Naval Submarine Medical Research Laboratory

NSMRL/F1016,F2002/TM—2021-1358 December 14, 2021

Impulse Assessment of the
New Dynamics Corporation Sound Guard™ Ear Plug

Alexa H. Kolias, AuD [1, 2]
Natalie Silvia, AuD [1, 2]
Derek W. Schwaller, BS [1]
Stephanie J. Karch, AuD, PhD [1]
Jeremy S. Federman, PhD [1]

[1] Naval Submarine Medical Research Laboratory, Groton, CT, United States
[2] Leidos, Inc., Reston, VA, United States

Approved and Released by:
K. K. Shobe, CAPT, MSC, USN
Commanding Officer
NAVSUBMEDRSCHLAB

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
14-12-2021	Technical Memorandum	October 2020- October 2021

4. TITLE AND SUBTITLE

Impulse Assessment of the New Dynamics Corporation Sound Guard™ Ear Plug

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Alexa H. Kolias, AuD
Natalie Silvia, AuD
Derek W. Schwaller, BS
Stephanie J. Karch, AuD, PhD
Jeremy S. Federman, PhD

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

F1016, F2002

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Submarine Medical Research Laboratory
Box 900
Groton, CT 06349-5900

8. PERFORMING ORGANIZATION REPORT NUMBER

NSMRL/F1016,F2002/TM--2021-1358

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Bureau of Medicine and Surgery
7700 Arlington Blvd #5113
Falls Church, VA 22042

Office of Naval Research
875 N Randolph St.
Arlington, VA 22217

10. SPONSOR/MONITOR'S ACRONYM(S)

BUMED, ONR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

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 New Dynamics Corporation Sound Guard™ Two Color Disposable Ear Plugs (Sound Guard™; Model: 6345). Testing was in accordance with the American National Standards Institute (ANSI) standard S12.42-2010. All samples were tested at the nominal levels of 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 for each nominal level were 51.4 (2.2) dB at 160 dBP and 53.7 (3.5) dB at 170 dBP (see Table 1). These results suggest that when properly fit and functional, the Sound Guard™ will adequately protect (i.e., reduce exposure to less than 140 dBP) for impulses below 180.0 dBP.

15. SUBJECT TERMS

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

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			NAVSUBMEDRSCHLAB Commanding Officer
U	U	U	SAR		19b. TELEPHONE NUMBER *(Include area code)* 860-694-3263

Reset

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

[THIS PAGE INTENTIONALLY LEFT BLANK]

Impulse Assessment of the New Dynamics Corporation Sound Guard™ Ear Plug

Alexa H. Kolias, AuD [1, 2]
Natalie Silvia, AuD [1, 2]
Derek W. Schwaller, BS [1]
Stephanie J. Karch, AuD, PhD [1]
Jeremy S. Federman, PhD [1]

[1] Naval Submarine Medical Research Laboratory, Groton, CT, United States
[2] Leidos, Inc., Reston, VA, United States

Naval Submarine Medical Research Laboratory

Approved and Released by:

SHOBE.KATHARINE.KRAUSE.1242518280
Digitally signed by SHOBE.KATHARINE.KRAUSE.1242518280
Date: 2021.12.13 14:17:15 -05'00'

CAPT K. K. Shobe, MSC USN
Commanding Officer
Naval Submarine Medical Research Laboratory
Submarine Base New London Box 900
Groton, CT 06349-5900

This work was supported by the U.S. Navy Bureau of Medicine and Surgery funding work unit F1016 and the Office of Naval Research funding work unit F2002. The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, nor the U.S. Government. This work was prepared by employees of the U.S. Government as part of their official duties. Title 17 U.S.C. §105 provides that 'Copyright protection under this title is not available for any work of the United States Government.' Title 17 U.S.C. §101 defines a U.S. Government work as a work prepared by a military service member or employee of the U.S. Government as part of that person's official duties.

[THIS PAGE INTENTIONALLY LEFT BLANK]

CONTENTS

EXECUTIVE SUMMARY 1
INTRODUCTION 2
METHODS 2
RESULTS 6
DISCUSSION 7
CONCLUSIONS 7
REFERENCES 8
APPENDIX A 9
APPENDIX B 14
APPENDIX C 19
APPENDIX D 24
APPENDIX E 29
APPENDIX F 32

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 New Dynamics Corporation Sound Guard™ Two Color Disposable Ear Plugs (Sound Guard™; Model: 6345). 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. All samples were tested at the nominal levels of 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 for each nominal level were 51.4 (2.2) dB at 160 dBP and 53.7 (3.5) dB at 170 dBP (see Table 1). These results suggest that when properly fit and functional, the Sound Guard™ will adequately protect (i.e., reduce exposure to less than 140 dBP) for impulses below 180.0 dBP.

Table 1.
Sound Guard™ mean (SD) IPIL value (in dB) for all test conditions.

160 dBP	170 dBP
51.4 (2.2)	53.7 (3.5)

Introduction

The New Dynamics Corporation Sound Guard™ Two Color Disposable Ear Plug (Sound Guard™; New Dynamics Corp., Middletown, NY) is a one size fits all, single use, uncorded, passive two-color plug made of hypoallergenic polyvinyl chloride (PVC) foam. Per manufacturer documentation, the two-color orange and green Sound Guard™ design serves the purpose of confirming proper earplug insertion. When inserted properly, only the green portion of the earplug should be visible outside of the ear canal (New Dynamics Corp., 2015).

Per the Department of Defense Instruction 6055.12 (2015), 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 Sound Guard™ at 160 and 170 dBP is unknown. The current effort determined the IPIL value for the uncorded Sound Guard™ earplug. 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

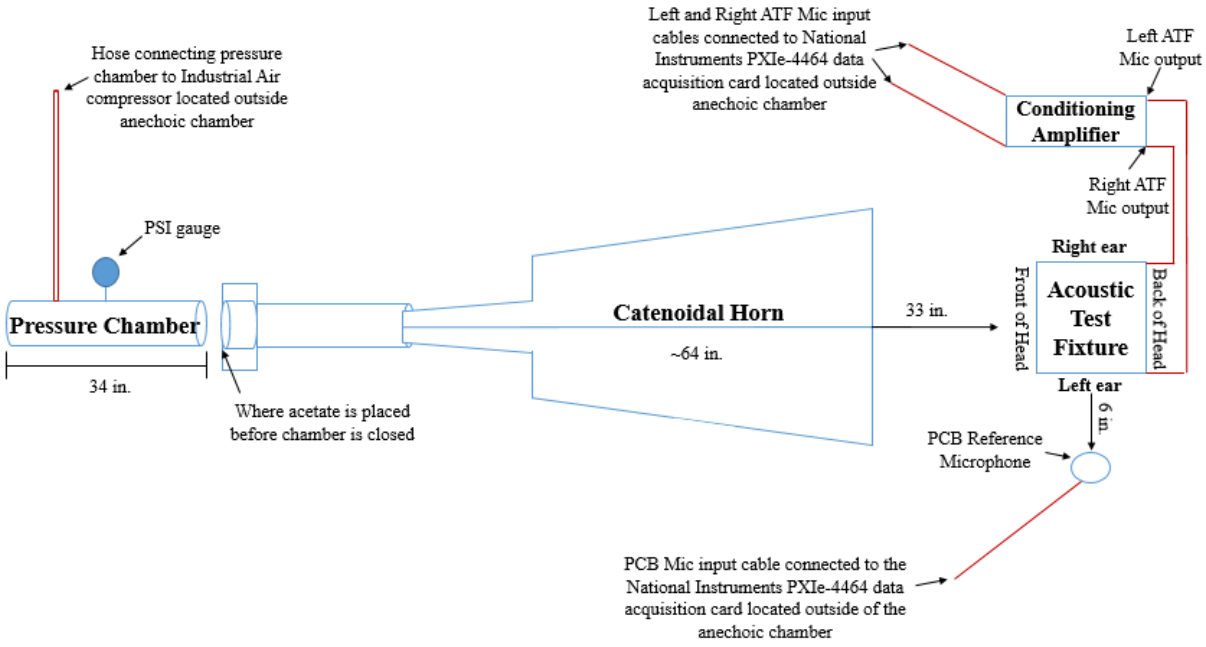
Hardware. Acoustic impulses were generated by NSMRL's 4 inch (in., 10.2 centimeters (cm)) shock tube (B/C Precision, Inc., Greendale, IN). The shock tube pressure chamber is approximately 34 in. (86.4 cm) long, with an inner diameter of 4 in. (10.2 cm). A 64 in. (162.6 cm) long catenoidal tube horn consisting 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 inches (2.0 mil) 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). Additionally, 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.

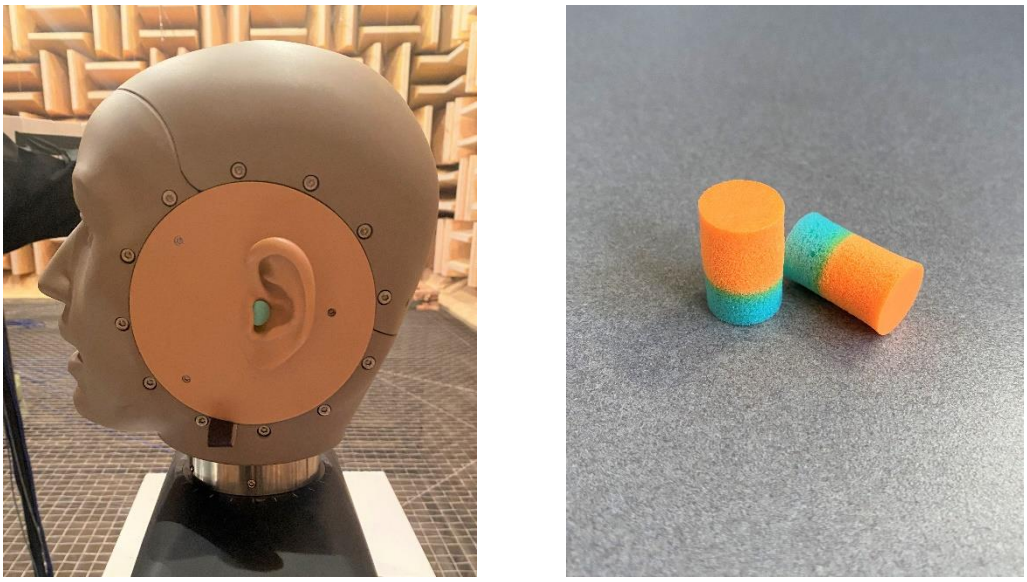
Rather than using an ANSI/ASA S12.42-2010 standardized in-line analog external Bessel filter (6^{th} order, corner frequency 20.0 kHz [3 dB down]) to filter

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 160 decibel peak (dBP) and 170 dBP data (see Data Analysis below).

Hearing Protection Device Samples. Five samples of the New Dynamics Corporation Sound Guard™ Two Color Disposable Ear Plugs (Manufacturer Product Number: 6345) were tested IAW ANSI/ASA S12.42-2010. Each sample, consisting of one set of two earplugs, was randomly assigned a number 1 through 5. Each earplug in the sampled set was labeled 'L' for left or 'R' for right to indicate which ATF ear they were to be inserted for all trials.

Figure 2.
Sound Guard™ Ear Plugs.



Procedure

Each sampled HPD set 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, extreme hardness, or damage prior to use. Once inspected, the each earplug was rolled down until thin and inserted into the ear canal orange-end first. Proper insertion was confirmed by ensuring that only the green component of the plug was visible outside of the ear canal. Earplugs were given at least two minutes to fully expand in the ATF ear canal before impulse testing was performed.

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. 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 inserted) and unoccluded (i.e., without the HPD inserted) test configurations. For all occluded measures, the earplugs 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 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.

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.

Data Analysis

MATLAB (Natick, MA) was used to calculate 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

As shown in Table 2, the overall mean IPIL value was 51.4 dB at the 160 dBP test condition and at 53.7 dB at the 170 dBP test condition. Calculated IPIL values for all individual sample trials ranged between 45.4 and 54.9 dB at the 160 dBP test condition and between 48.7 and 60.7 dB at the 170 dBP test condition. The waveforms for all trials with the uncorded Sound Guard™ are provided in Appendices A to F.

Table 2.
Mean (SD) IPIL values (in dB) for Tested Sound Guard™ Samples.

	160 dBP		**170 dBP**	
	Right	*Left*	*Right*	*Left*
HPD 1, Trial A	53.0	48.9	50.5	51.0
HPD 1, Trial B	49.4	45.4	50.6	50.3
HPD 2, Trial A	54.1	50.6	56.2	51.8
HPD 2, Trial B	51.6	49.5	55.6	52.5
HPD 3, Trial A	53.4	51.2	48.7	51.7
HPD 3, Trial B	54.9	50.1	49.6	52.5
HPD 4, Trial A	53.4	50.9	59.8	53.3
HPD 4, Trial B	53.3	52.5	59.6	53.0
HPD 5, Trial A	51.2	52.9	56.2	60.7
HPD 5, Trial B	51.5	50.4	53.3	56.9
Ear Specific Mean (SD)	52.6 (1.6)	50.2 (2.1)	54.0 (4.1)	53.4 (3.1)
Level Overall Mean (SD)	51.4 (2.2)		53.7 (3.5)	

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 51.4 dB at 160 dBP and 53.7 dB at 170 dBP. Across ears, the individual trial mean IPIL values were found to vary as much as 9.5 dB at 160 dBP and 12.0 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 fit twice. Results indicate that a greater variety of attenuation was present in the individual trials at the 170 dBP level compared to 160 dBP. This is noted with a larger SD at the 170 dBP (3.5 dB) nominal level compared to that at the 160 dBP (2.2 dB) nominal level.

It is important to note that these results do not guarantee similar Sound Guard™ product performance across all users and environments. Product performance may be impacted by factors such as variability in physical fit of the device 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 uncorded Sound Guard™ Earplug at 160 dBP and 170 dBP nominal levels. The calculated overall mean (SD) IPIL values for the Sound Guard™ were found to be 51.4 (2.2) dB at 160 dBP and 53.7 (3.5) dB at 170 dBP.

These results imply that when properly fit and functional, the Sound Guard™ Two Color Disposable Ear Plug will adequately protect (i.e., reduce the exposure below 140 dBP) the user from impulses below 180 dBP. This value is based on the 180 dBP limit of the applicability of IPIL values measured at 170 dBP in MIL-STD-1474E B.5.3.3 (Department of Defense, 2015).

References

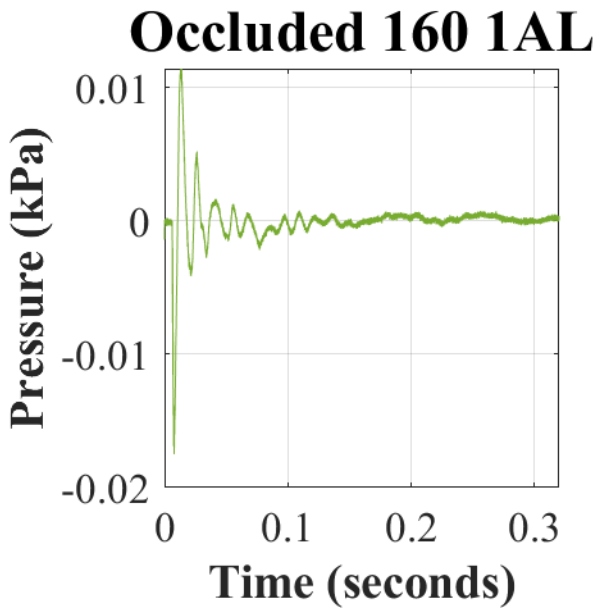
American National Standards Institute, Inc. (2010). *ANSI S12.42-2010: Methods for the Measurement of Insertion Loss of Hearing Protection Devices in Continuous or Impulsive Noise Using Microphone-in-Real-Ear or Acoustic Test Fixture Procedures.* Acoustical Society of America.

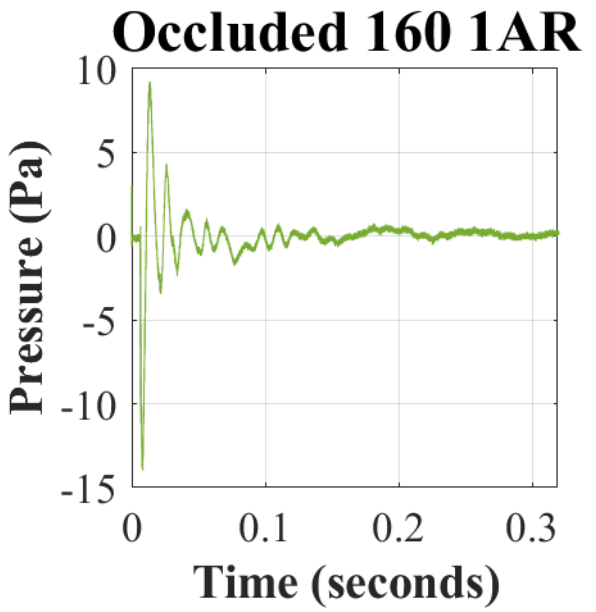
Department of Defense (2015). *MIL-STD-1474E Department of Defense Design Criteria Standard Noise Limits.* Washington, DC: Department of Defense.

