

Naval Submarine Medical Research Laboratory

NSMRL/F1016/TM-2021--1352

September 22, 2021



Impulse Peak Insertion Loss Testing of the Elvex® Quattro™ EP-401 Reusable Earplug

Natalie Silvia, AuD ^{1,2}
Alexa H. Kolias, 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**

Approved for public release: distribution unlimited.

REPORT DOCUMENTATION PAGE

*Form Approved
OMB No. 0704-0188*

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to the Department of Defense, Executive Services and Communications Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.

1. REPORT DATE (DD-MM-YYYY)		2. REPORT TYPE		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE			5a. CONTRACT NUMBER		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S)			5d. PROJECT NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (Include area code)

[THIS PAGE INTENTIONALLY LEFT BLANK]

Impulse Peak Insertion Loss Testing of the Elvex® Quattro™ EP-401 Reusable Earplug

Natalie Silvia, AuD ^{1,2}
Alexa H. Kolias, AuD ^{1,2}
Derek W. Schwaller, BS ¹
Stephanie 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:

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. 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.

Approved for public release: distribution unlimited.

[THIS PAGE INTENTIONALLY LEFT BLANK]

CONTENTS

EXECUTIVE SUMMARY	1
INTRODUCTION.....	2
METHODS	2
RESULTS	5
DISCUSSION	6
CONCLUSIONS.....	7
REFERENCES.....	8
APPENDIX A.....	9
APPENDIX B	14
APPENDIX C	19
APPENDIX D.....	24
APPENDIX E	29
APPENDIX F.....	32
APPENDIX G.....	35
APPENDIX H.....	40
APPENDIX I	45
APPENDIX J	50
APPENDIX K.....	55
APPENDIX L	58

Executive Summary

The impulse peak insertion loss (IPIL) is the standard measure of attenuation provided by hearing protection devices (HPDs) in response to an impulsive noise. This technical memorandum describes the IPIL testing conducted on the Elvex® Quattro™ EP-401 Reusable Earplug (Quattro™; Model: EP-401). Testing was done 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”. Rather than testing at the nominal test levels specified by ANSI S12.42-2010 (i.e., 130, 150, and 170 decibel peak (dB_P, re: 20 μPa)), all samples were tested at the nominal levels of 160 and 170 dB_P, as these higher levels are more representative of military occupation impulse noise exposures. 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 were rejected. The mean and standard deviation (SD) IPIL values for each nominal level were 36.8 (1.9) dB at 160 dB_P and 36.9 (1.6) dB at 170 dB_P (see Table 1). Calculated overall mean IPIL values exceeded the Quattro™ manufacturer reported noise reduction rating (NRR) for continuous noise (i.e., 27 dB).

Table 1.

Quattro™ mean (SD) IPIL value (in dB) for all test conditions.

160 dB_P	170 dB_P
36.8 (1.9)	36.9 (1.6)

Introduction

The Elvex[®] Quattro[™] EP-401 Reusable Earplug (Quattro[™]; DeltaPlus Corporation, Shelton, CT) is an uncorded, universal sized four flange earplug made with non-allergenic polymer material. Per manufacturer documentation, the design and material composing this passive earplug allow for maximum comfort and resistance of cerumen and oils in order to outlast comparable polyvinyl chloride (PVC) plugs (DeltaPlus Corporation, n.d.). The Quattro[™] can be cleaned and reused multiple times over a span of weeks without compromising effective attenuation.

This technical memorandum details the procedures followed to determine the impulse peak insertion loss (IPIL) value for the uncorded Quattro[™] earplug. In addition to reporting an overall device IPIL, ear-specific IPILs are reported for the tested nominal levels.

Methods

Facility & Personnel

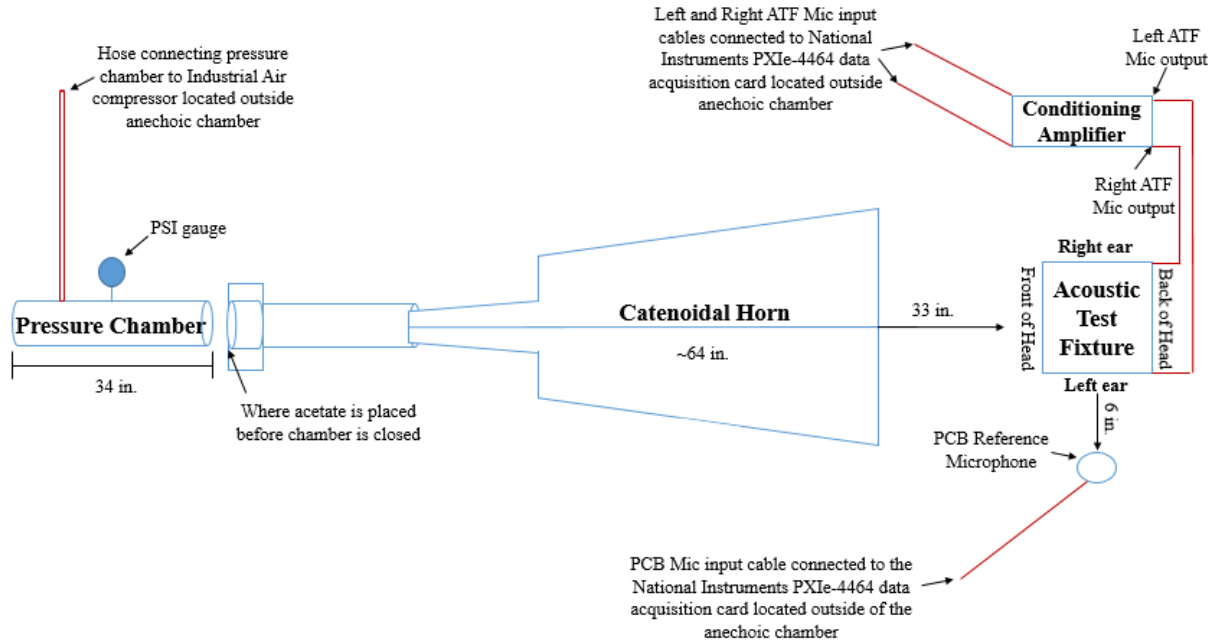
IPIL testing described herein was completed in the Naval Submarine Medical Research Laboratory (NSMRL) 1000 m³ anechoic chamber in order to minimize any effects of sound reflections.

Equipment

Hardware. Acoustic impulses were generated by NSMRL's 4-inch shock tube (B/C Precision, Inc., Greendale, IN). The shock tube pressure chamber is approximately 34 inches (in.) long, with an inner diameter of 4.0 in. A 64-inch-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. 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. by 7 in., 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 2 millimeters (mil.) thick.

The acoustic test fixture (ATF) used (GRAS 45CB; GRAS Sound and Vibration, Twinsburg, OH) for all data acquisition was set up in accordance with (IAW) ANSI/ASA 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". The ATF was connected to a conditioning amplifier which also served as the power supply (GRAS Type 12AA; GRAS Sound and Vibration, Twinsburg, OH). A reference microphone (Type 378C20; PCB Piezotronics Inc., Depew, NY) was placed 6 in. 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 Hz tone. A diagram depicting the aerial view of the NSMRL shock tube and test system can be seen in Figure 1.

Figure 1.
Diagram of the NSMRL Acoustic Shock Tube and ATF.

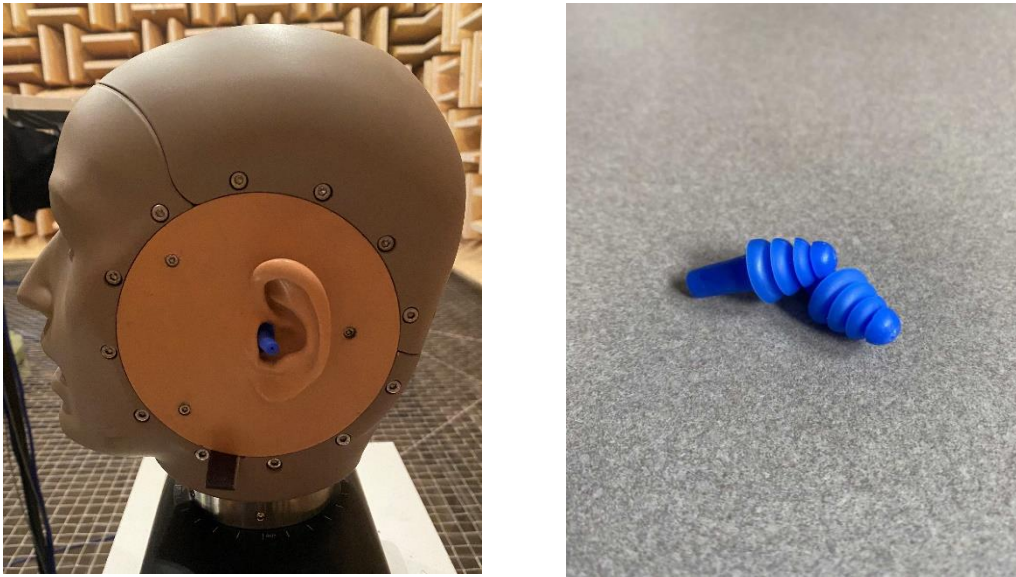


Data Acquisition System. The data acquisition system (NI chassis PXIe-1071 with NI PXIe-4460 and NI PXIe-4464; National Instruments Corp., Austin, TX) was controlled by a standalone laptop computer running project specific software (LabVIEW; National Instruments Corp., Austin, TX). The data acquisition 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 0.01 seconds, with a trigger level of 110 dB SPL. Each recording was 0.3 seconds in duration. Deviating from ANSI/ASA S12.42-2010, an electronic anti-aliasing filter (corner frequency of 93.0 kHz [3 dB down]) was applied to all waveforms by the data acquisition system during data collection instead of an analog filter.

The custom-written software program saved all recorded waveforms as files (.tdms), which were exported from the software for conversion into 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). The revised script processed and outputted all IPIL values reported herein, along with generating the closed-ear, open-ear, and free-field waveform plots (See Appendices A-F).

Hearing Protection Device Samples. Five samples of the Quattro™ uncorded reusable earplugs (Manufacturer Product Number: EP-401) 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.
Elvex® Quattro™ EP-401 Reusable Earplugs.



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 dB). No samples were rejected. To achieve an appropriate fit that would provide maximum attenuation, each sample was expertly fitted to the ATF IAW instructions on the device packaging. The manufacturer fitting guidelines stated that all samples be inspected for any wear, cracks, or damage prior to use. Once inspected, the earplug was inserted into the ear canal with a slight rocking and twisting motion until all flanges entered the ear canal. Once inserted, appropriate fit of each earplug was confirmed by pulling gently on the earplug to confirm it did not easily come out of the canal.

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 or 170 nominal level impulses using the NSMRL acoustic shock tube (160 range: 19.5 to 22.1 psi, 170 range: 28.5 to 29.5 psi).

The acetate was then punctured, 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 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.

A Butterworth filter (6th order, low-pass, corner frequency of 20 kHz [3 dB down]) was applied to all waveforms post-data collection by a programming software script (MATLAB, Natick, MA) post-processing.

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 zero 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.

Results

The overall mean IPIL values at the 160 dBp nominal level and the 170 dBp nominal level were found to be within 0.1 dB. As shown in Table 2, the overall mean IPIL value at the 160 dBp test condition was found to be 36.8 dB and at the 170 test condition 36.9 dB. Calculated IPIL values for all individual sample trials ranged between 32.2 and 39.6 dB at 160 dBp and between 34.7 and 39.4 dB at 170 dBp. Also presented in Table 2 are the individual attenuations for each sample, the ear-specific means and standard deviations (SD) across all samples and trials, and the overall means

and SD across all samples, trials, and ears. The waveforms for all trials with the uncorrelated Quattro™ are provided in Appendices A to F.

Table 2.

Mean (SD) IPIL values (in dB) for Tested Quattro™ Samples.

	160 dBP		170 dBP	
	<i>Right</i>	<i>Left</i>	<i>Right</i>	<i>Left</i>
HPD 1, Trial A	37.3	35.4	35.6	37.7
HPD 1, Trial B	37.8	36.3	36.2	38.0
HPD 2, Trial A	38.1	35.7	36.5	36.8
HPD 2, Trial B	32.2	35.5	39.4	40.0
HPD 3, Trial A	39.1	36.7	34.8	36.4
HPD 3, Trial B	37.9	39.6	39.3	34.9
HPD 4, Trial A	38.9	35.6	36.5	36.7
HPD 4, Trial B	39.4	34.9	35.6	35.3
HPD 5, Trial A	37.7	34.9	39.0	34.7
HPD 5, Trial B	37.2	35.4	37.8	36.5
Ear Specific Mean (SD)	37.6 (2.0)	36.0 (1.4)	37.1 (1.7)	36.7 (1.6)
Level Overall Mean (SD)	36.8 (1.9)		36.9 (1.6)	

Discussion

The aim of this report was to document the measured attenuation provided by the Quattro™ to loud impulsive noises IAW ANSI S12.42-2010, which requires the impulse noise to be generated and directed to the front of the ATF at 0° elevation and 0° azimuth. All calculated overall mean IPIL values were found to exceed the Quattro™ manufacturer reported noise reduction rating (NRR) for continuous noise (i.e., 27 dB). Across ears, the individual trial mean IPIL values were found to vary as much as 7.4 dB at 160 dBP and 4.7 dB at 170 dBP. This may be due to a combination of inherent variance within the impulse system and test-retest variability. Results indicate that while the overall mean IPIL values were within 0.1 dB of each other, a greater variety of attenuation was present in the individual trials at the 160 dBP level compared to 170 dBP. This is noted with a larger SD at the 160 dBP (1.9 dB) nominal level compared to that at the 170 dBP (1.6 dB) nominal level.

