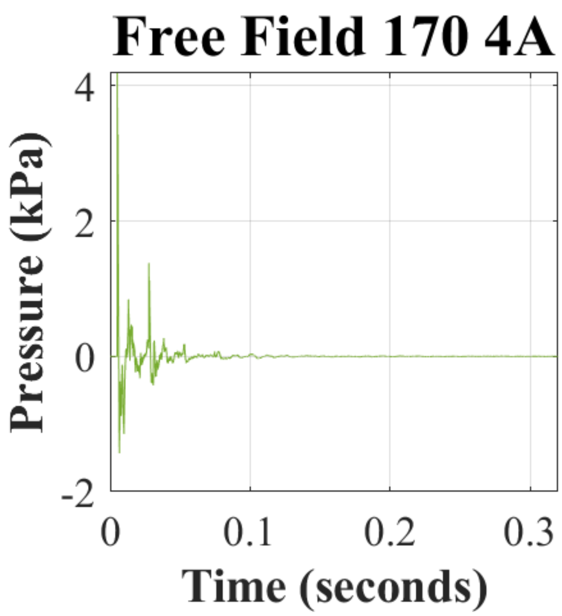
Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (170 dBP), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or B).

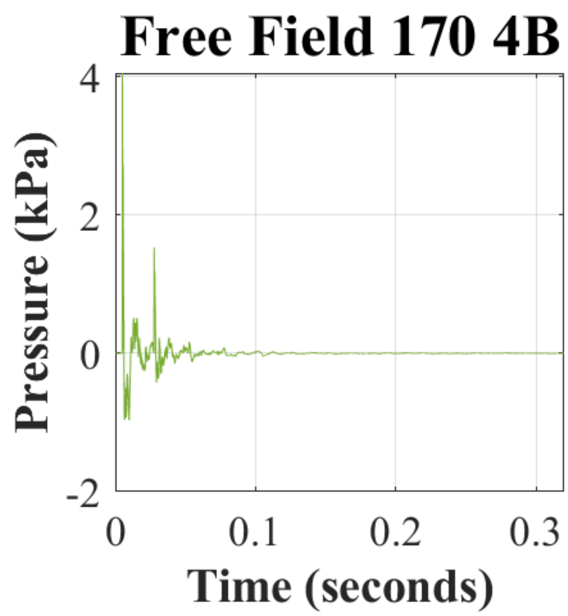
Appendix F. Recorded waveform of the impulse measured with the free-field probe at 170 dBP and the PELTOR™ Optime™ 105 donned.

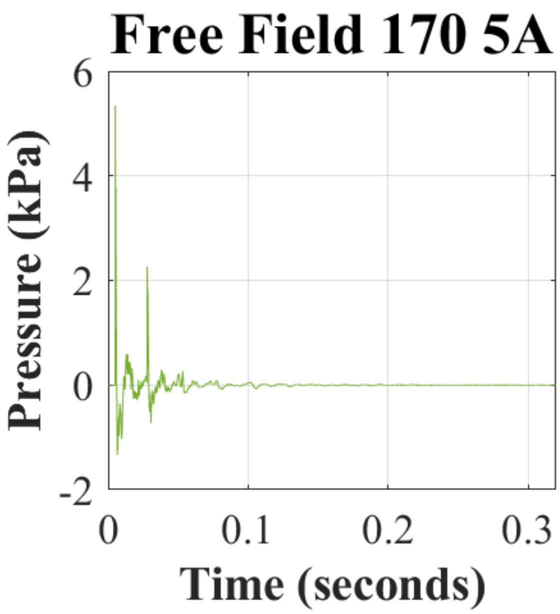


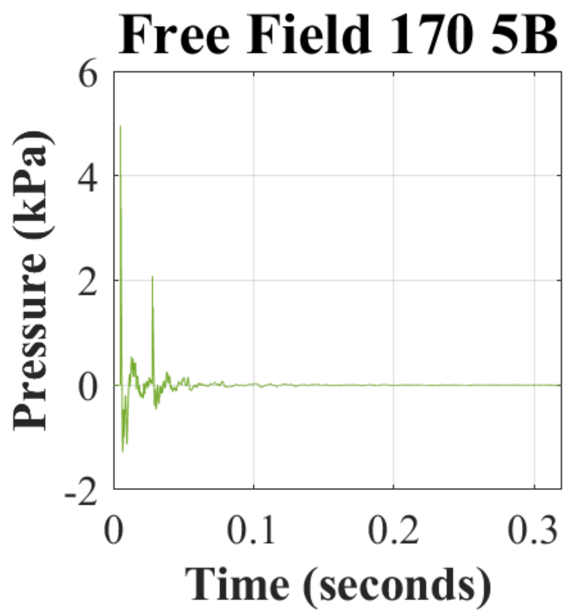

Free Field 170 3A
Pressure (kPa)
6
4
2
0
-2
0
0.1
0.2
0.3
Time (seconds)


Free Field 170 3B
Pressure (kPa)
4
2
0
-2
0
0.1
0.2
0.3
Time (seconds)


Free Field 170 4A
Pressure (kPa)
4
2
0
-2
0
0.1
0.2
0.3
Time (seconds)


Free Field 170 4B
Pressure (kPa)
4
2
0
-2
0
0.1
0.2
0.3
Time (seconds)





Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (170 dBP), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or B).