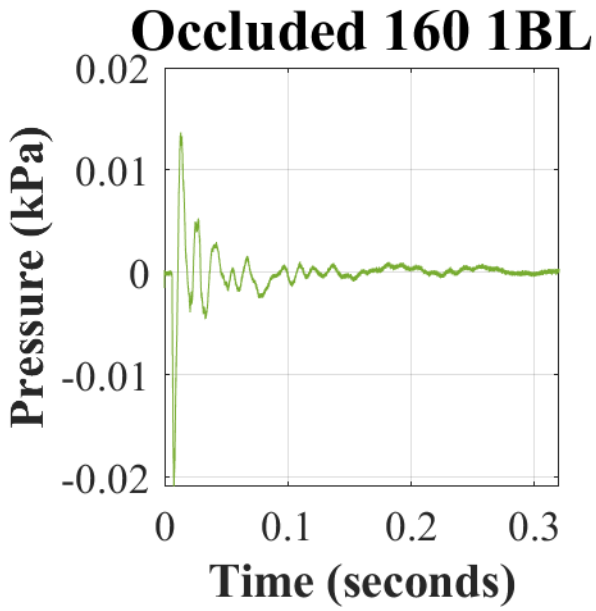
New Dynamics Corporation. (2015). *Sound Guard™ Two Color Disposable Ear Plugs* [Package Instructions]. Middletown, NY: Access: Supports For Living Inc.

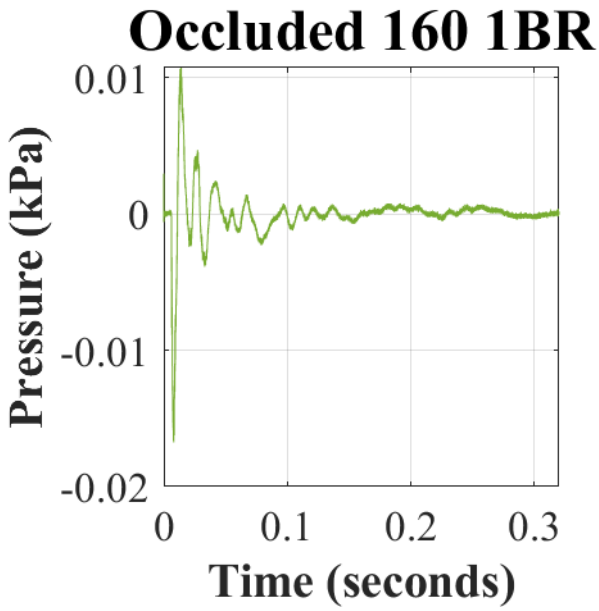
Office of the Under Secretary of Defense for Personnel and Readiness (2019). *DoD Instruction 6055.12 Hearing Conservation Program (HCP).* Washington, DC: Department of Defense.

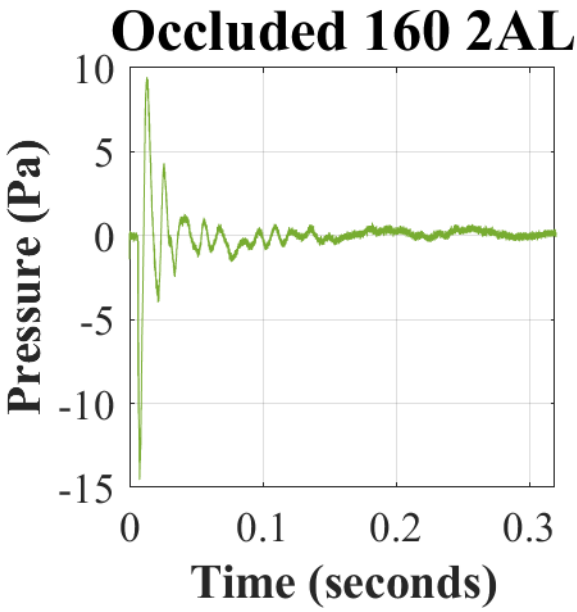
Appendix A. Recorded occluded (closed-ear) waveforms in response to 160 dBP with the Sound Guard™ Ear Plugs.

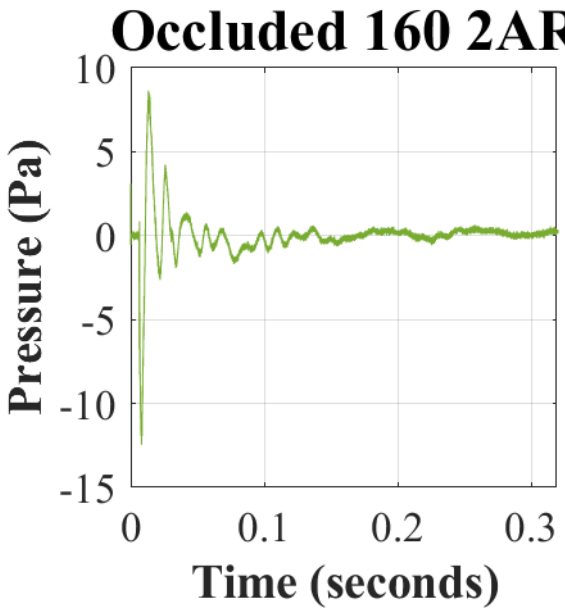


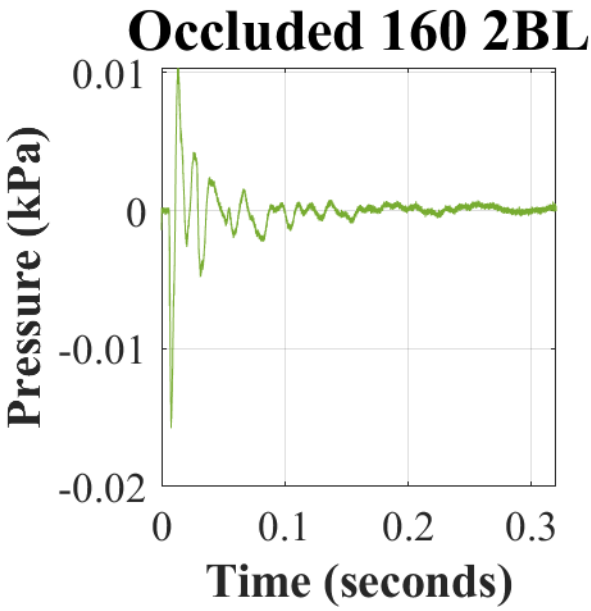


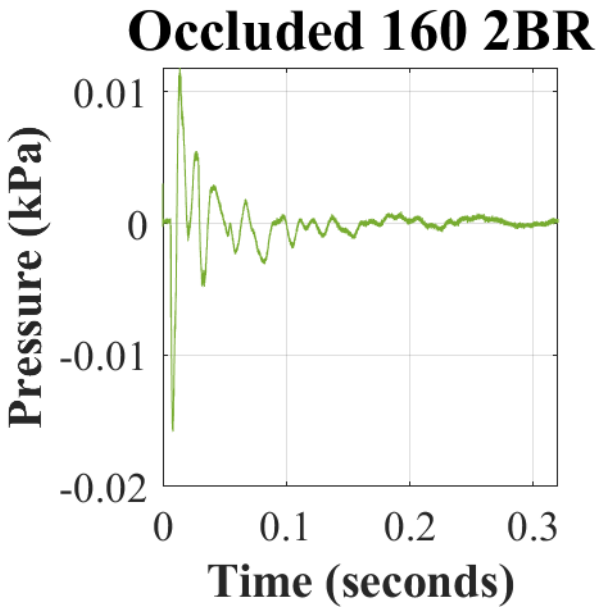


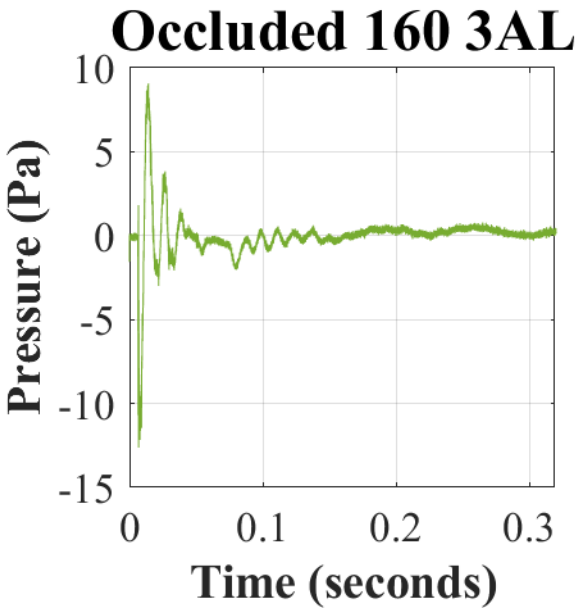


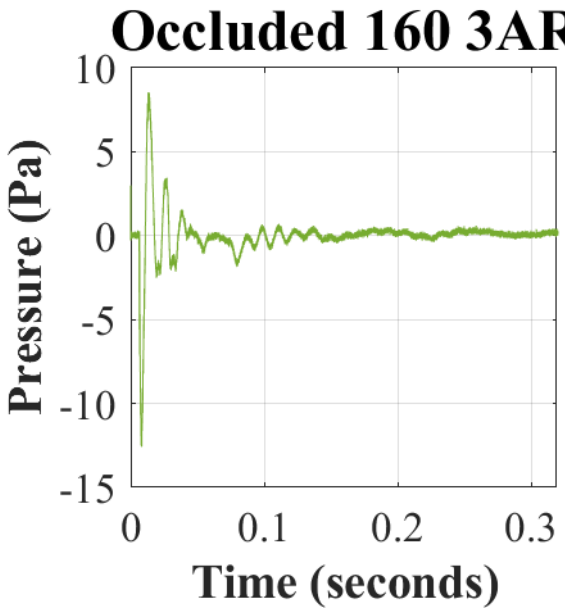

Occluded 160 2AL
Pressure (Pa)
10
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

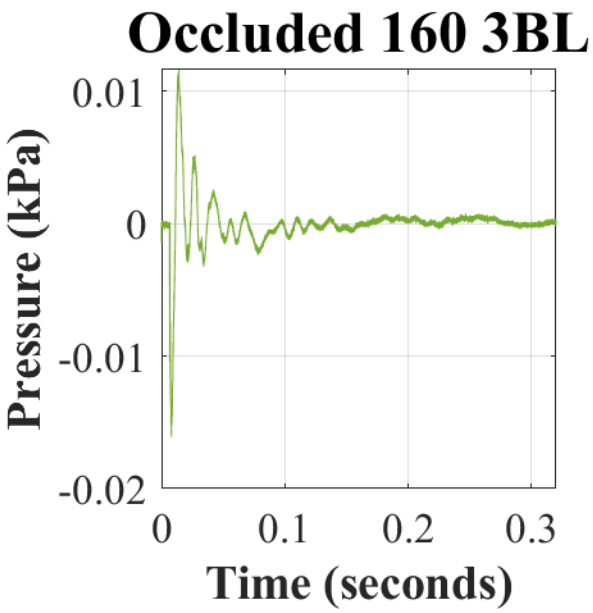

Occluded 160 2AR
Pressure (Pa)
10
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

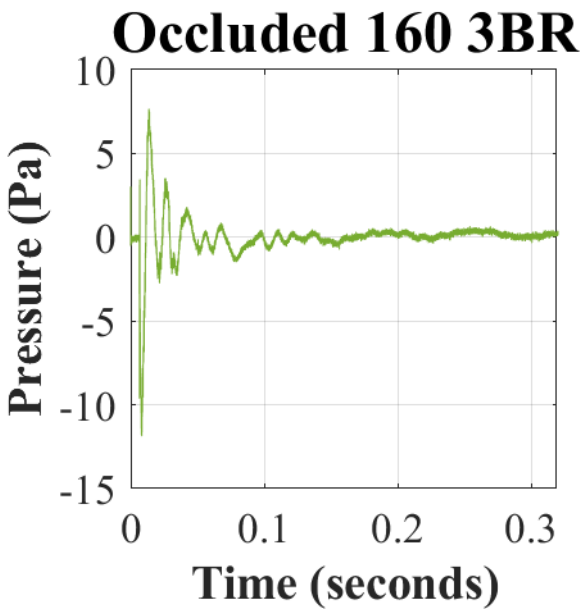

Occluded 160 2BL
Pressure (kPa)
0.01
0
-0.01
-0.02
0
0.1
0.2
0.3
Time (seconds)

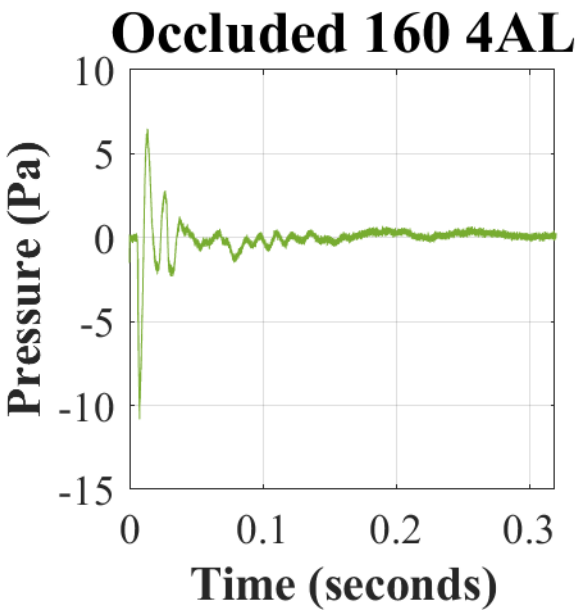

Occluded 160 2BR
Pressure (kPa)
0.01
0
-0.01
-0.02
0
0.1
0.2
0.3
Time (seconds)

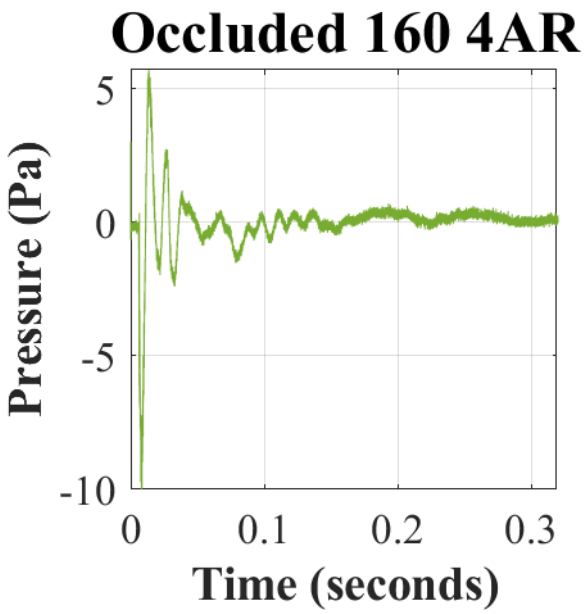

Occluded 160 3AL
Pressure (Pa)
10
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

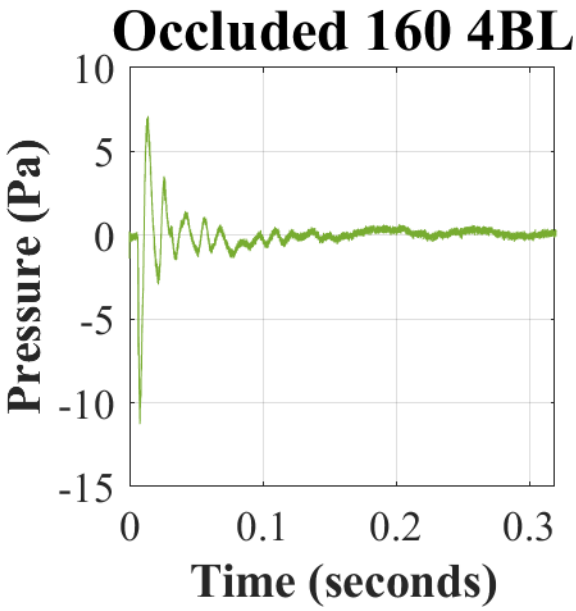

Occluded 160 3AR
Pressure (Pa)
10
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

