Naval Submarine Medical Research Laboratory

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Impulse Assessment of the
3M™ PELTOR™ Optime™ 105 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 and the calculated mean IPIL values for the 3M™ PELTOR™ Optime™ 105 Earmuff (3M™ PELTOR™ Optime™ 105; Model: H10A). Testing was completed in accordance with the ANSI standard S12.42-2010. All device samples were tested at the nominal levels of 150, 160, and 170 decibel peak (dBP, re: 20 µPa). 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. The mean and standard deviation (SD) IPIL values were 29.4 (1.8) dB SPL at 150 dBP, 32.1 (1.9) dB SPL at 160 dBP, and 34.5 (1.4) dB SPL at 170 dBP (see Table 1). These results suggest that, when properly fit and functional, the 3M™ PELTOR™ Optime™ 105 will adequately protect (i.e., reduce exposure to less than 140 dBP) against impulses below 174.5 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 and the calculated mean IPIL values for the 3M™ PELTOR™ Optime™ 105 Earmuff (3M™ PELTOR™ Optime™ 105; Model: H10A). Testing was completed 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." All device samples were tested at the nominal levels of 150, 160, and 170 decibel peak (dBP, re: 20 µPa). 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. The mean and standard deviation (SD) IPIL values were 29.4 (1.8) dB SPL at 150 dBP, 32.1 (1.9) dB SPL at 160 dBP, and 34.5 (1.4) dB SPL at 170 dBP (see Table 1). These results suggest that, when properly fit and functional, the 3M™ PELTOR™ Optime™ 105 will adequately protect (i.e., reduce exposure to less than 140 dBP) against impulses below 174.5 dBP.

Table 1.
3M™ PELTOR™ Optime™ 105 mean (SD) IPIL value (in dB) for all test conditions.

150 dBP	**160 dBP**	**170 dBP**
29.4 (1.8)	32.1 (1.9)	34.5 (1.4)

Introduction

The 3M™ PELTOR™ Optime™ 105 Earmuff (3M™ PELTOR™ Optime™ 105; 3M™, St. Paul, MN) is a passive, universal sized over-the-head earmuff built with a double-shell ear cup design and stainless steel headband that allows for a low-pressure fit on the user. In 2008, 3M™ acquired Aearo Technologies, Inc., and has continued to manufacture the 3M™ PELTOR™ Optime™ 105 since (3M™, 2008). All tested earmuff samples were manufactured by 3M™. According to 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).

The Department of Defense Instruction 6055.12 (2019) "Hearing Conservation Program (HCP)" limits impulse noise exposure to 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 to prevent hearing loss resulting from occupational and operational illness and injury are mandated. One conservation measure used to reduce the user's noise hazard below the 140 dBP limit is the use of hearing protection devices (HPDs; e.g., earplug or earmuff).

In order to calculate whether the issued HPD will reduce the impulse 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 an HPD in response to impulse noise. At present, the IPIL value of the 3M™ PELTOR™ Optime™ 105 at 150, 160, and 170 dBP is unknown. This report describes the methods and results used to determine the IPIL value for the 3M™ PELTOR™ Optime™ 105 Earmuff. In addition to reporting an overall device IPIL, ear-specific IPILs are reported for the tested nominal levels.

Methods

Facility

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.

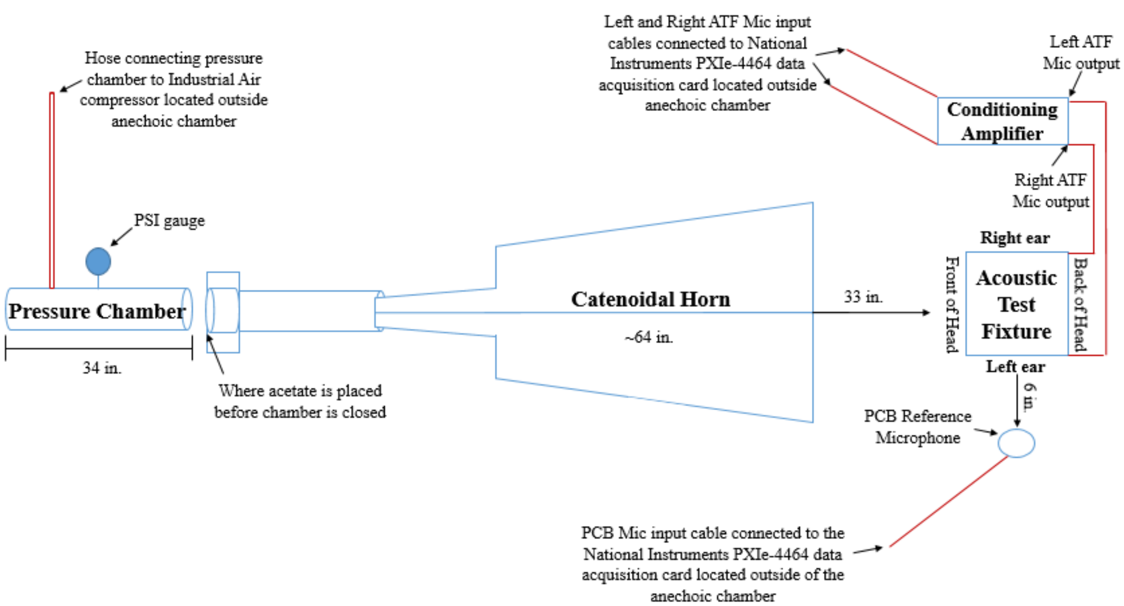
For each trial at 150 dBP, a 7 in. (17.8 cm) by 7 in. (17.8 cm) polyester sheet (SEVA Technical Services, Inc, Newport News, VA) was used as a membrane between the pressurized chamber and the catenoidal tube horn to enable pressurization of the air chamber. Each polyester sheet was 0.001 in. (1.0 mil, 25.4 micrometer [μm]) thick. For each trial at 160 and 170 dBP, a 7 in. (17.8 cm) by 7 in. (17.8 cm) acetate sheet (Grafix Plastic, Maple Heights, OH) was used as a membrane 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 is presented 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 (6^{th} 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 150 dBP, 160 dBP, and 170 dBP data (see Data Analysis below).

Hearing Protection Device Samples. Five samples (See Figure 2 for example) of the 3M™ PELTOR™ Optime™ 105 Earmuff (Manufacturer Product Number: H10A) were tested in accordance with ANSI/ASA S12.42-2010. Each sample, consisting of one earmuff, was randomly assigned a number 1 through 5.

Figure 2.
Photograph of a 3M™ PELTOR™ Optime™ 105 Earmuff Sample.

Procedure

Each HPD sample 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 (150, 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 in accordance with 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 ATF ears to encompass the pinnae and seal tightly against the head, and the headband adjusted to just rest on the head of the ATF.

Testing at the 130 dBP nominal level was omitted, and the nominal level of 160 dBP was incorporated as impulses generated with the NSMRL 4 in. (10.2 cm) shock tube at levels below the nominal level of 150 dBP were found to be without a shock front. Measurement of IPIL at 160 dBP was included in order to provide accurate guidance for exposures between 150 and 170 dBP. At the measured levels described herein, all generated impulses had a shock front. As previously stated, the action level for the US DoD is 140 dBP for impulse noises. Therefore, the measurement of IPIL values below 140 dBP are of marginal value to the DoD. Due to non-linear effects of HPDs on IPIL, it is best to use IPIL values measured close to the level of the predicted exposure (Department of Defense, 2015).

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 in accordance with 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 150 dBP (8.9 to 9.3 psi, 61 to 64 kilopascals [kPa]), 160 dBP (19.5 to 22.1 psi, 134 to 152 kPa), or 170 dBP (28.5 to 29.5 psi, 197 to 203 kPa). 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 emitted was dependent upon the amount of air pressure released.

In place of the ANSI/ASA S12.42-2010 standardized calibration impulses at 130 dBP, six total calibration impulses (three pre-, three post-testing) were generated per nominal level (150,160 dBP) in the unoccluded (i.e., without HPD) test configuration. 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 IPIL values at the 150, 160, and 170 dBP nominal levels and to generate all waveform graphs (See Appendices A to I). 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 levels. The mean transfer function for each ear at each level was then calculated, and the first elements of the transfer functions were 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 150 and 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., 150 dBP, 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

As shown in Table 2, the overall mean (SD) IPIL value was 29.4 (1.8) dB for the 150 dBP test condition, 32.1 (1.9) dB for the 160 dBP test condition, and 34.5 (1.4) dB for the 170 dBP test condition. Calculated IPIL values for all individual sample trials ranged between 24.9 and 32.1 dB at 150 dBP, between 28.3 and 35.5 dB at 160 dBP, and between 31.2 and 36.8 dB at 170 dBP. The waveforms for all trials with the 3M™ PELTOR™ Optime™ 105 are provided in Appendices A to I.

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Table 2.
Mean (SD) IPIL values (in dB) for Tested 3M™ PELTOR™ Optime™ 105 Samples.

	150 dBP		160 dBP		170 dBP	
	Right	*Left*	*Right*	*Left*	*Right*	*Left*
HPD 1, Trial A	28.6	31.3	32.5	34.6	34.8	36.8
HPD 1, Trial B	24.9	31.5	28.3	33.9	31.2	36.0
HPD 2, Trial A	29.1	31.2	32.1	33.5	34.9	35.6
HPD 2, Trial B	28.0	29.0	30.4	31.2	32.8	33.8
HPD 3, Trial A	26.8	29.6	29.1	31.0	33.1	33.5
HPD 3, Trial B	27.9	30.5	30.7	32.8	34.5	35.5
HPD 4, Trial A	29.2	31.3	32.9	34.5	35.2	35.5
HPD 4, Trial B	29.5	32.1	29.3	32.5	34.5	35.5
HPD 5, Trial A	26.8	31.0	32.5	35.5	32.6	35.7
HPD 5, Trial B	29.7	29.3	32.7	32.9	34.1	35.2
Ear Specific Mean (SD)	28.1 (1.5)	30.7 (1.0)	31.1 (1.7)	33.2 (1.5)	33.8 (1.3)	35.3 (1.0)
Level Overall Mean (SD)	29.4 (1.8)		32.1 (1.9)		34.5 (1.4)	

The measured clamping force of the 3M™ PELTOR™ Optime™ 105 ranged from 2.5 to 2.7 lbf, with a mean (SD) of 2.1 (0.1) lbf (as shown in Table 3).

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

	Band Force
HPD 1	2.6
HPD 2	2.7
HPD 3	2.5
HPD 4	2.6
HPD 5	2.5
MEAN (SD)	2.6 (0.1)

Discussion

The overall mean IPIL value was 29.4 dB at 150 dBP, 32.1 dB at 160 dBP, and 34.5 dB at 170 dBP. Across ears, the individual trial mean IPIL values were found to vary as much as 7.2 dB at 150 dBP, 7.2 dB at 160 dBP, and 5.6 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.

It is important to note that these results do not guarantee similar 3M™ PELTOR™ Optime™ 105 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), 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 3M™ PELTOR™ Optime™ 105 Earmuff (3M™ PELTOR™ Optime™ 105) at 150, 160, and 170 dBP nominal levels. The calculated overall mean (SD) IPIL values for the 3M™ PELTOR™ Optime™ 105 were found to be 29.4 (1.8) dB at 150 dBP, 32.1 (1.9) dB at 160 dBP, and 34.5 (1.4) dB at 170 dBP. The results of this effort imply that, when properly fit and functional, the 3M™ PELTOR™ Optime™ 105 can adequately protect (i.e., reduce the exposure below 140 dBP) the user from impulses below 174.5 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.

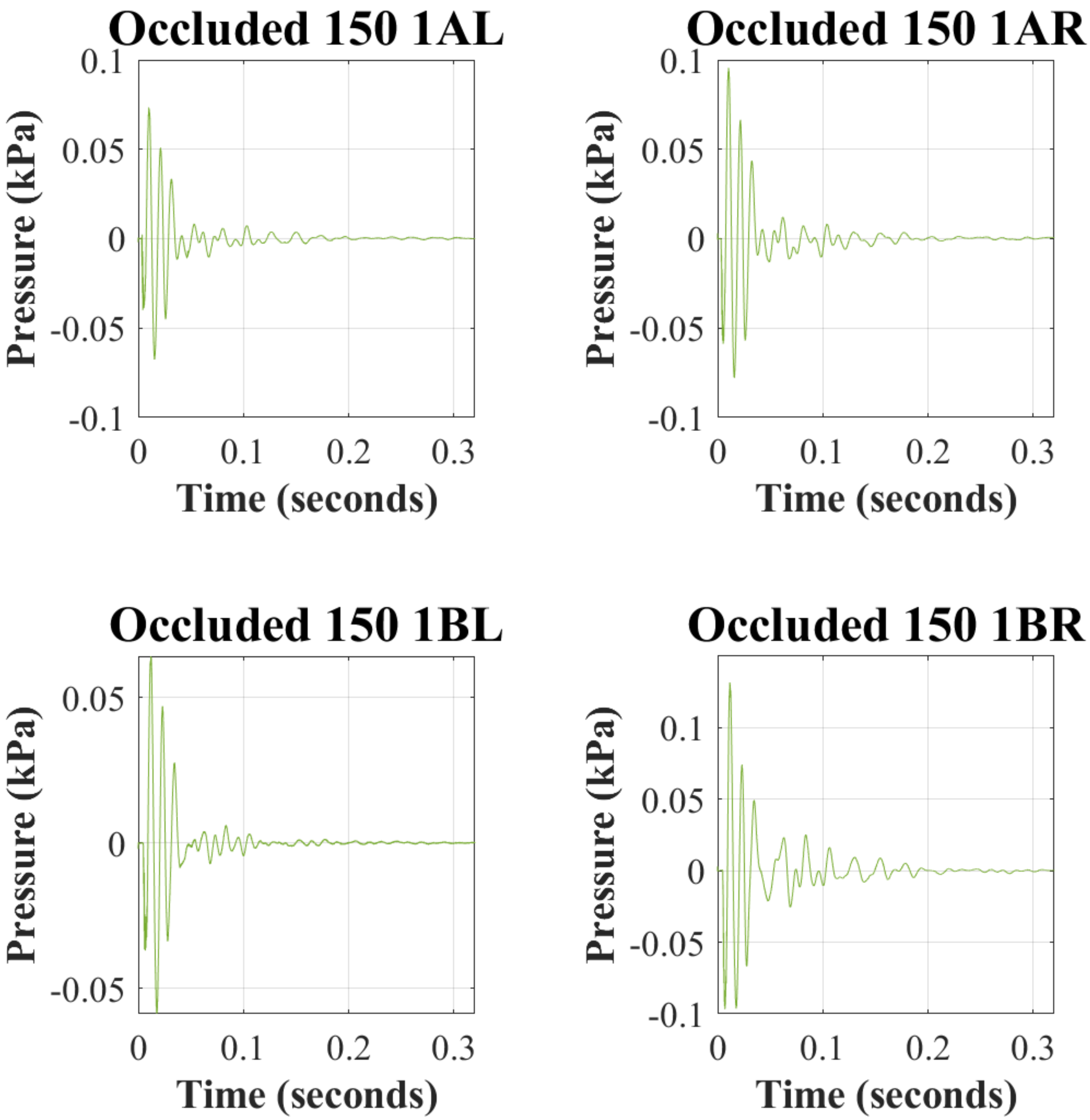
Office of the Under Secretary of Defense for Personnel and Readiness (2019). *DoD Instruction 6055.12 Hearing Conservation Program (HCP).* Department of Defense.

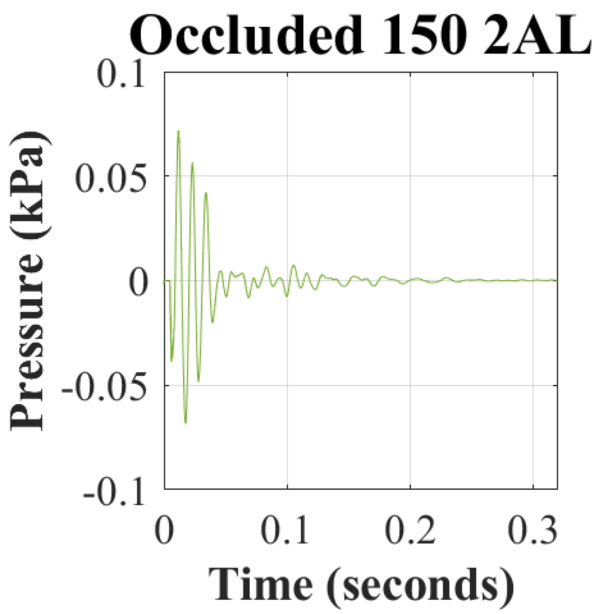
3M (2021). *3M™ PELTOR™ Optime™ 105 Earmuffs H10A, Over-the-Head*. [Webpage]. St. Paul, MN: 3M.

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

3M Personal Safety Division (2016). *Hearing Solutions Catalog*. St. Paul, MN: 3M Company.

Appendix A. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 150 dBP with the 3M™ PELTOR™ Optime™ 105 Earmuffs.