In the current effort, deviations were made from the ANSI/ASA S12.42-2010 standard governing impulse noise testing due to equipment and software limitations. First, rather than using an in-line analog external Bessel filter (6th order, corner frequency 20.0 kHz [3 dB down]) to filter impulses during data acquisition, anti-alias filtering was accomplished by an analog filter and a digital filter. The analog filter was an anti-aliasing filter (corner frequency of 93.0 kHz [3 dB down]) applied to all waveforms by the National Instruments data acquisition hardware during data acquisition. The digital filter was a Butterworth filter (6th order, low-pass, corner

frequency of 20 kHz [3 dB down]) applied by the MATLAB post-processing script. This filter was used to mimic the effect of the ANSI/ASA S12.42-2010 standard required anti-aliasing Bessel filter.

Second, testing at the 130 dB and 150 dB nominal levels was omitted. The decision to exclude these test levels was the result of a prior analysis of impulse waveforms (unrelated to this report) generated at those levels with the NSMRL shock tube that resulted in signals without a shock front. In addition, impulse noise levels that are commonly observed in military occupational environments regularly exceed 150 dB resulting in test results at such levels of limited value for military application. At the measured levels described herein, all generated impulses had a shock front. Inclusion of the 160 dB nominal level was beneficial, as data at 160 and 170 dB provided a more representative indication of device performance at military- relevant impulse noise levels. It is important to note that these results do not guarantee similar Quattro™ product performance across all users and environments. Product performance may be impacted by factors including variability in physical fit of the device and HPD configuration (i.e., double- or triple- configuration with combat helmet, earmuffs, eye wear, etc.).

Conclusions

This report described the determination of the mean impulse peak insertion loss (IPIL) values provided by the Quattro™ earplug at 160 dB and 170 dB nominal levels. Results revealed mean IPIL values within 0.1 dB at the 160 dB and 170 dB nominal levels, with a greater standard deviation observed at 160 dB. As shown in Table 3, the overall calculated mean (SD) IPIL values for the Quattro™ at 160 dB was 36.8 (1.9) dB and at 170 dB was 36.9 (1.6) dB.

Table 3.

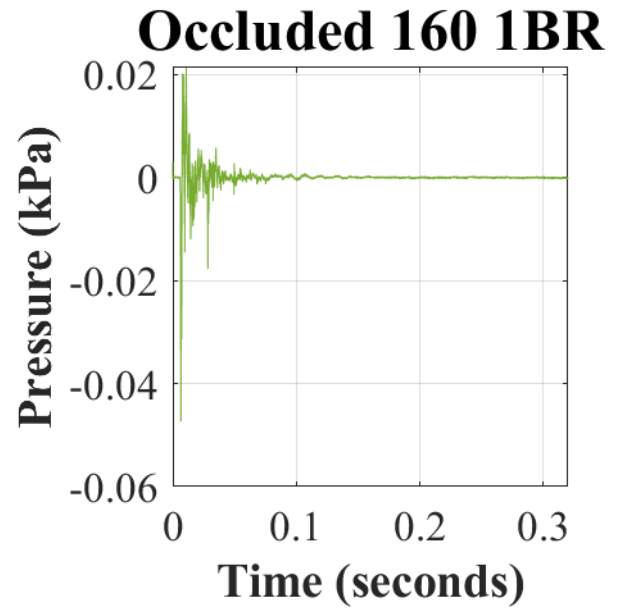
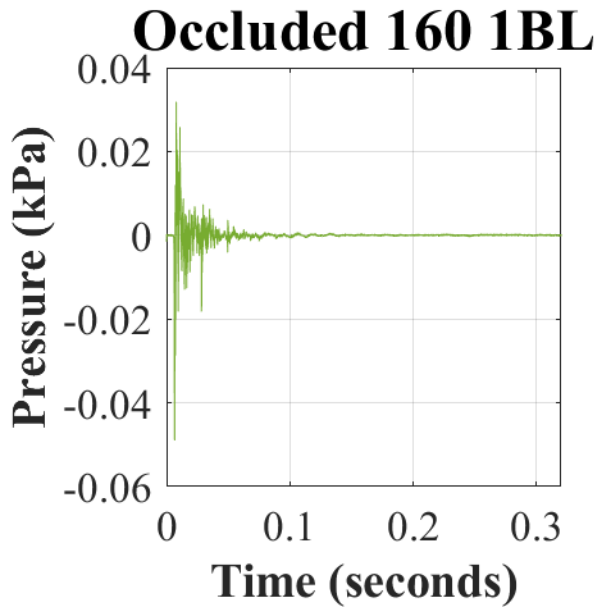
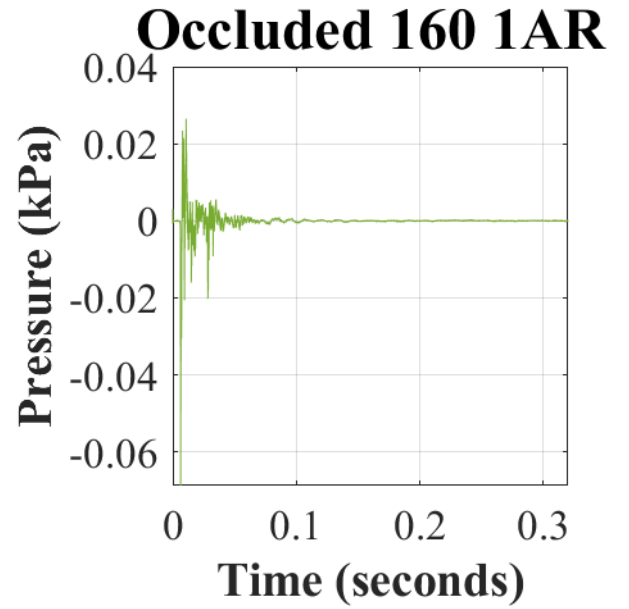
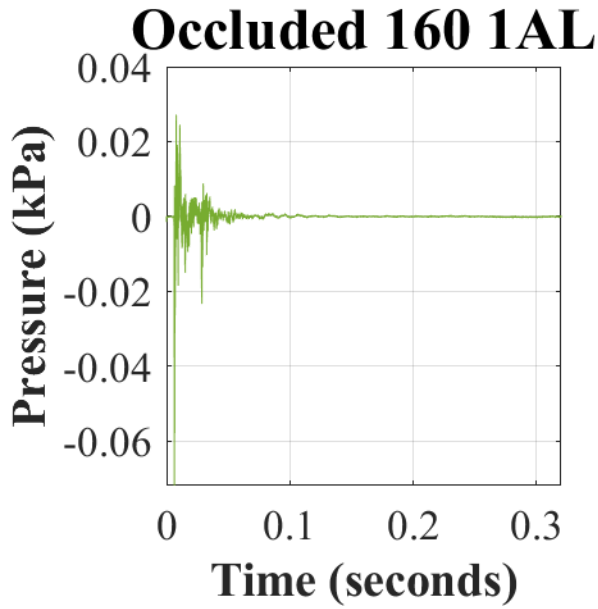
Quattro™ mean (SD) IPIL value (in dB) for all test conditions.

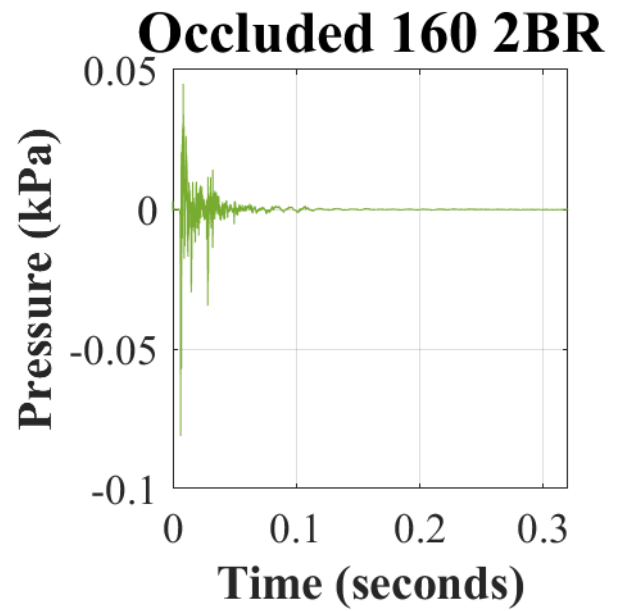
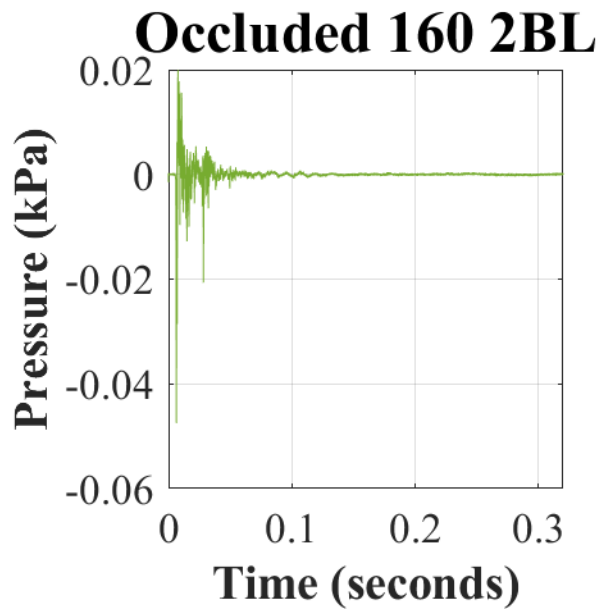
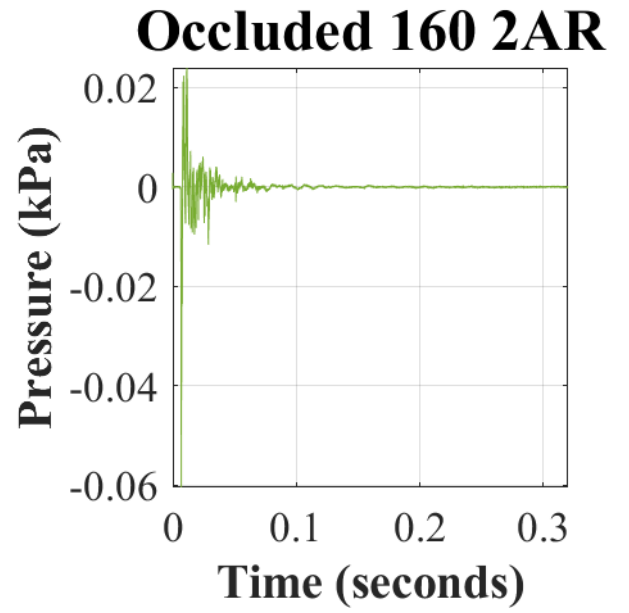
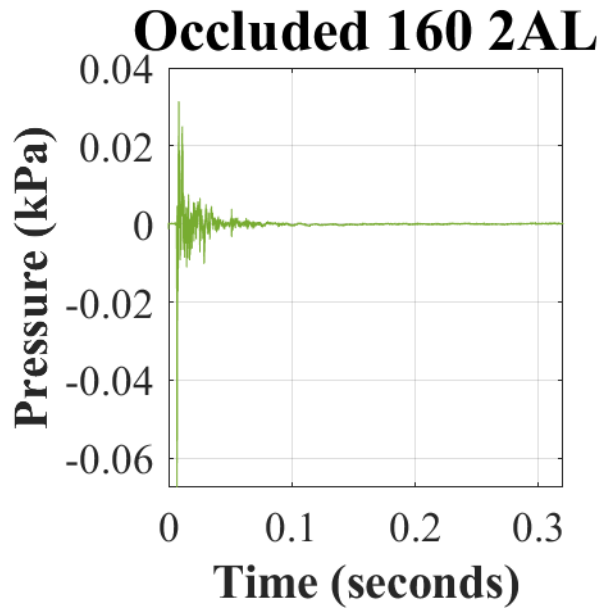
160 dB	170 dB
36.8 (1.9)	36.9 (1.6)