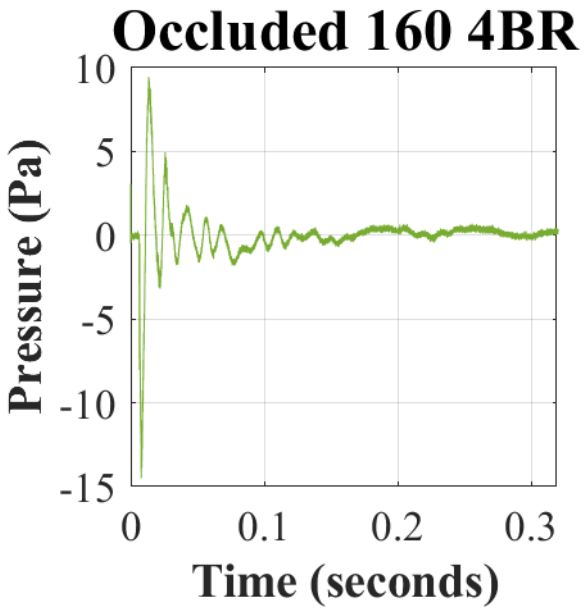

Occluded 160 3BL
Pressure (kPa)
0.01
0
-0.01
-0.02
0
0.1
0.2
0.3
Time (seconds)

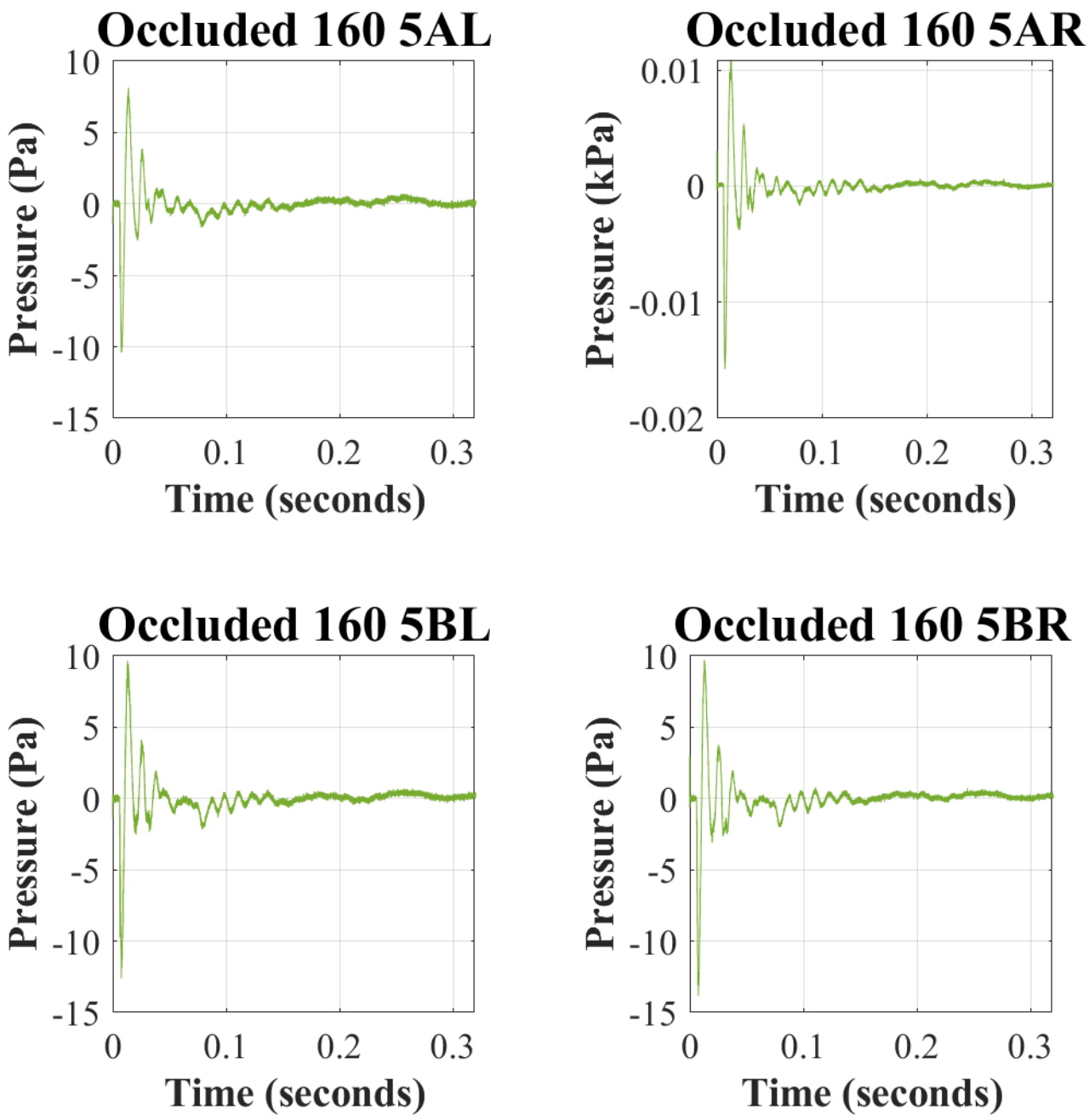

Occluded 160 3BR
Pressure (Pa)
10
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)


Occluded 160 4AL
Pressure (Pa)
Time (seconds)
10
5
0
-5
-10
-15
0
0.1
0.2
0.3


Occluded 160 4AR
Pressure (Pa)
Time (seconds)
5
0
-5
-10
0
0.1
0.2
0.3

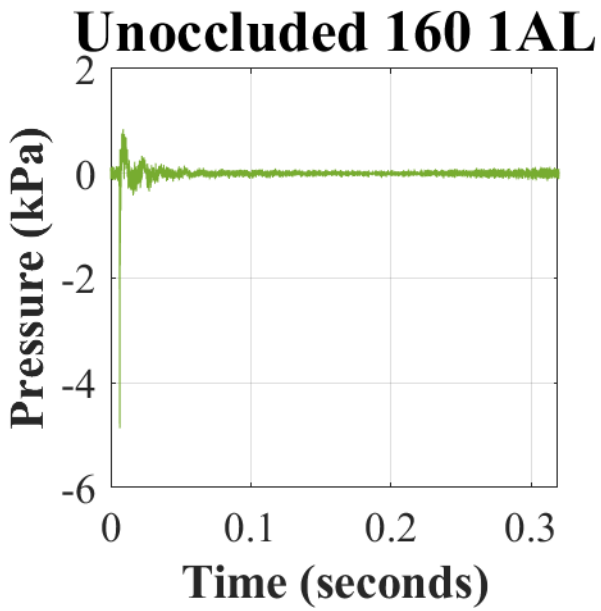

Occluded 160 4BL
Pressure (Pa)
Time (seconds)
10
5
0
-5
-10
-15
0
0.1
0.2
0.3

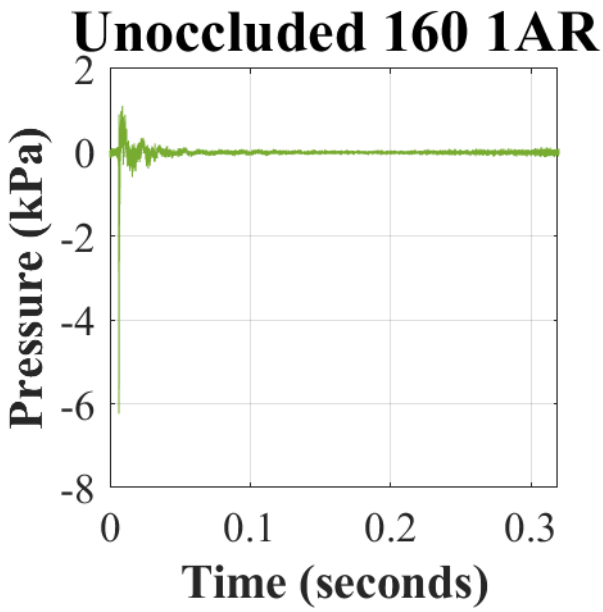

Occluded 160 4BR
Pressure (Pa)
Time (seconds)
10
5
0
-5
-10
-15
0
0.1
0.2
0.3

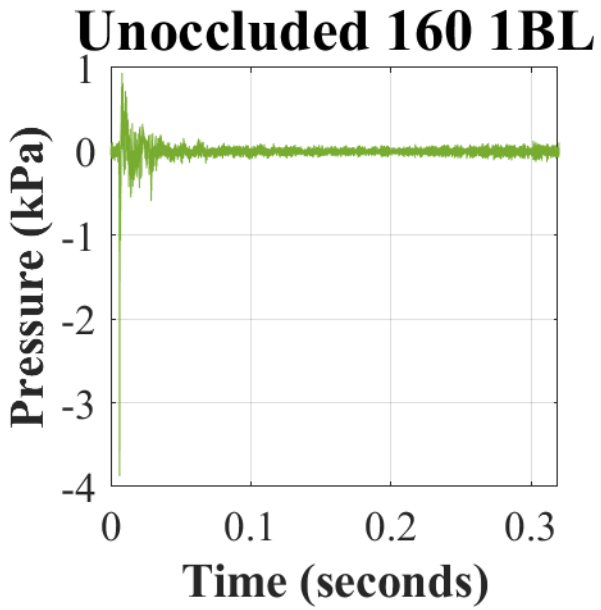


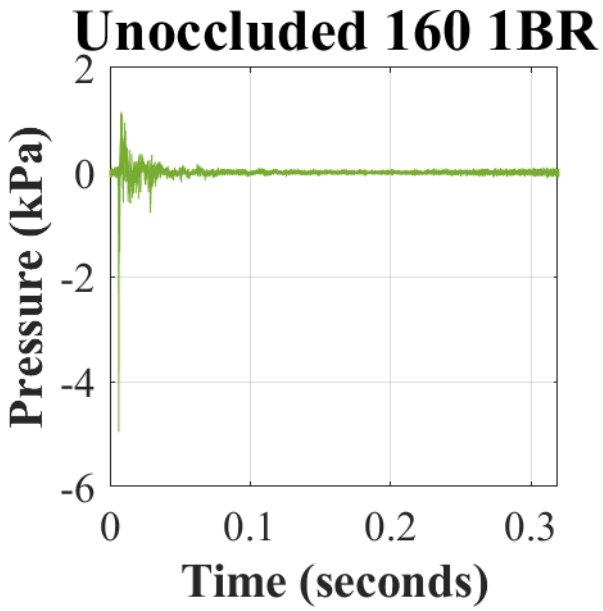
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating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

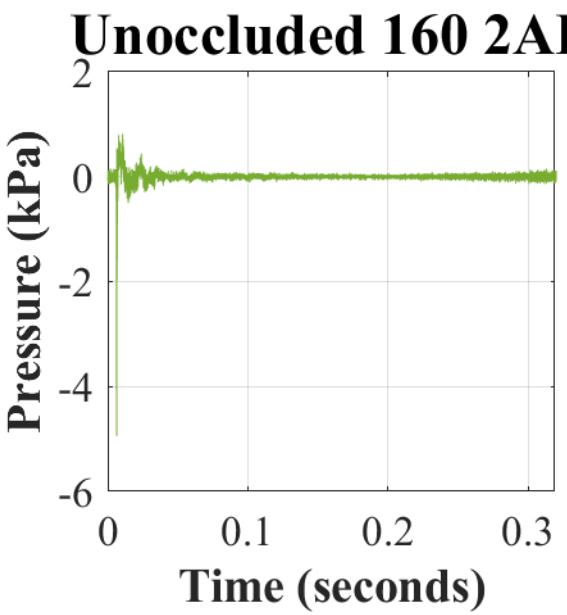
Appendix B. Estimated unoccluded (open-ear) waveforms in response to 160 dBP with the Sound Guard™ Ear Plugs.