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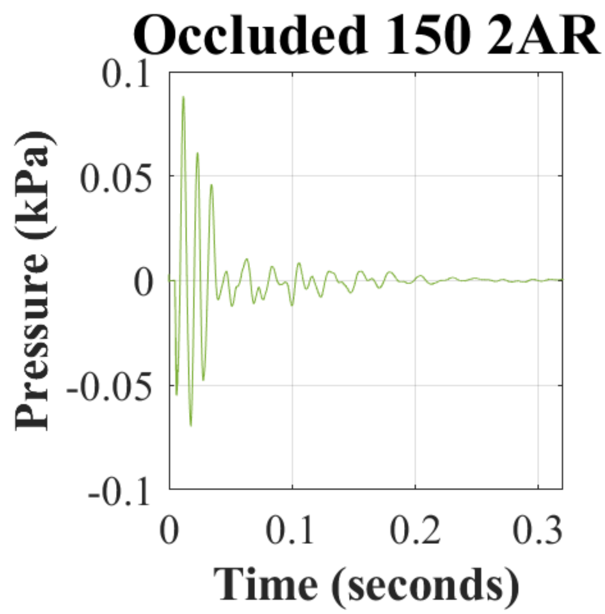
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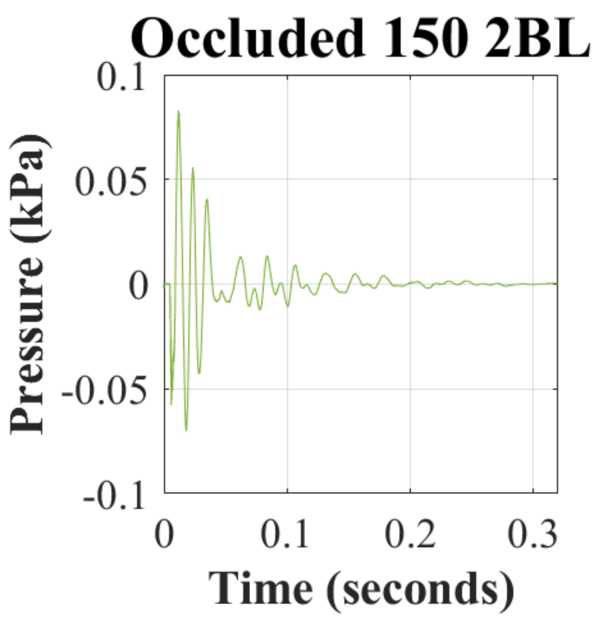
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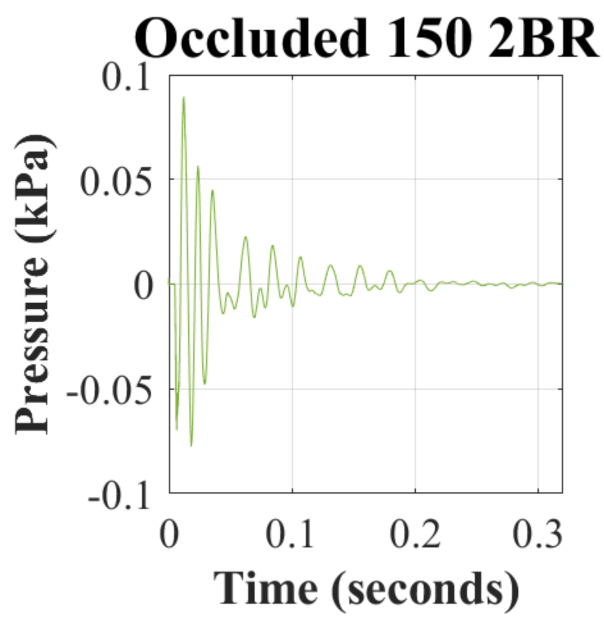
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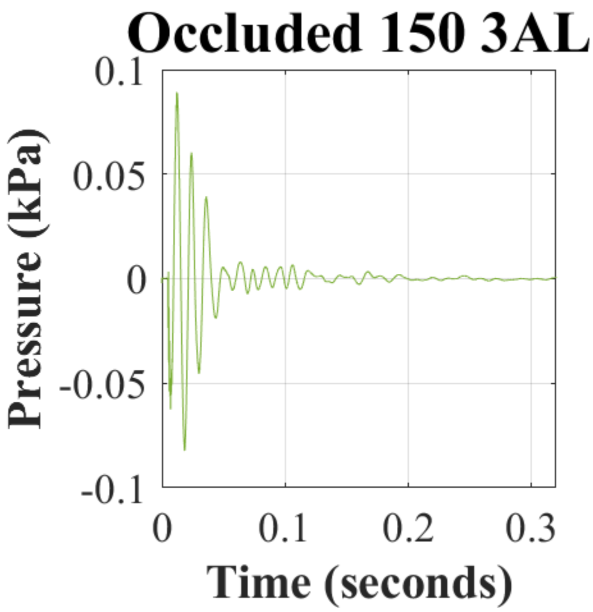
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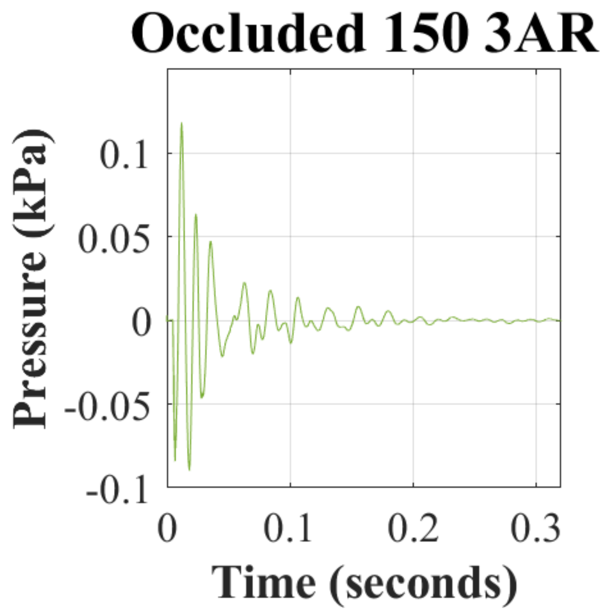
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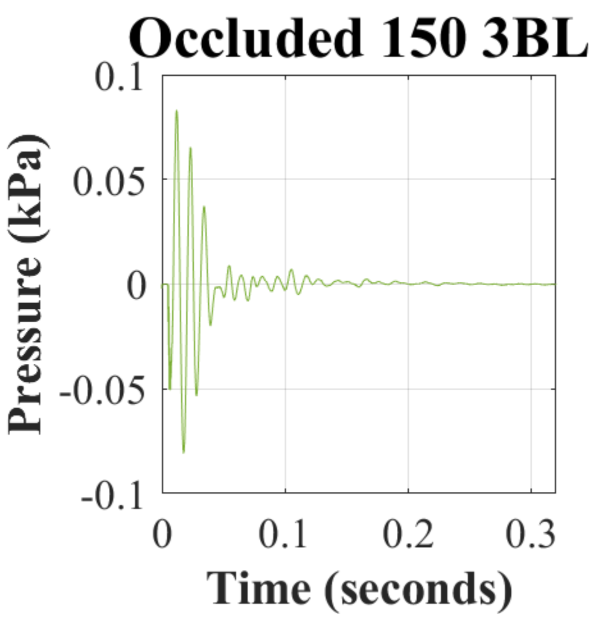
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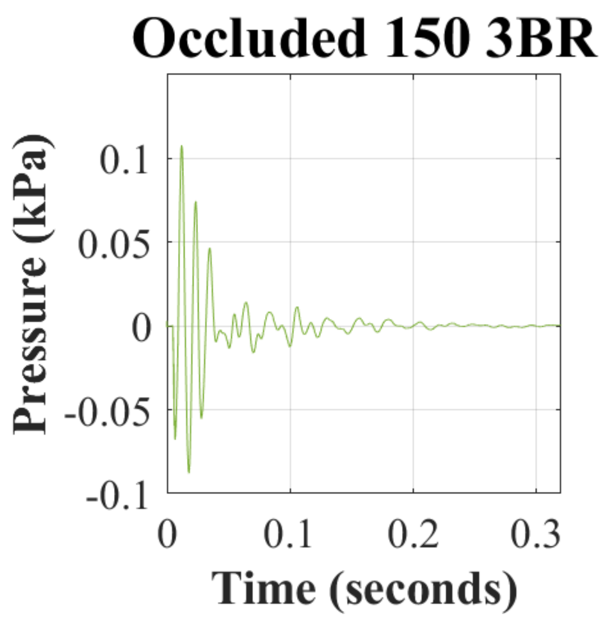
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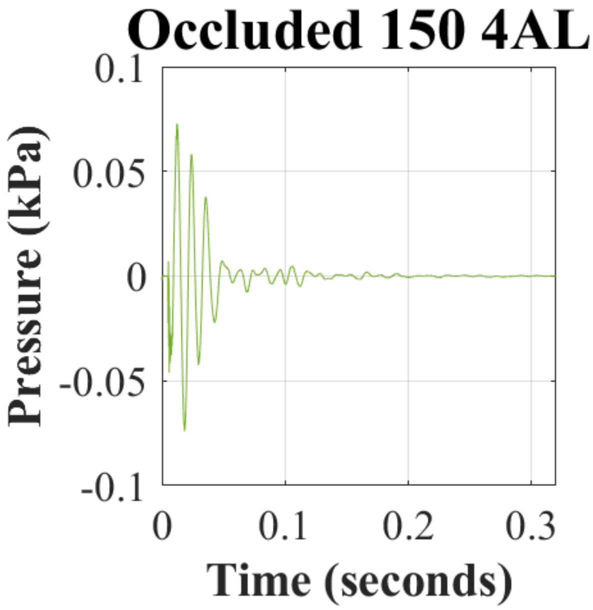
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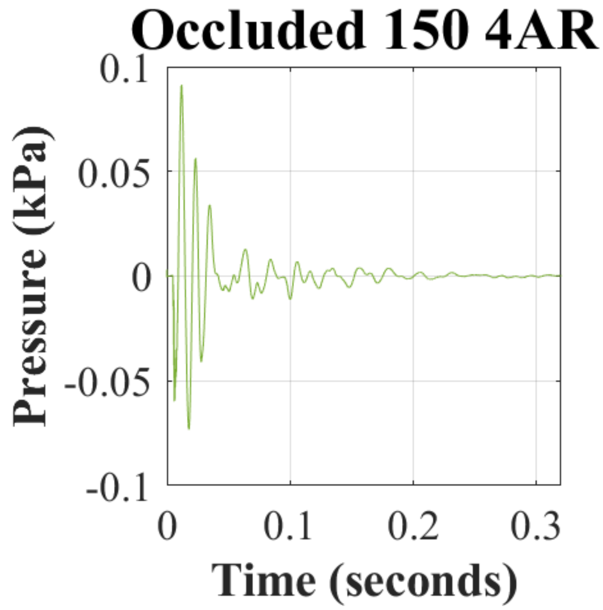
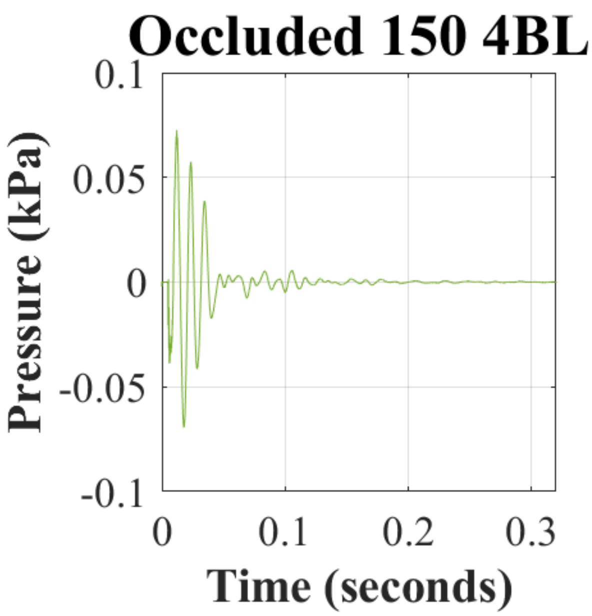
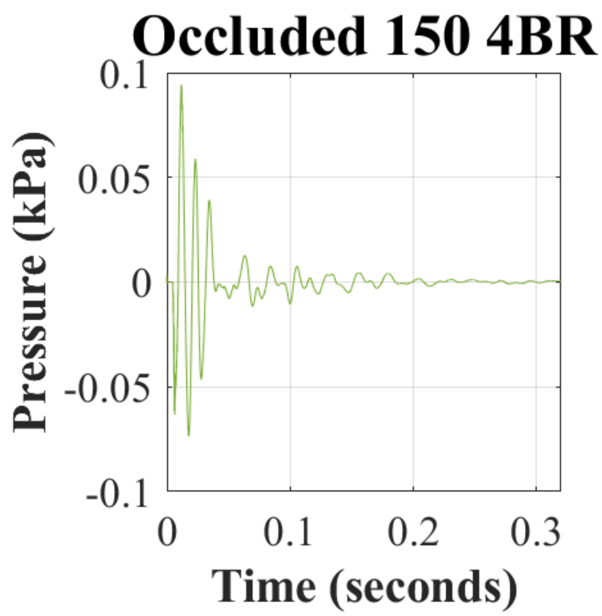
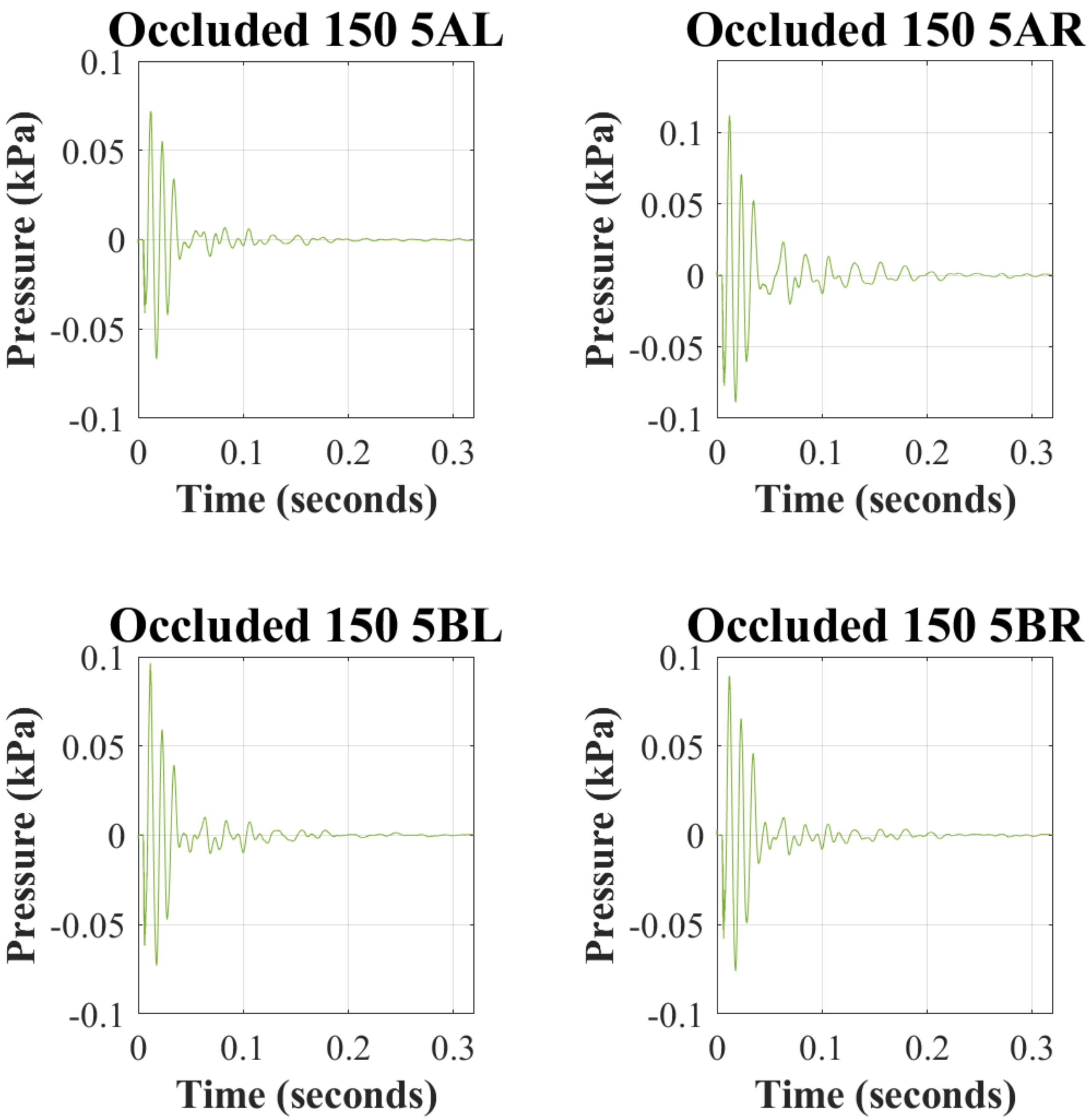
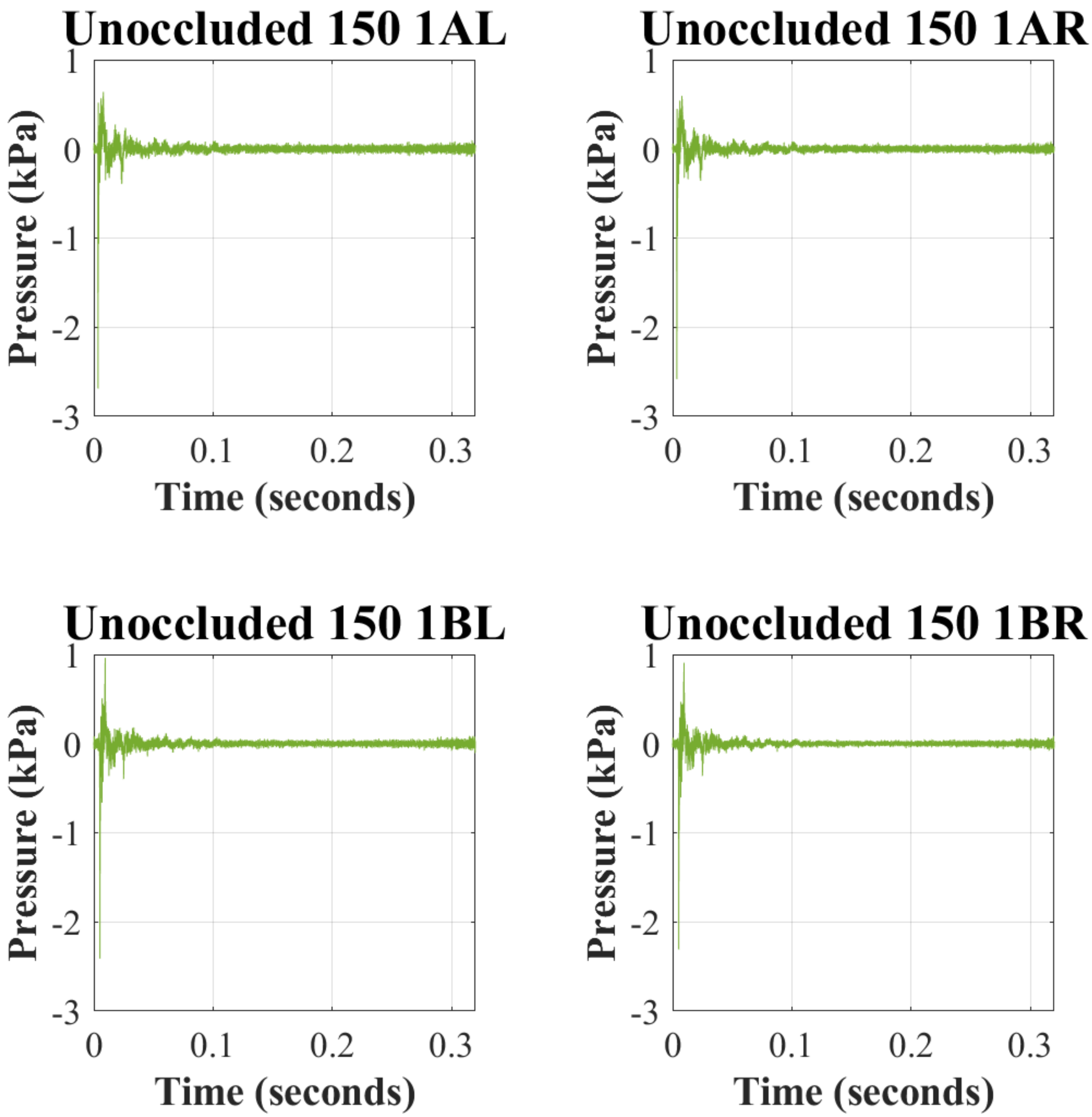
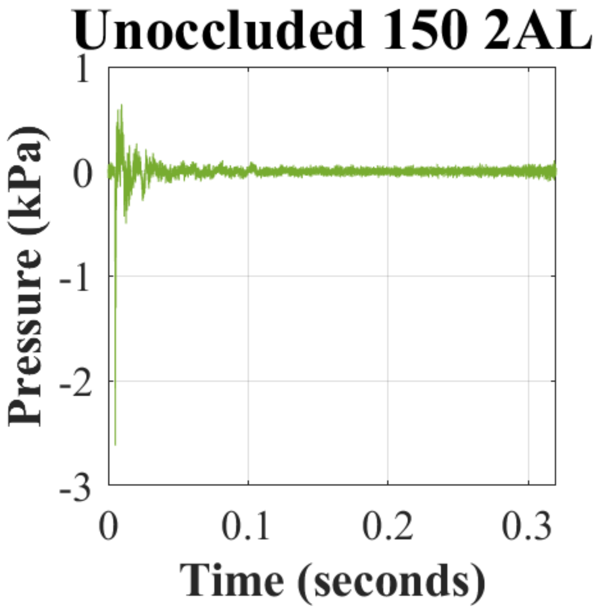

Occluded 150 4AR
Pressure (kPa)
Time (seconds)
0.1
0.05
0
-0.05
-0.1
0
0.1
0.2
0.3

Occluded 150 4BL
Pressure (kPa)
Time (seconds)
0.1
0.05
0
-0.05
-0.1
0
0.1
0.2
0.3

Occluded 150 4BR
Pressure (kPa)
Time (seconds)
0.1
0.05
0
-0.05
-0.1
0
0.1
0.2
0.3

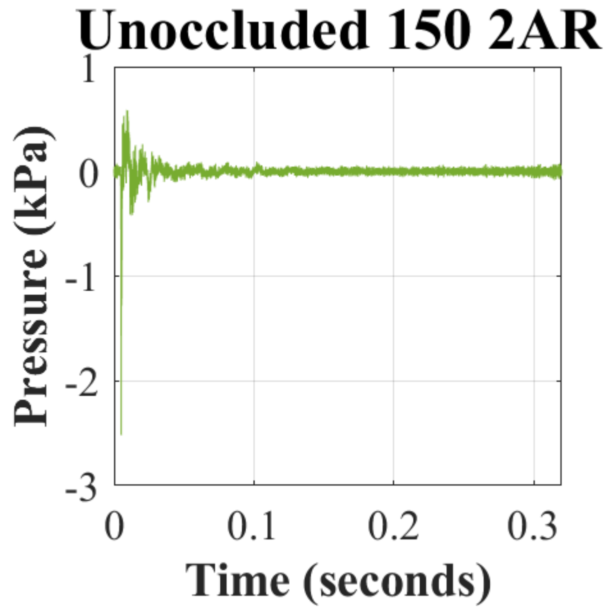


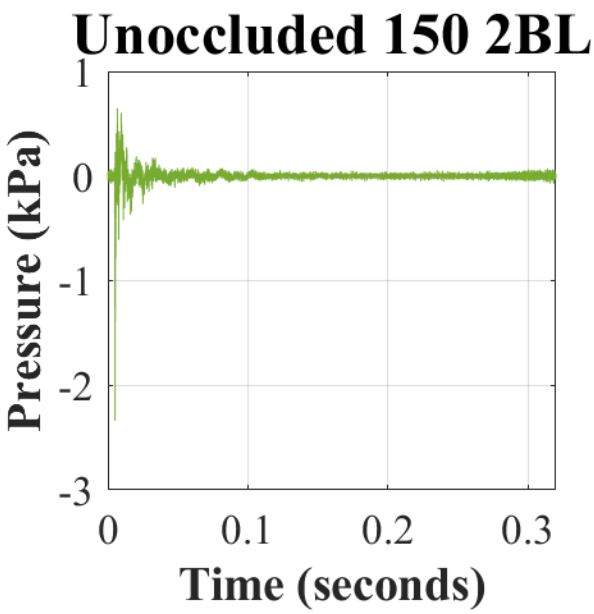
Note. The naming convention for all occluded waveforms is "Occluded LvL NnX", where 'Occluded' is the test condition (i.e., ATF has the HPD donned), 'LvL' is the nominal test level (i.e., 150, 160 or 170 dBP), 'N' is the sample number (i.e., 1 to 5) of the device tested, 'n' is the trial (i.e., A or B) indicating HPD 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).

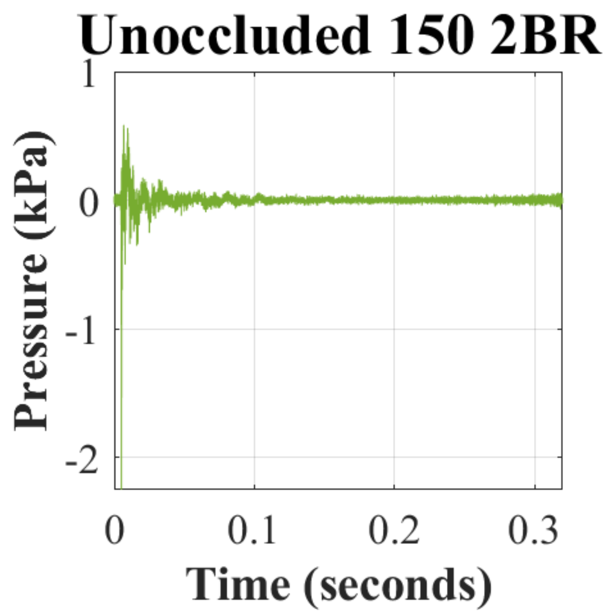
Appendix B. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 150 dBP with the 3M™ PELTOR™ Optime™ 105 Earmuffs.