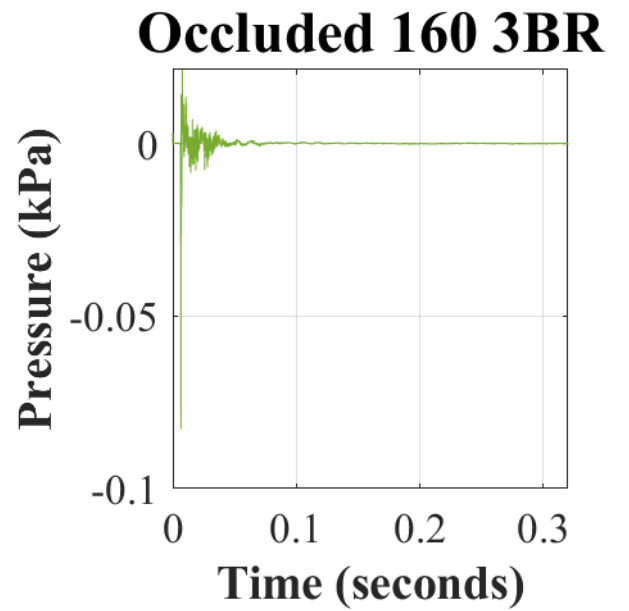
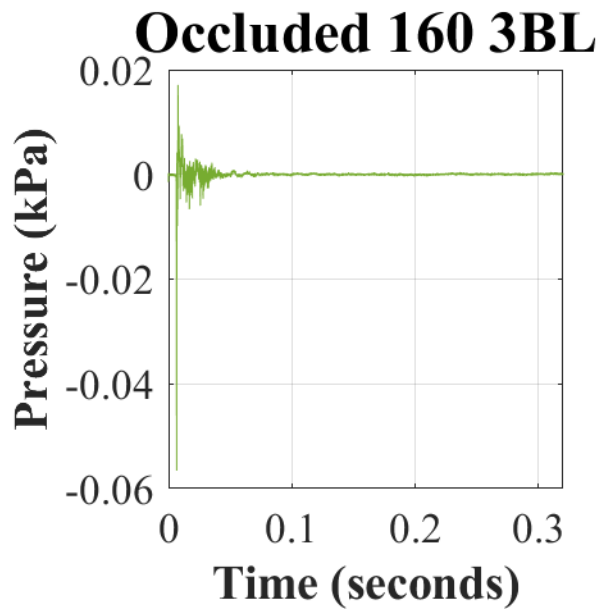
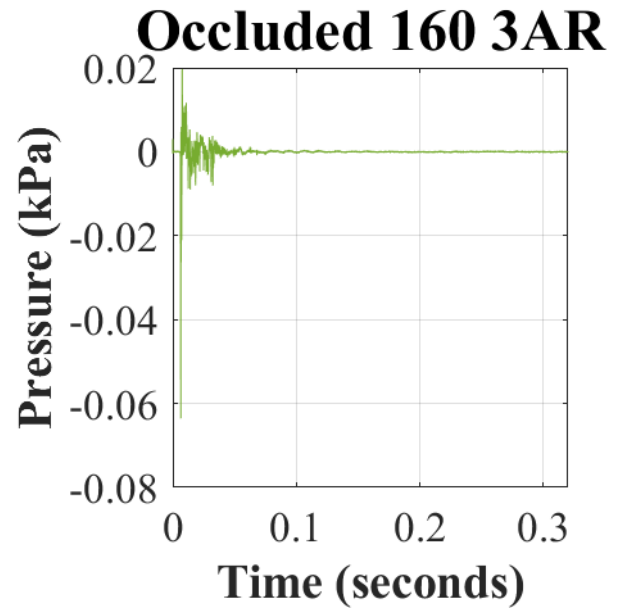
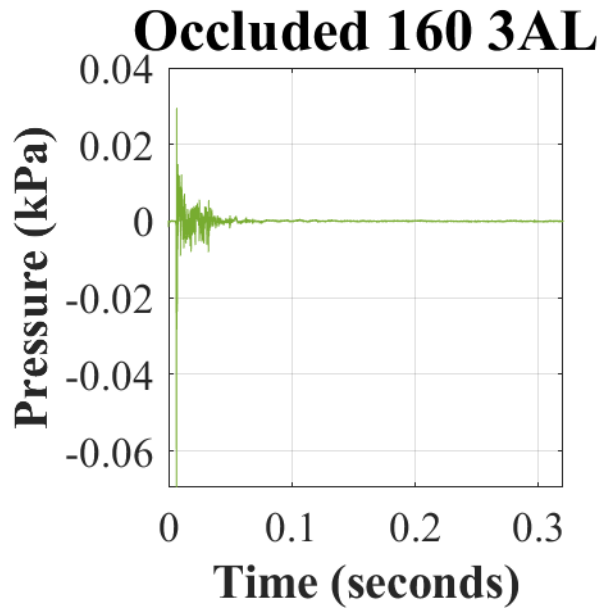
References

- 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.
- DeltaPlus Corporation. (n.d.). *Quattro EP-401: Quattro™ Un-Corded Reusable Ear Plugs* [Product Sheet]. Shelton, CT: DeltaPlus Corporation.

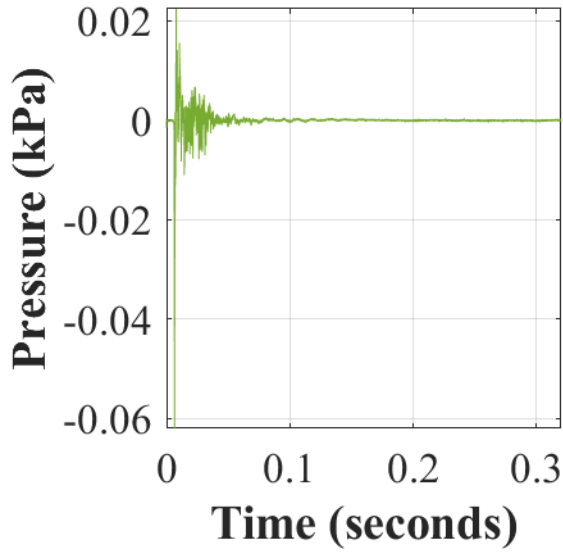
Appendix A. Recorded occluded (closed-ear) waveforms in response to 160 dBp with the Quattro™ earplugs.



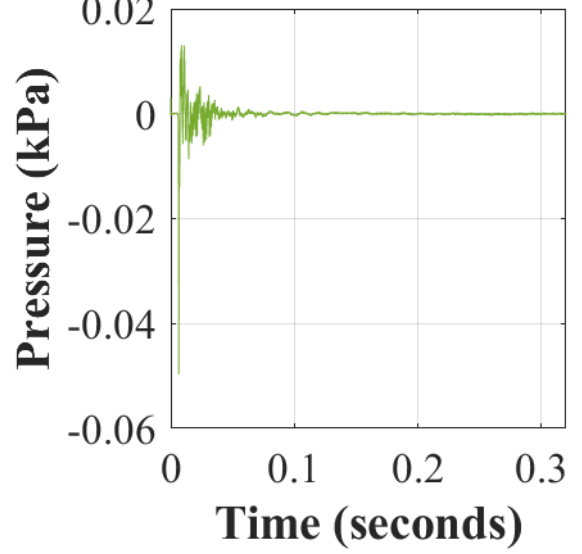




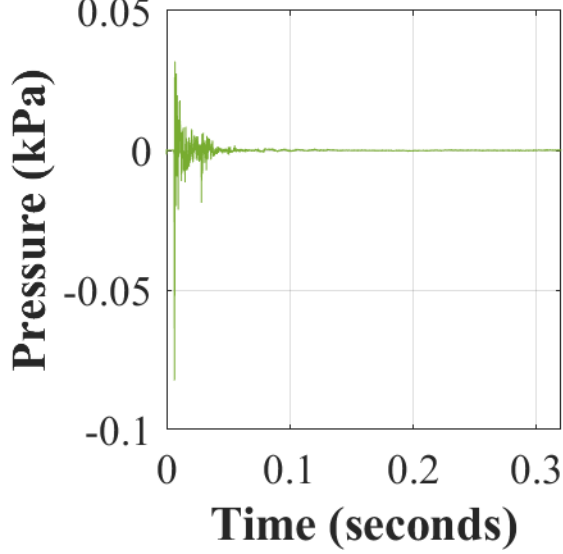
Occluded 160 4AL



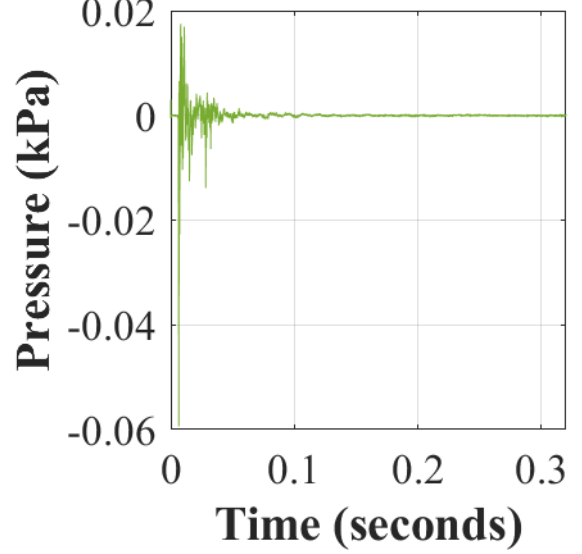
Occluded 160 4AR

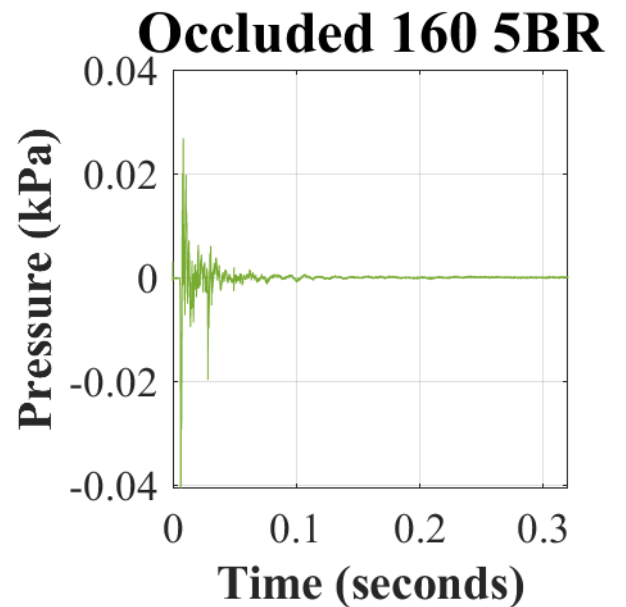
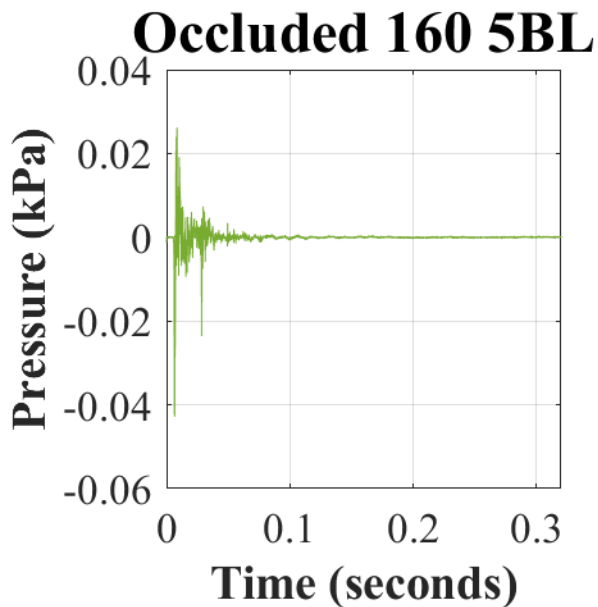
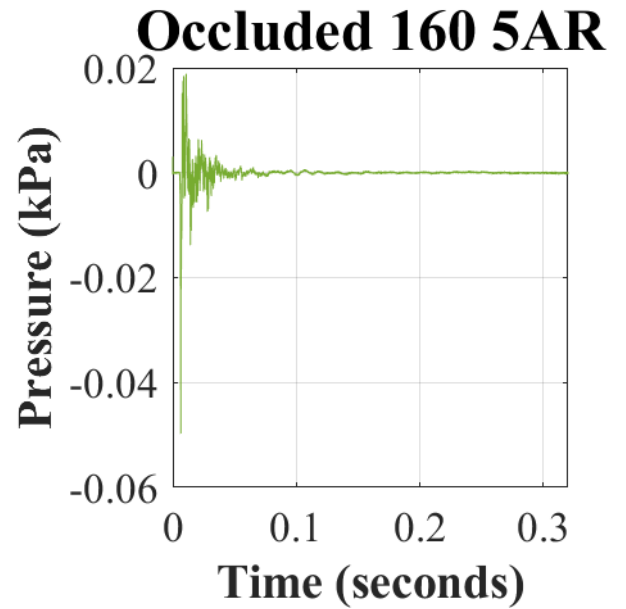
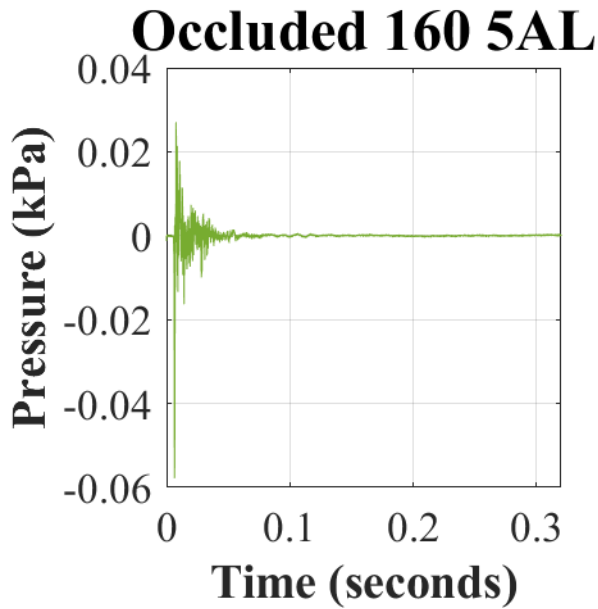