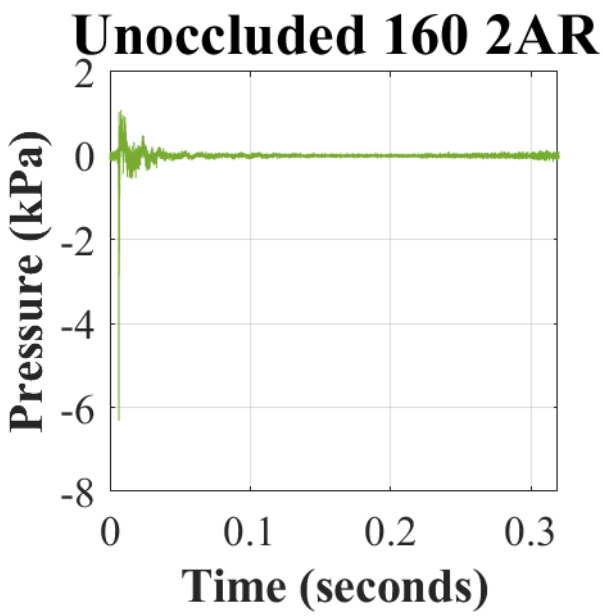


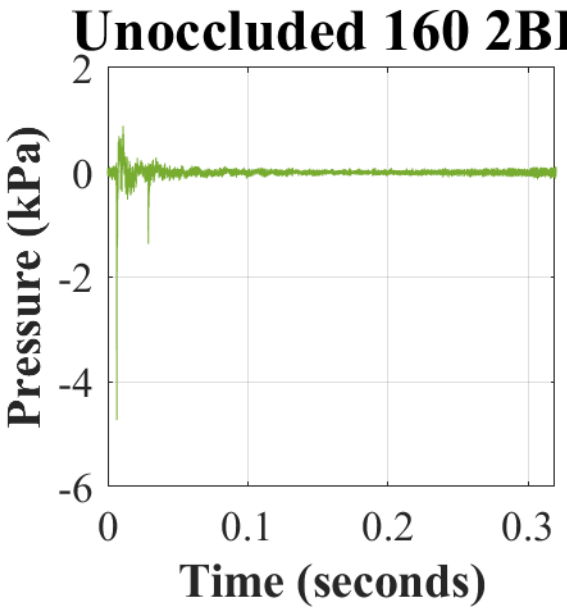


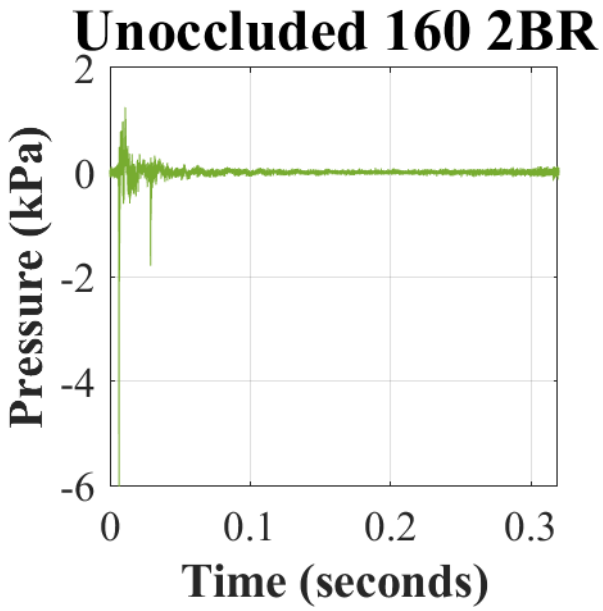


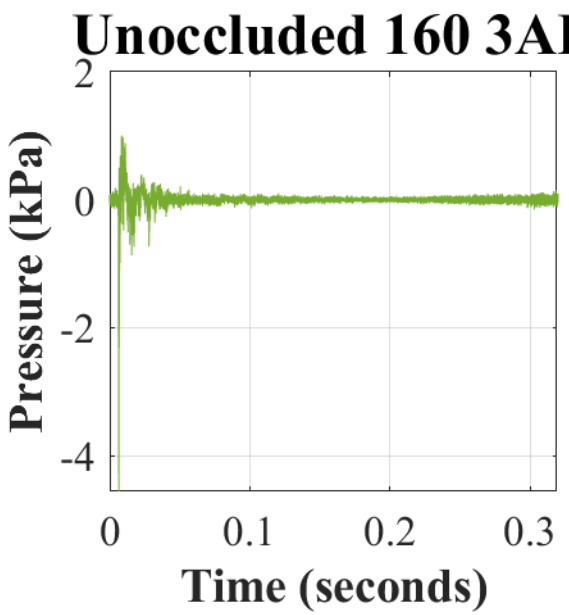


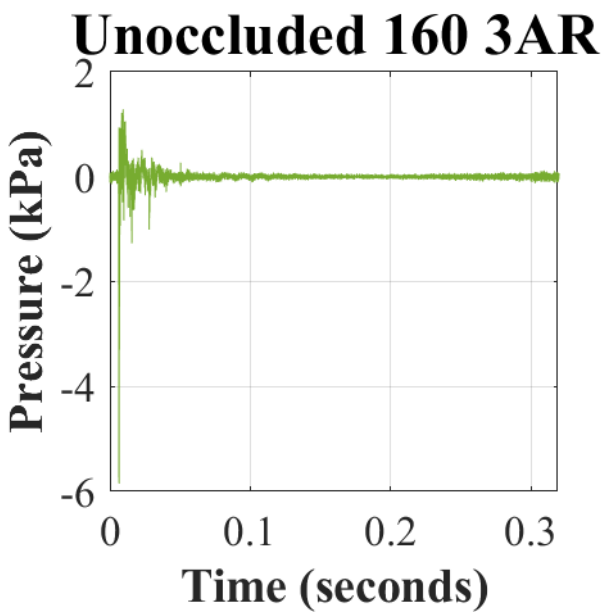

Unoccluded 160 2AL
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

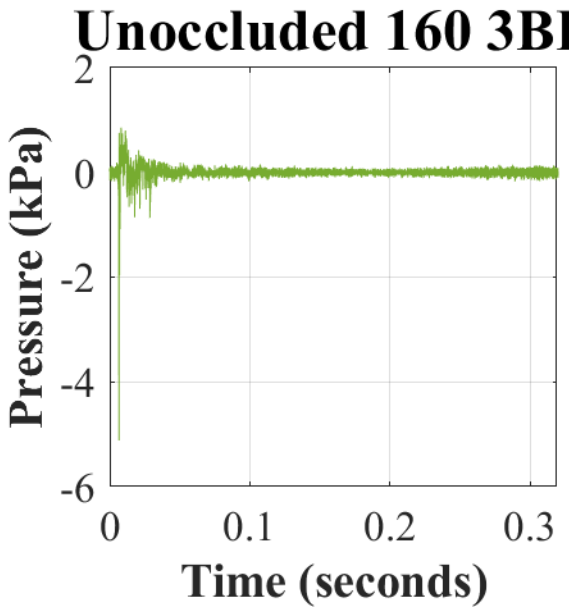

Unoccluded 160 2AR
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

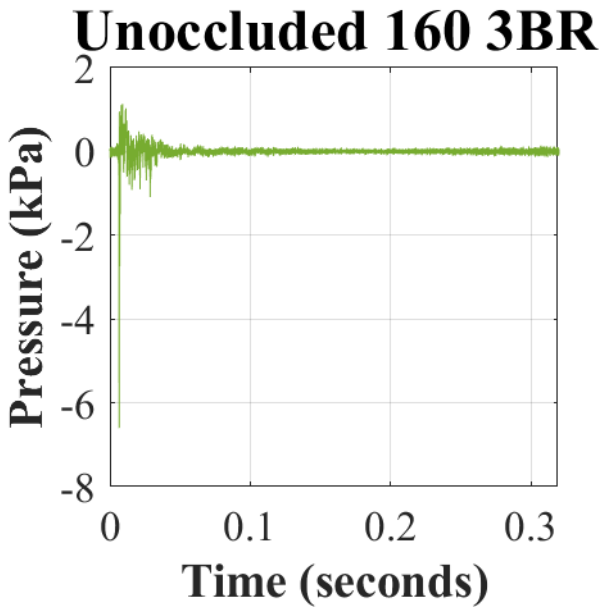

Unoccluded 160 2BL
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

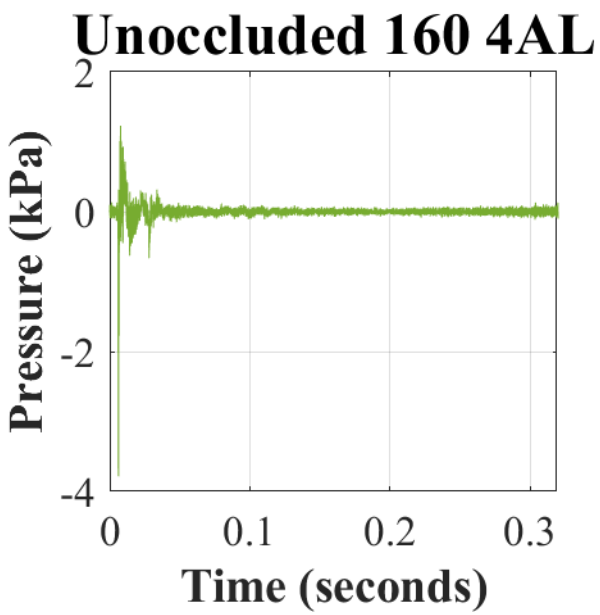

Unoccluded 160 2BR
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

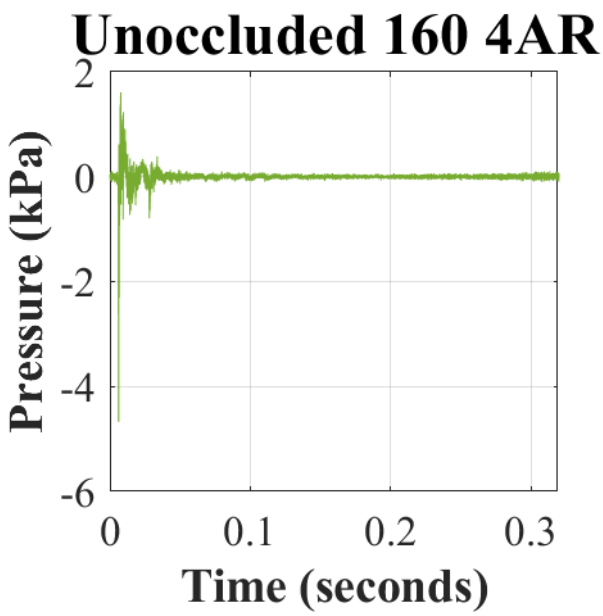

Unoccluded 160 3AL
Pressure (kPa)
2
0
-2
-4
0
0.1
0.2
0.3
Time (seconds)

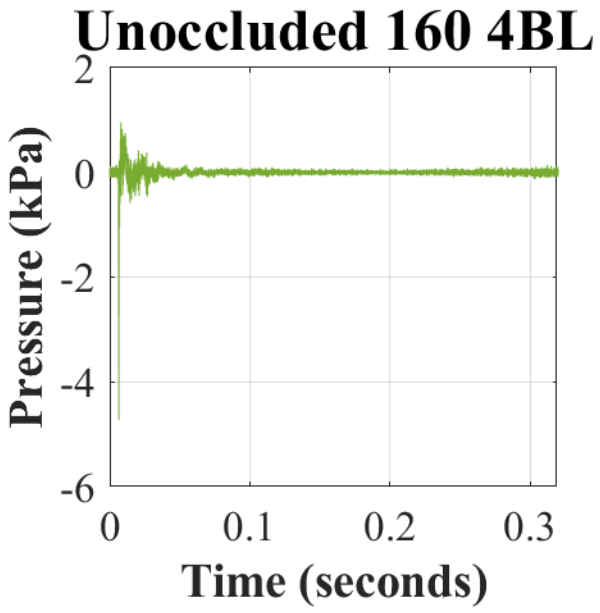

Unoccluded 160 3AR
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

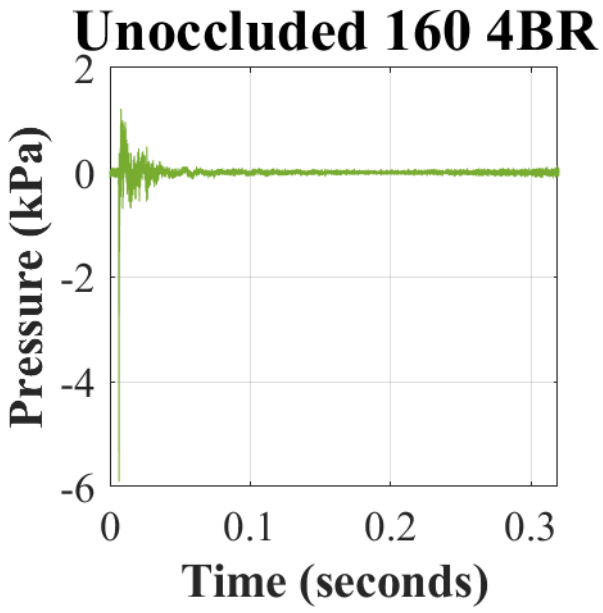

Unoccluded 160 3BL
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

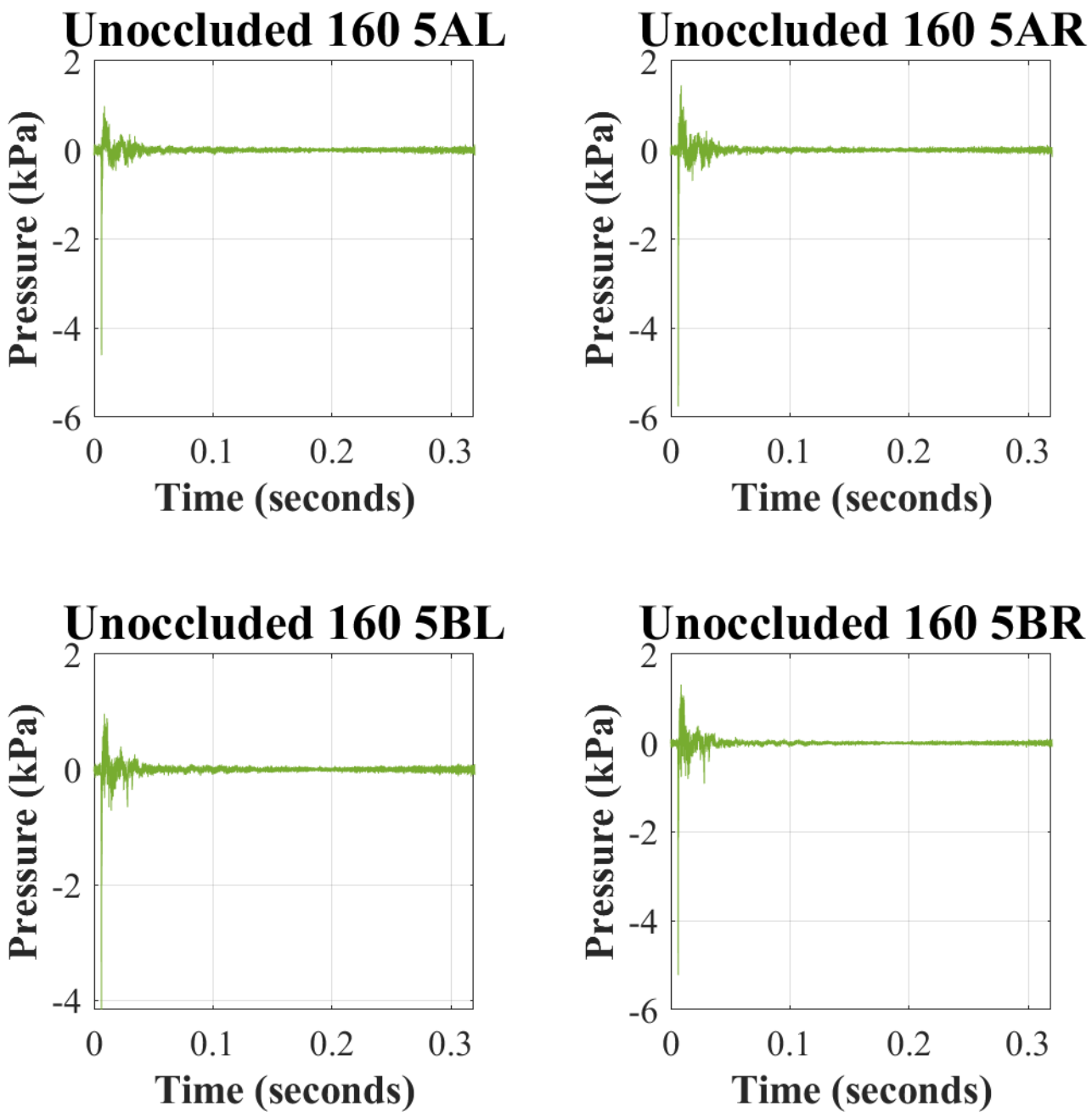

Unoccluded 160 3BR
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)


Unoccluded 160 4AL
Pressure (kPa)
2
0
-2
-4
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)

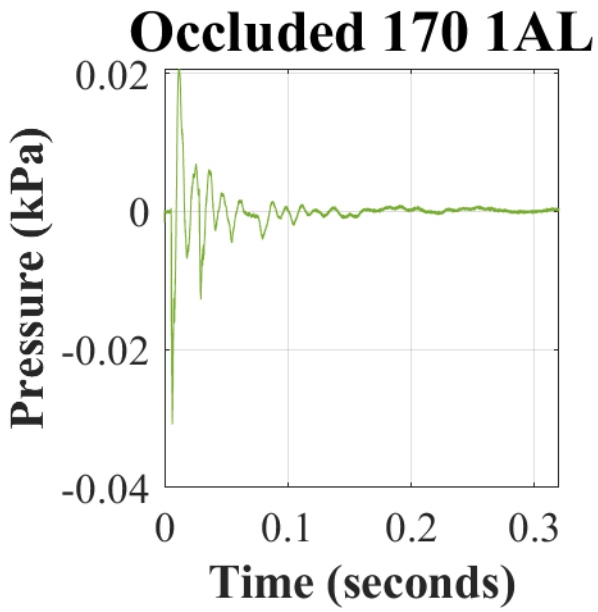

Unoccluded 160 4BL
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

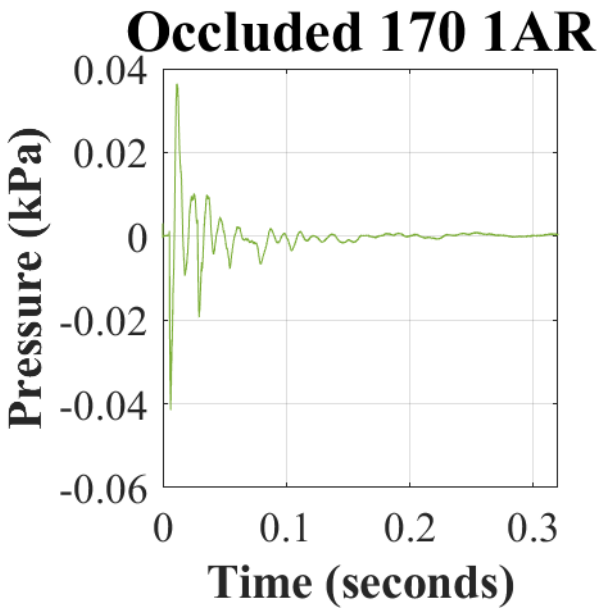

Unoccluded 160 4BR
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

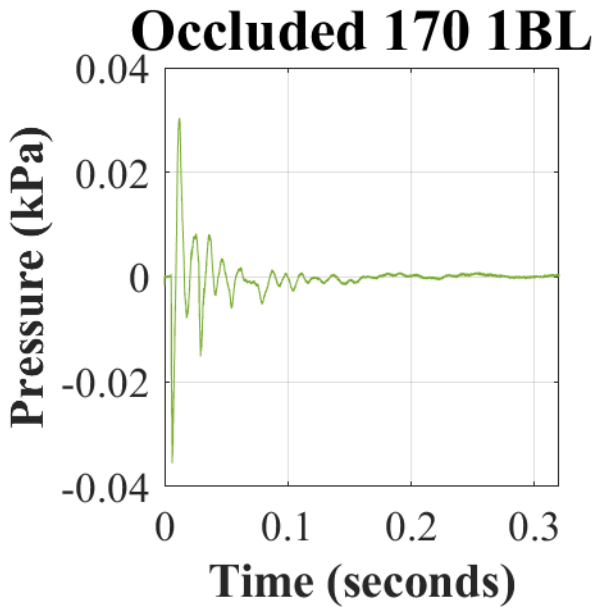


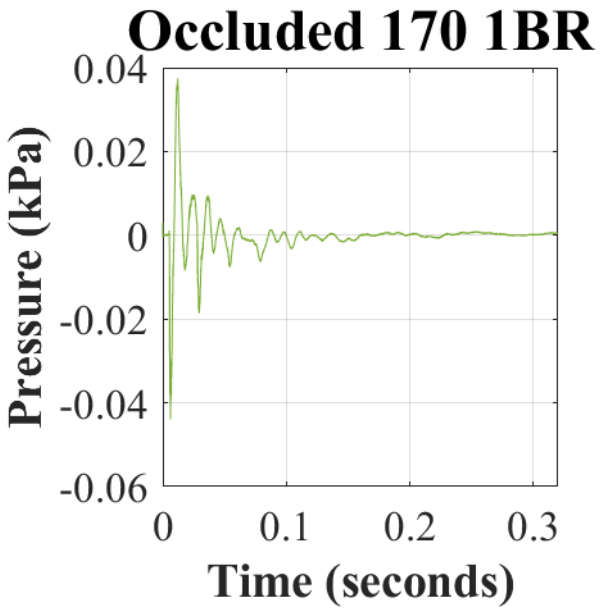
Note. The naming convention for all occluded waveforms is “Unoccluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the HPD doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B)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

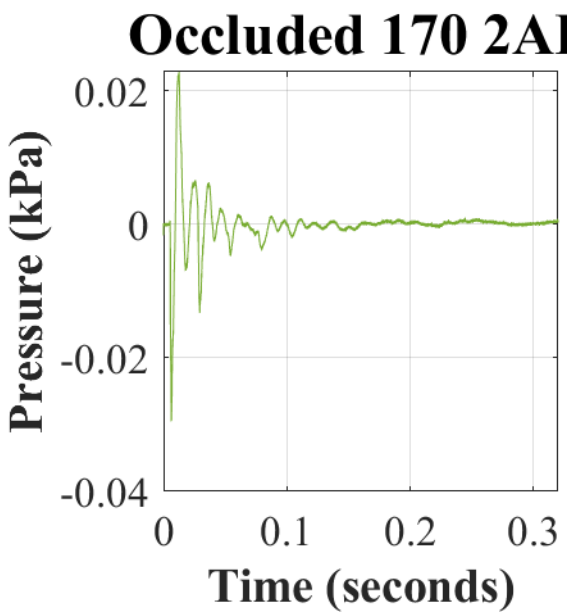
Appendix C. Recorded occluded (closed-ear) waveforms in response to 170 dBP with the Sound Guard™ Ear Plugs.