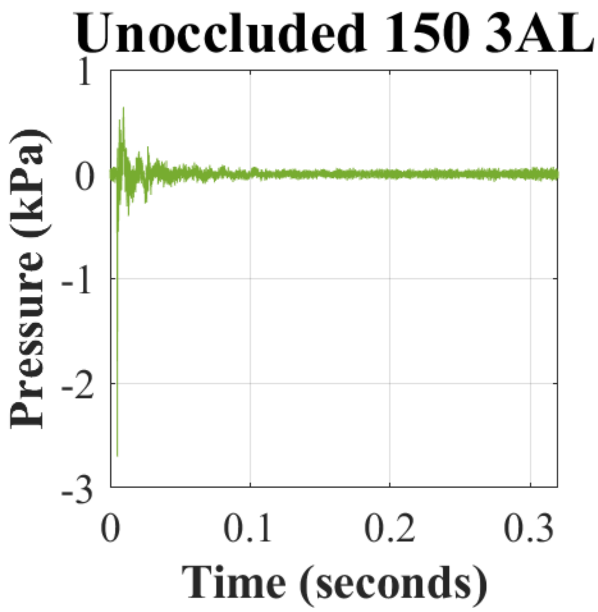


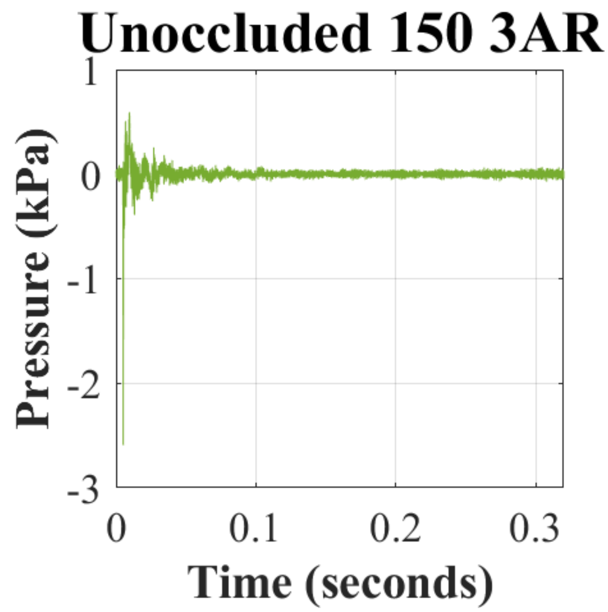

Unoccluded 150 2AL
Pressure (kPa)
Time (seconds)

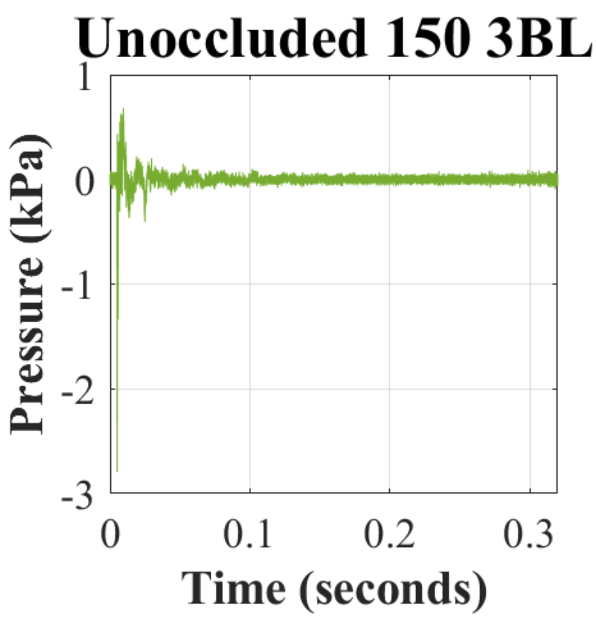

Unoccluded 150 2AR
Pressure (kPa)
Time (seconds)

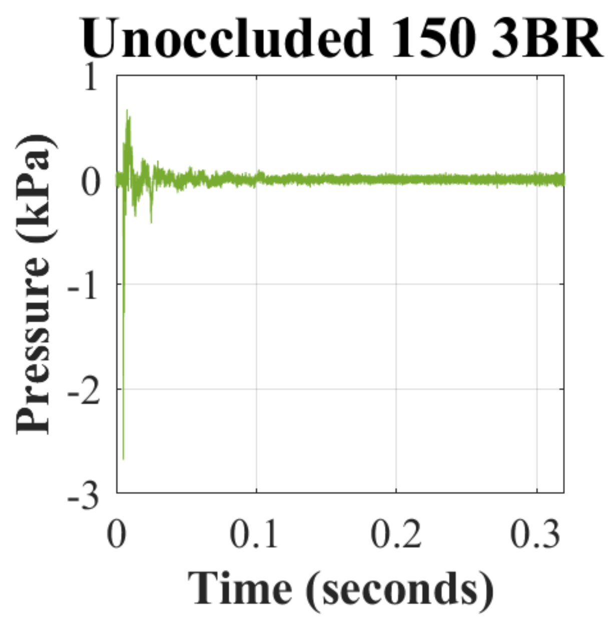

Unoccluded 150 2BL
Pressure (kPa)
Time (seconds)

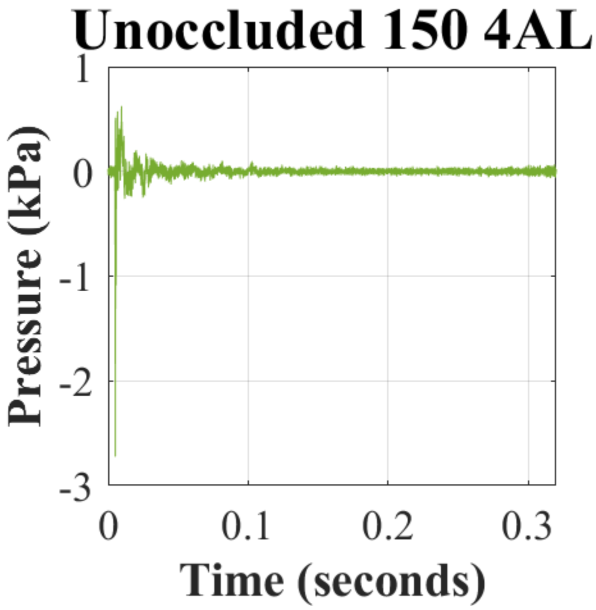

Unoccluded 150 2BR
Pressure (kPa)
Time (seconds)

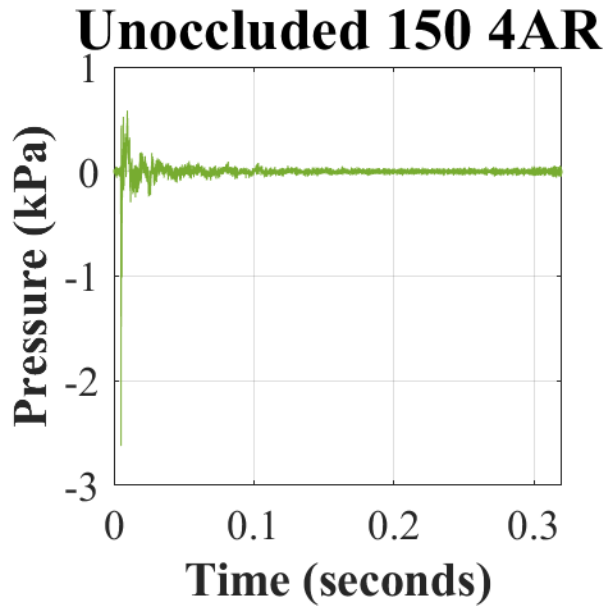

Unoccluded 150 3AL
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

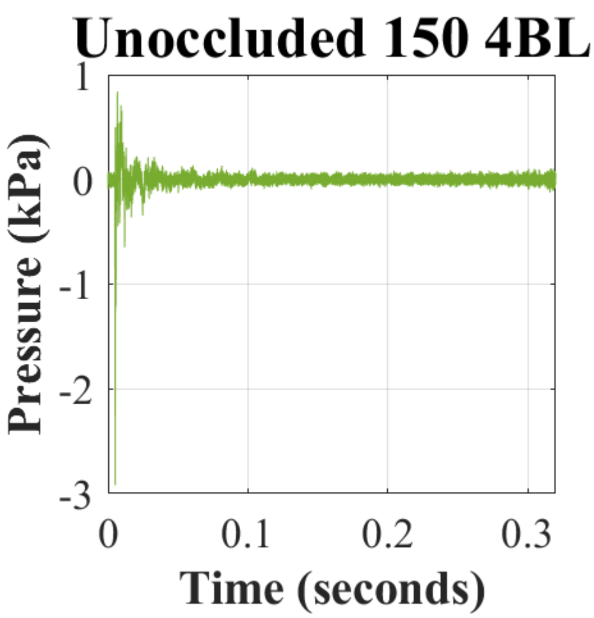

Unoccluded 150 3AR
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

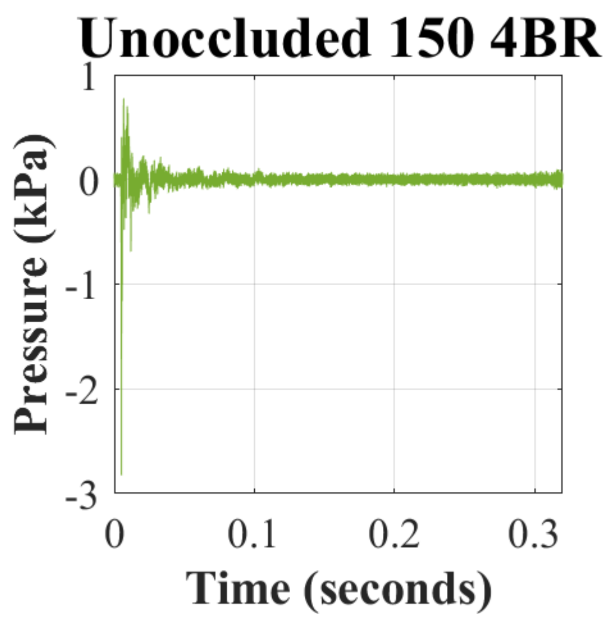

Unoccluded 150 3BL
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

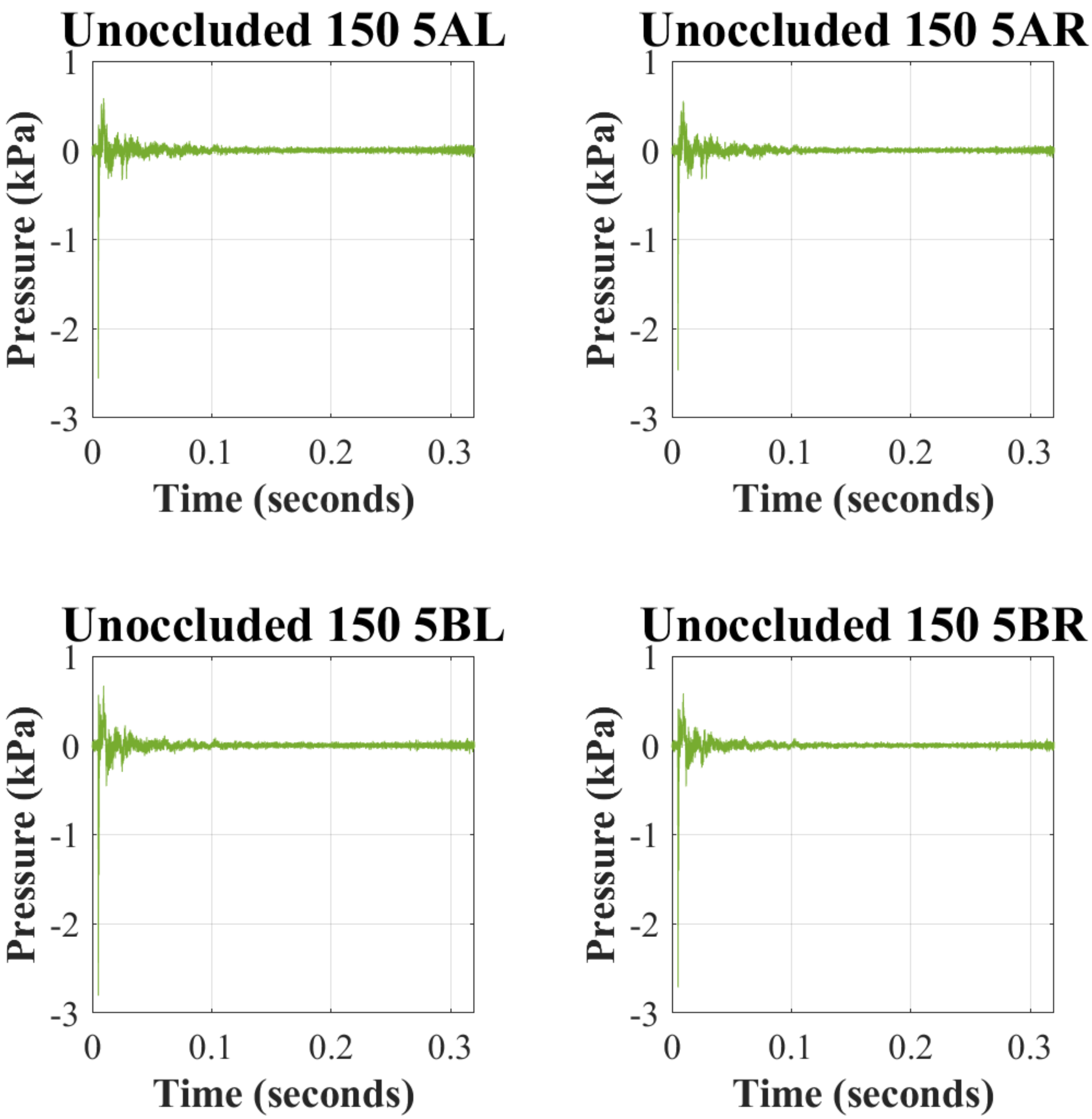

Unoccluded 150 3BR
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)


Unoccluded 150 4AL
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)


Unoccluded 150 4AR
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

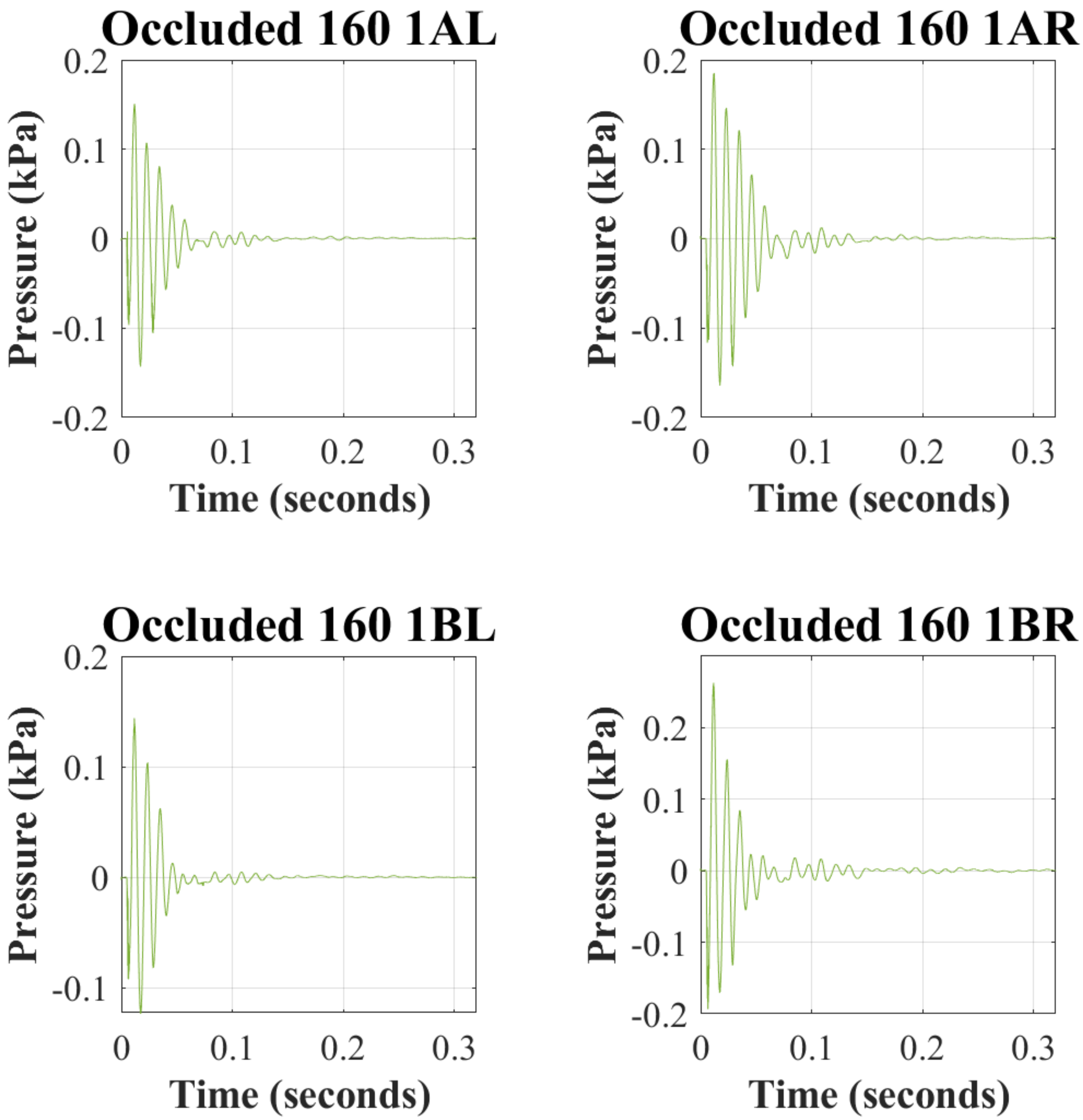

Unoccluded 150 4BL
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

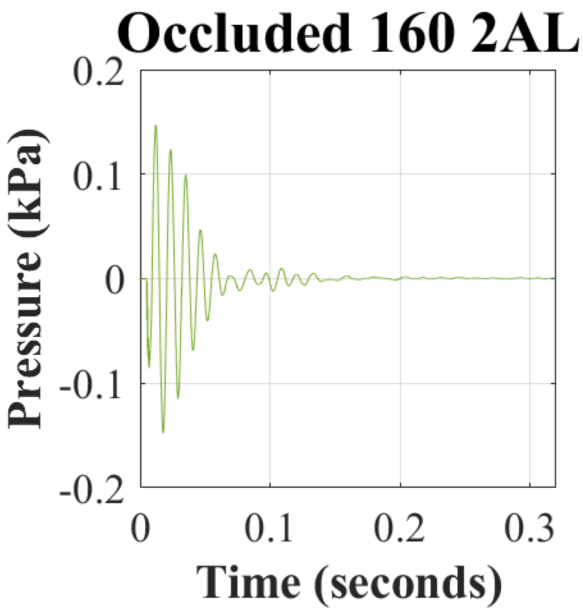

Unoccluded 150 4BR
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

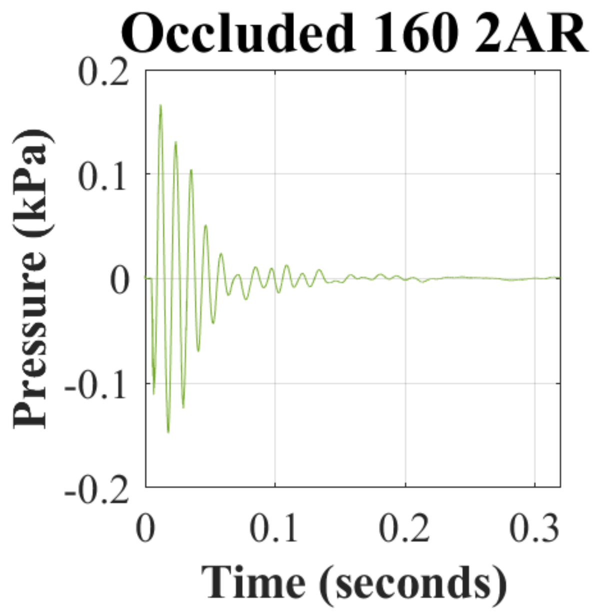


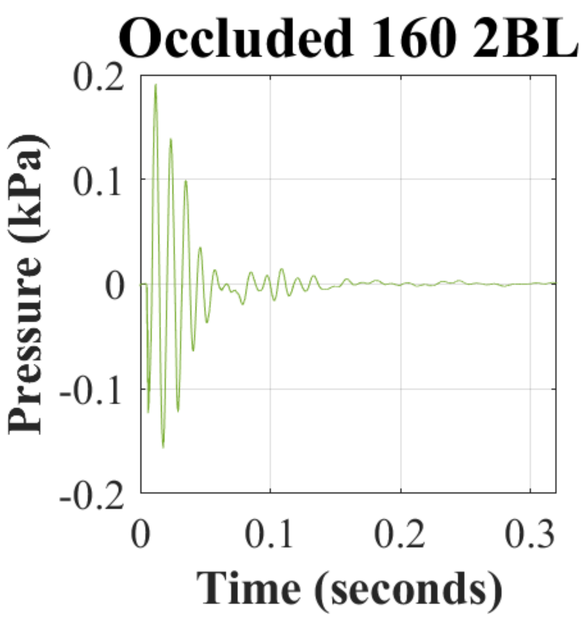
Note. The naming convention for all unoccluded waveforms is "Unoccluded LvL NnX", where 'Unoccluded' is the test condition (i.e., ATF has the HPD doffed), 'LvL' is the nominal test level (i.e., 150, 160 or 170 dBP), 'N' is the sample number (i.e., 1 to 5) of the device tested, 'n' is the trial (i.e., A or B) indicating HPD 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).

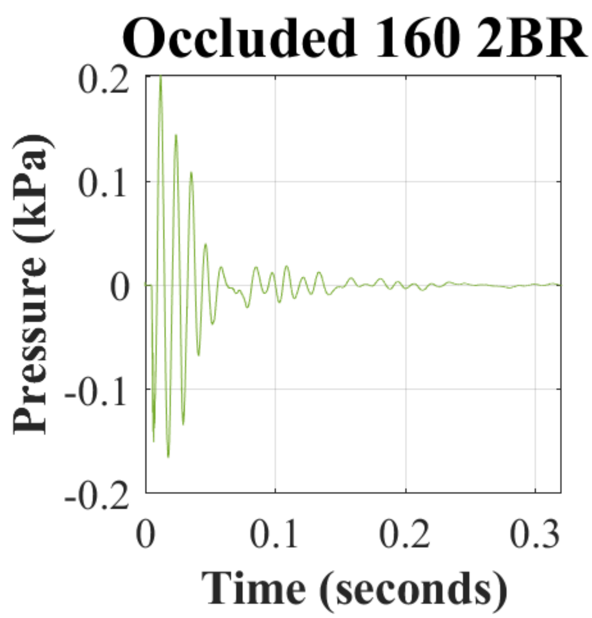
Appendix C. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 160 dBP with the 3M™ PELTOR™ Optime™ 105 Earmuffs.