Occluded 160 4BL



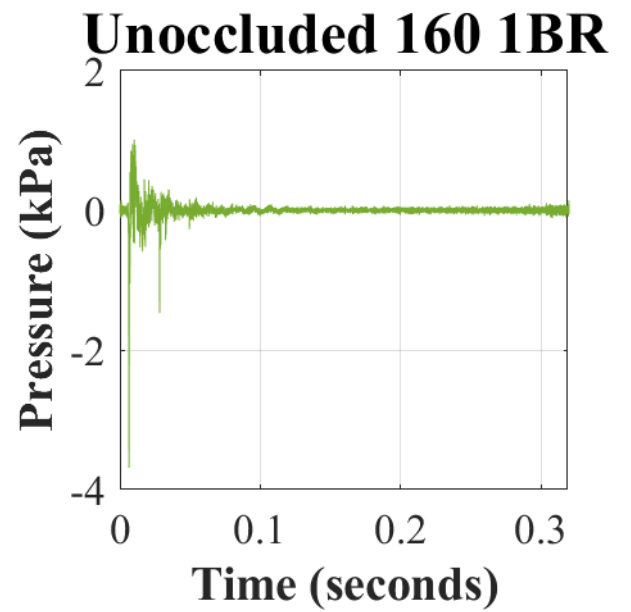
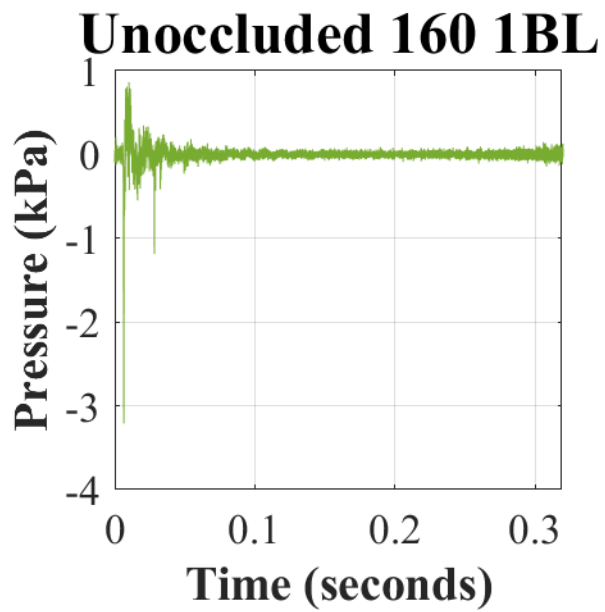
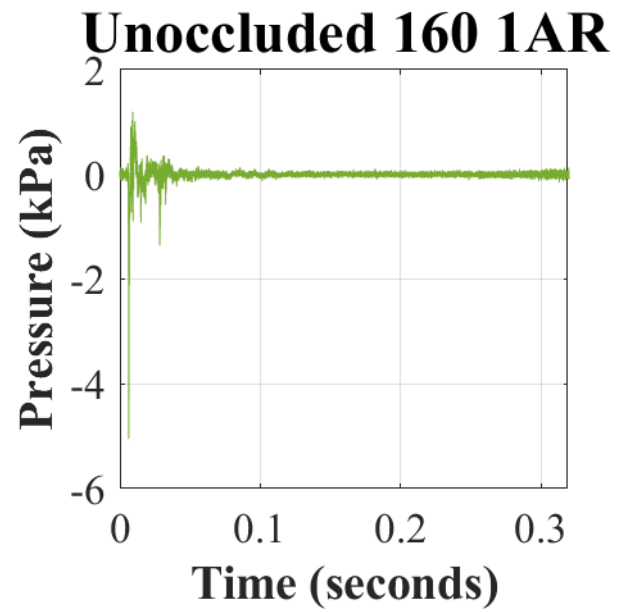
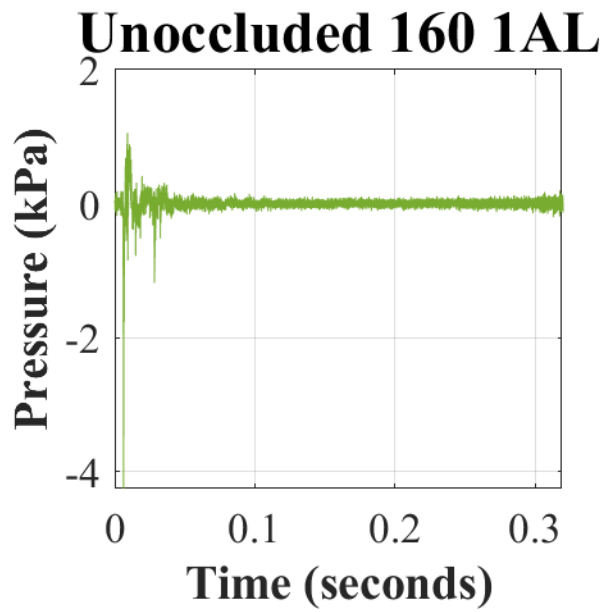
Occluded 160 4BR

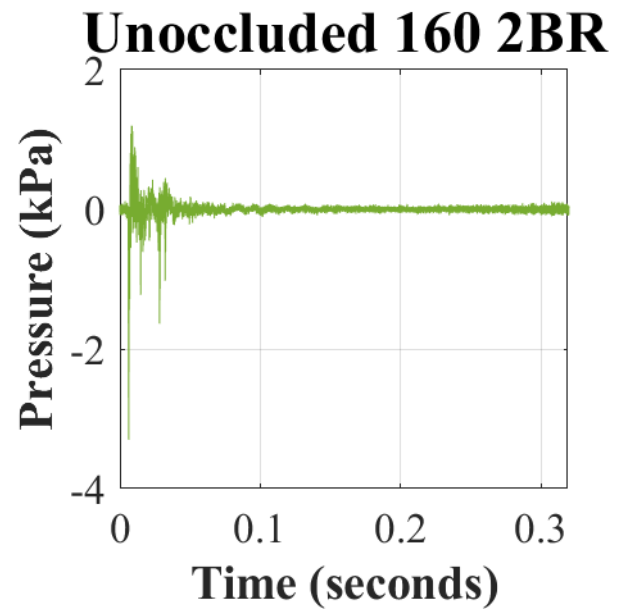
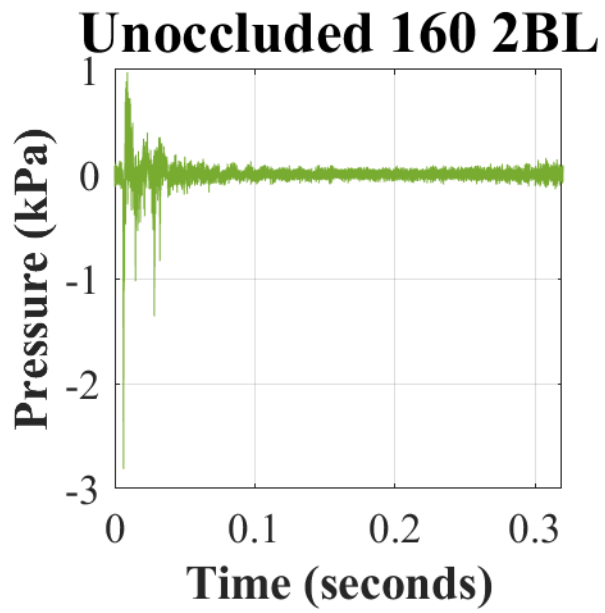
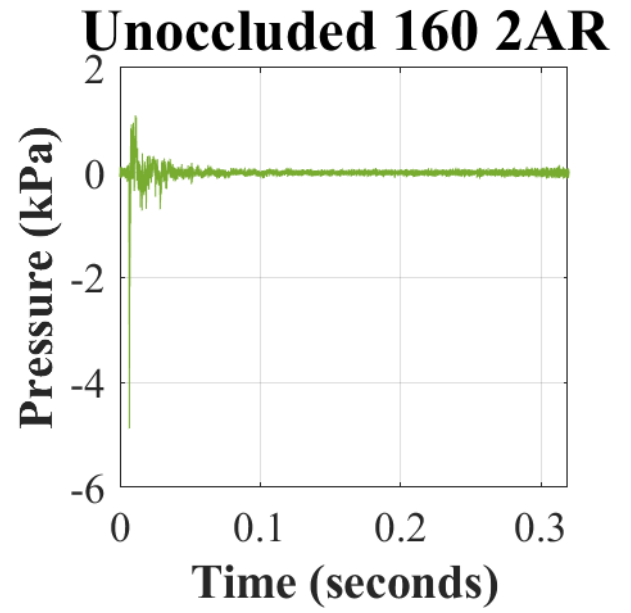
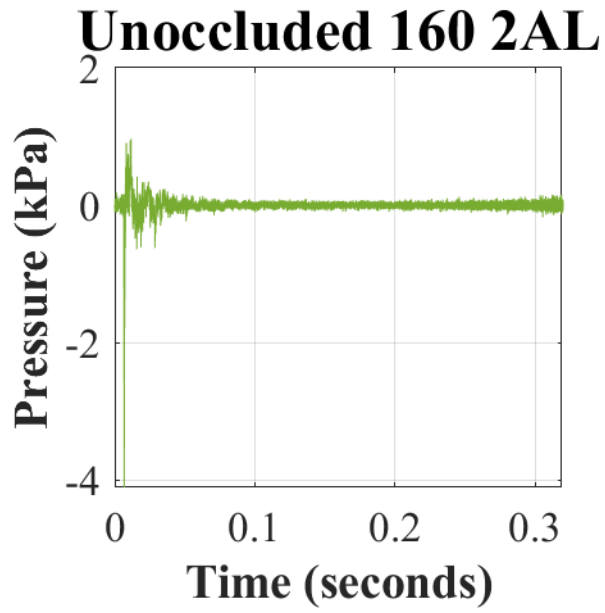


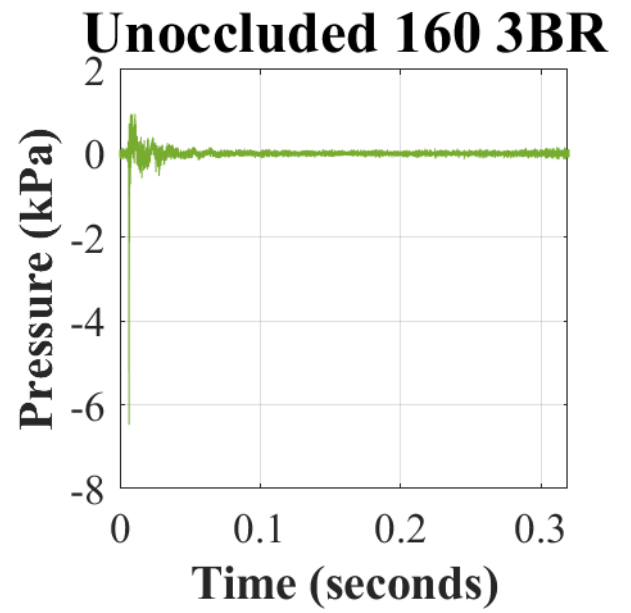
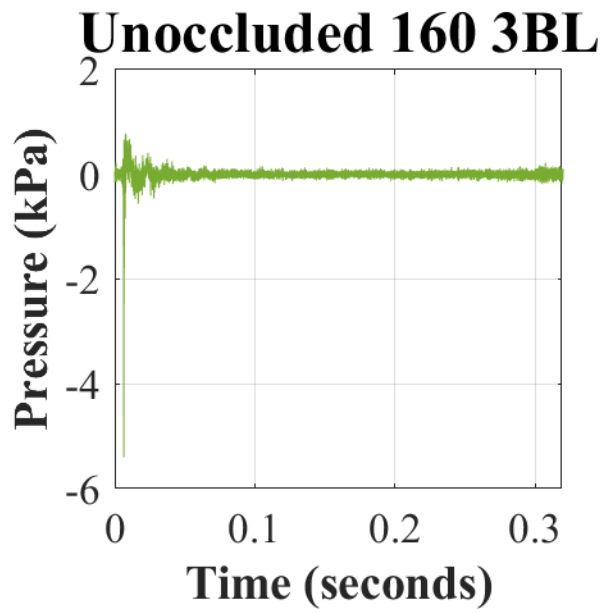
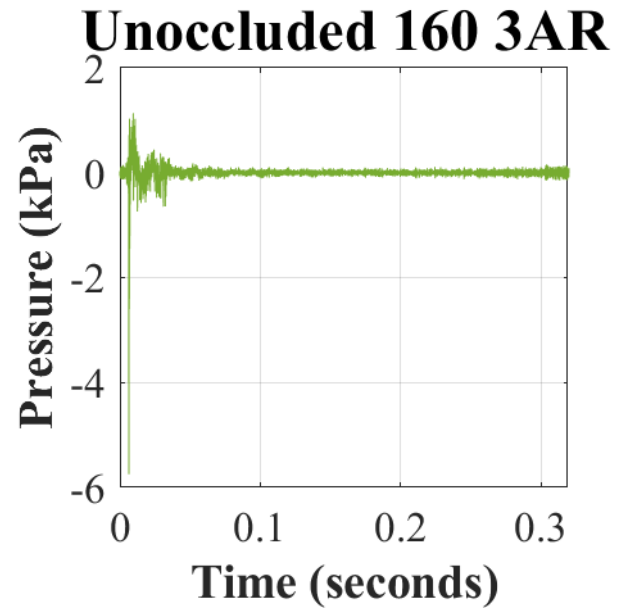
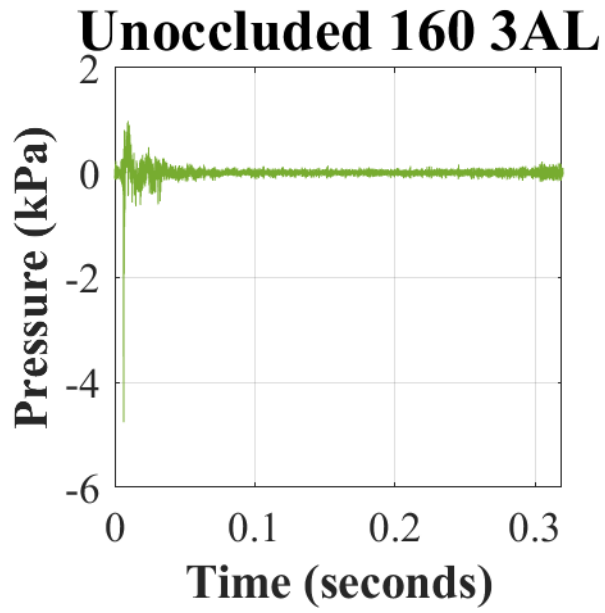