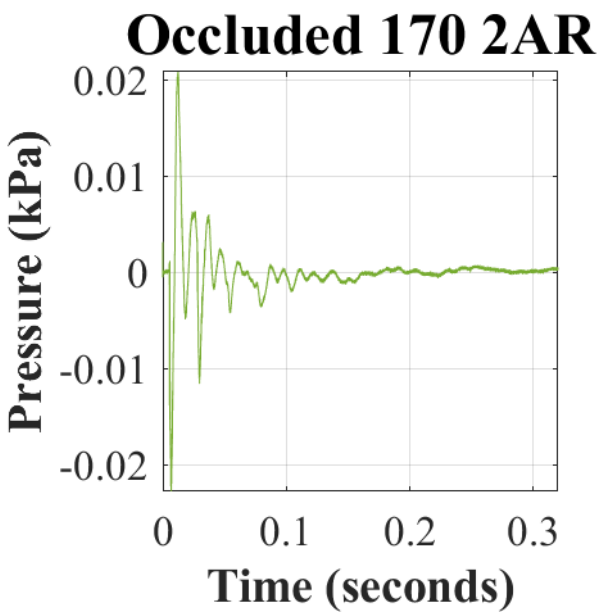


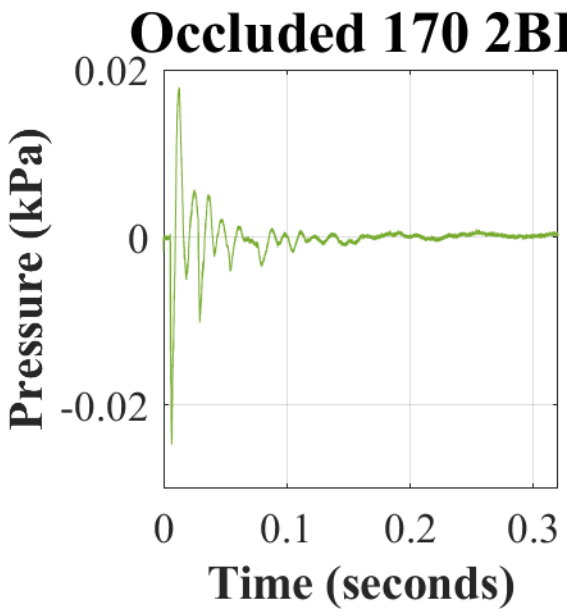


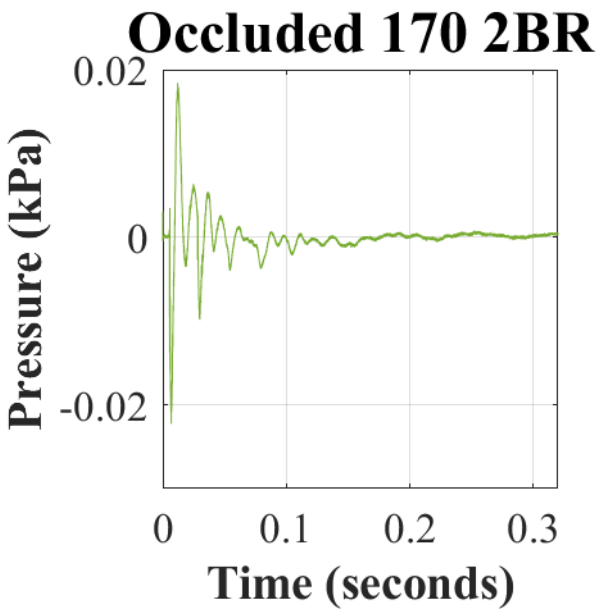


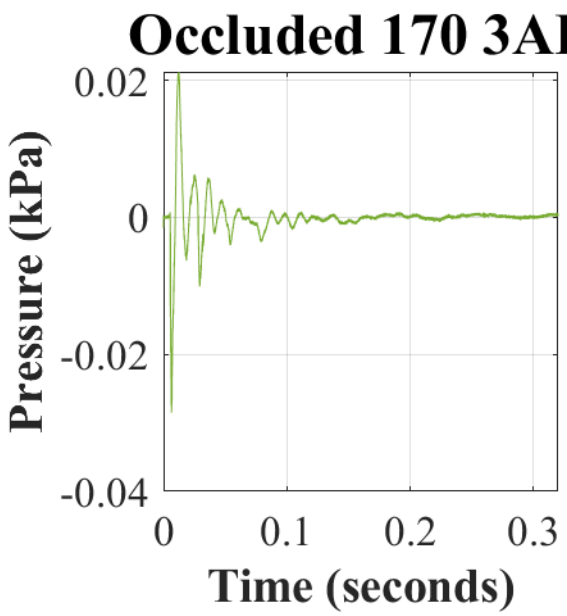


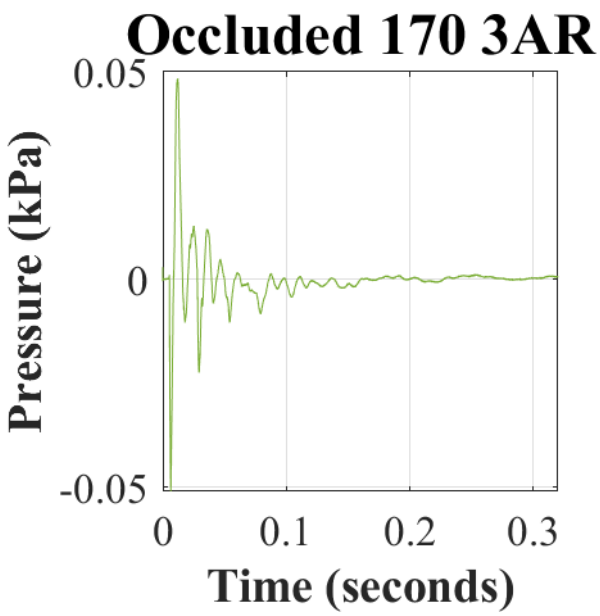

Occluded 170 2AL
Pressure (kPa)
0.02
0
-0.02
-0.04
0
0.1
0.2
0.3
Time (seconds)

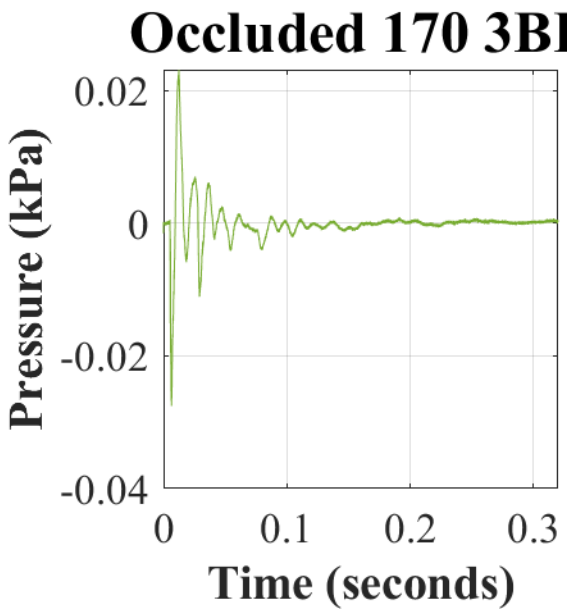

Occluded 170 2AR
Pressure (kPa)
0.02
0.01
0
-0.01
-0.02
0
0.1
0.2
0.3
Time (seconds)

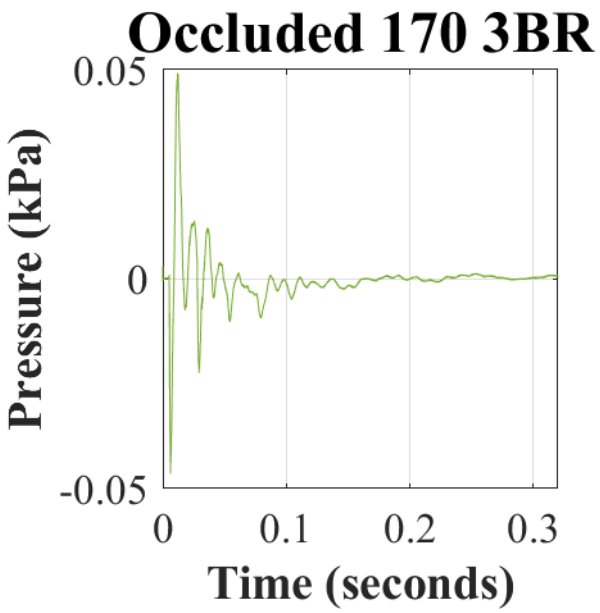

Occluded 170 2BL
Pressure (kPa)
0.02
0
-0.02
0
0.1
0.2
0.3
Time (seconds)

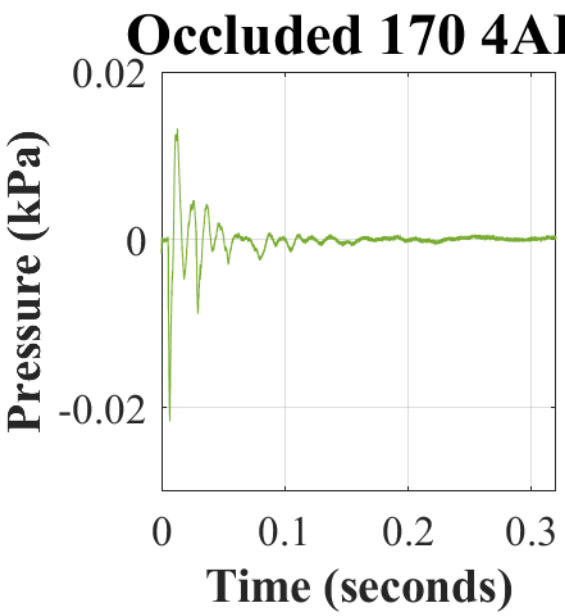

Occluded 170 2BR
Pressure (kPa)
0.02
0
-0.02
0
0.1
0.2
0.3
Time (seconds)

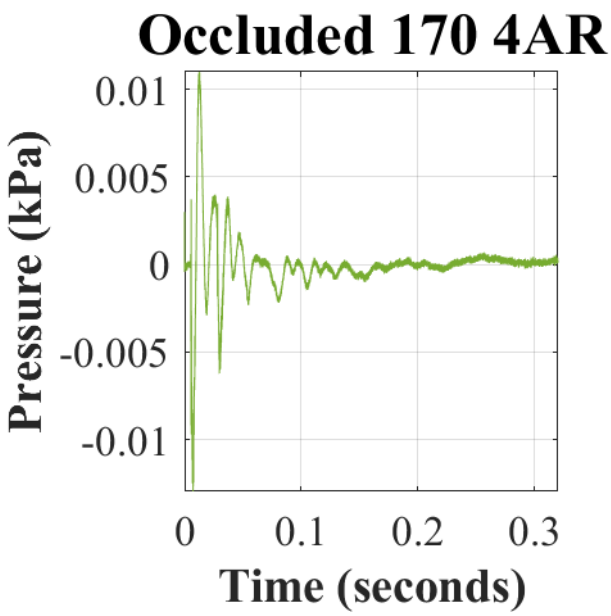

Occluded 170 3AL
Pressure (kPa)
0.02
0
-0.02
-0.04
0
0.1
0.2
0.3
Time (seconds)

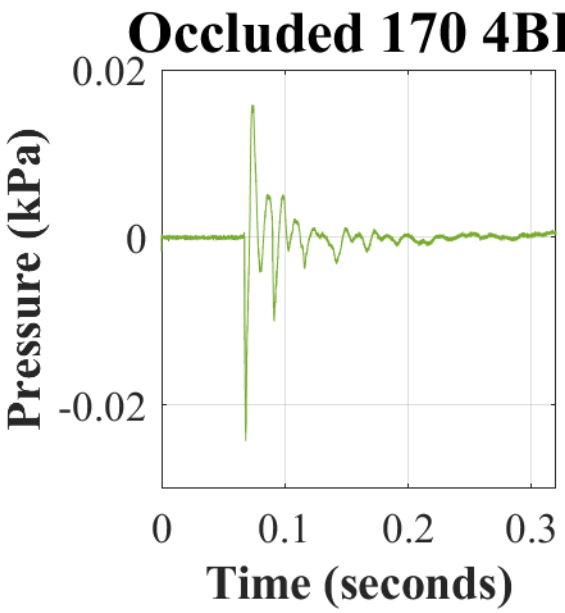

Occluded 170 3AR
Pressure (kPa)
0.05
0
-0.05
0
0.1
0.2
0.3
Time (seconds)

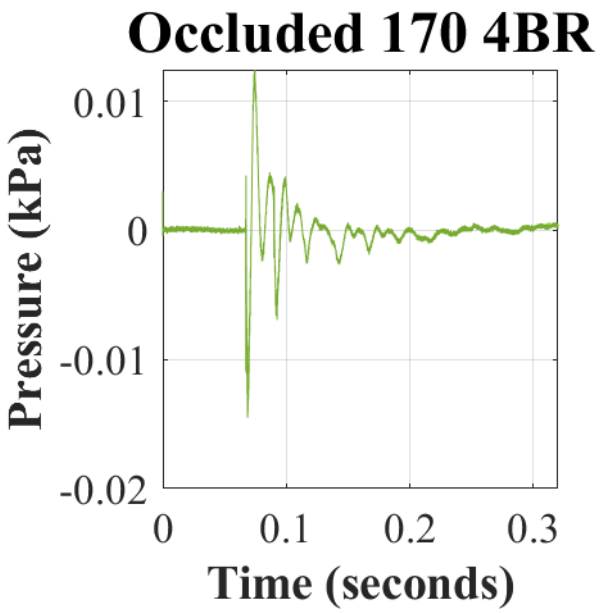

Occluded 170 3BL
Pressure (kPa)
0.02
0
-0.02
-0.04
0
0.1
0.2
0.3
Time (seconds)