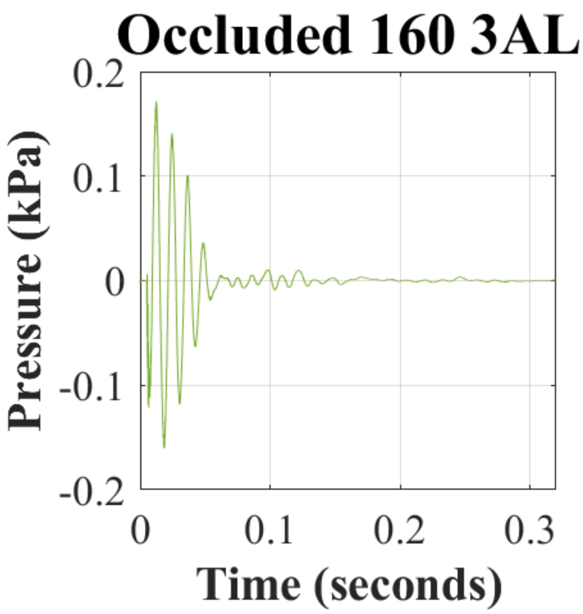


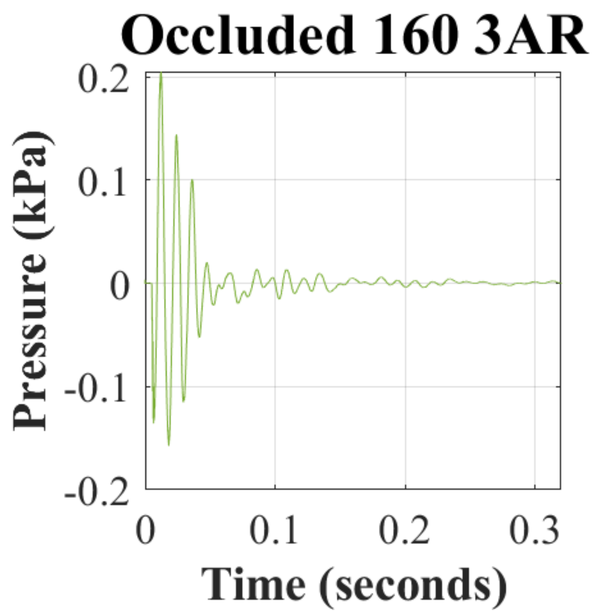

Occluded 160 2AL
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)

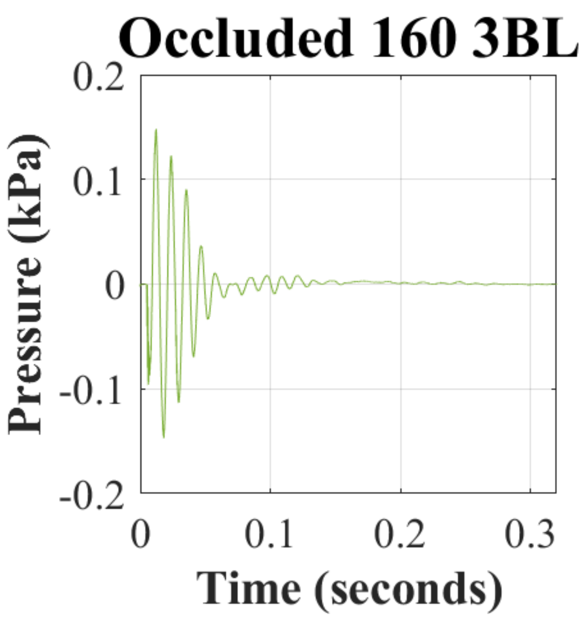

Occluded 160 2AR
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)

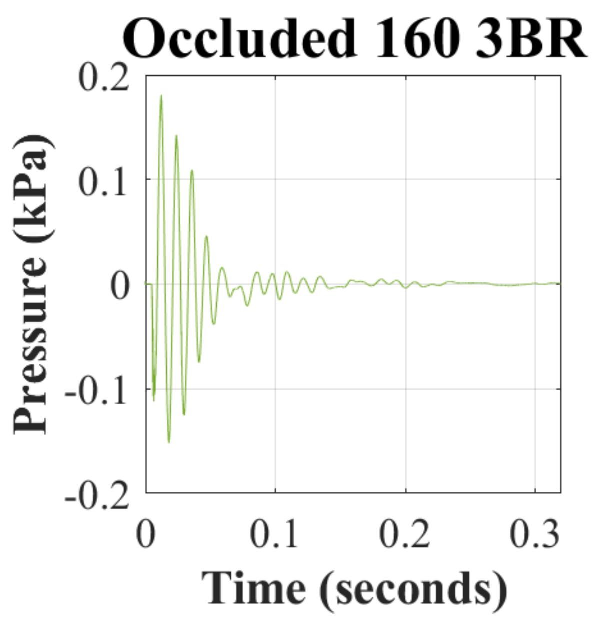

Occluded 160 2BL
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)

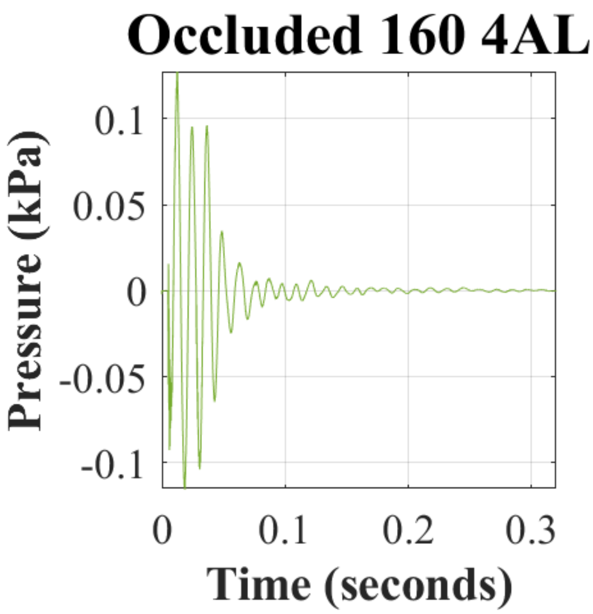

Occluded 160 2BR
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)

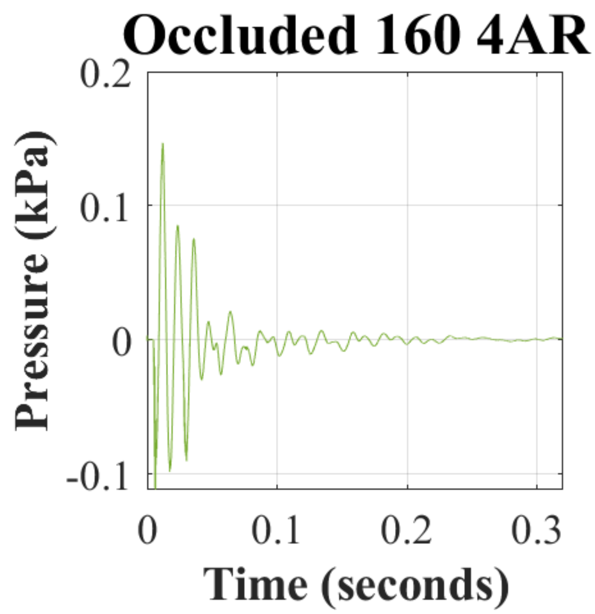

Occluded 160 3AL
0.2
0.1
0
-0.1
-0.2
Pressure (kPa)
0
0.1
0.2
0.3
Time (seconds)

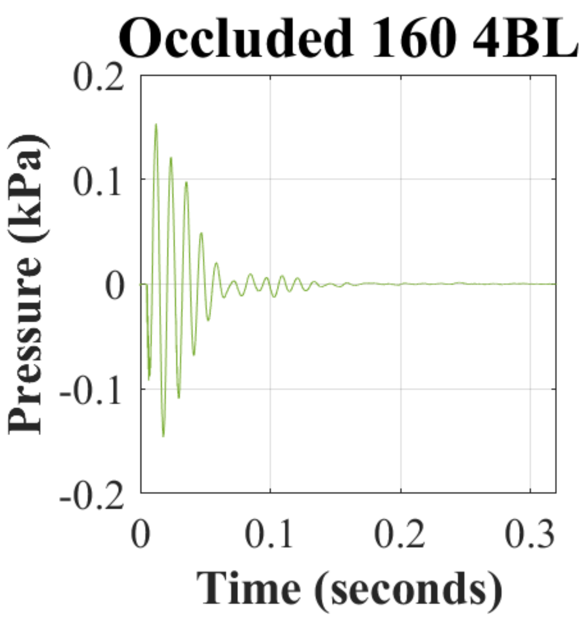

Occluded 160 3AR
0.2
0.1
0
-0.1
-0.2
Pressure (kPa)
0
0.1
0.2
0.3
Time (seconds)

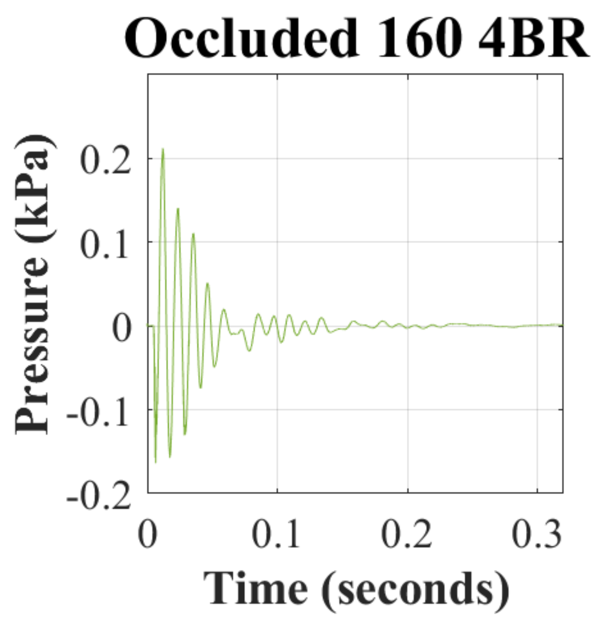

Occluded 160 3BL
0.2
0.1
0
-0.1
-0.2
Pressure (kPa)
0
0.1
0.2
0.3
Time (seconds)

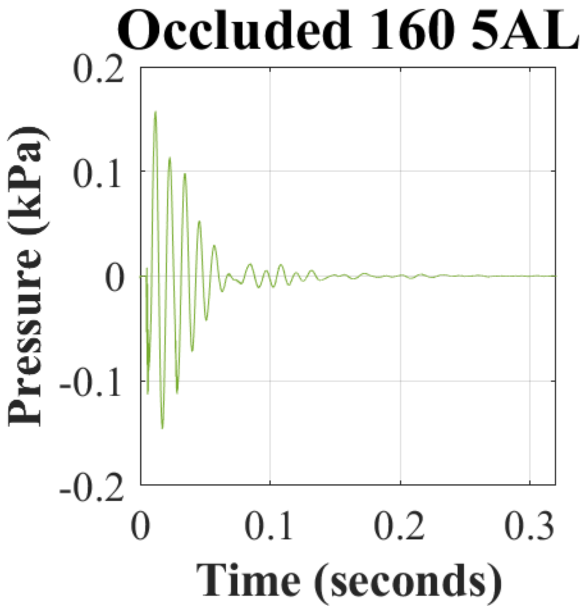

Occluded 160 3BR
0.2
0.1
0
-0.1
-0.2
Pressure (kPa)
0
0.1
0.2
0.3
Time (seconds)

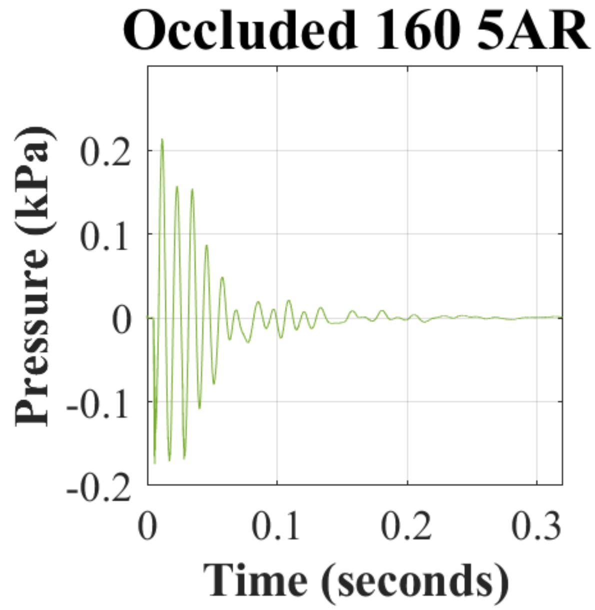

Occluded 160 4AL
Pressure (kPa)
0.1
0.05
0
-0.05
-0.1
0
0.1
0.2
0.3
Time (seconds)

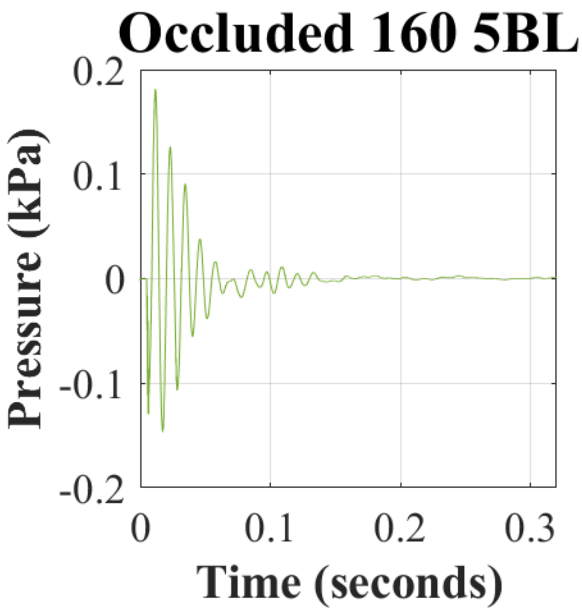

Occluded 160 4AR
Pressure (kPa)
0.2
0.1
0
-0.1
0
0.1
0.2
0.3
Time (seconds)

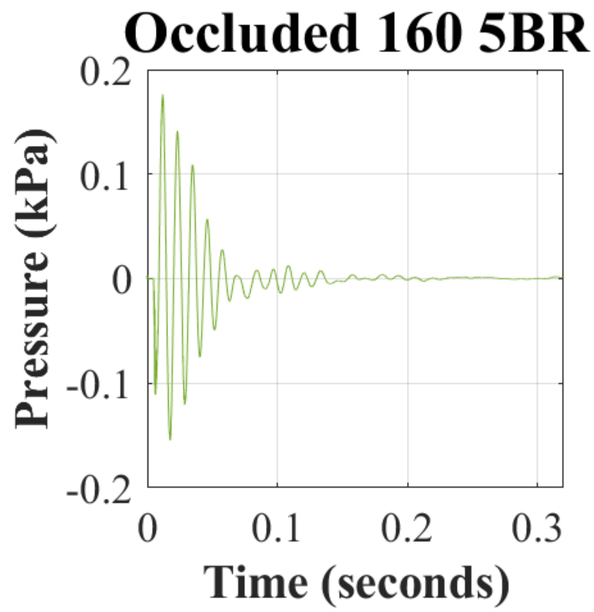

Occluded 160 4BL
Pressure (kPa)
0.2
0.1
0
-0.1
-0.2
0
0.1
0.2
0.3
Time (seconds)


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



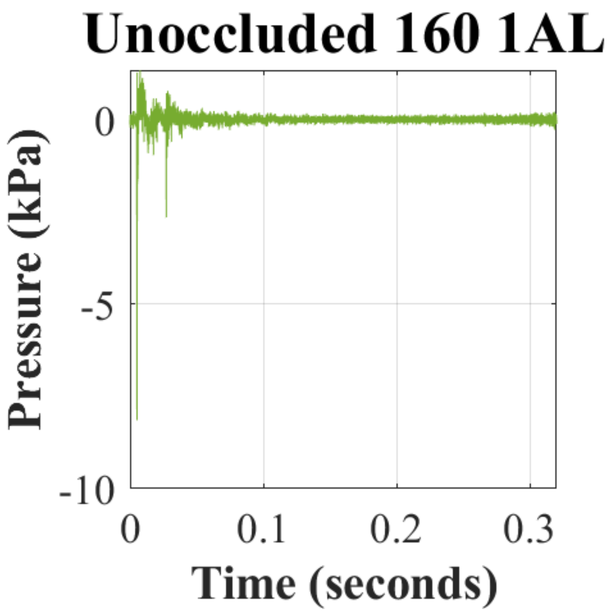


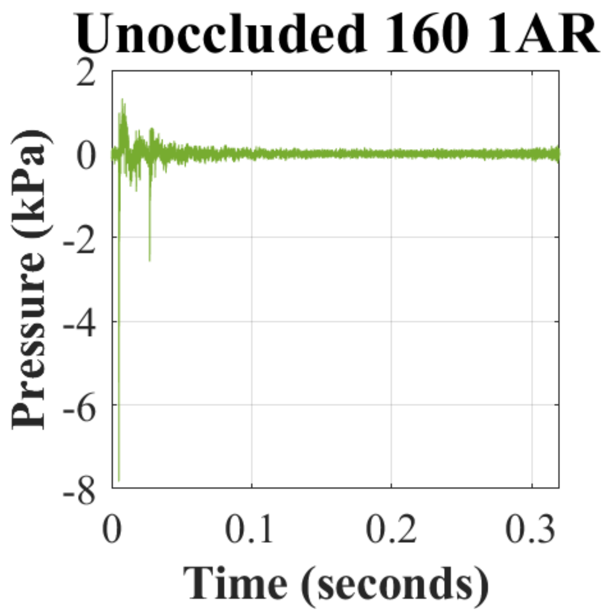


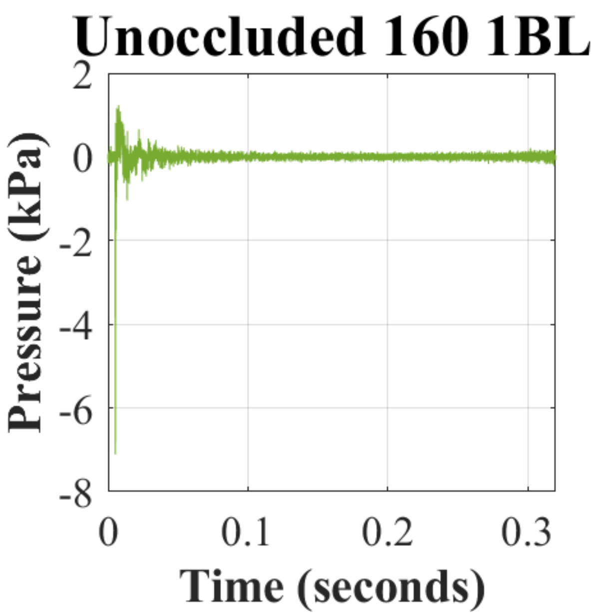


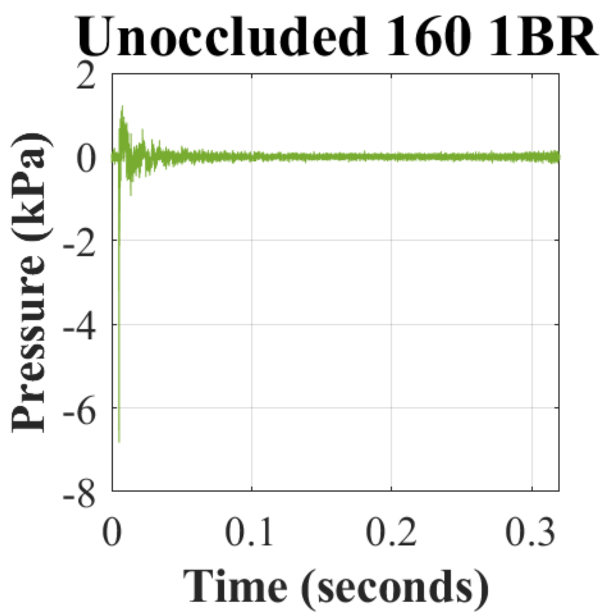
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating HPD 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).

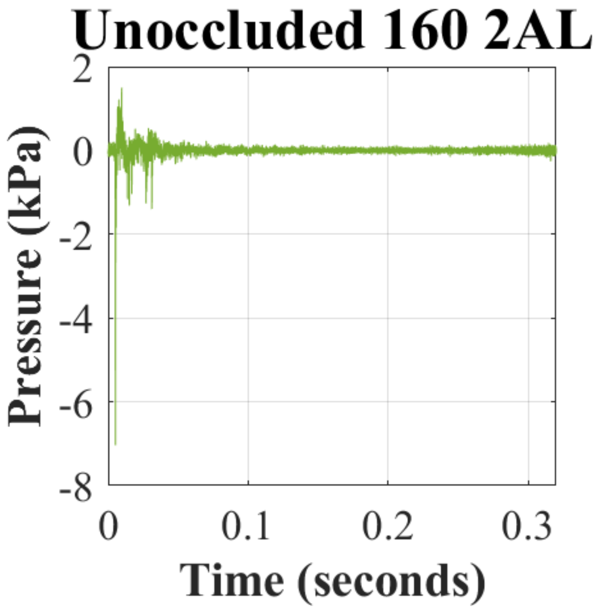
Appendix D. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 160 dBP with the 3M™ PELTOR™ Optime™ 105 Earmuffs.