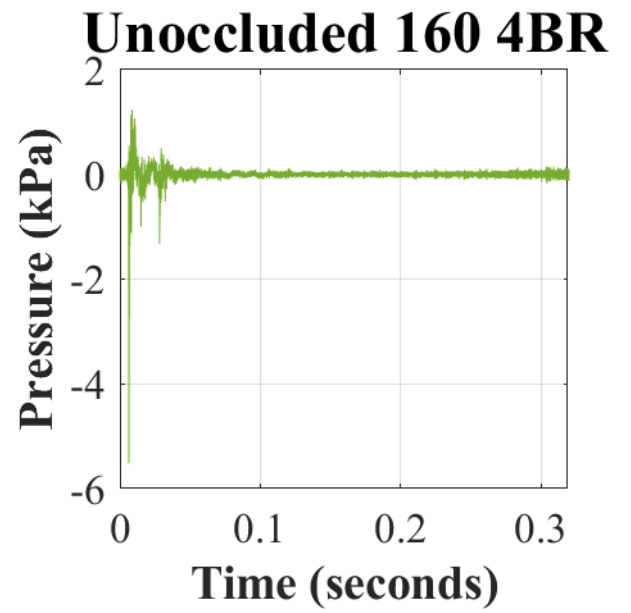
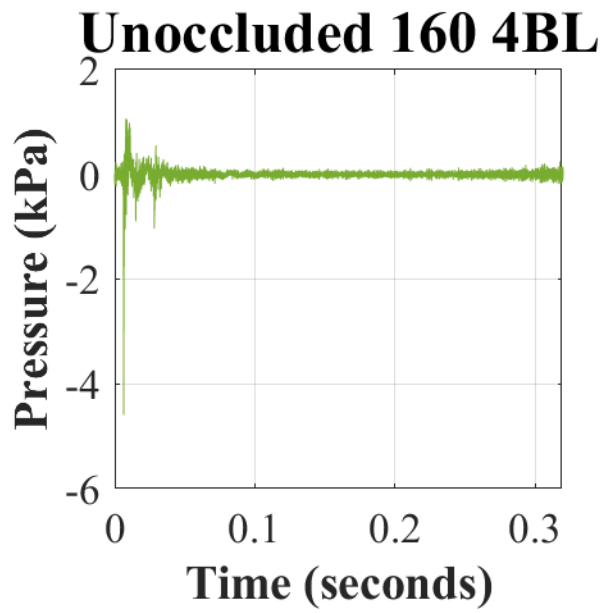
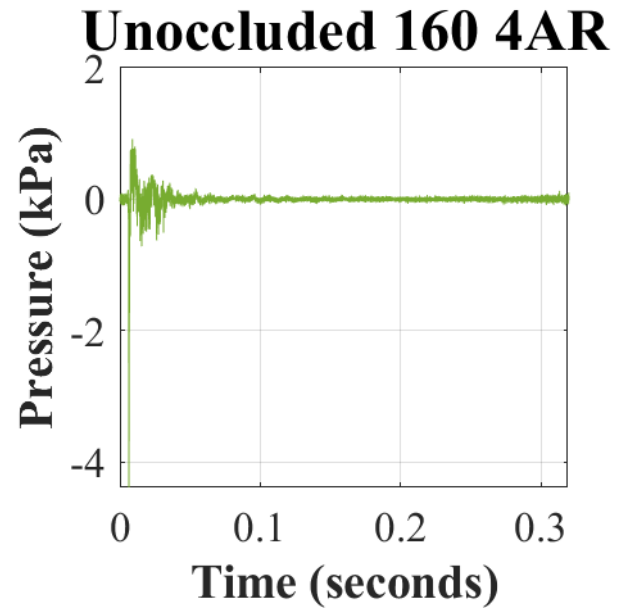
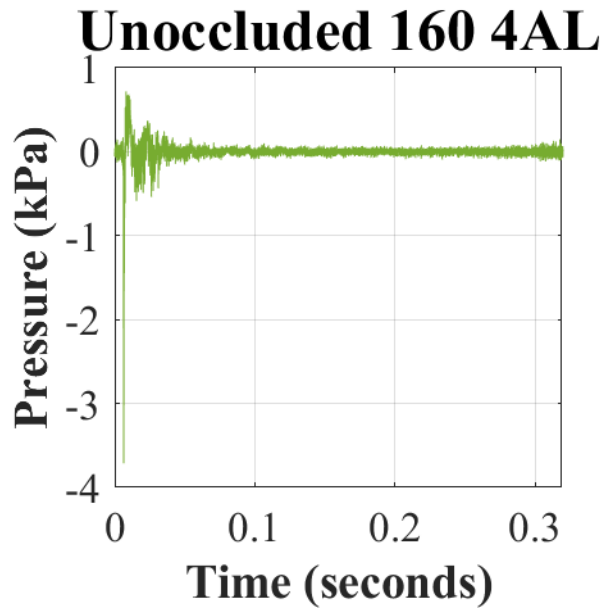
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating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

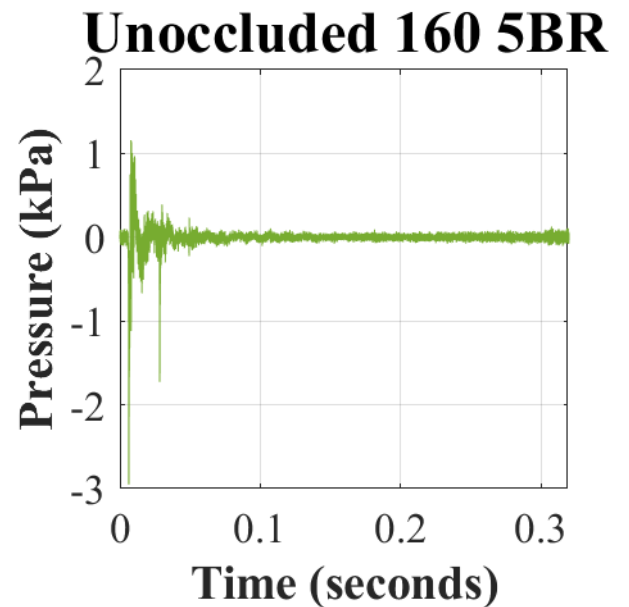
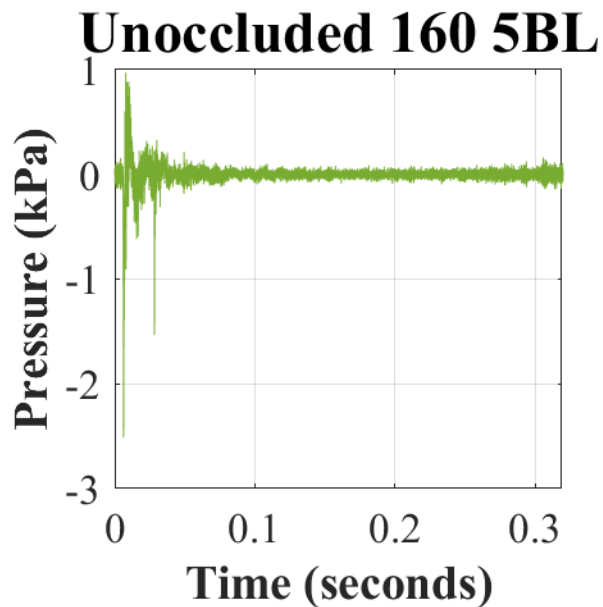
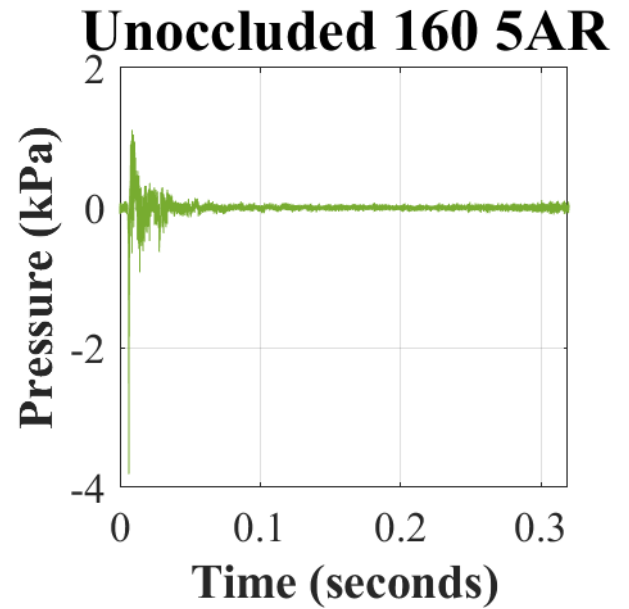
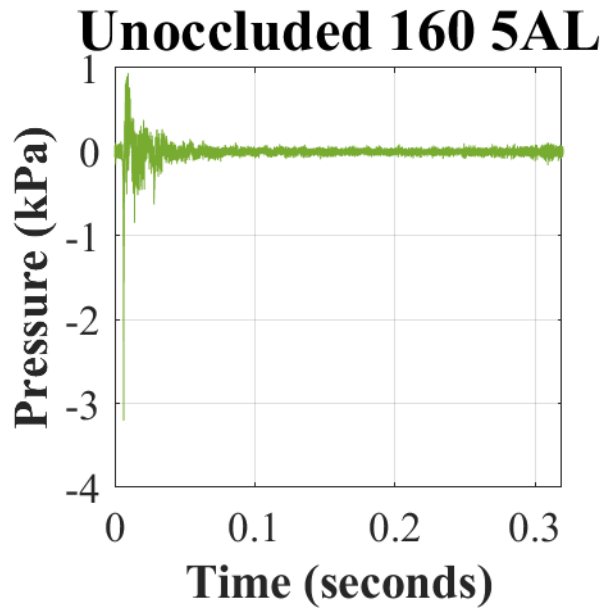
Appendix B. Estimated unoccluded (open-ear) waveforms in response to 160 dBp with the Quattro™ earplugs.





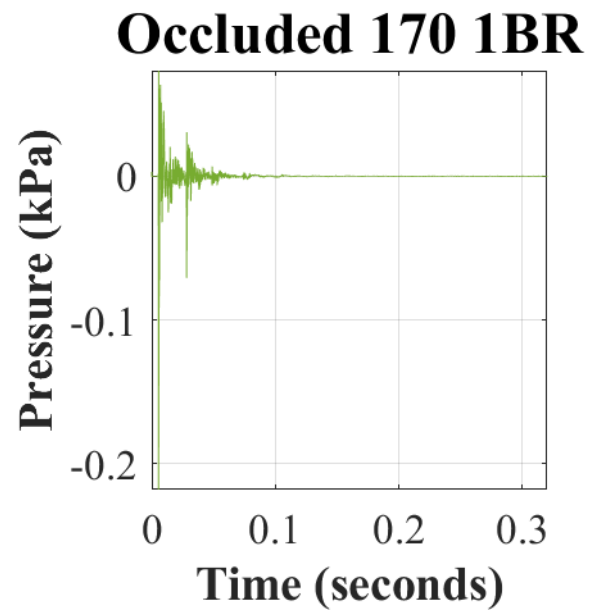
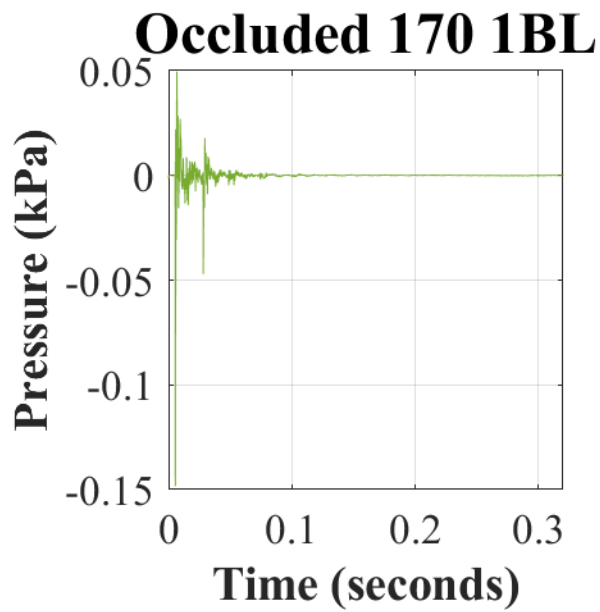
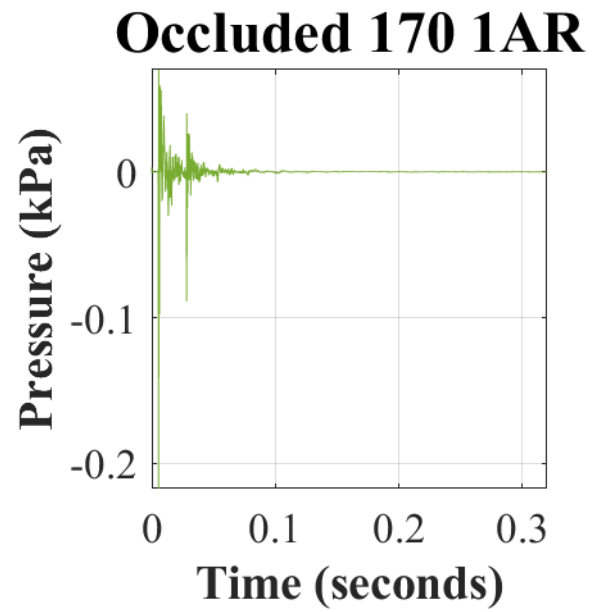
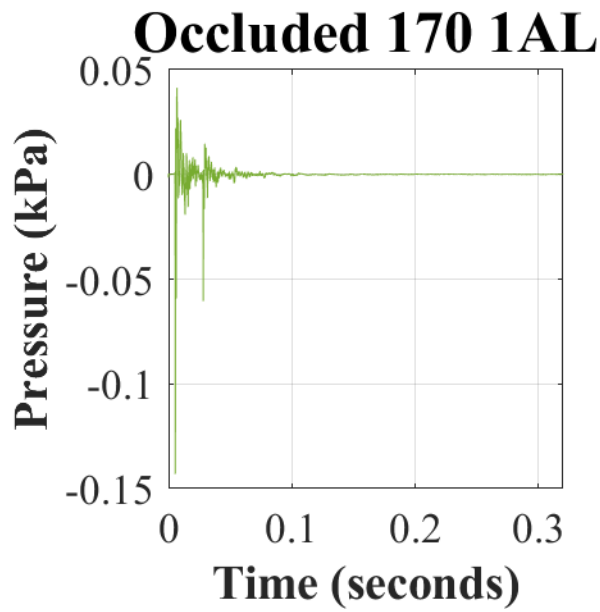