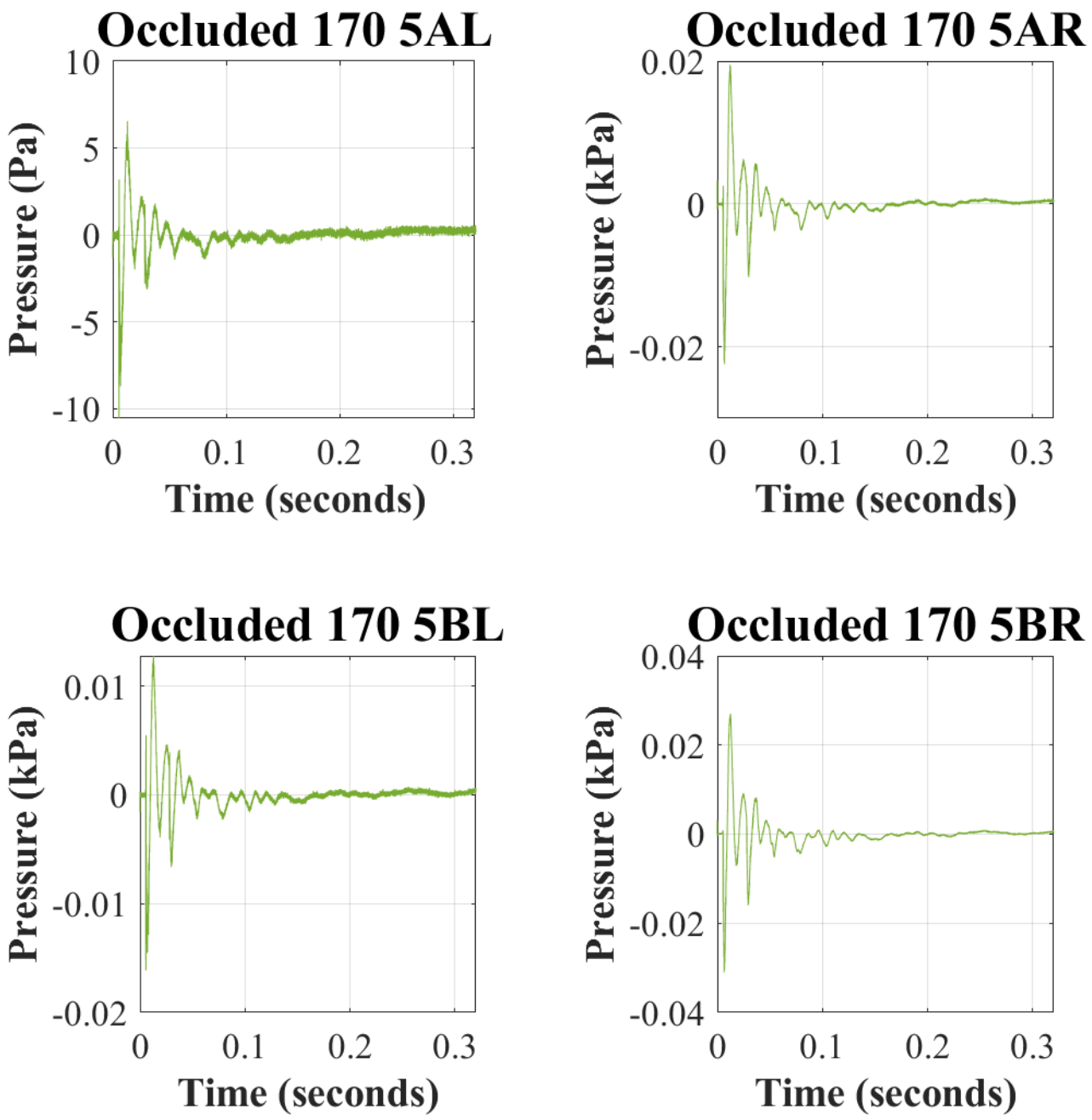

Occluded 170 3BR
Pressure (kPa)
0.05
0
-0.05
0
0.1
0.2
0.3
Time (seconds)


Occluded 170 4AL
Pressure (kPa)
0.02
0
-0.02
0
0.1
0.2
0.3
Time (seconds)


Occluded 170 4AR
Pressure (kPa)
0.01
0.005
0
-0.005
-0.01
0
0.1
0.2
0.3
Time (seconds)

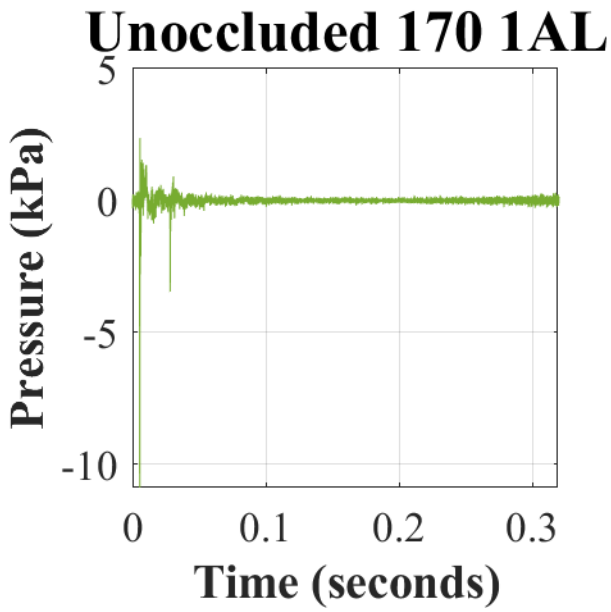

Occluded 170 4BL
Pressure (kPa)
0.02
0
-0.02
0
0.1
0.2
0.3
Time (seconds)

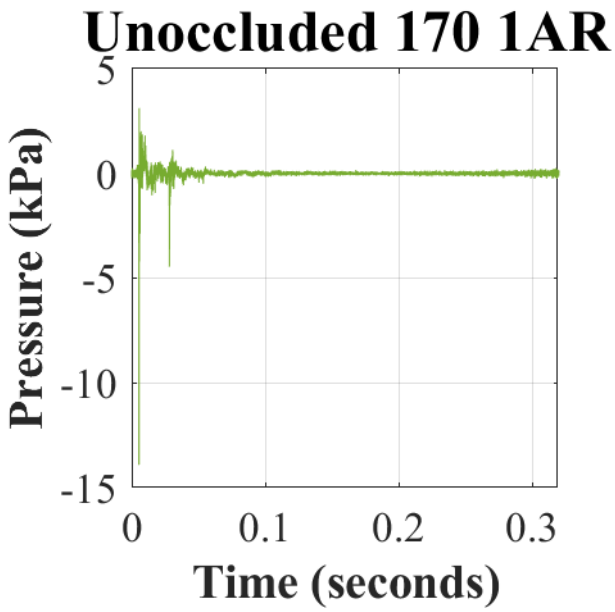

Occluded 170 4BR
Pressure (kPa)
0.01
0
-0.01
-0.02
0
0.1
0.2
0.3
Time (seconds)

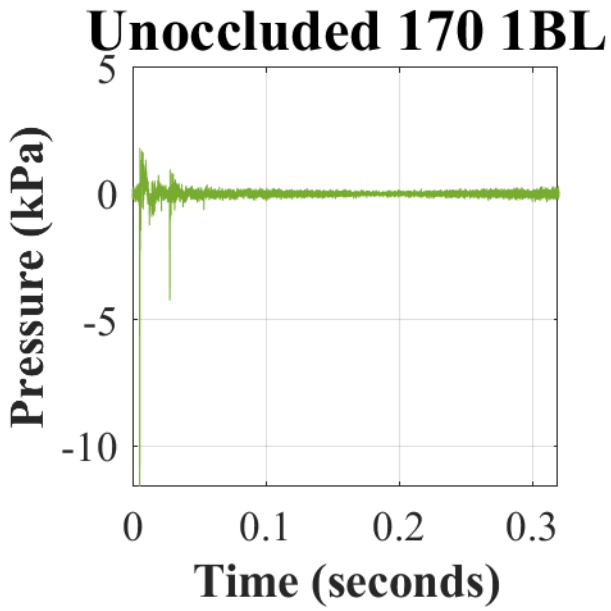


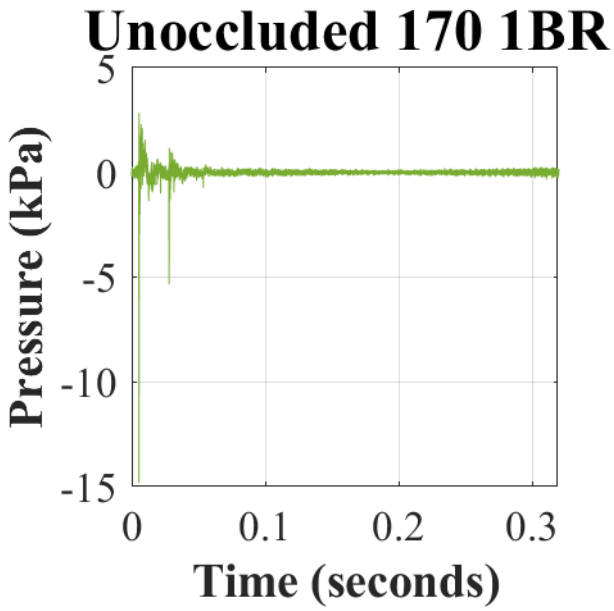
Note. The naming convention for all occluded waveforms is "Occluded LvL NnX", where 'Occluded' is the test condition (i.e., ATF has the HPD donned), 'LvL' is the nominal test level (i.e., 160 or 170 dBP), 'N' is the sample number (i.e., 1 to 5) of the device tested, 'n' is the trial (i.e., A or B) indicating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

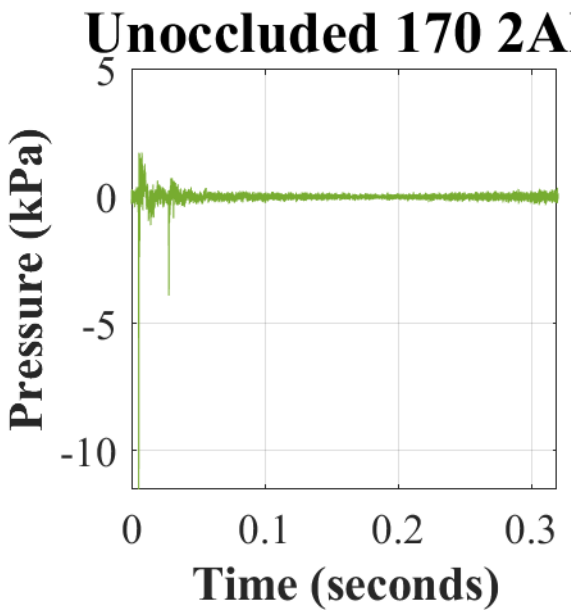
Appendix D. Estimated unoccluded (open-ear) waveforms in response to 170 dBP with the Sound Guard™ Ear Plugs.

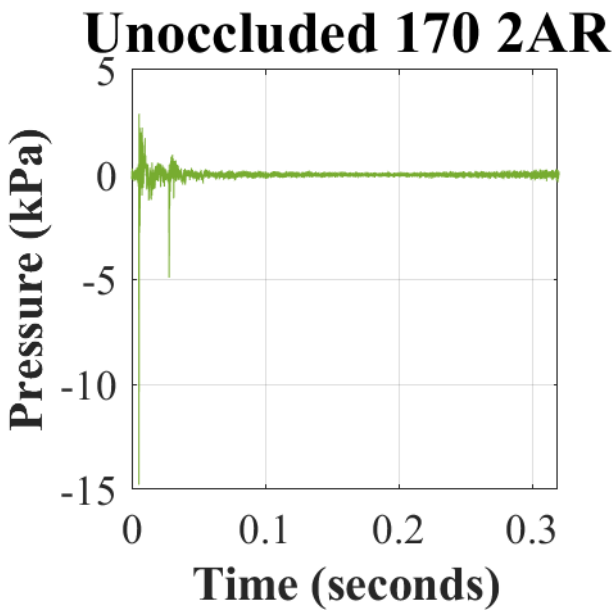


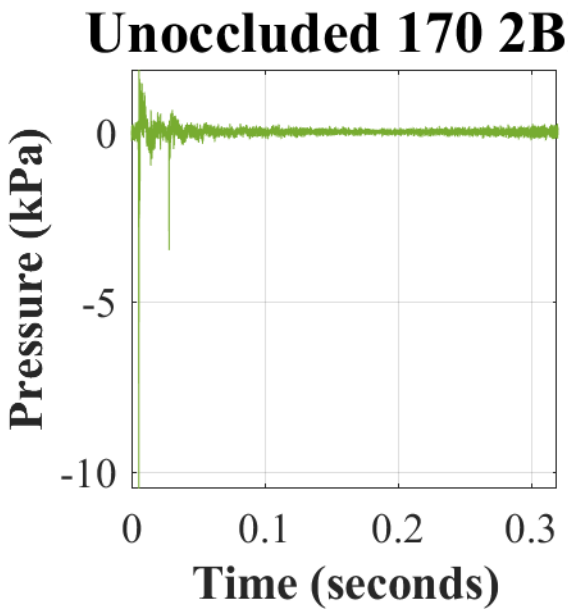


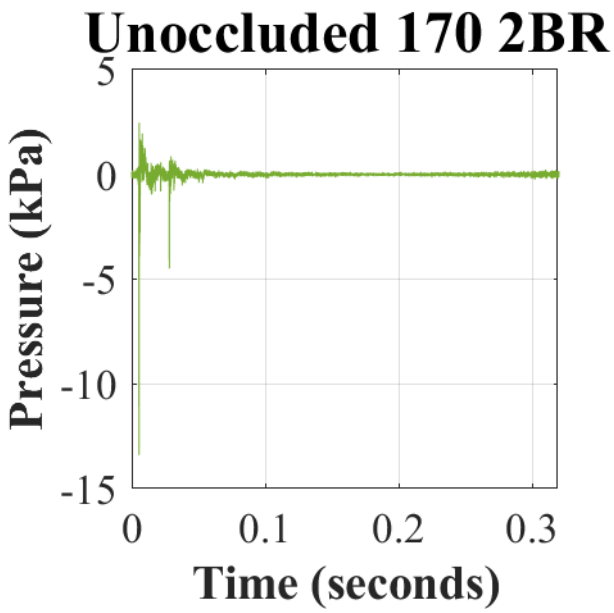


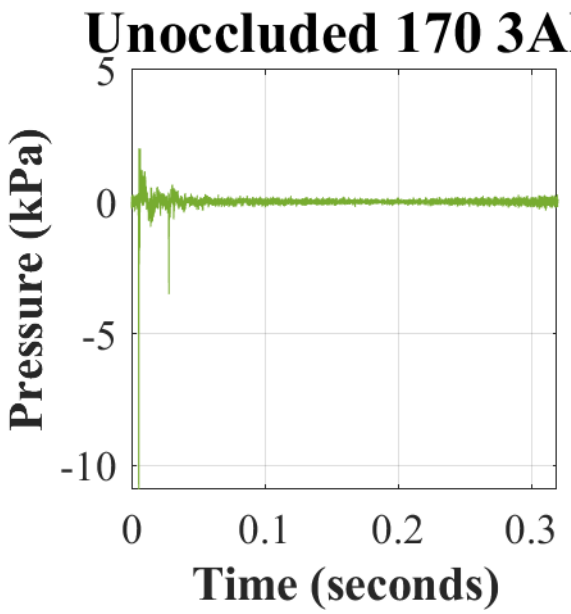


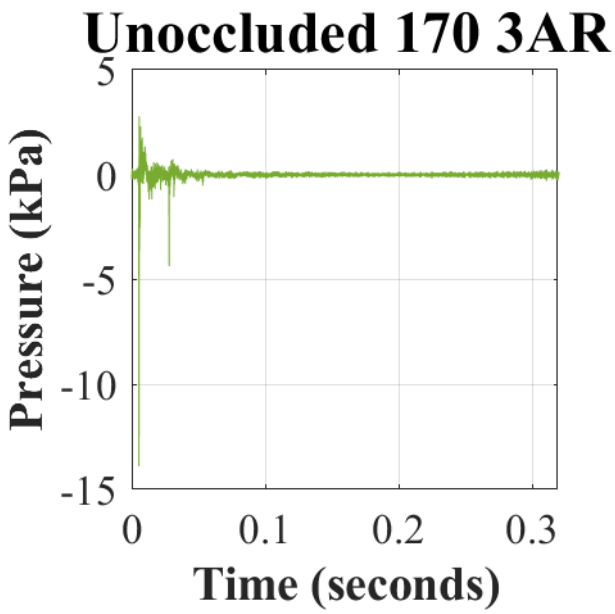

Unoccluded 170 2AL
Pressure (kPa)
5
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