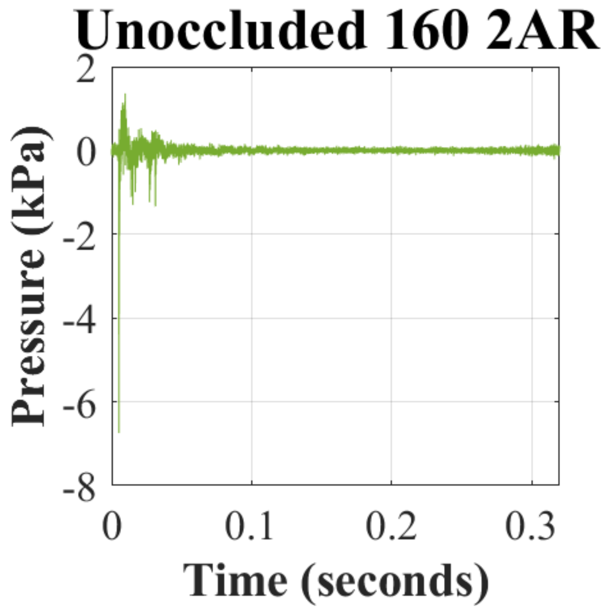


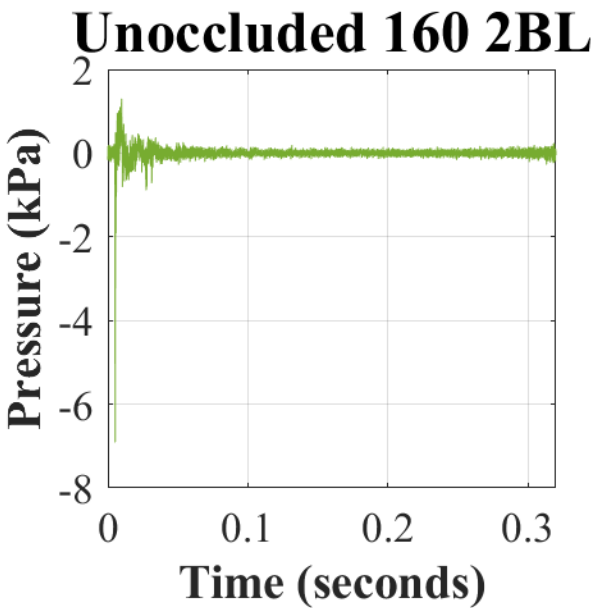


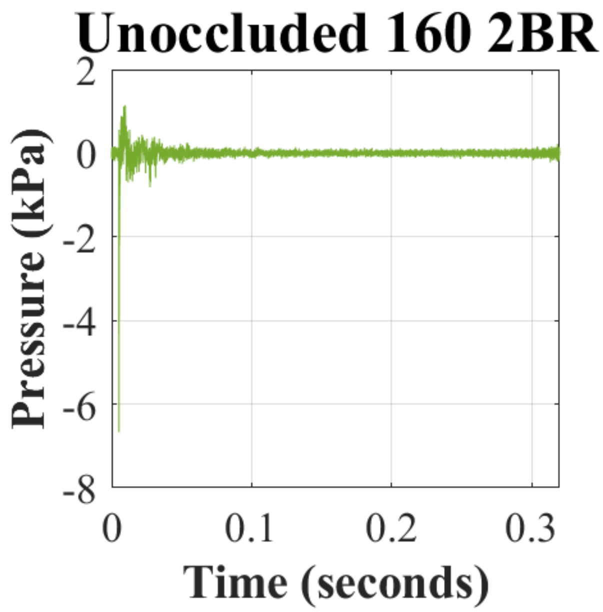


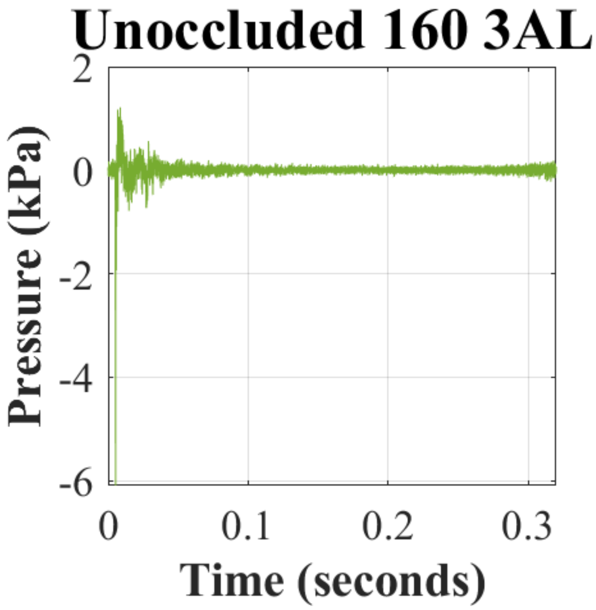


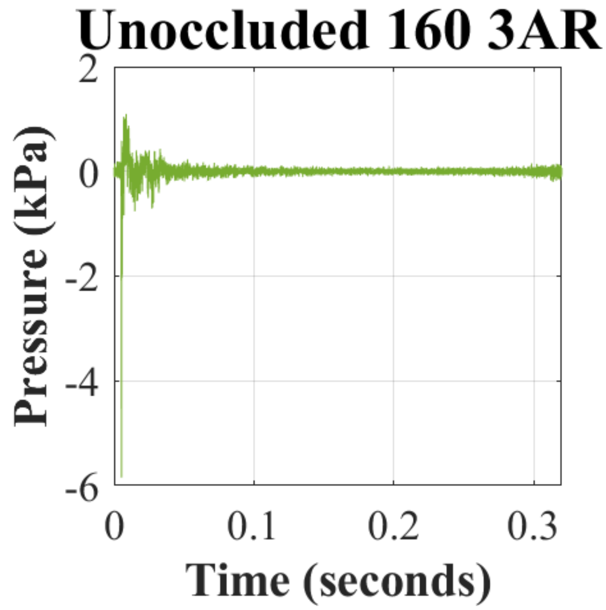

Unoccluded 160 2AL
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

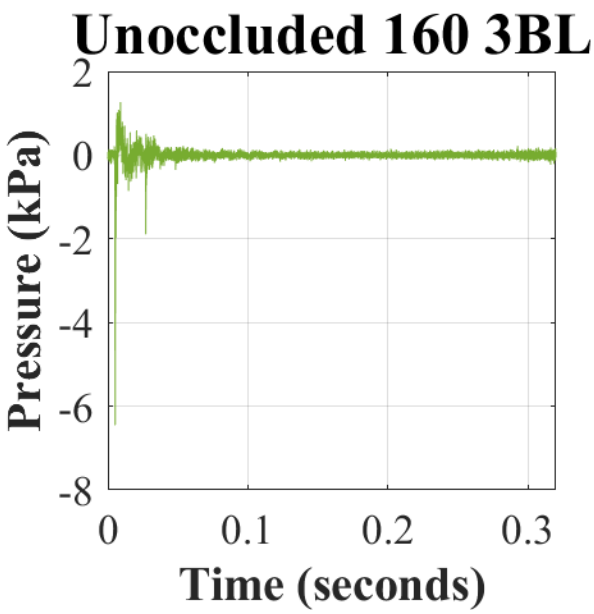

Unoccluded 160 2AR
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

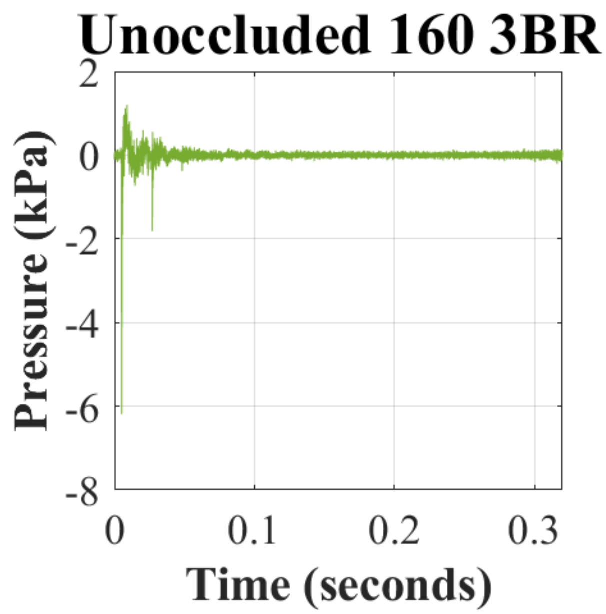

Unoccluded 160 2BL
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

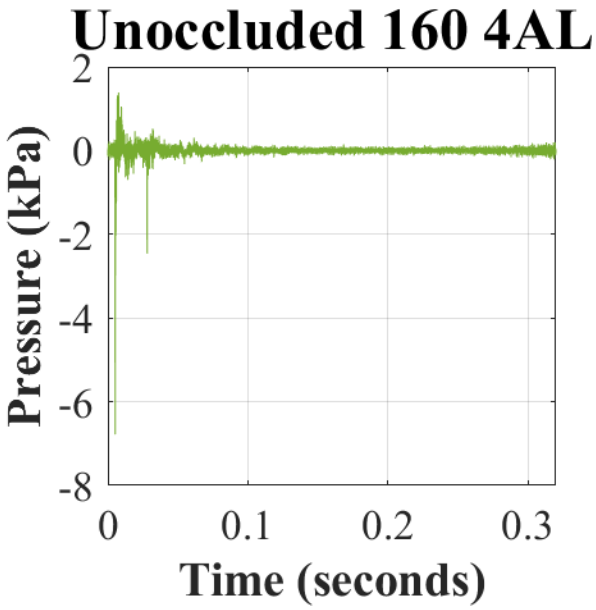

Unoccluded 160 2BR
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

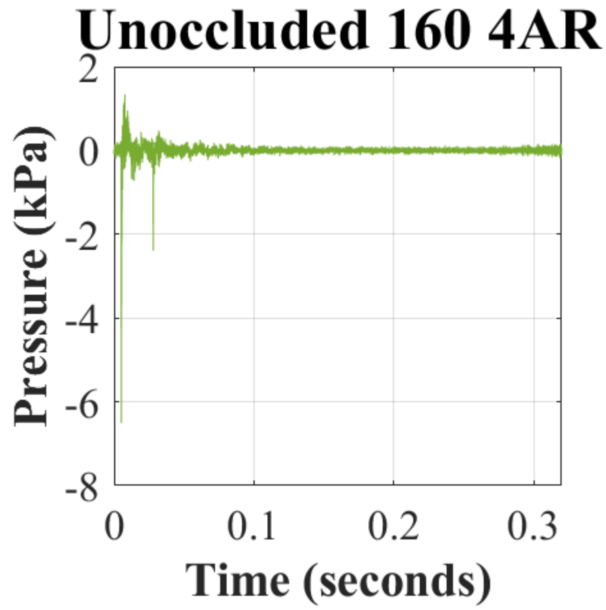

Unoccluded 160 3AL
Pressure (kPa)
Time (seconds)

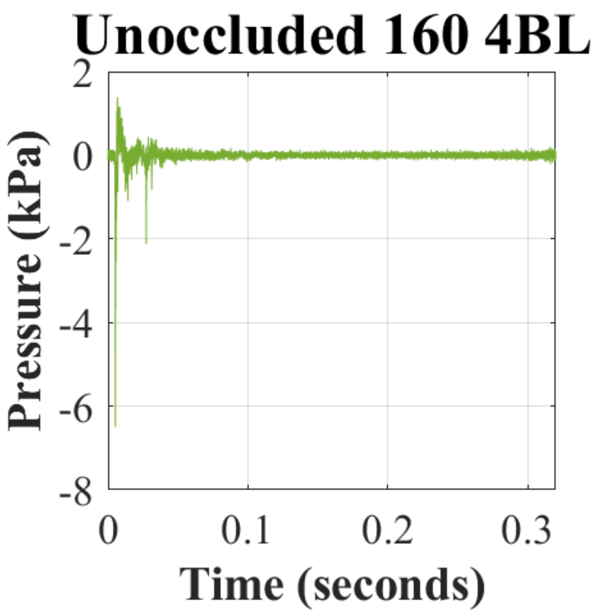

Unoccluded 160 3AR
Pressure (kPa)
Time (seconds)

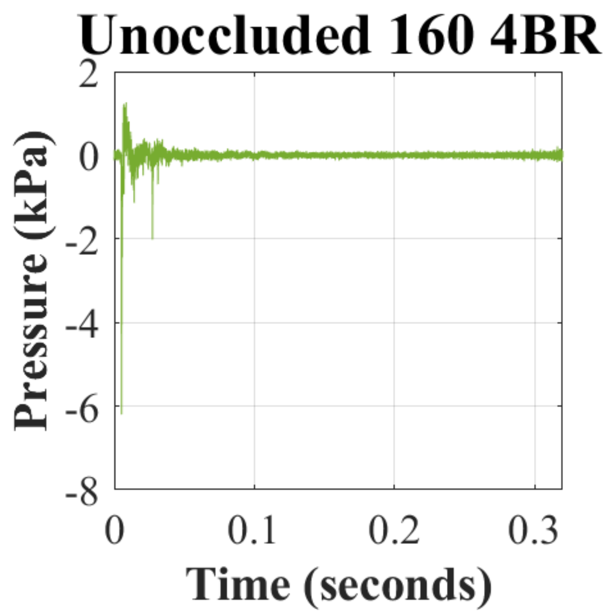

Unoccluded 160 3BL
Pressure (kPa)
Time (seconds)

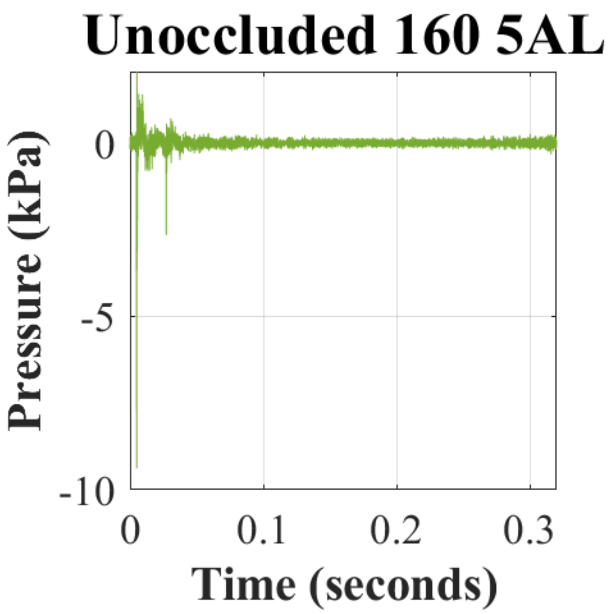

Unoccluded 160 3BR
Pressure (kPa)
Time (seconds)

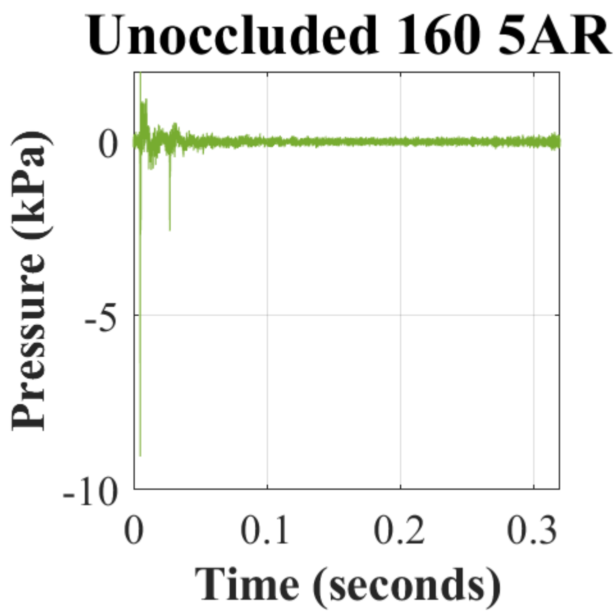

Unoccluded 160 4AL
2
0
-2
-4
-6
-8
Pressure (kPa)
0
0.1
0.2
0.3
Time (seconds)

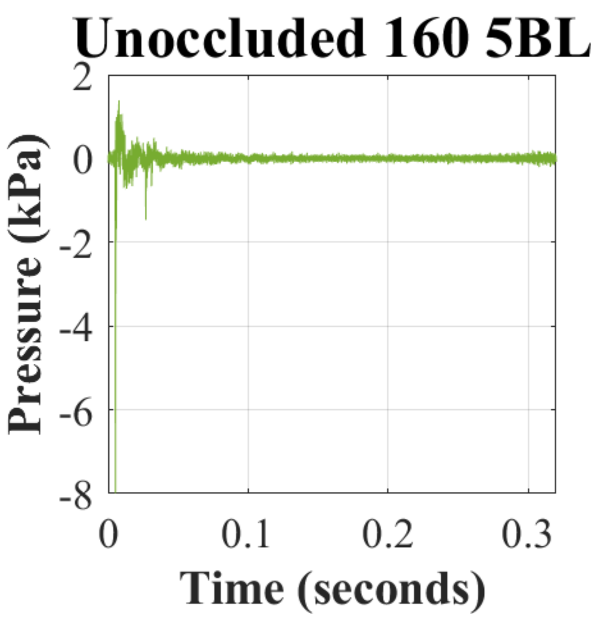

Unoccluded 160 4AR
2
0
-2
-4
-6
-8
Pressure (kPa)
0
0.1
0.2
0.3
Time (seconds)

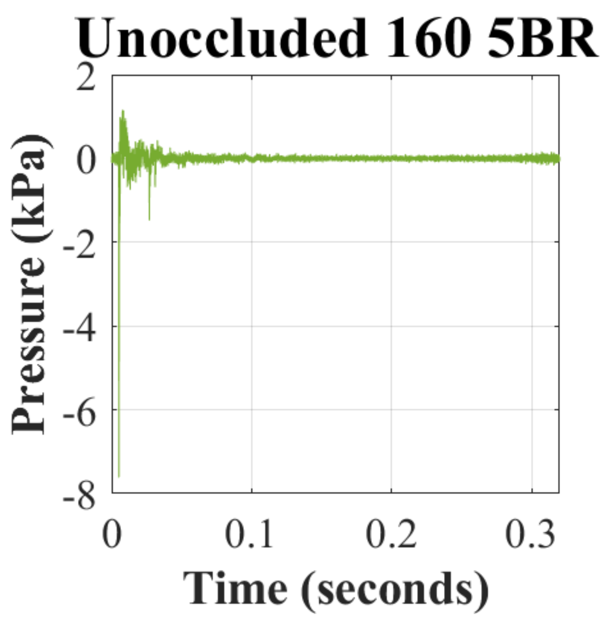

Unoccluded 160 4BL
2
0
-2
-4
-6
-8
Pressure (kPa)
0
0.1
0.2
0.3
Time (seconds)


Unoccluded 160 4BR
2
0
-2
-4
-6
-8
Pressure (kPa)
0
0.1
0.2
0.3
Time (seconds)



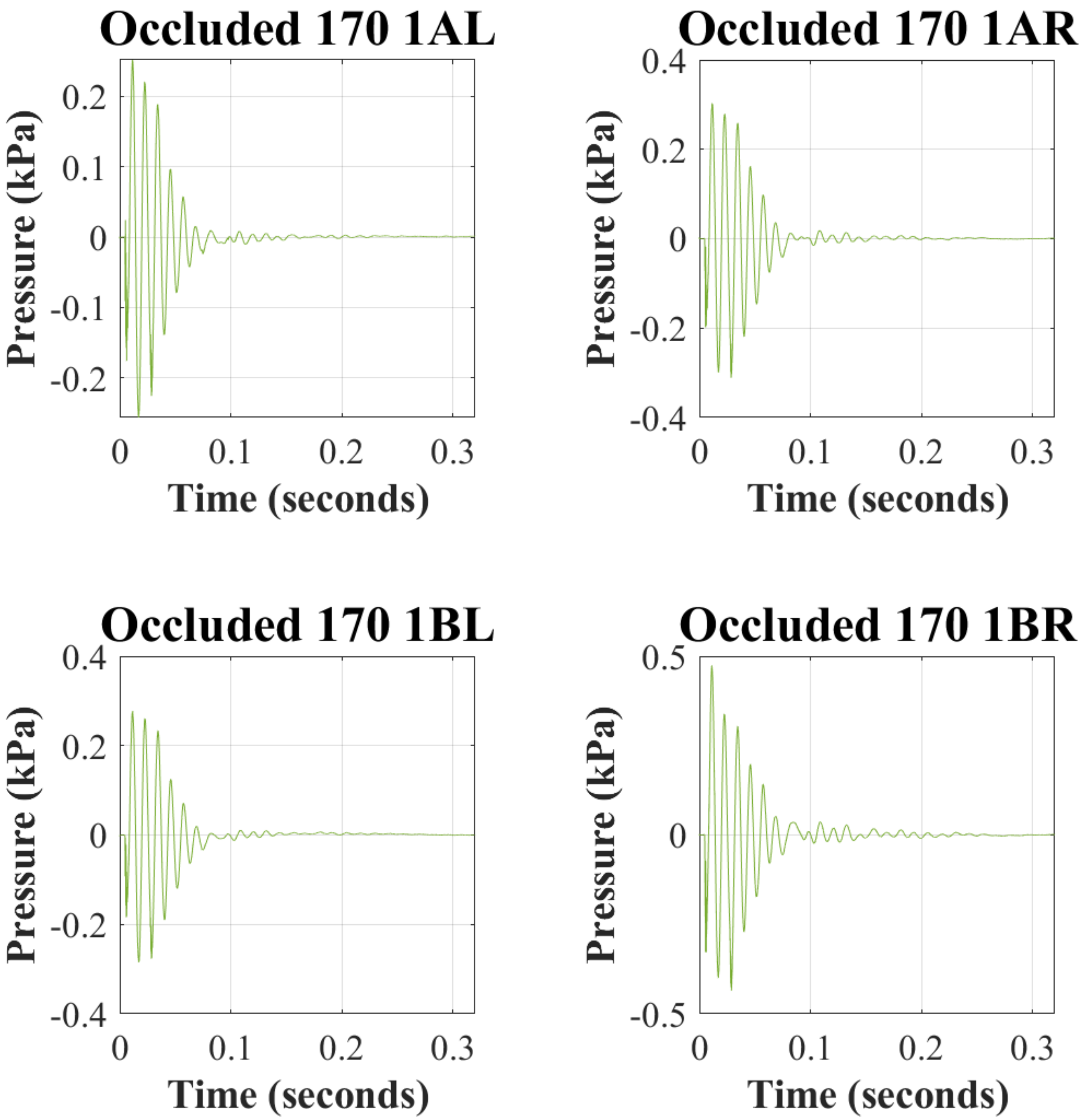


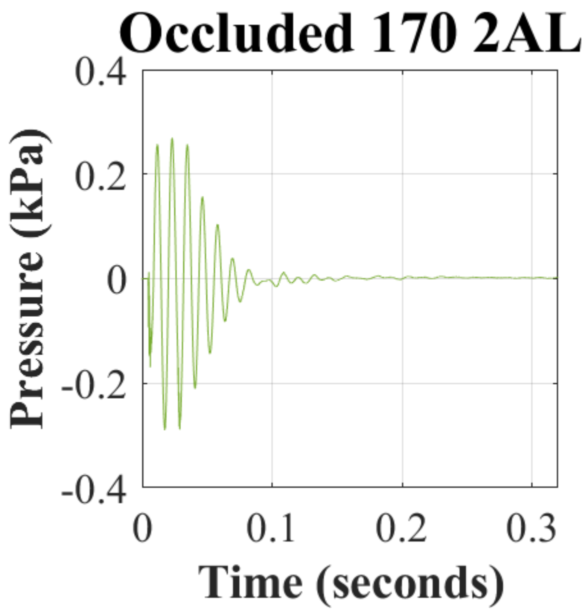


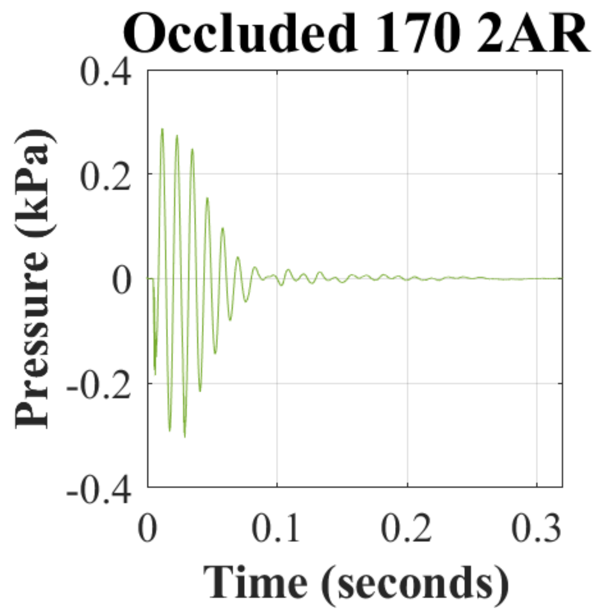


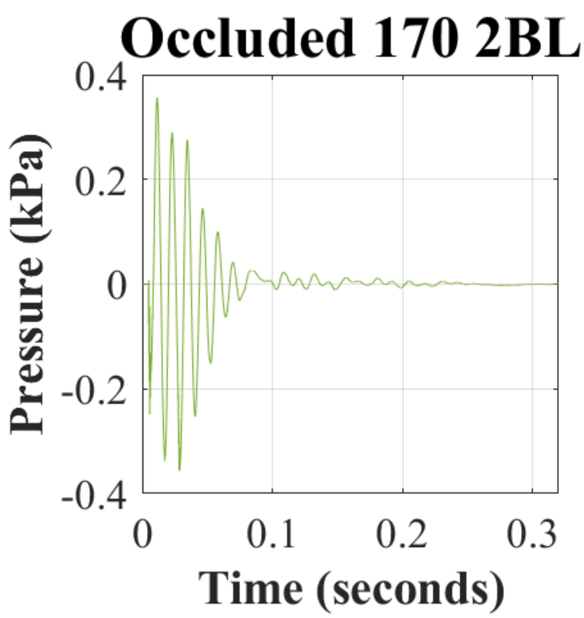
Note. The naming convention for all unoccluded waveforms is “Unoccluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the HPD doffed), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating HPD 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).

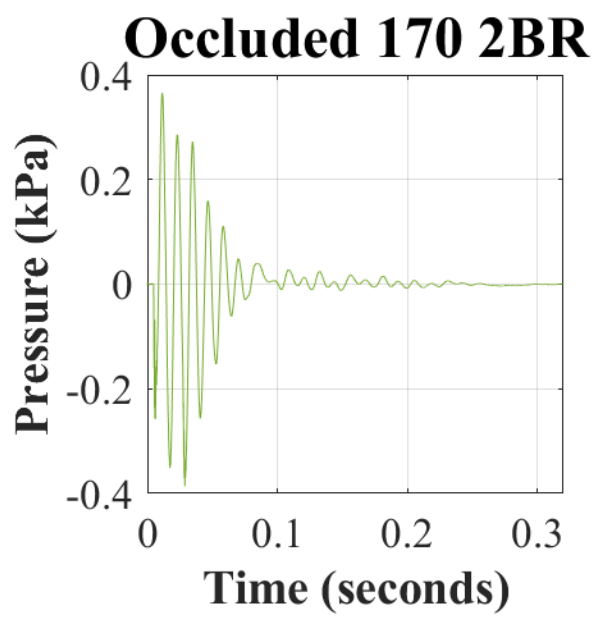
Appendix E. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 170 dBP with the 3M™ PELTOR™ Optime™ 105 Earmuffs.