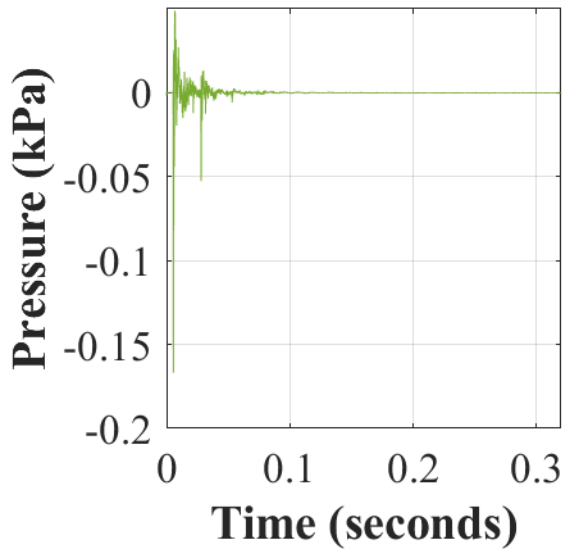


Note. The naming convention for all occluded waveforms is “Unoccluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the HPD doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B)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

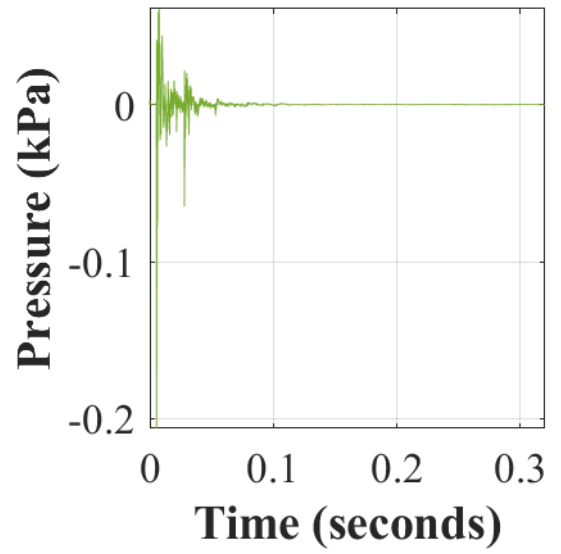
Appendix C. Recorded occluded (closed-ear) waveforms in response to 170 dBp with the Quattro™ earplugs.



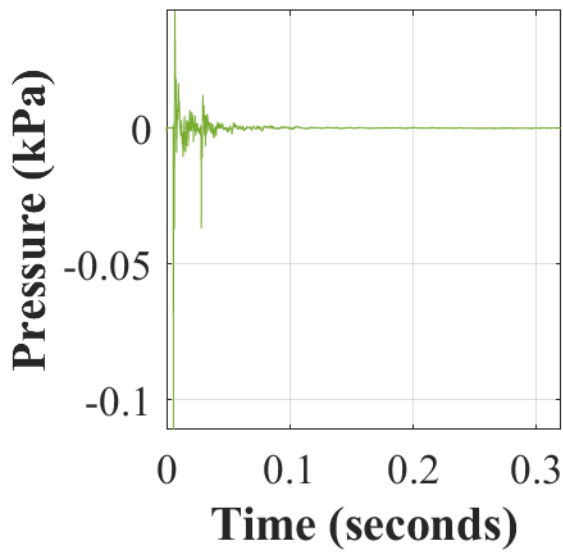
Occluded 170 2AL



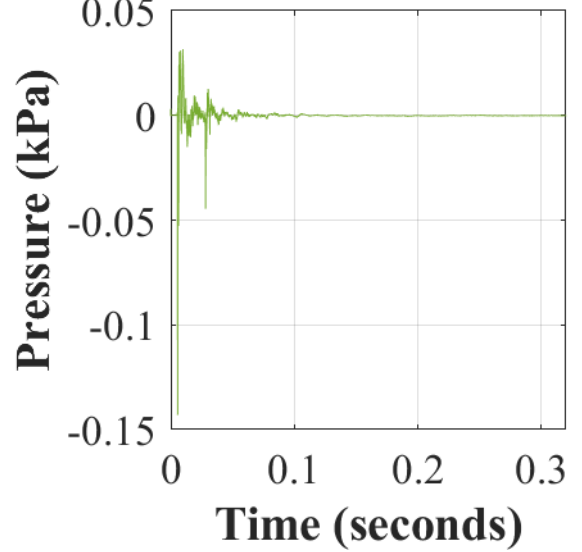
Occluded 170 2AR

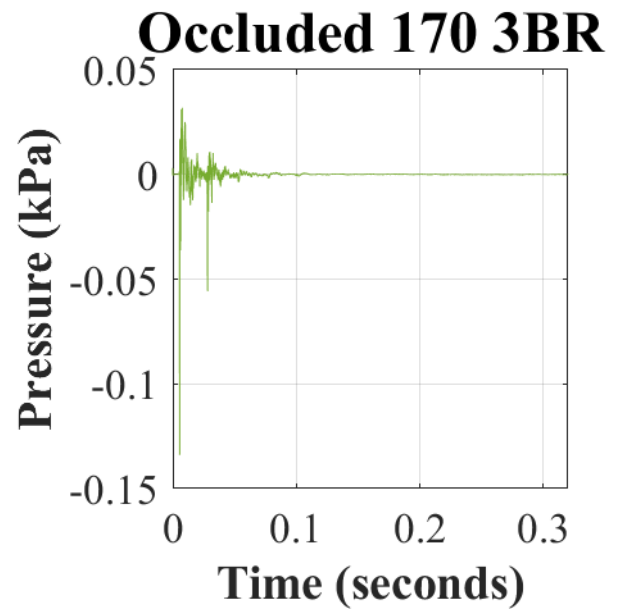
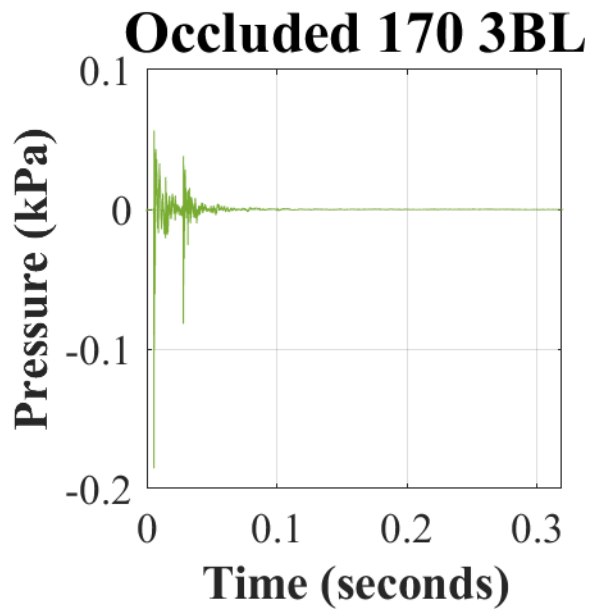
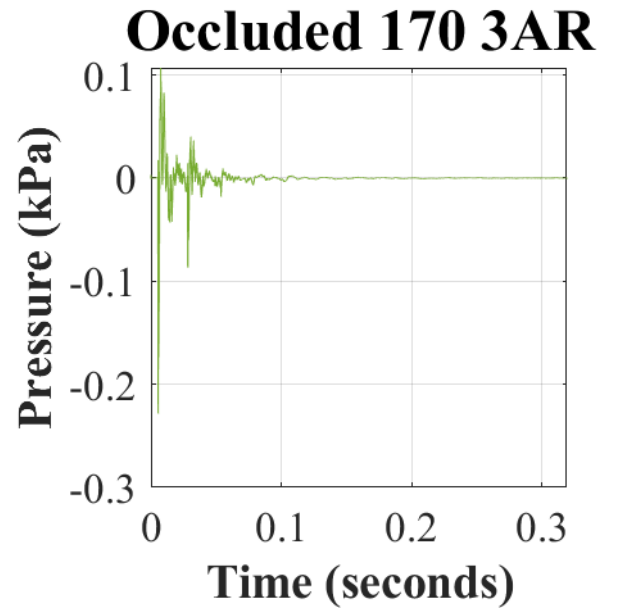
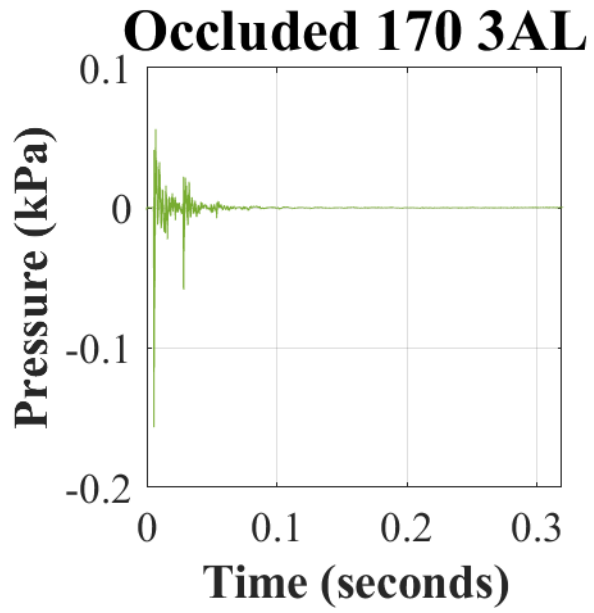