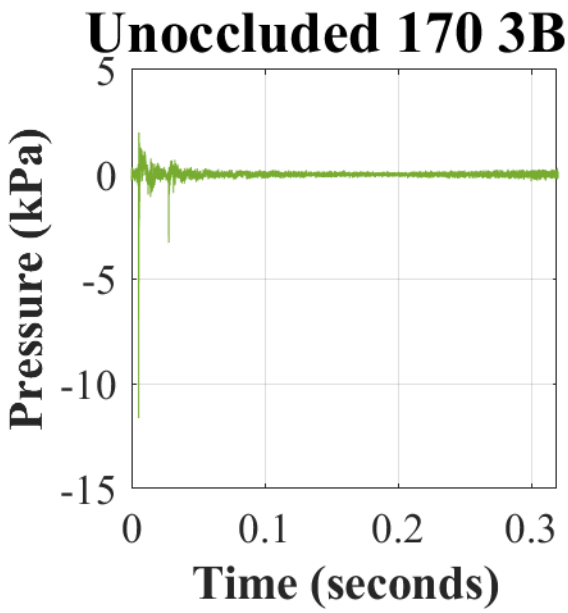

Unoccluded 170 2AR
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

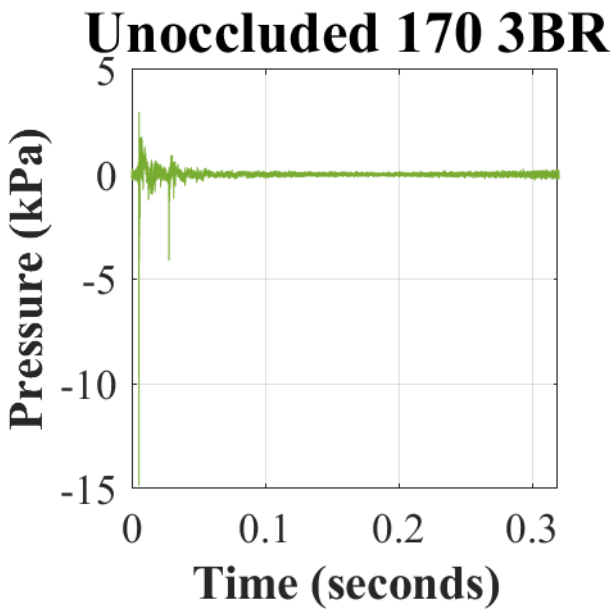

Unoccluded 170 2BL
Pressure (kPa)
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

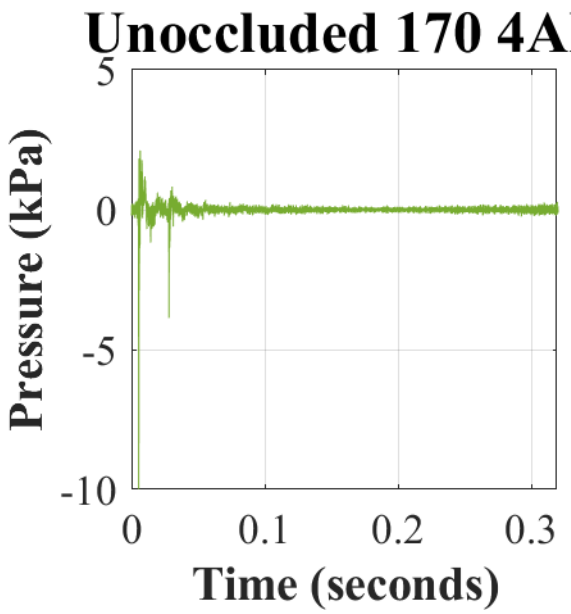

Unoccluded 170 2BR
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

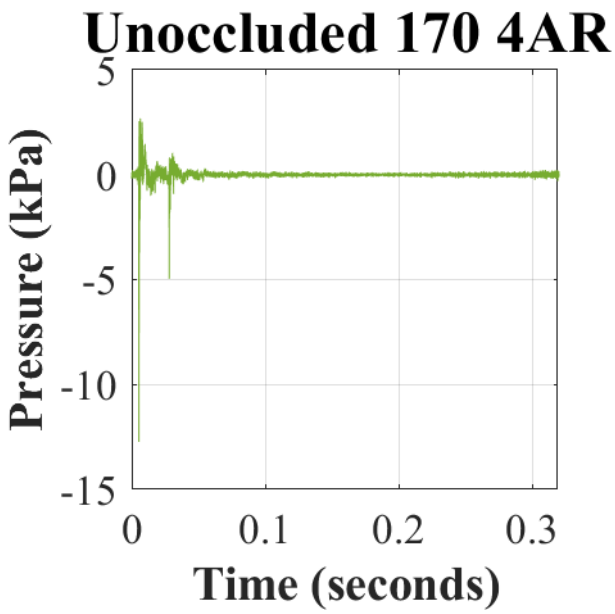

Unoccluded 170 3AL
Pressure (kPa)
5
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

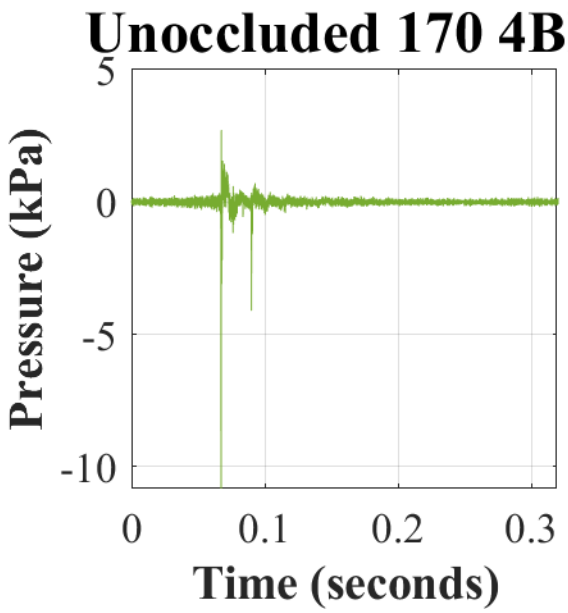

Unoccluded 170 3AR
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

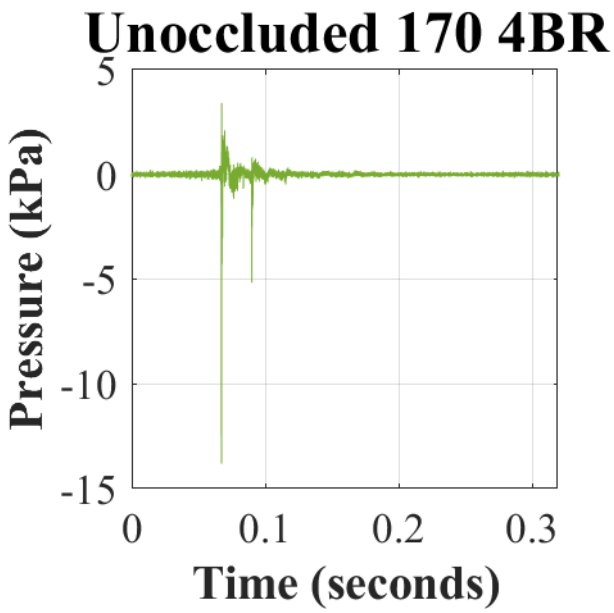

Unoccluded 170 3BL
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

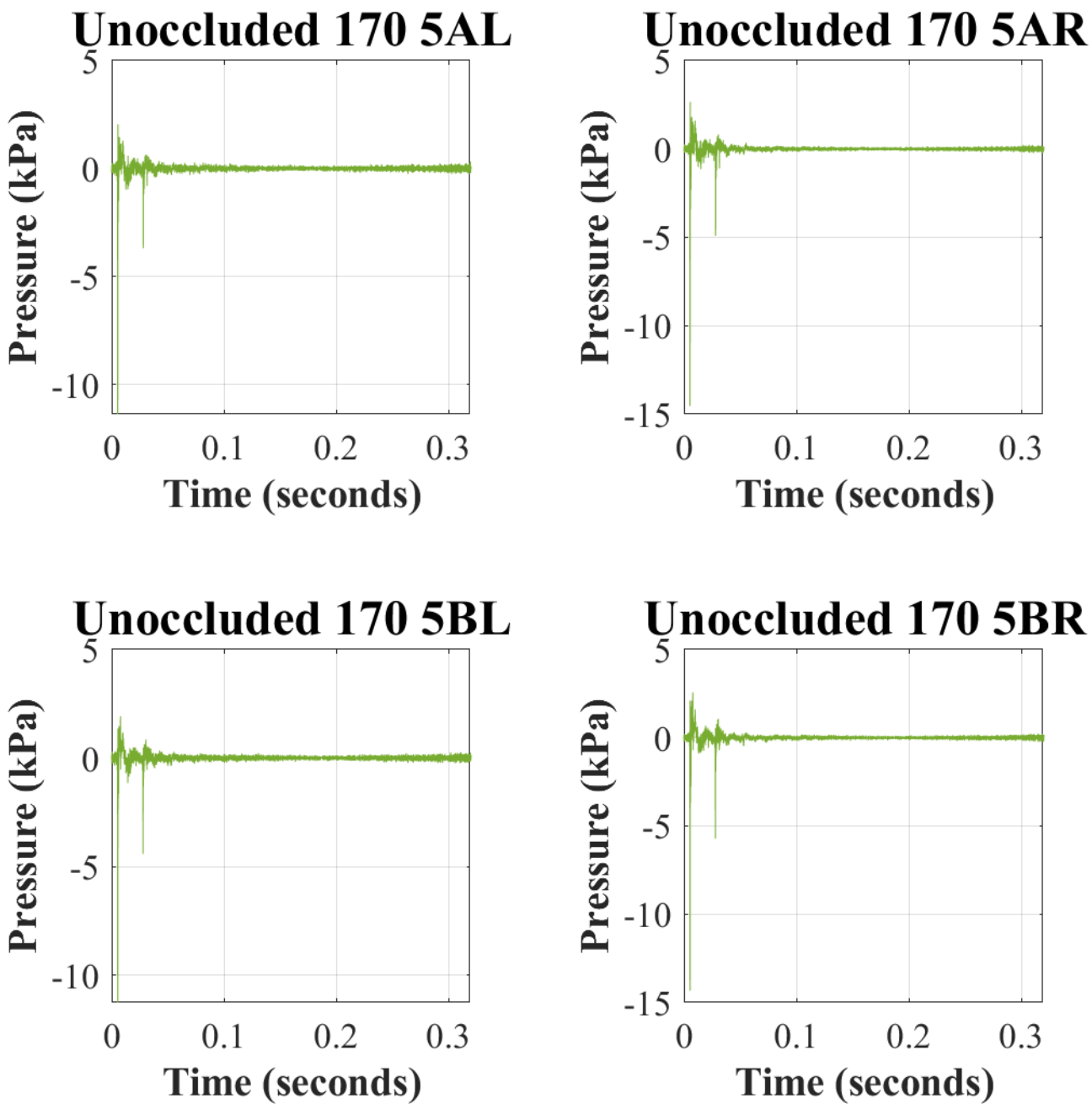

Unoccluded 170 3BR
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)


Unoccluded 170 4AL
Pressure (kPa)
5
0
-5
-10
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)

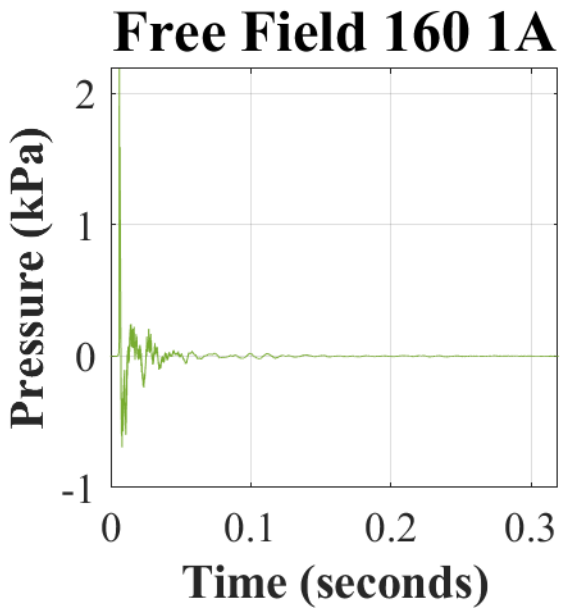

Unoccluded 170 4BL
Pressure (kPa)
5
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

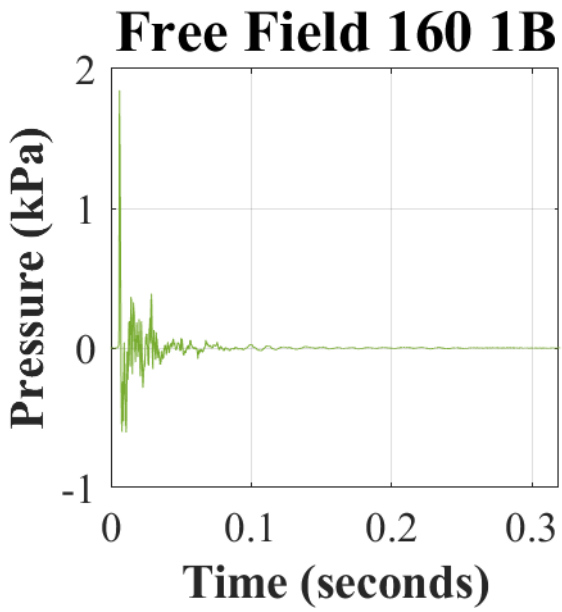

Unoccluded 170 4BR
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

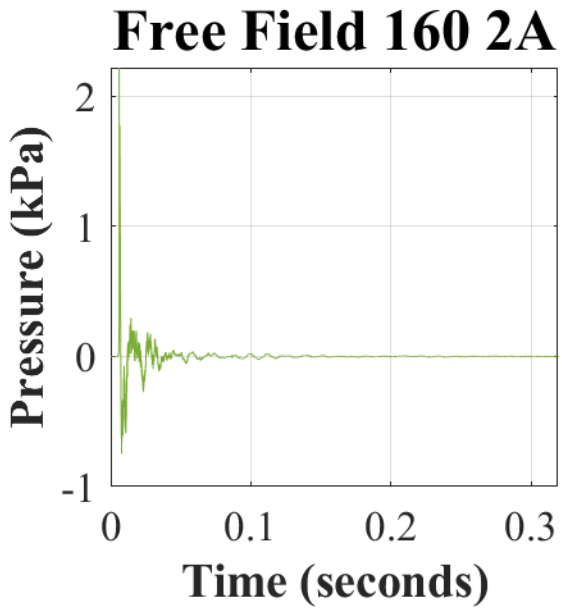


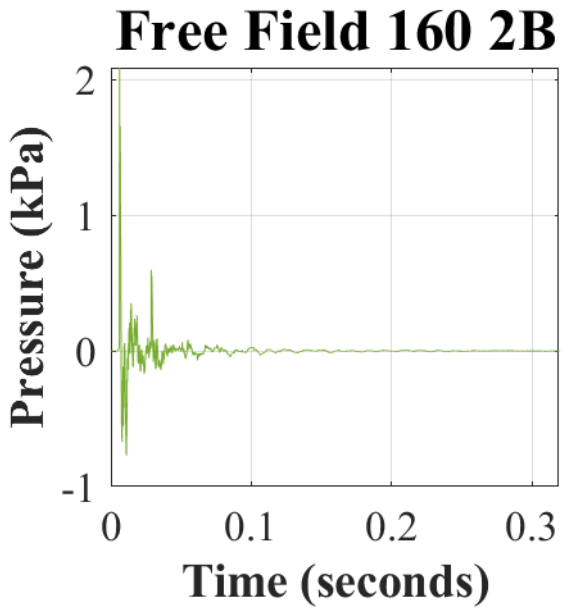
Note. The naming convention for all occluded waveforms is “Unoccluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the HPD doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B)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

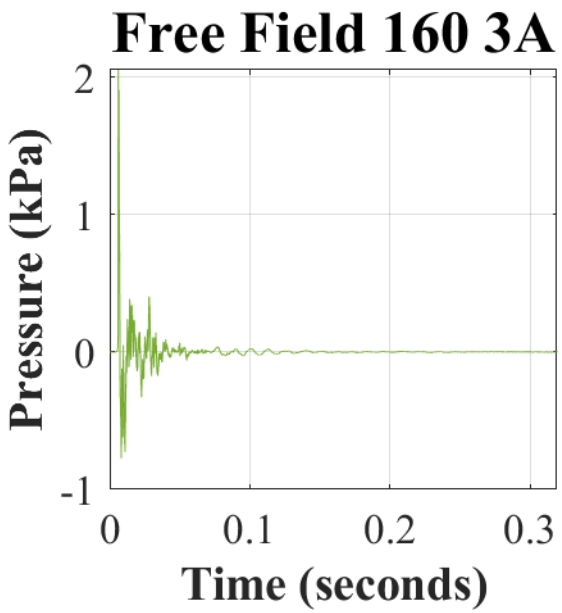
Appendix E. Recorded waveform of the impulse measured with the free-field probe at 160 dBP and the Sound Guard™ Ear Plugs donned.