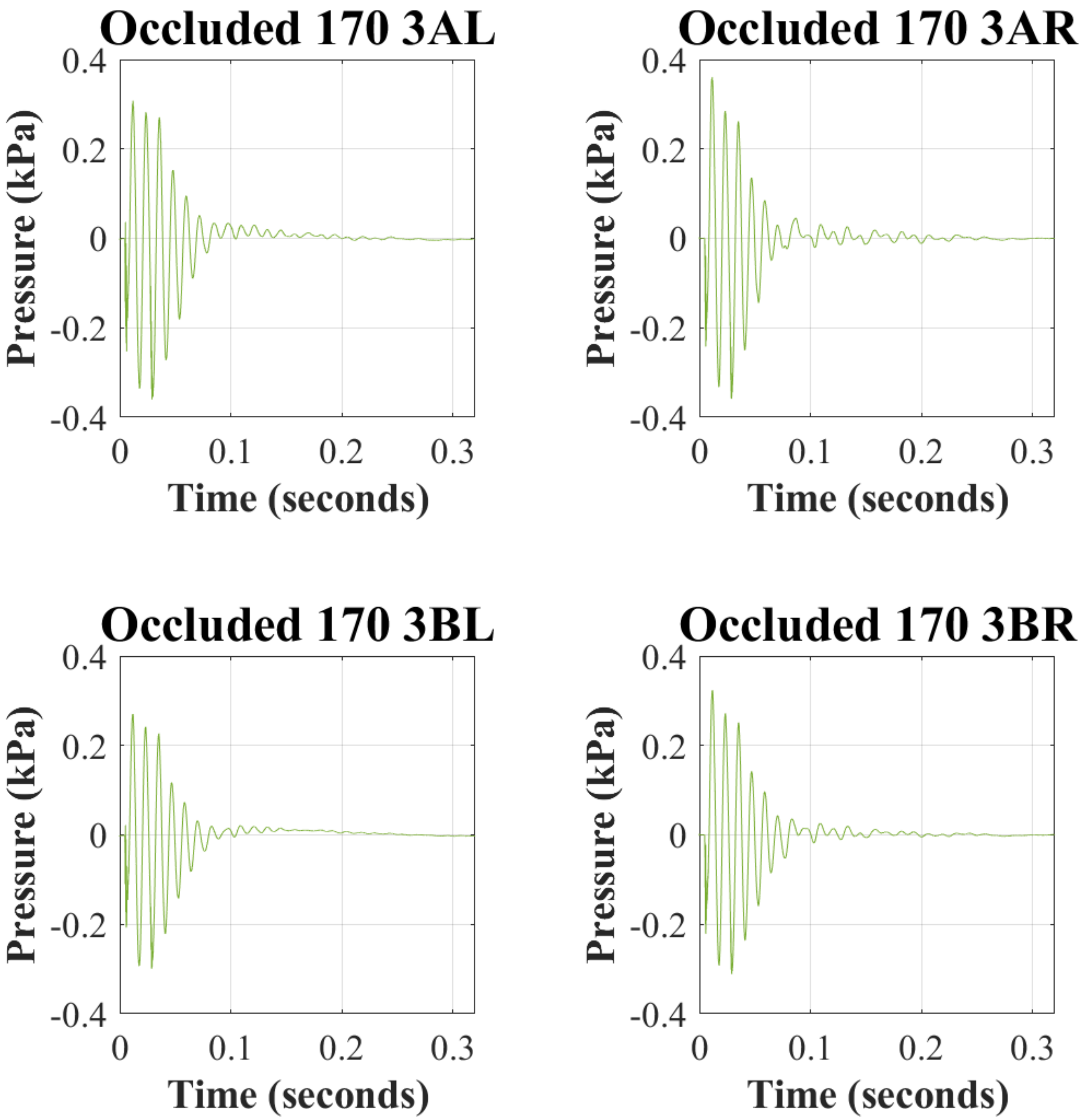


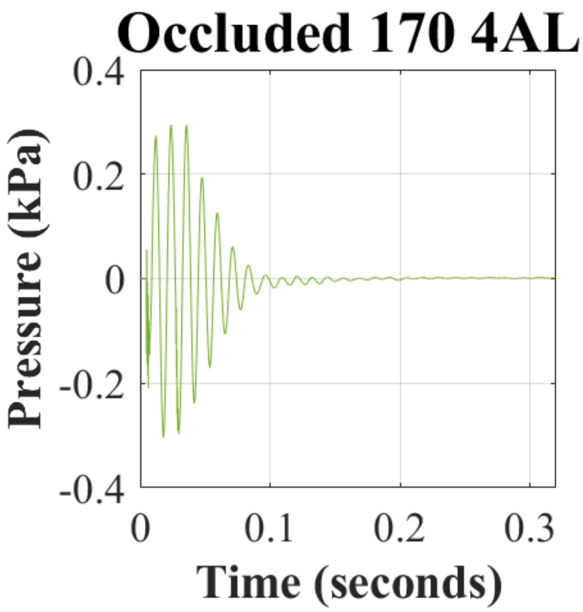

Occluded 170 2AL
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

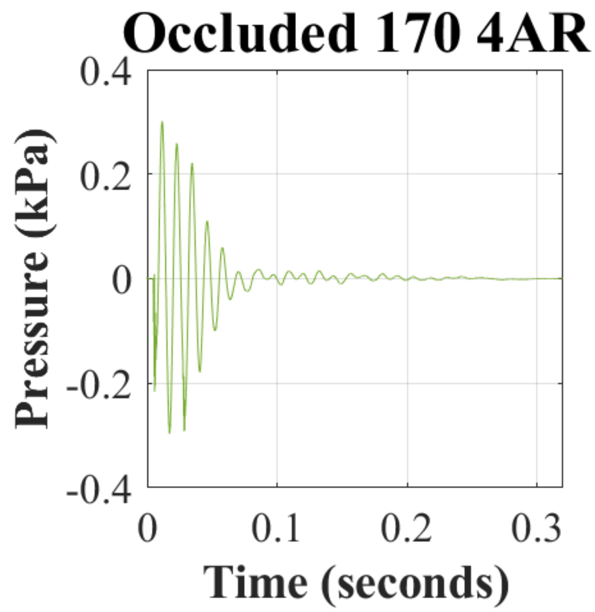

Occluded 170 2AR
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

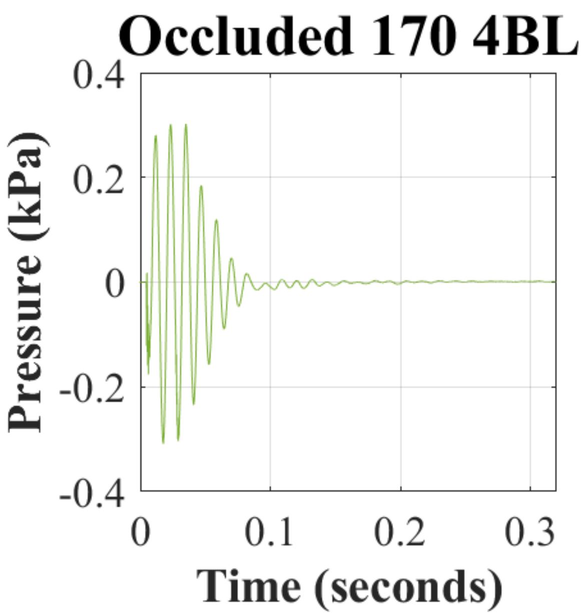

Occluded 170 2BL
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

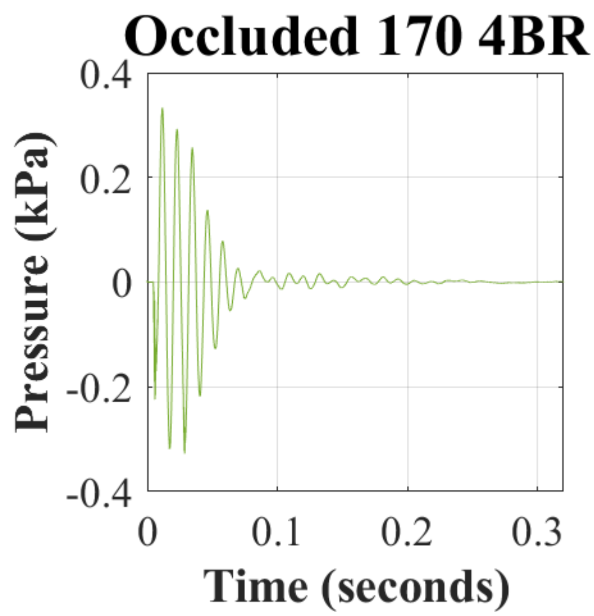

Occluded 170 2BR
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

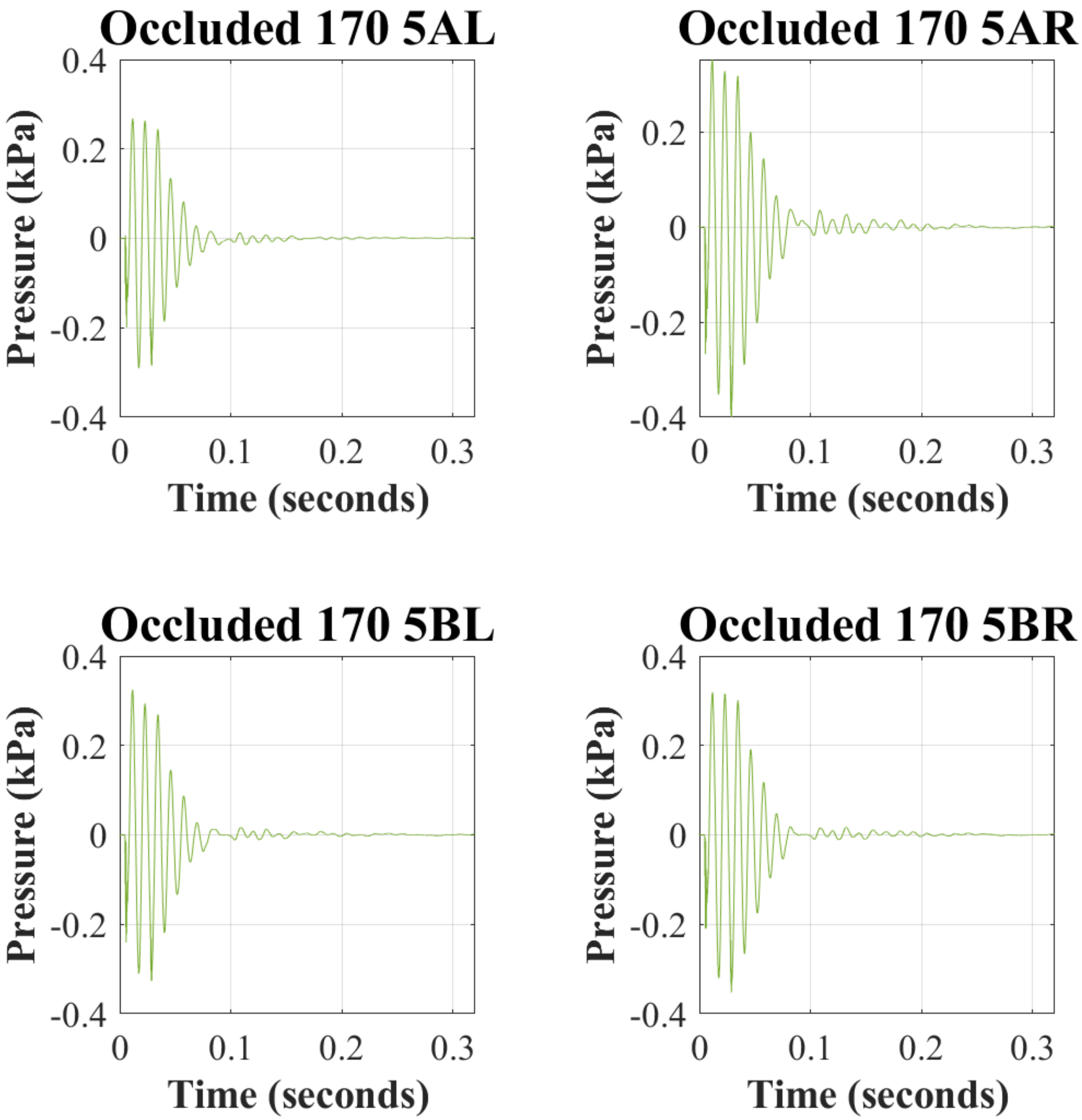

Occluded 170 3AL
Occluded 170 3AR
Occluded 170 3BL
Occluded 170 3BR
Pressure (kPa)
Time (seconds)
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3


Occluded 170 4AL
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)


Occluded 170 4AR
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

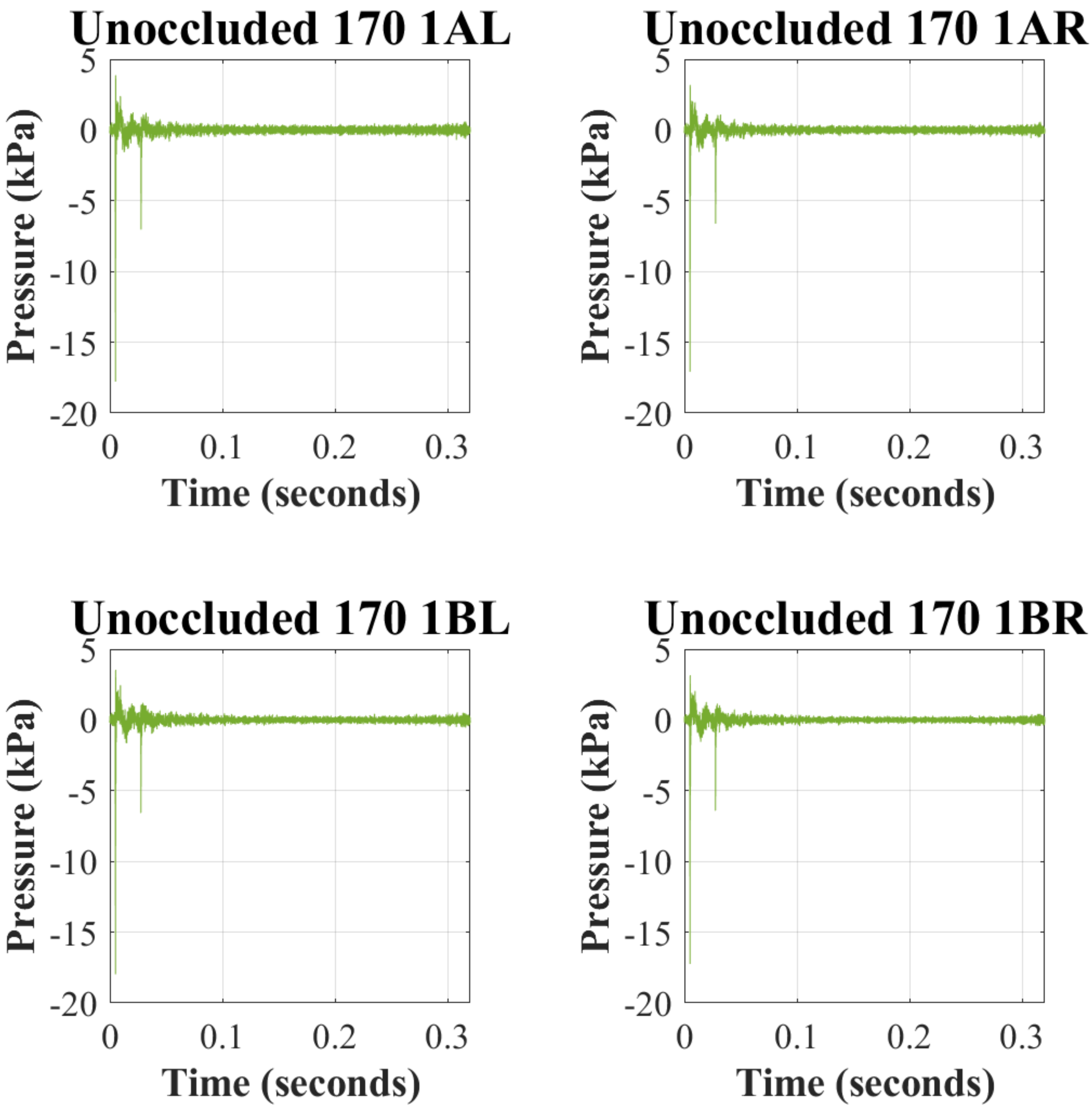

Occluded 170 4BL
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

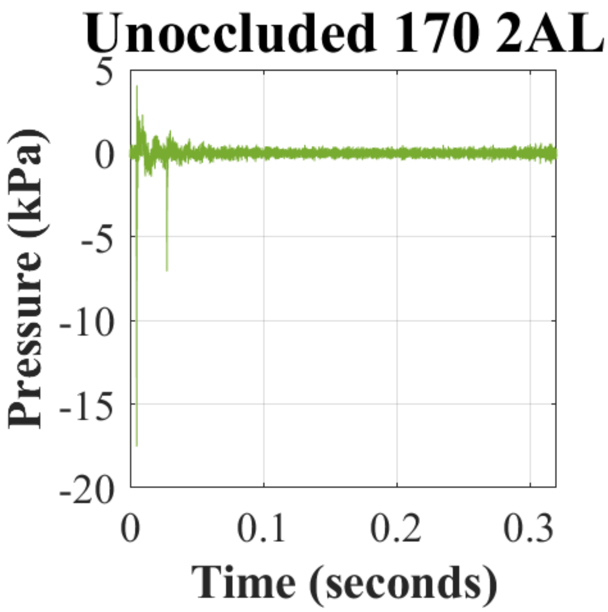

Occluded 170 4BR
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

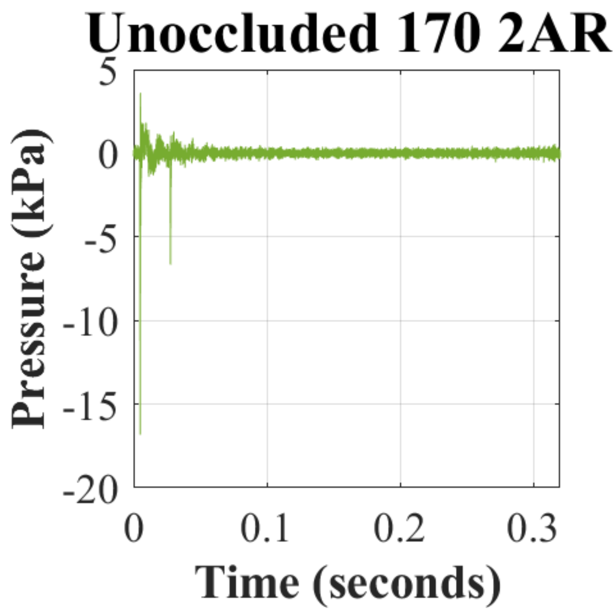


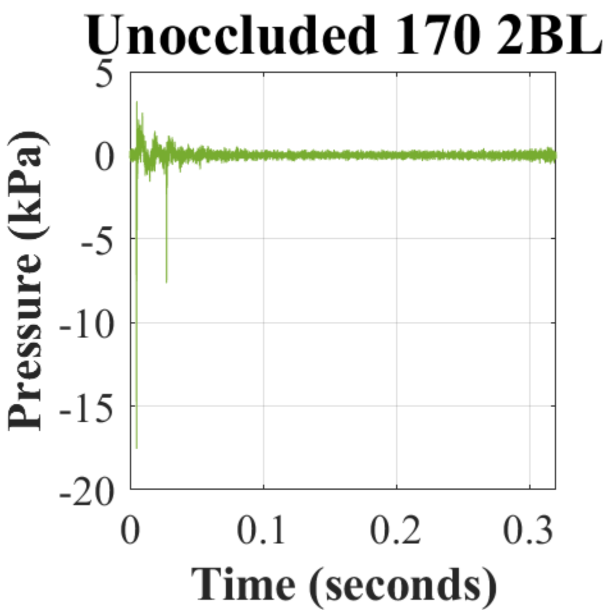
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating HPD 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).

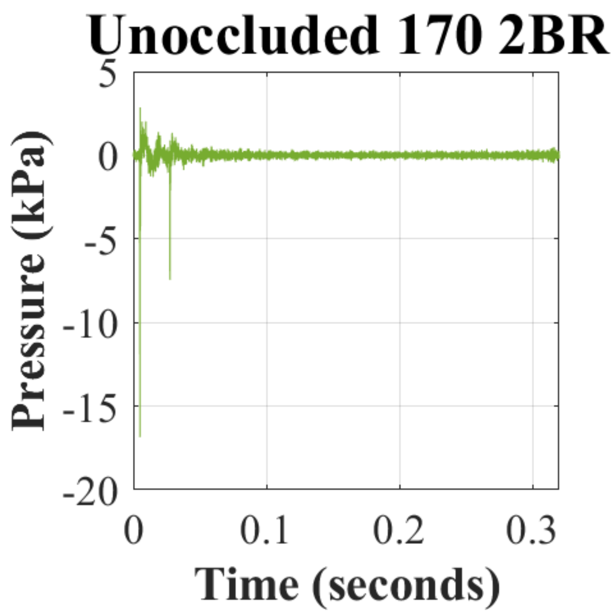
Appendix F. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 170 dBP with the 3M™ PELTOR™ Optime™ 105 Earmuffs.