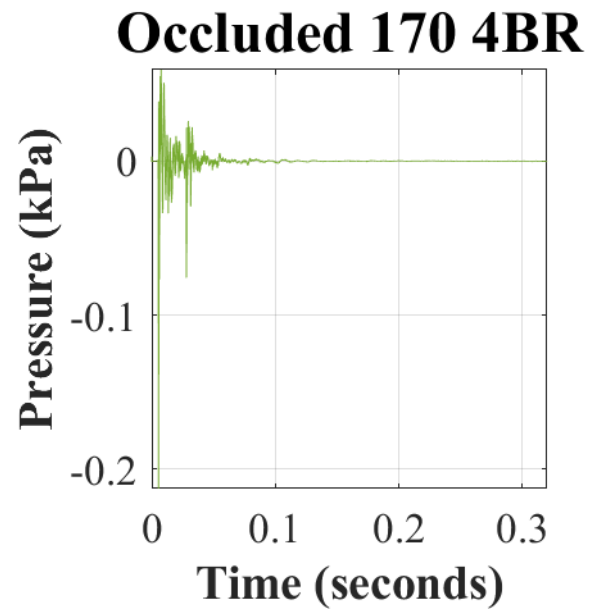
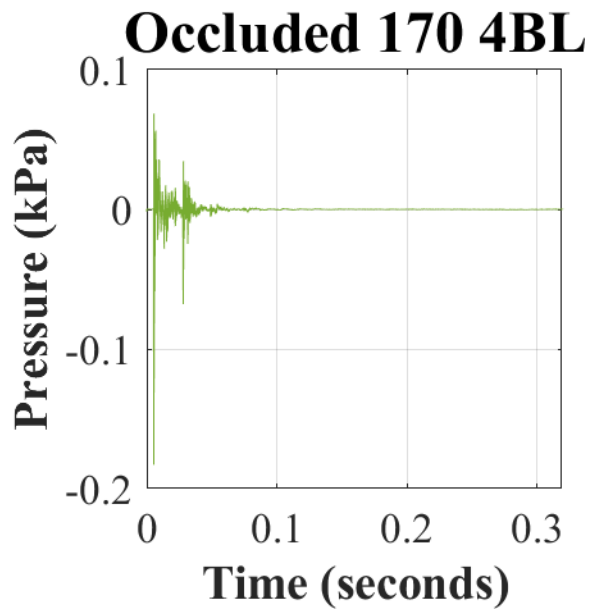
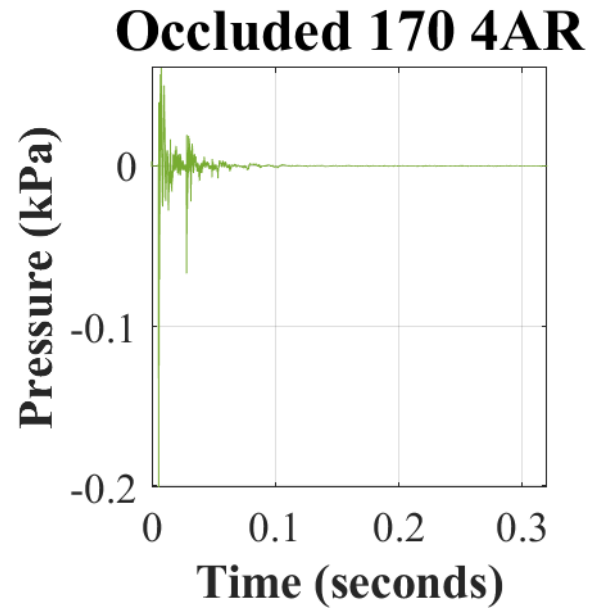
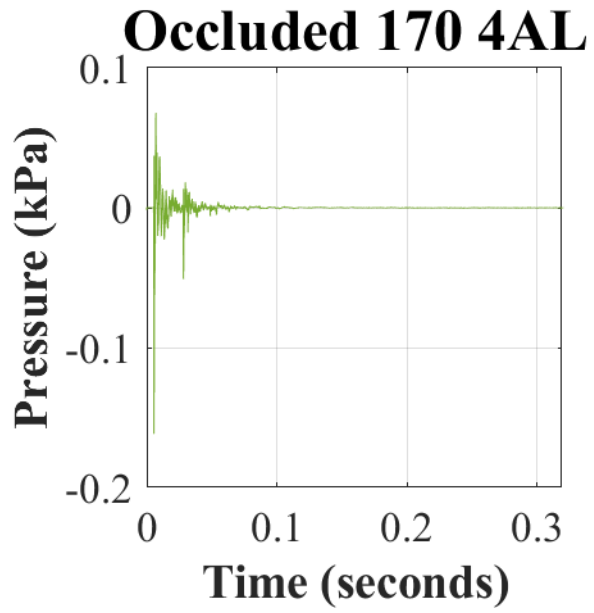
Occluded 170 2BL



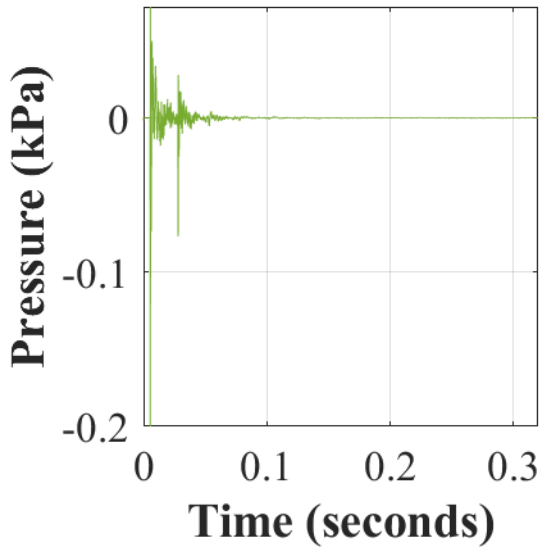
Occluded 170 2BR



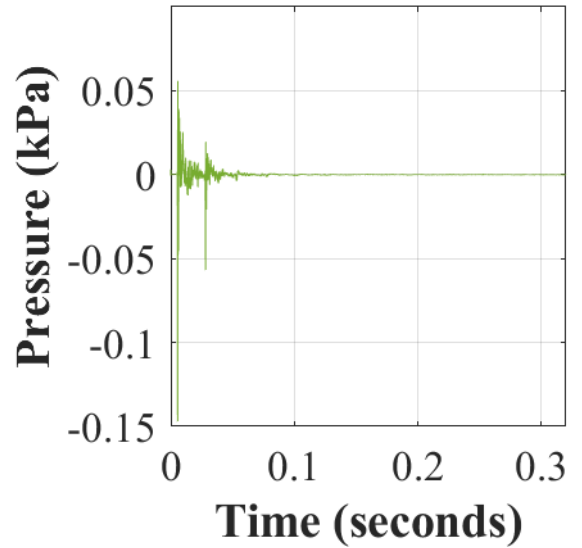




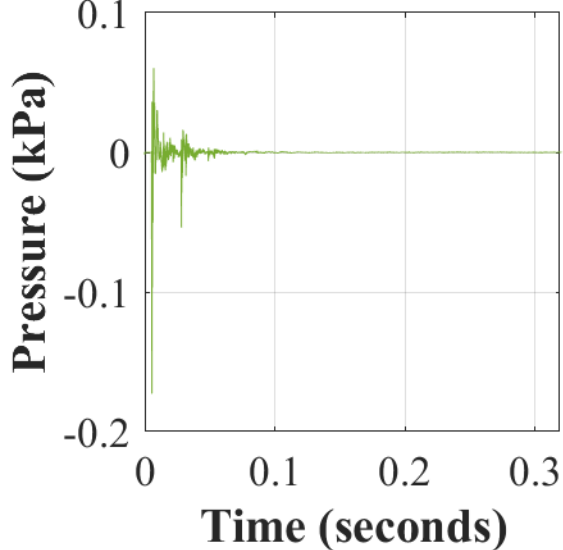
Occluded 170 5AL



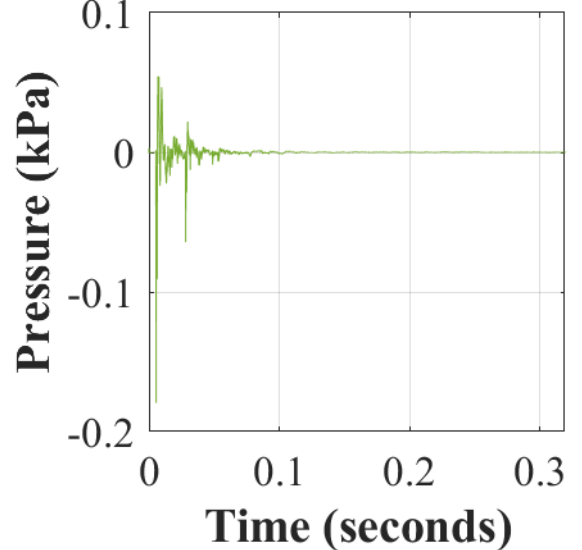
Occluded 170 5AR



Occluded 170 5BL

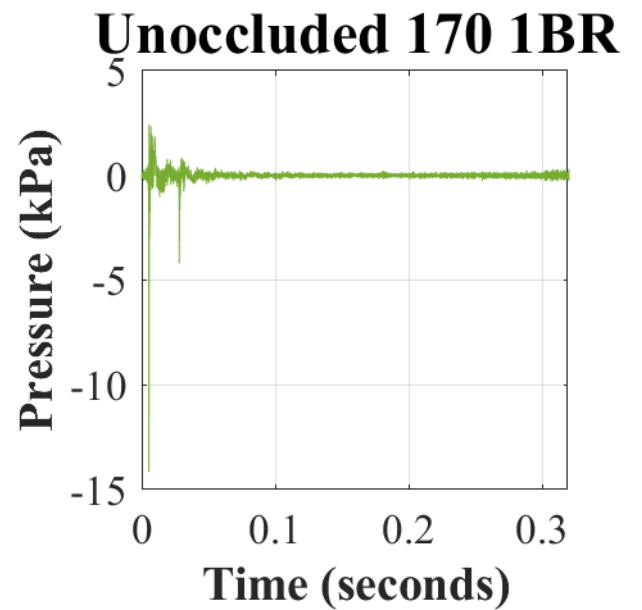
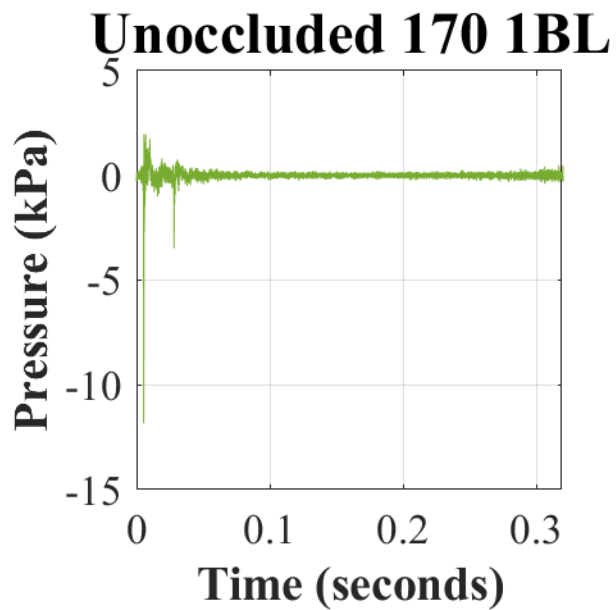
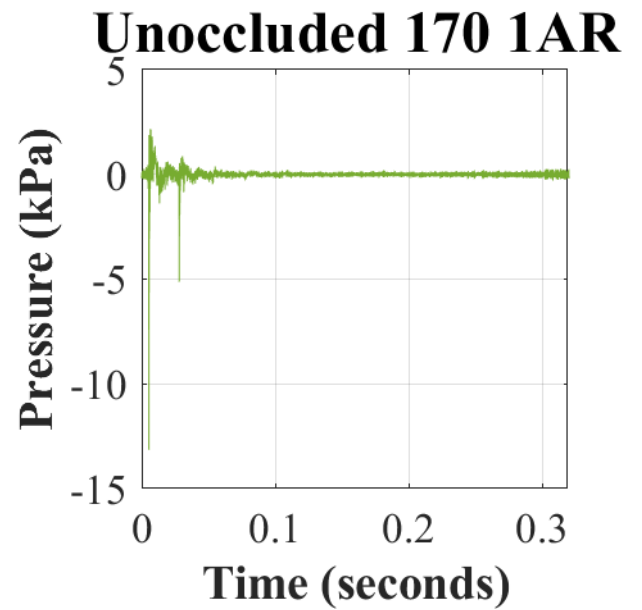
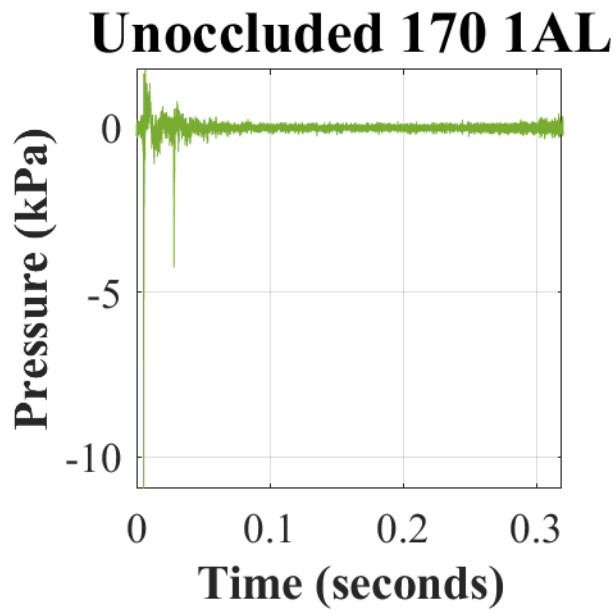