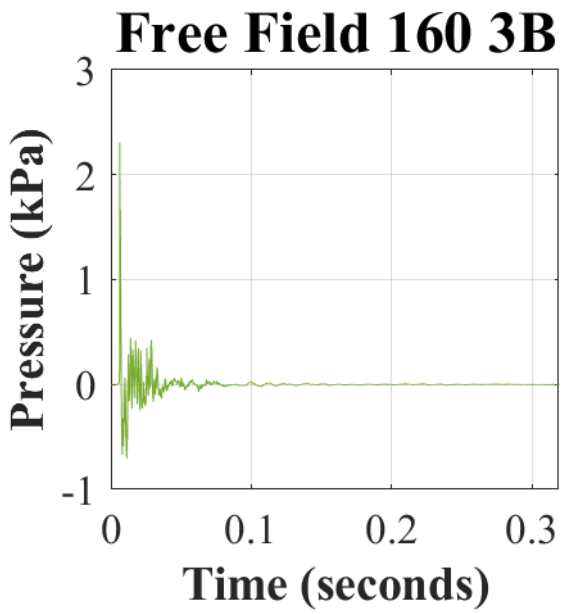


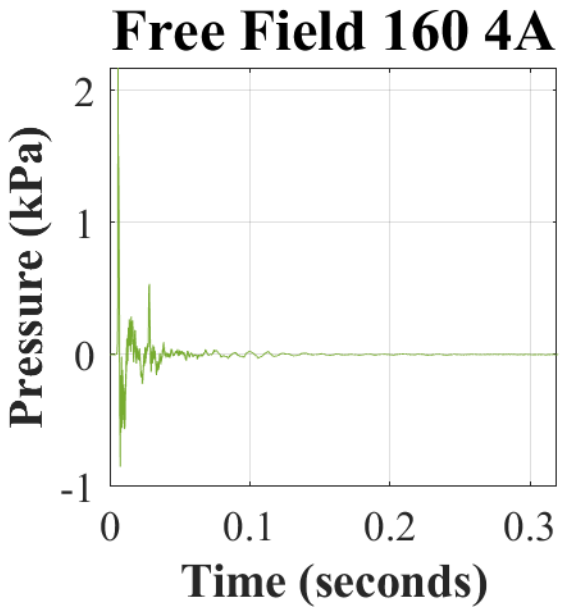


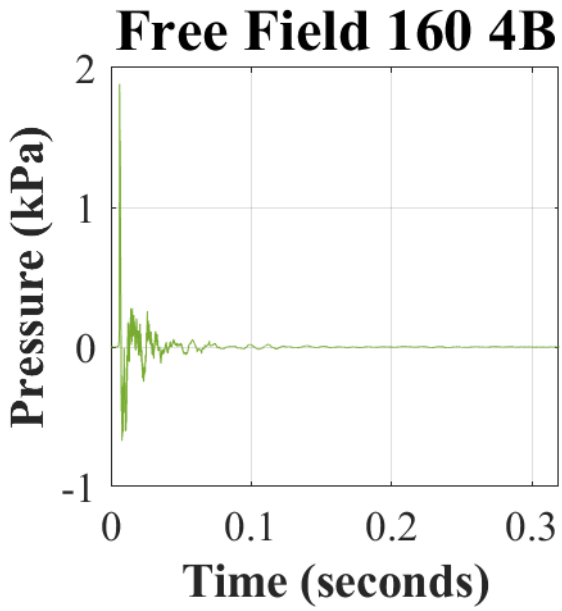


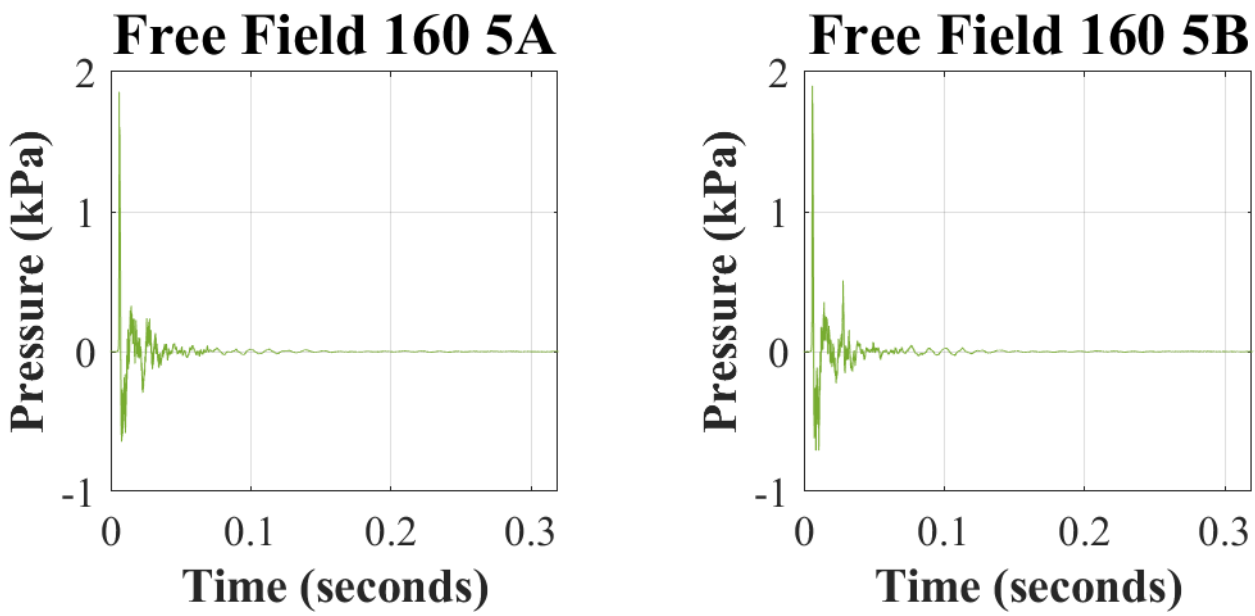



Free Field 160 3A
Pressure (kPa)
Time (seconds)
2
1
0
-1
0
0.1
0.2
0.3


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

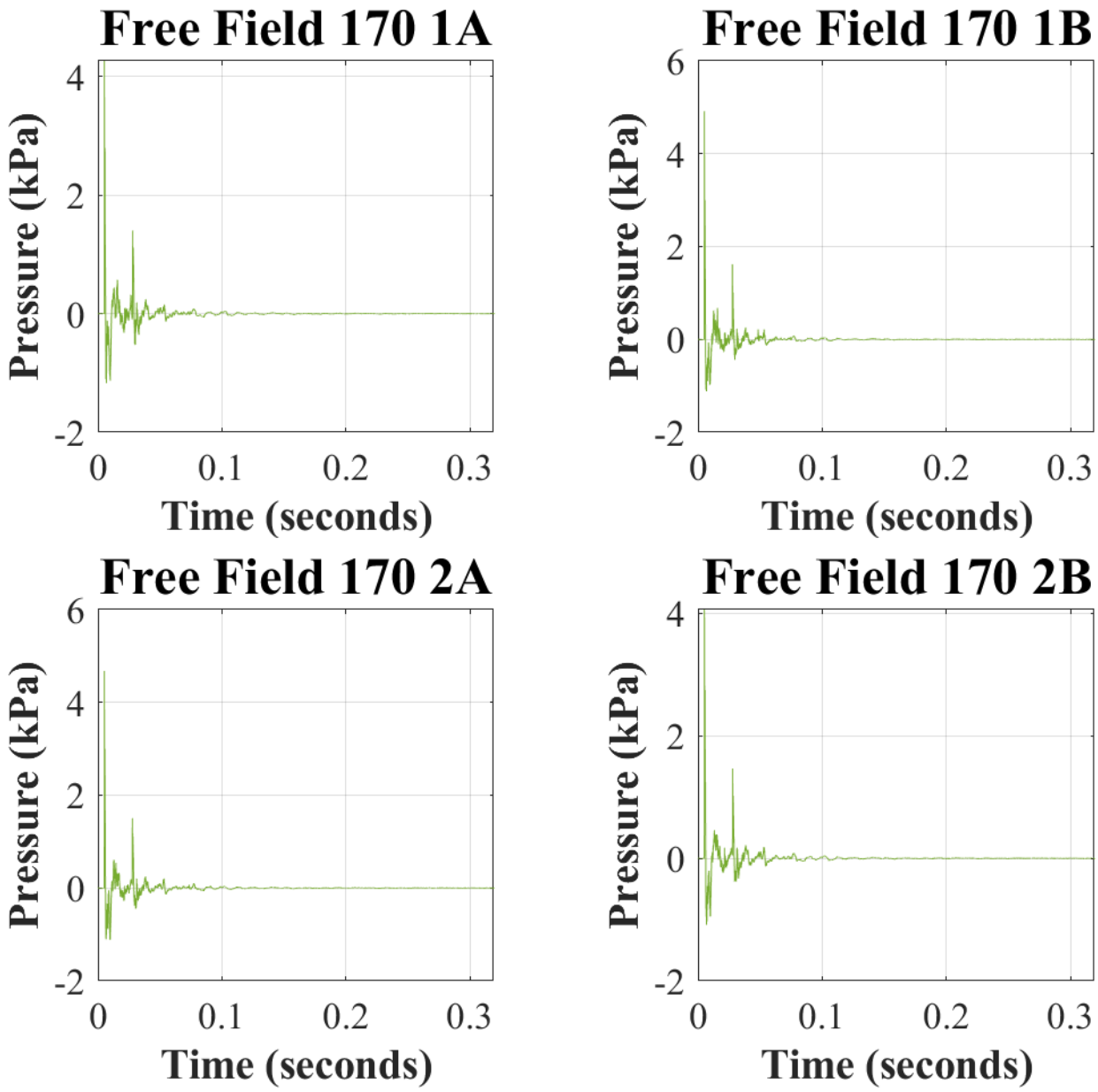

Free Field 160 4A
Pressure (kPa)
Time (seconds)
2
1
0
-1
0
0.1
0.2
0.3

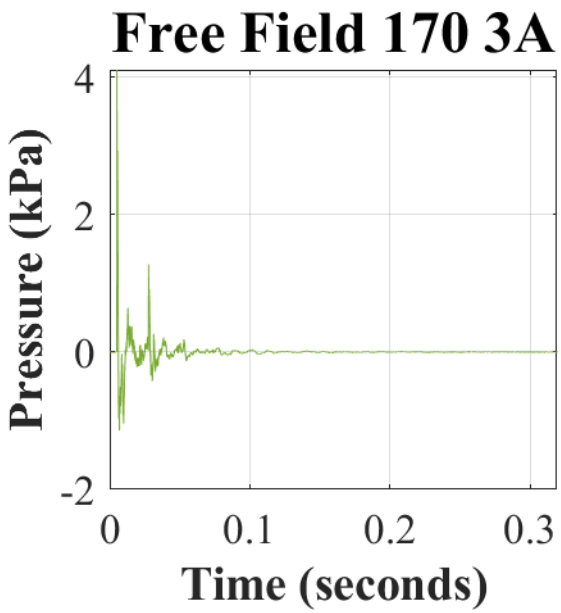

Free Field 160 4B
Pressure (kPa)
Time (seconds)
2
1
0
-1
0
0.1
0.2
0.3

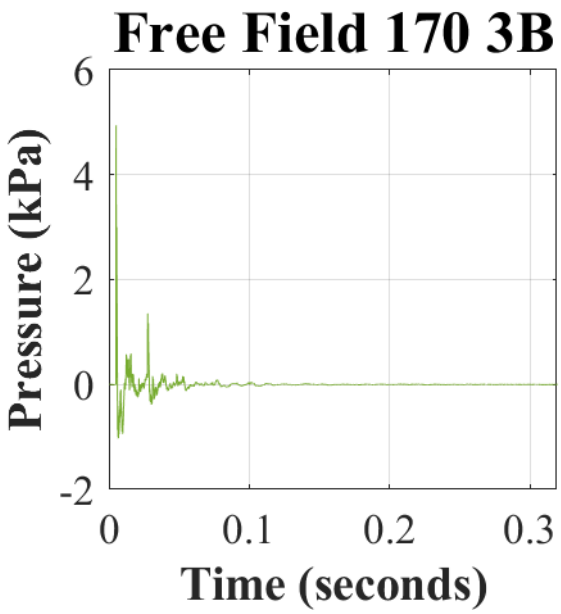


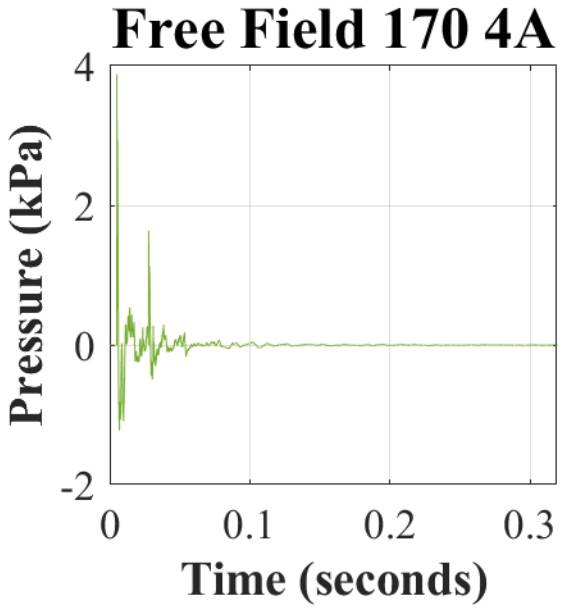
Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (170 dBP), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

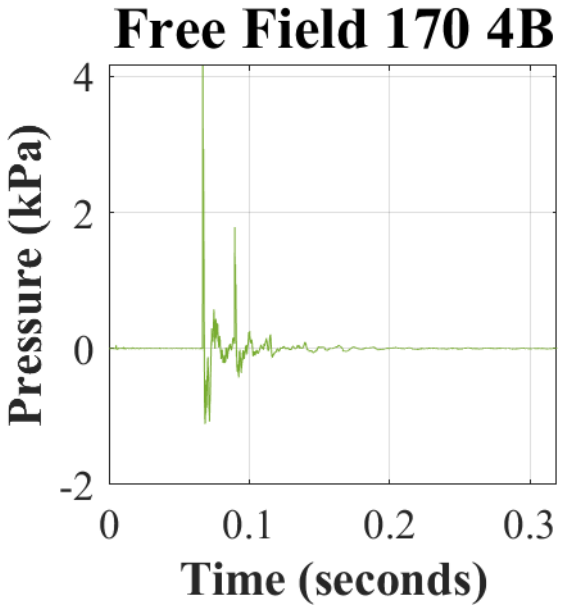
Appendix F. Recorded waveform of the impulse measured with the free-field probe at 170 dBP and the Sound Guard™ Ear Plugs donned.

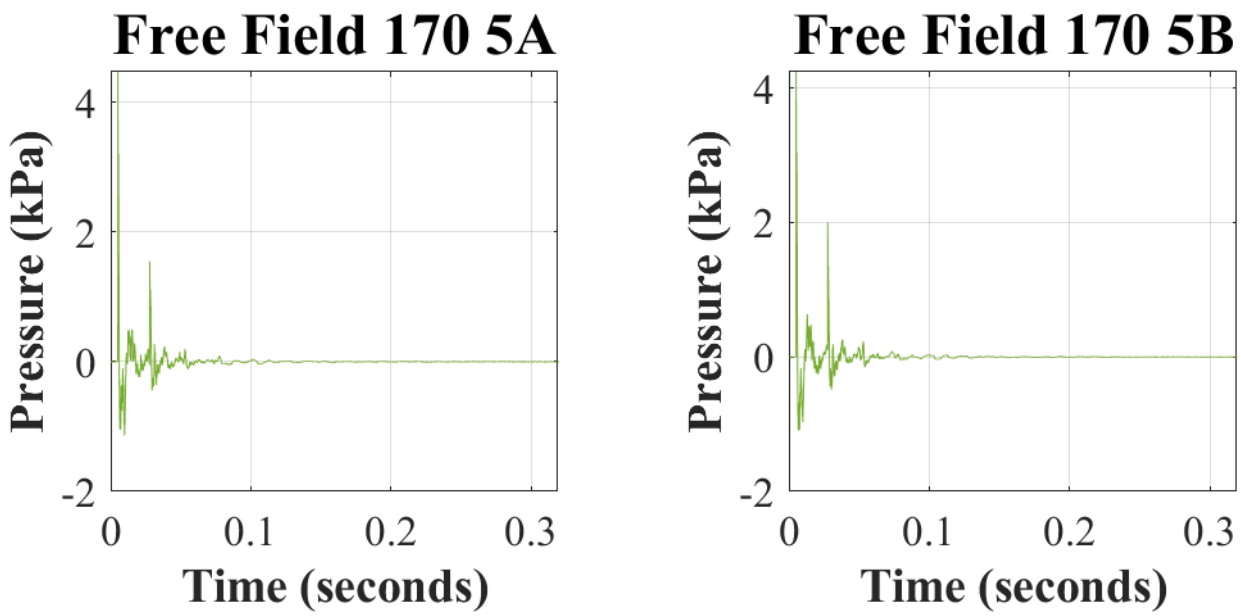



Free Field 170 3A
Pressure (kPa)
Time (seconds)
4
2
0
-2
0
0.1
0.2
0.3


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


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


Free Field 170 4B
Pressure (kPa)
Time (seconds)
4
2
0
-2
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).