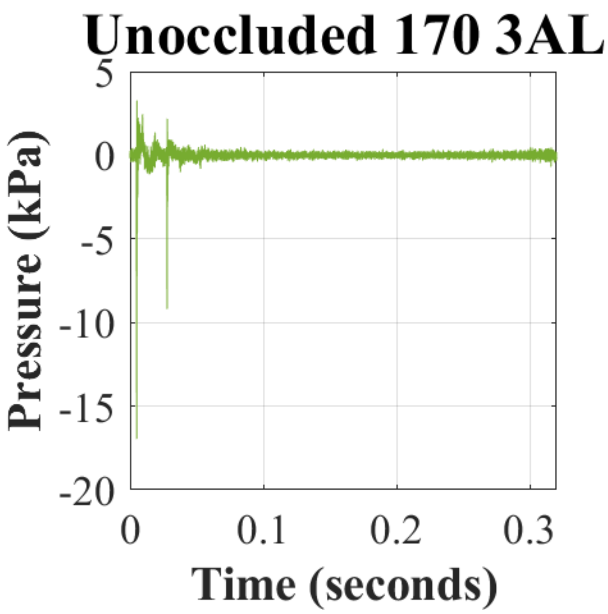



Unoccluded 170 2AL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

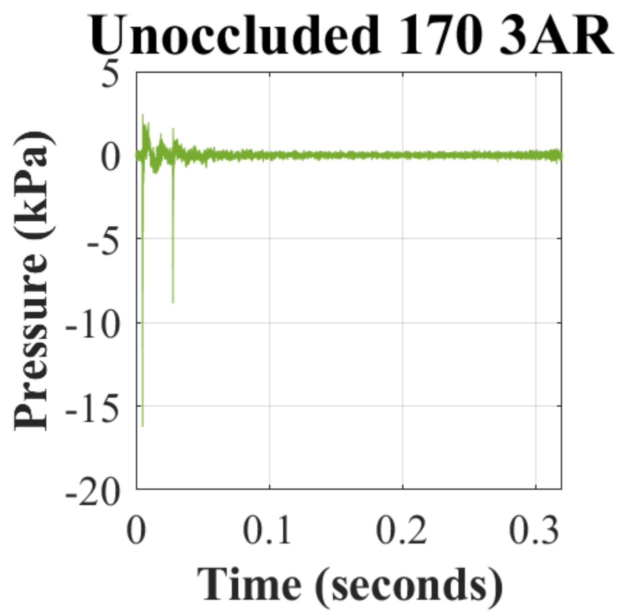

Unoccluded 170 2AR
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)


Unoccluded 170 2BL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

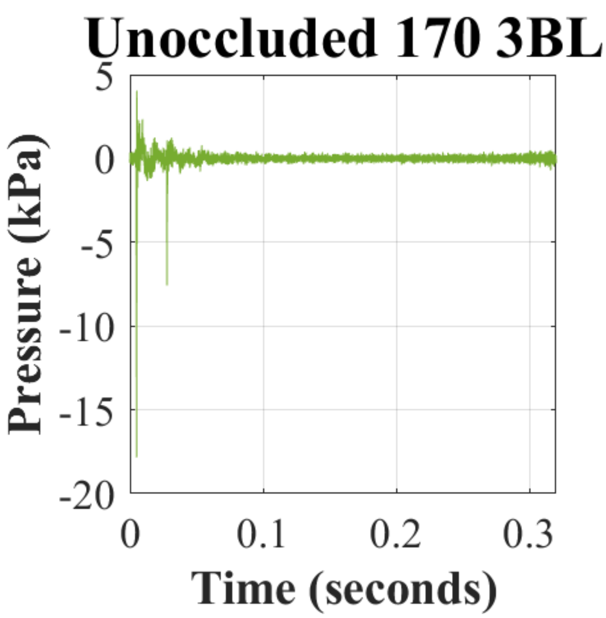

Unoccluded 170 2BR
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)



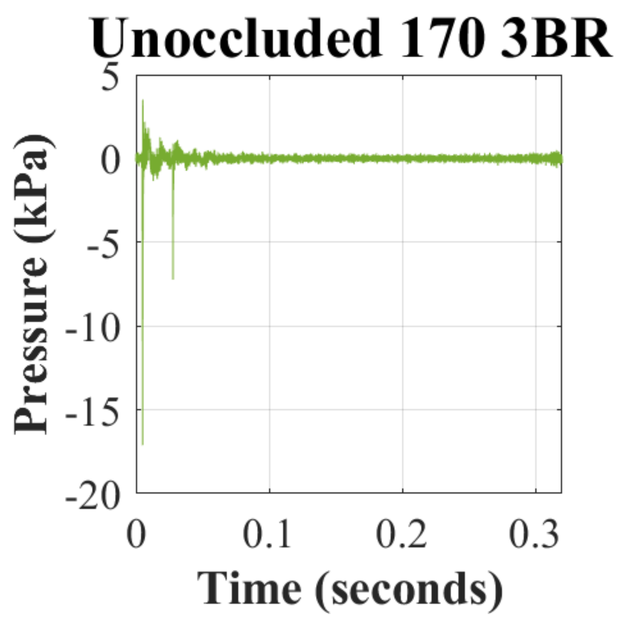
Unoccluded 170 3AL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)



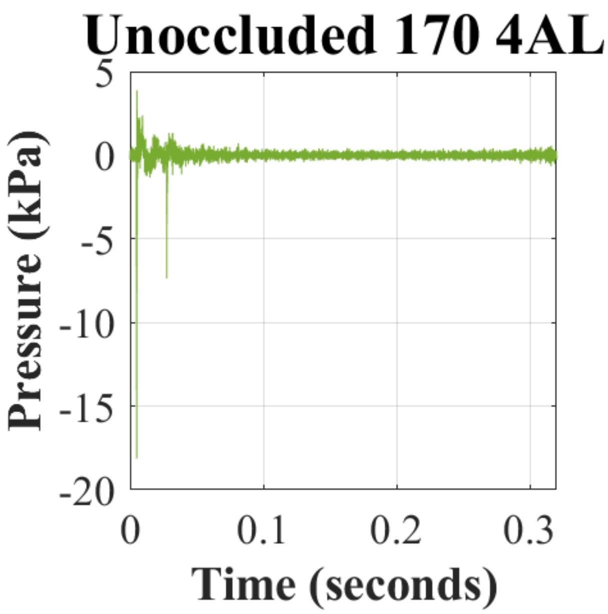
Unoccluded 170 3AR
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

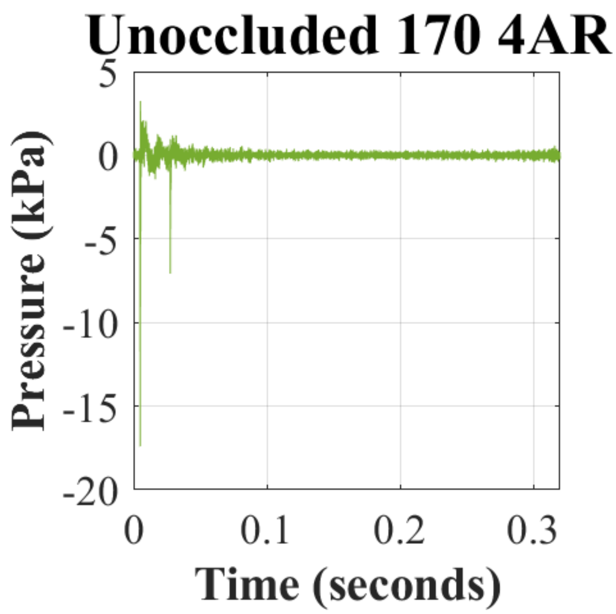


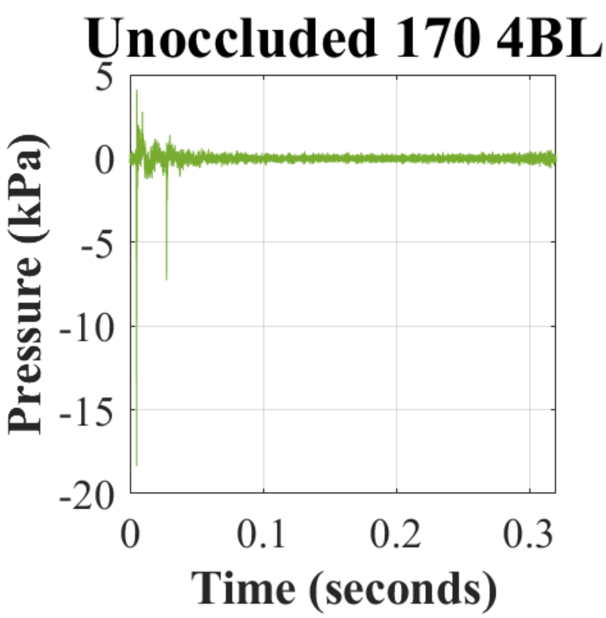
Unoccluded 170 3BL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

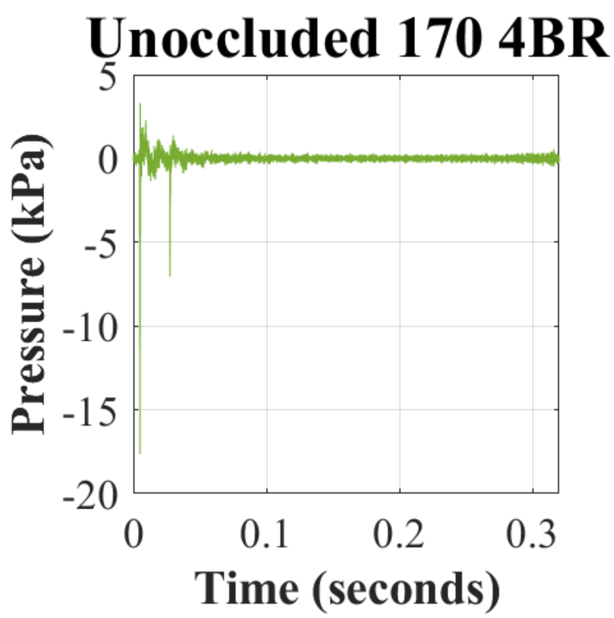


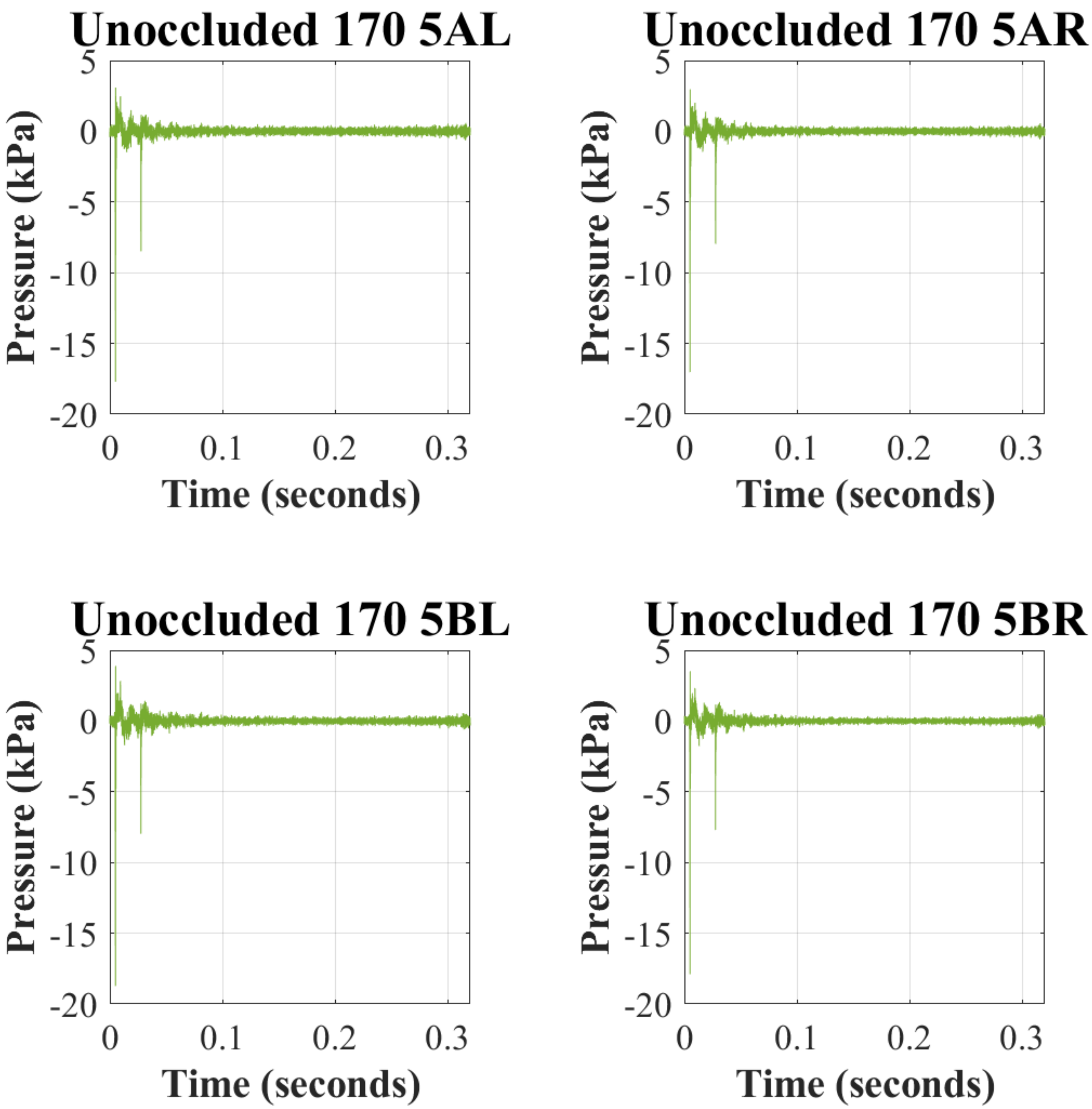
Unoccluded 170 3BR
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)


Unoccluded 170 4AL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)


Unoccluded 170 4AR
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

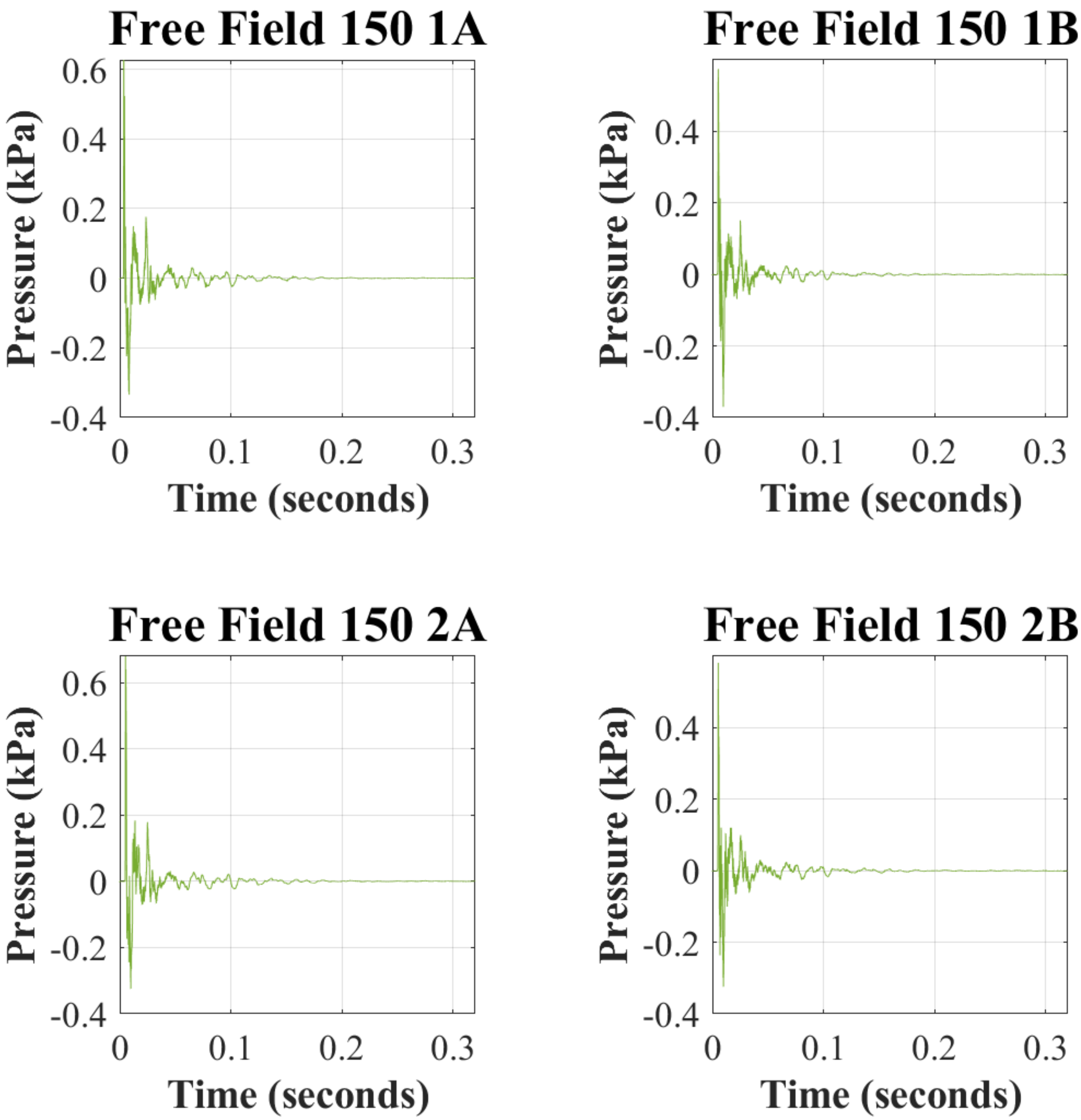

Unoccluded 170 4BL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

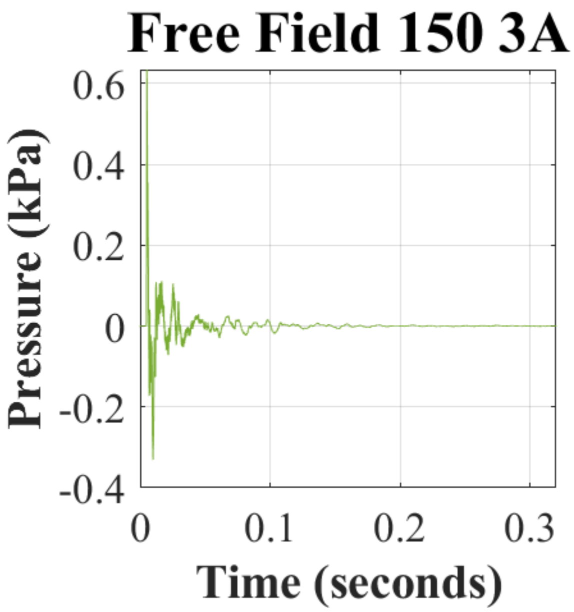

Unoccluded 170 4BR
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

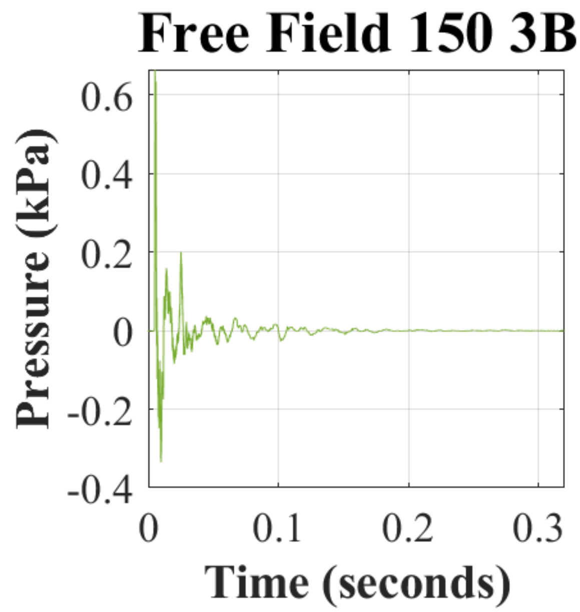


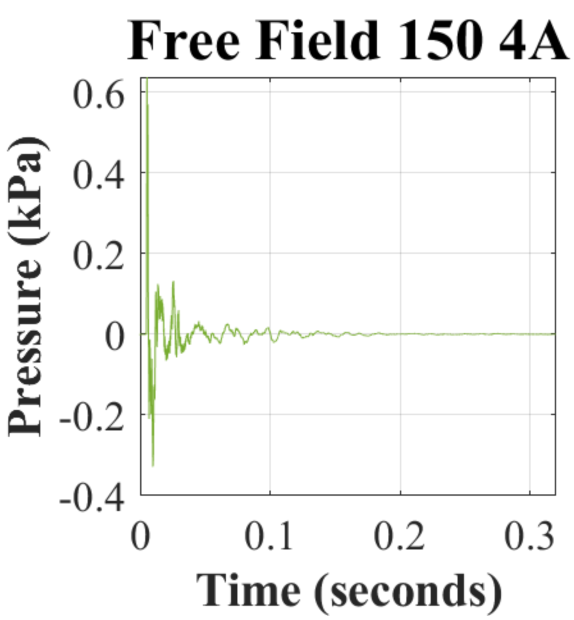
Note. The naming convention for all unoccluded waveforms is "Unoccluded LvL NnX", where 'Unoccluded' is the test condition (i.e., ATF has the HPD doffed), 'LvL' is the nominal test level (i.e., 150, 160 or 170 dBP), 'N' is the sample number (i.e., 1 to 5) of the device tested, 'n' is the trial (i.e., A or B) indicating HPD 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).

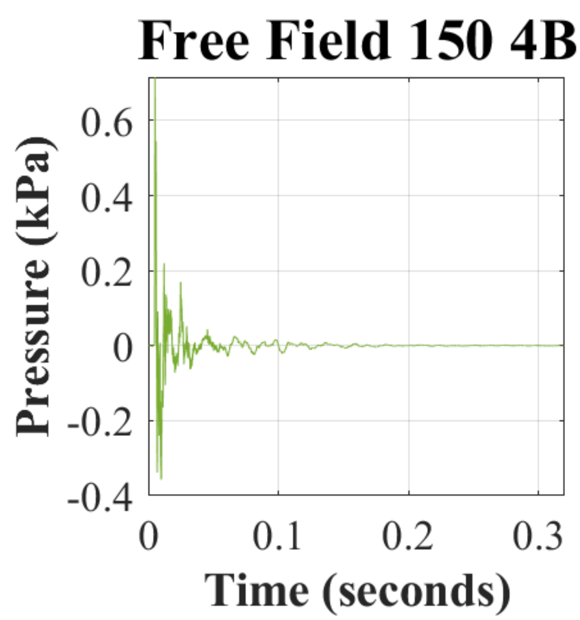
Appendix G. Recorded waveform (in kilopascals [kPa]) over time (in seconds [s]) of the impulse measured with the free-field probe at 150 dBP and the 3M™ PELTOR™ Optime™ 105 donned.

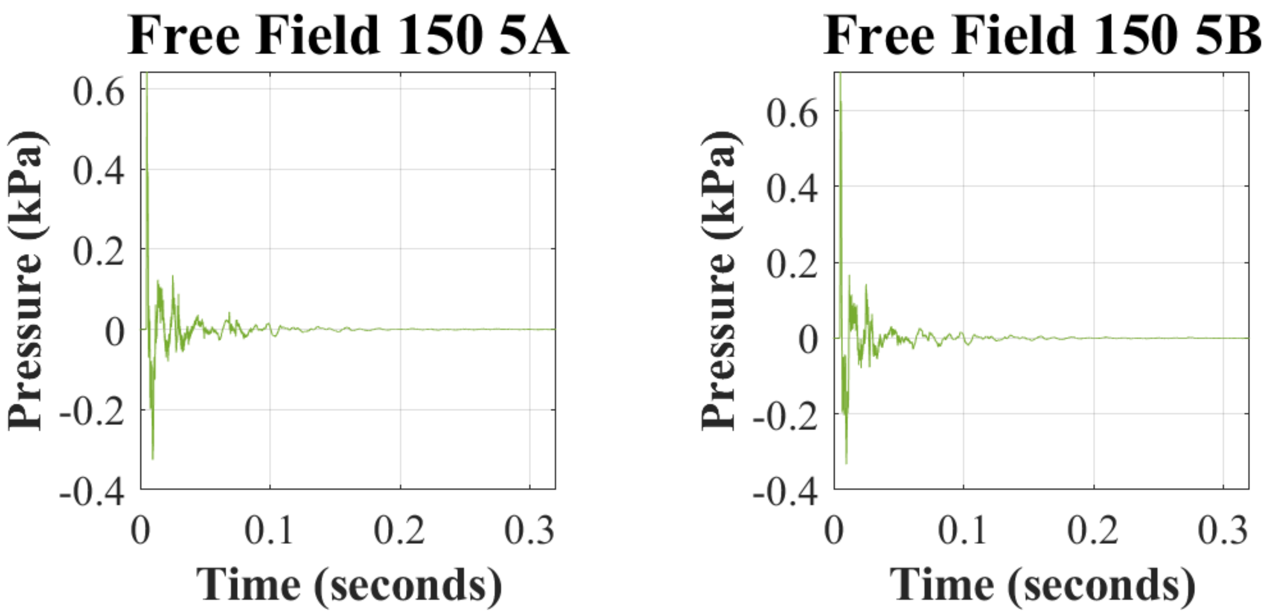



Free Field 150 3A
Pressure (kPa)
0.6
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)


Free Field 150 3B
Pressure (kPa)
0.6
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

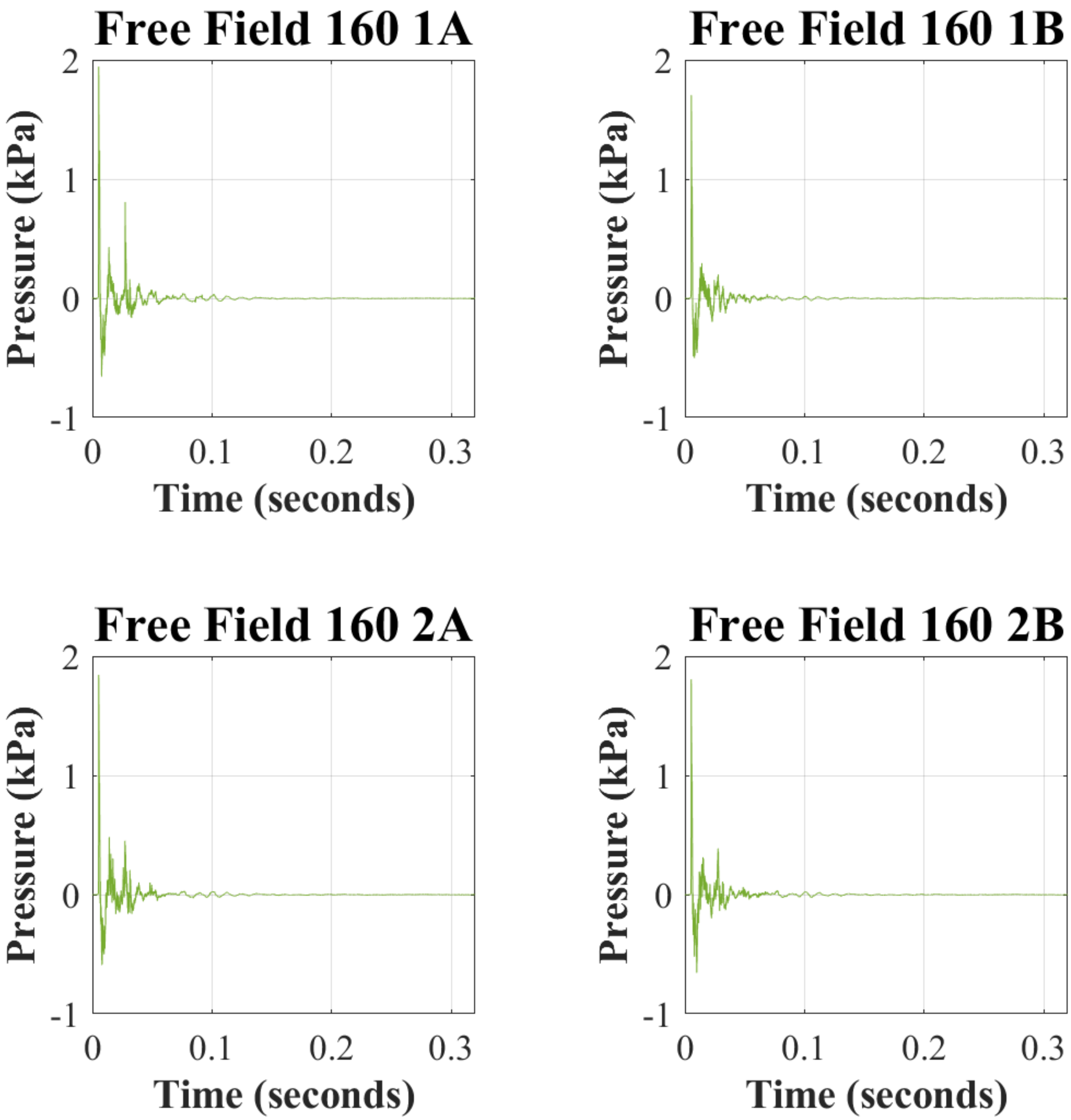

Free Field 150 4A
Pressure (kPa)
0.6
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

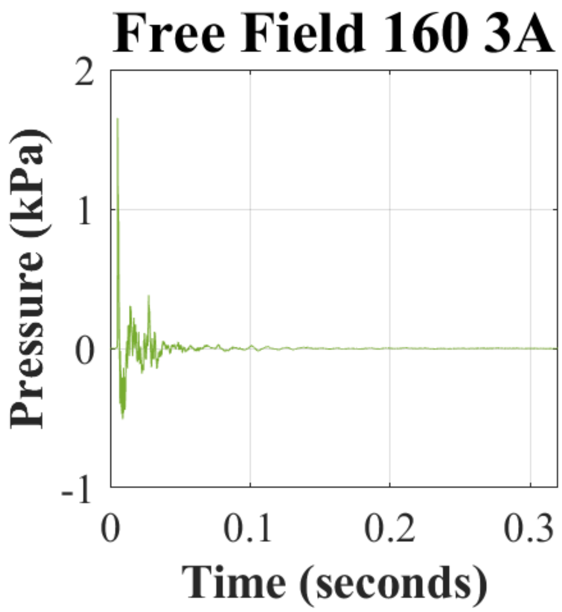

Free Field 150 4B
Pressure (kPa)
0.6
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

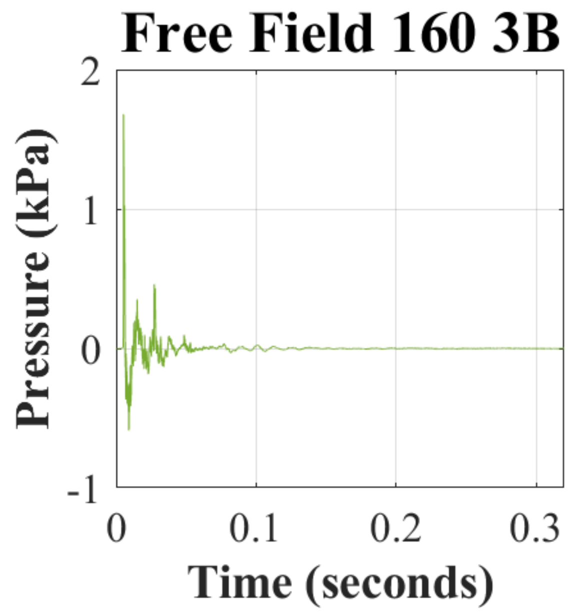


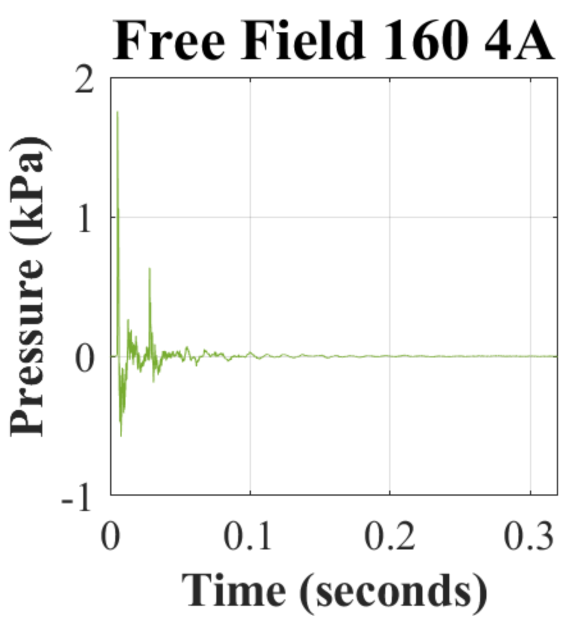
Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (150 dBP), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or B).

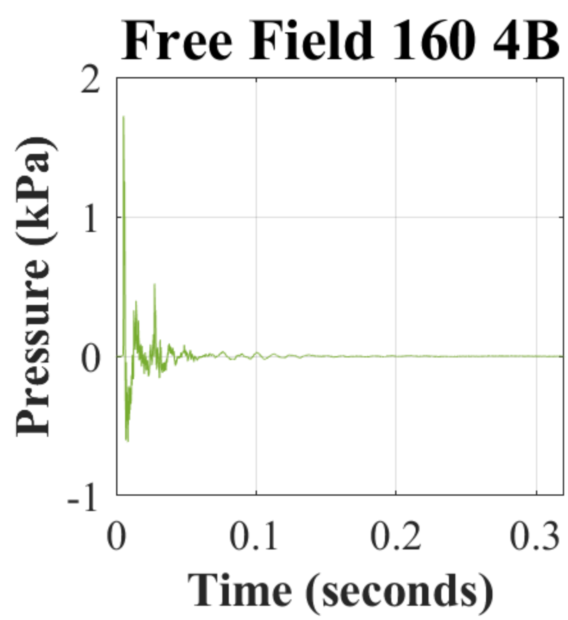
Appendix H. Recorded waveform (in kilopascals [kPa]) over time (in seconds [s]) of the impulse measured with the free-field probe at 160 dBP and the 3M™ PELTOR™ Optime™ 105 donned.

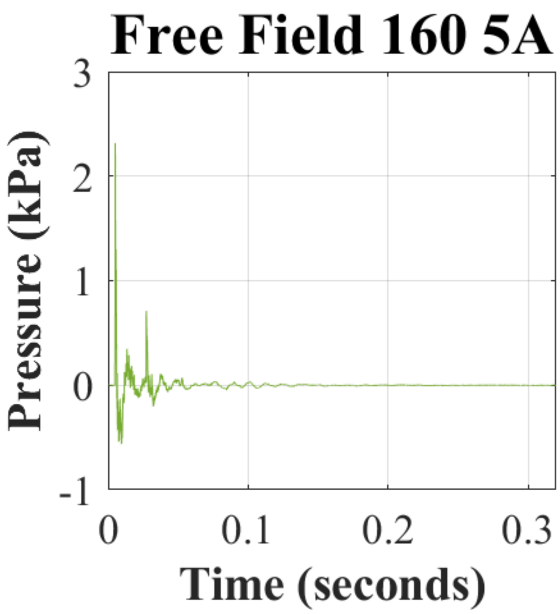


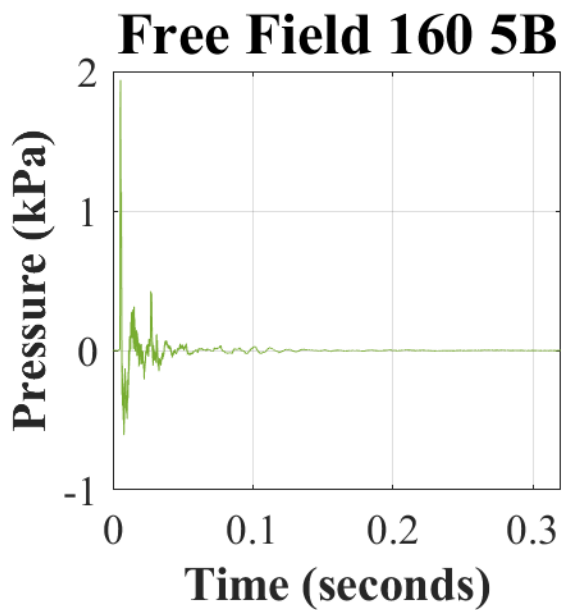

Free Field 160 3A
Pressure (kPa)
Time (seconds)


Free Field 160 3B
Pressure (kPa)
Time (seconds)


Free Field 160 4A
Pressure (kPa)
Time (seconds)

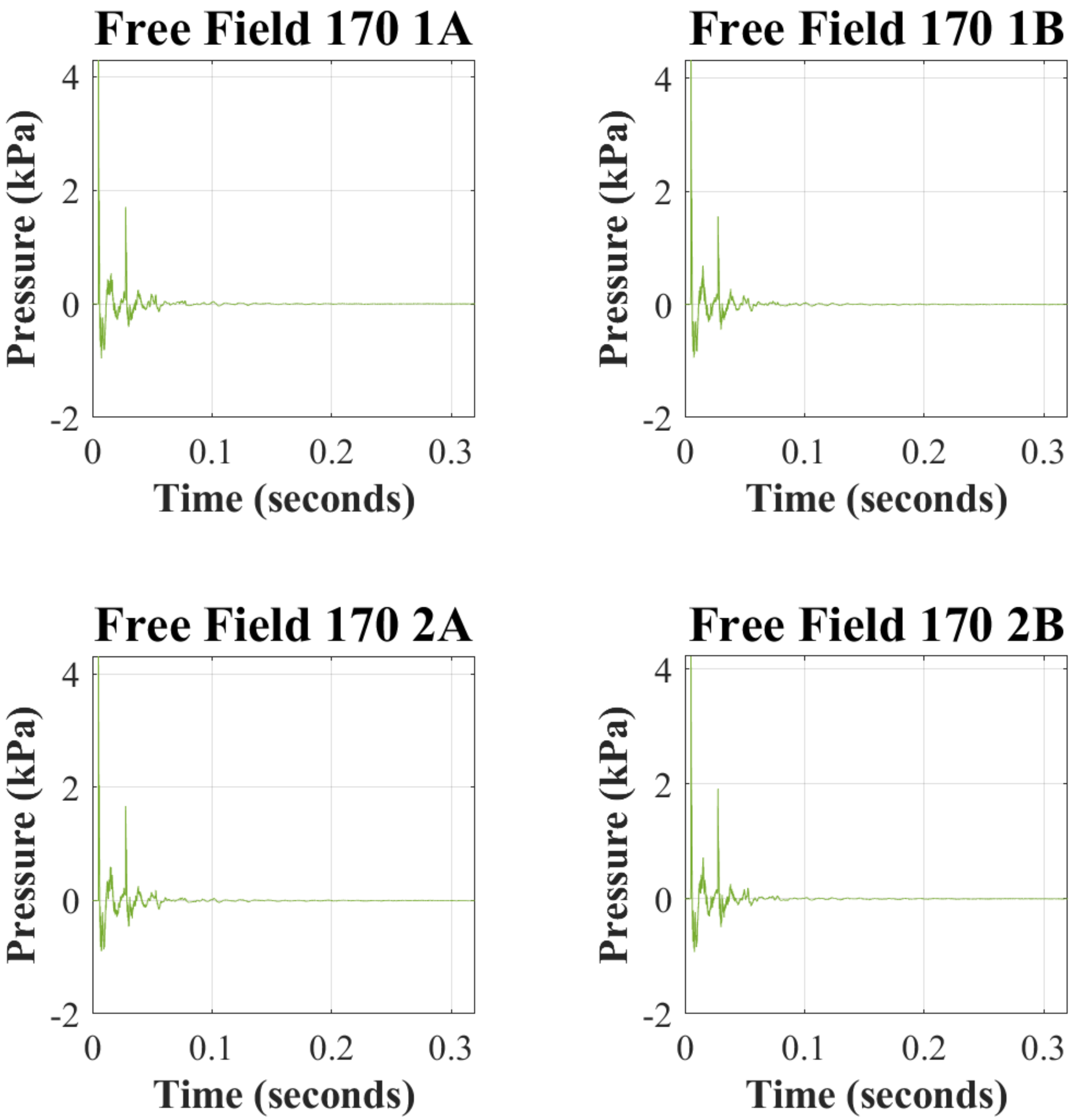

Free Field 160 4B
Pressure (kPa)
Time (seconds)

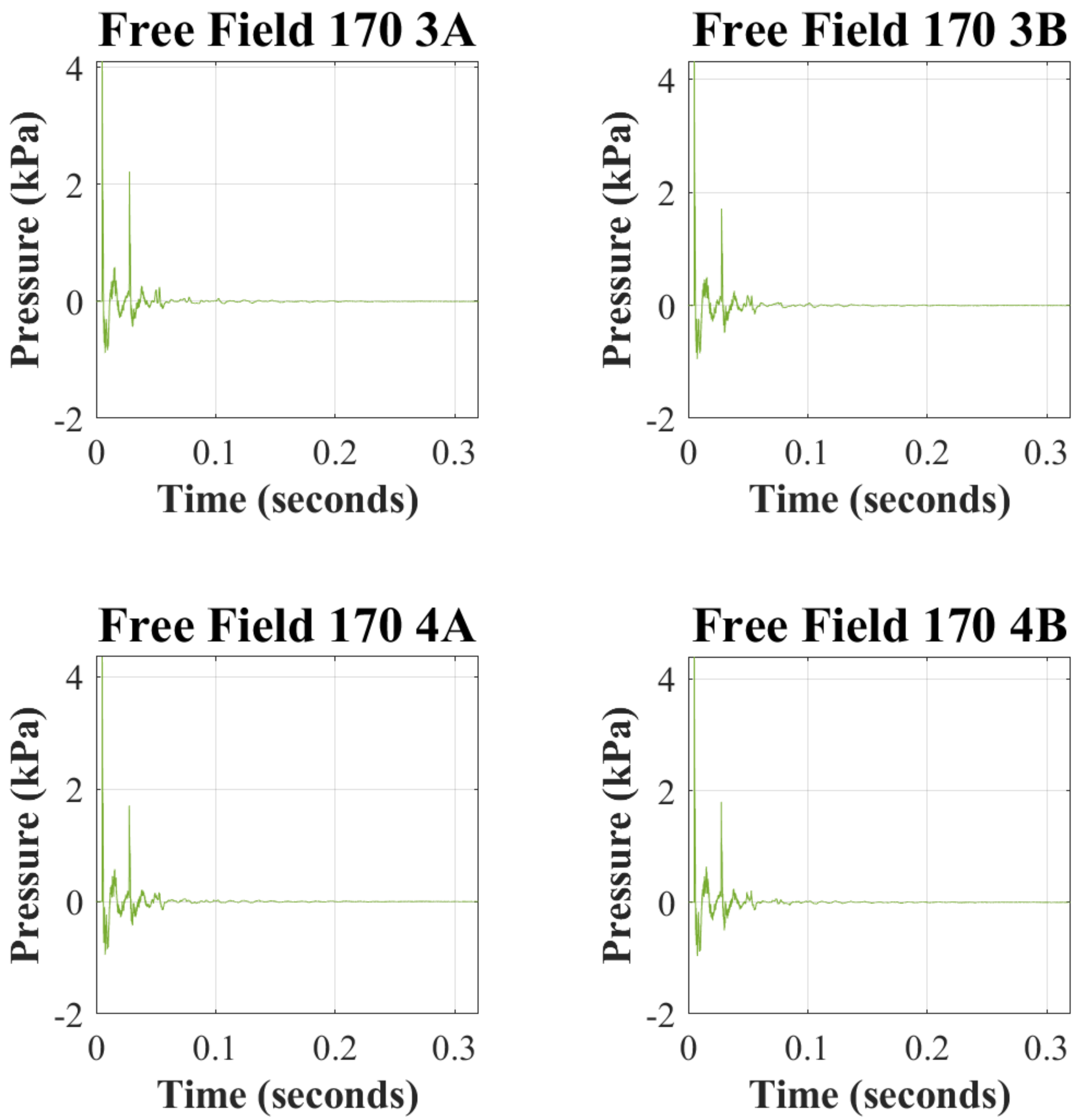




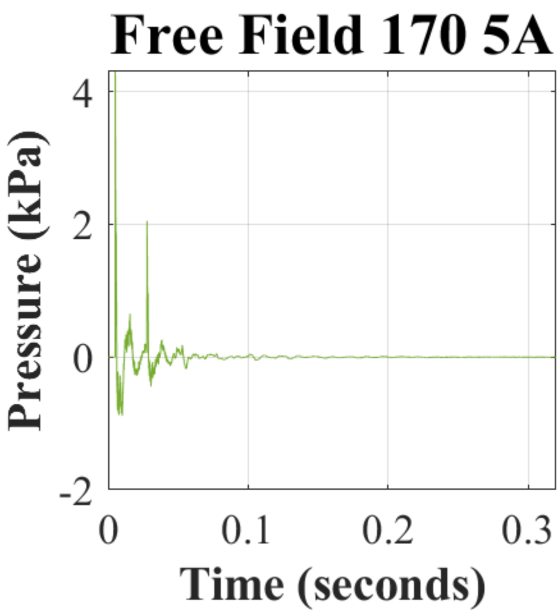
Note. The naming convention for all free-field waveforms is "Free Field LvL Nn", where 'Free Field' indicates that the recording was obtained using the PCB reference microphone, 'LvL' is the nominal test level (160 dBP), 'N' is the device sample number (1 to 5), and 'n' is the device trial (i.e., A or B).

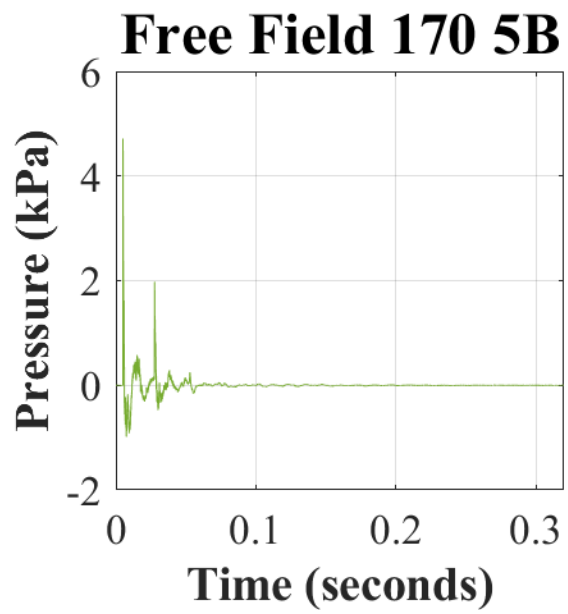
Appendix I. Recorded waveform (in kilopascals [kPa]) over time (in seconds [s]) of the impulse measured with the free-field probe at 170 dBP and the 3M™ PELTOR™ Optime™ 105 donned.





Free Field 170 3A
Pressure (kPa)
Time (seconds)
Free Field 170 3B
Pressure (kPa)
Time (seconds)
Free Field 170 4A
Pressure (kPa)
Time (seconds)
Free Field 170 4B
Pressure (kPa)
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).