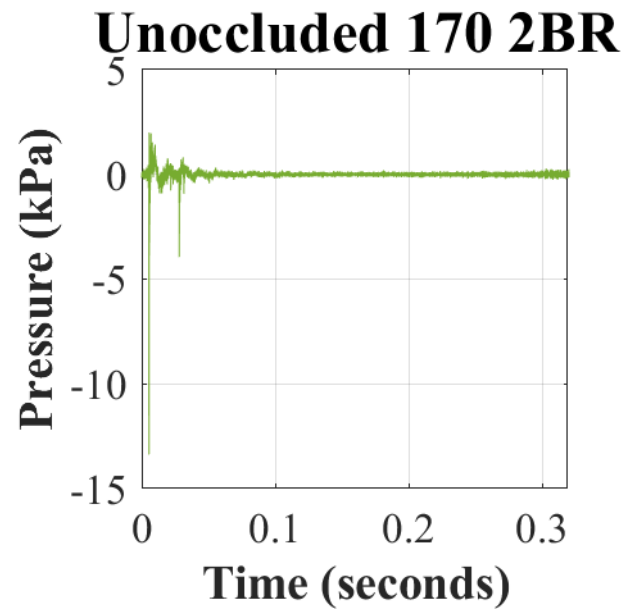
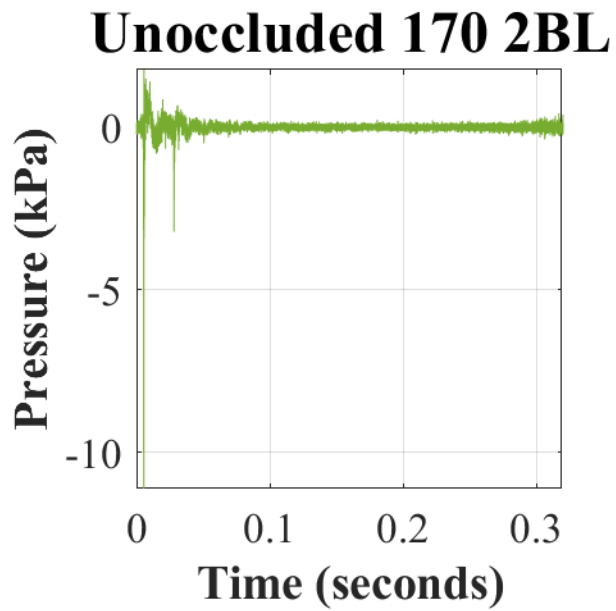
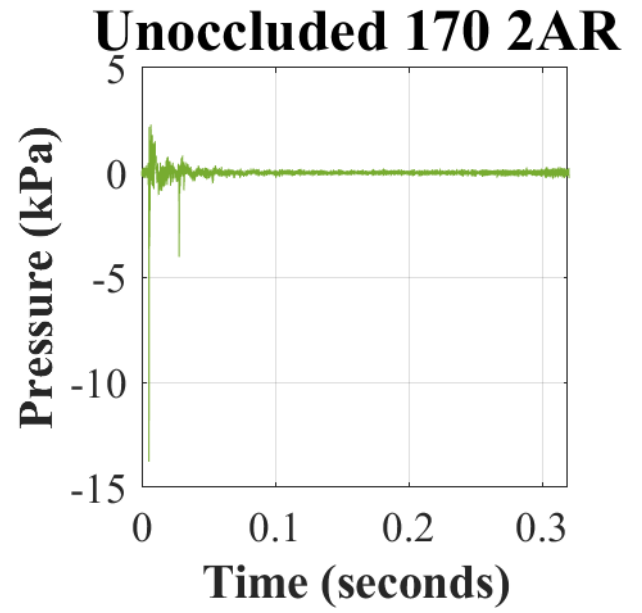
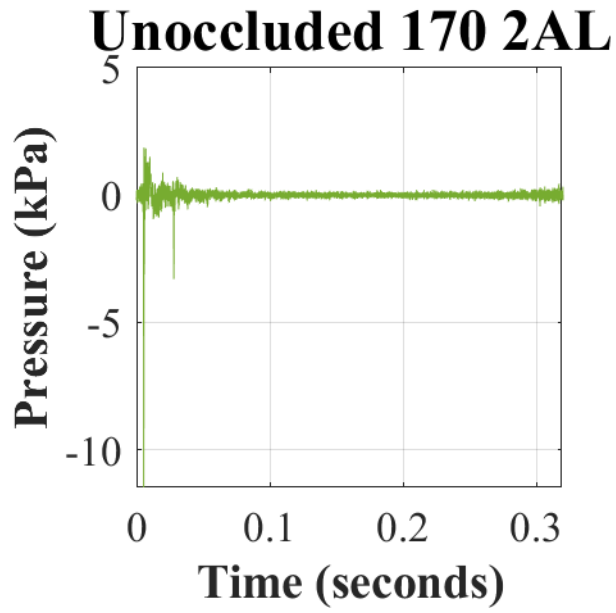
Occluded 170 5BR



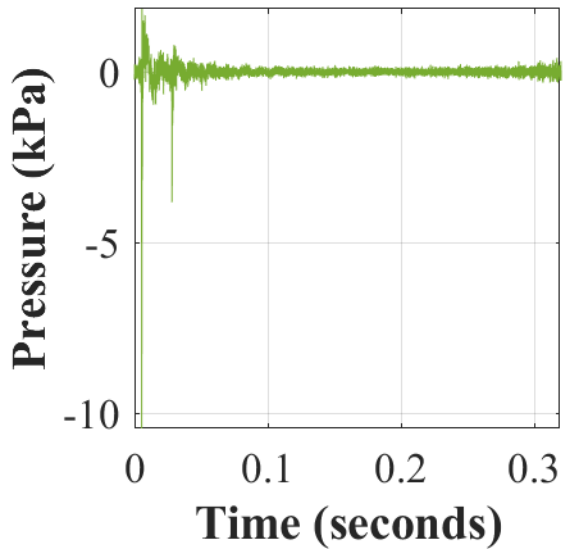
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating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

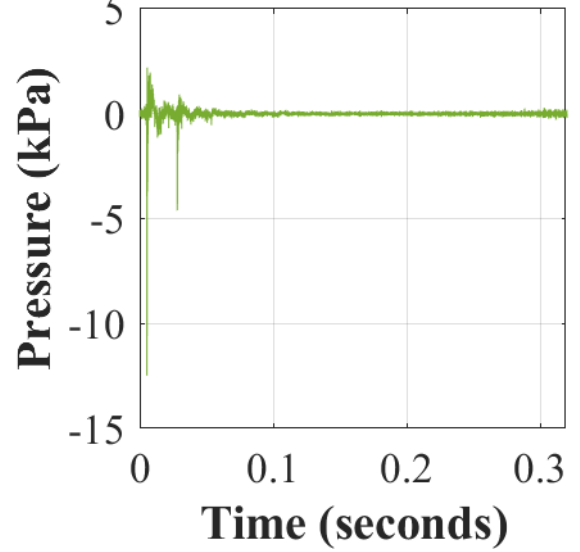




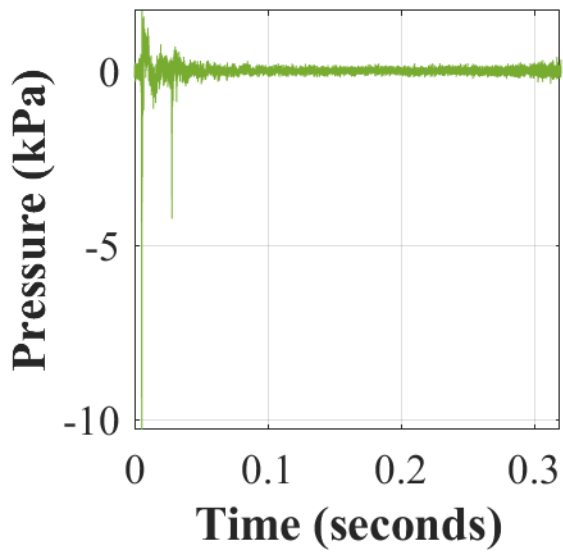
Unoccluded 170 3AL



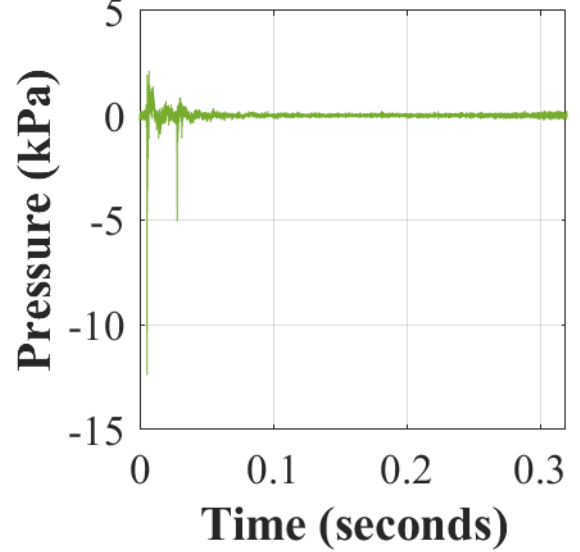
Unoccluded 170 3AR

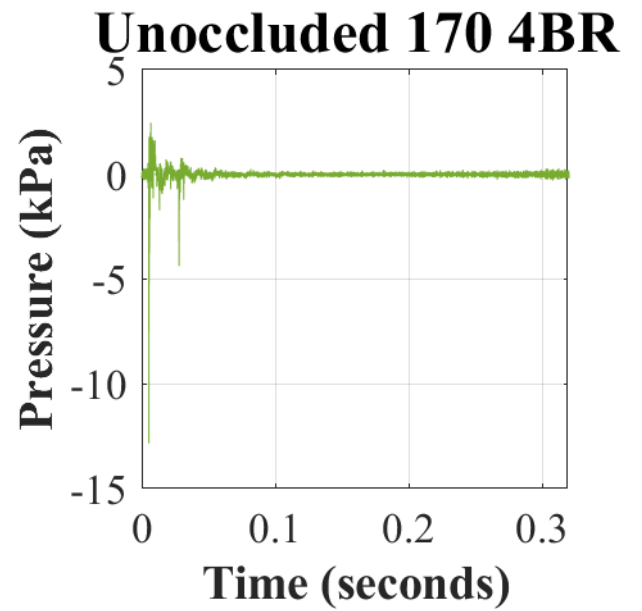
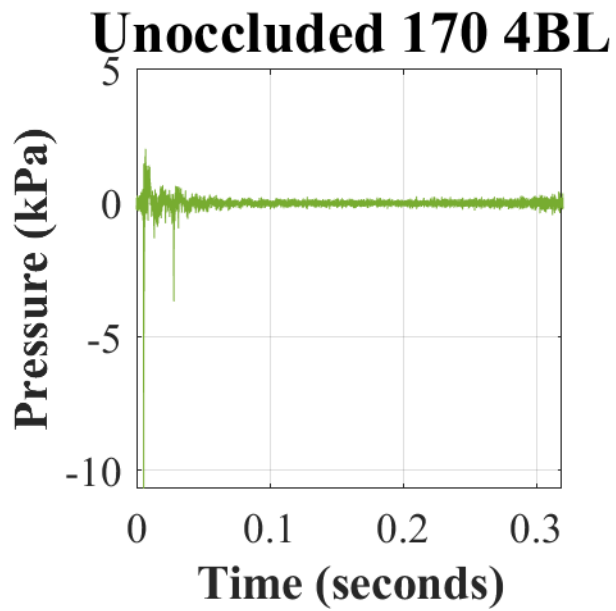
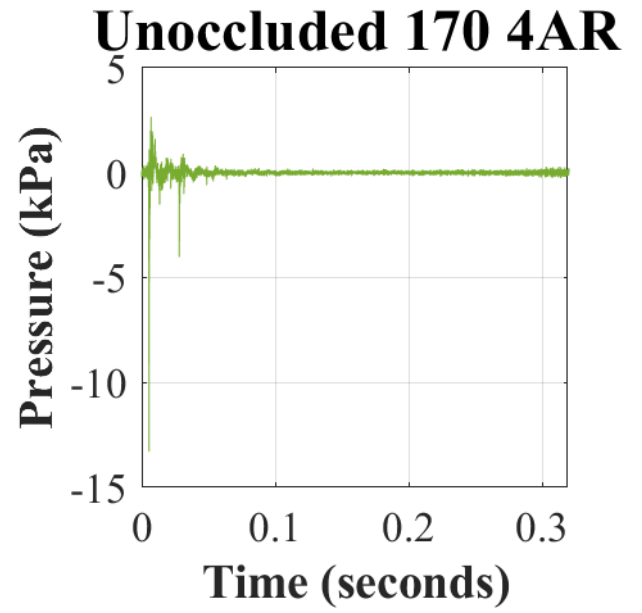
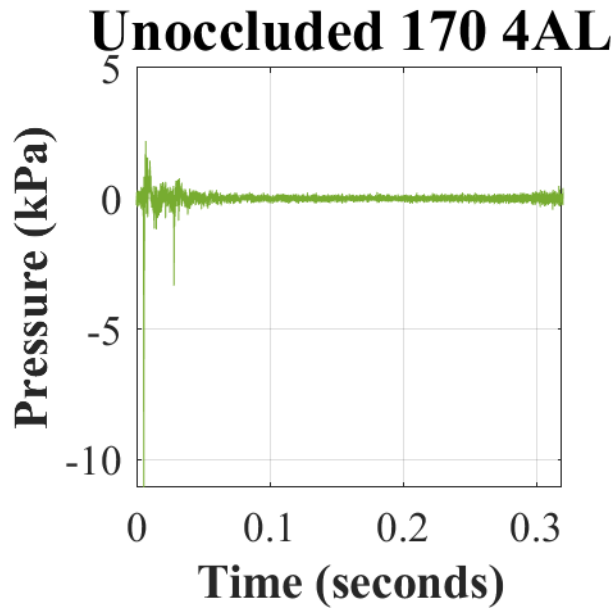


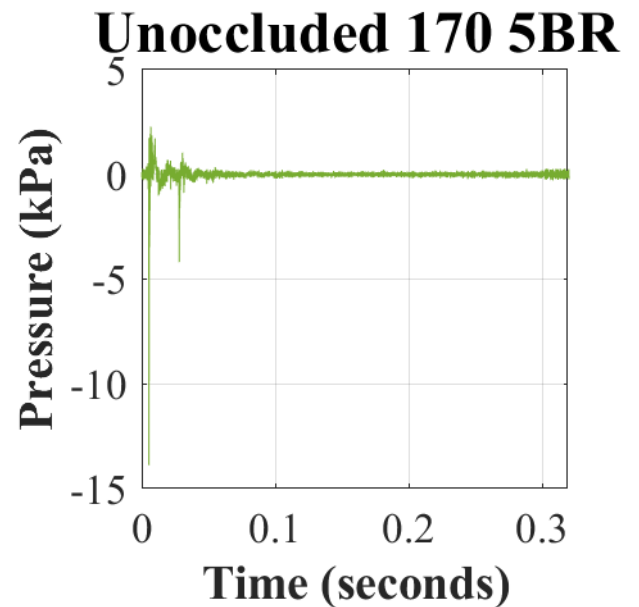
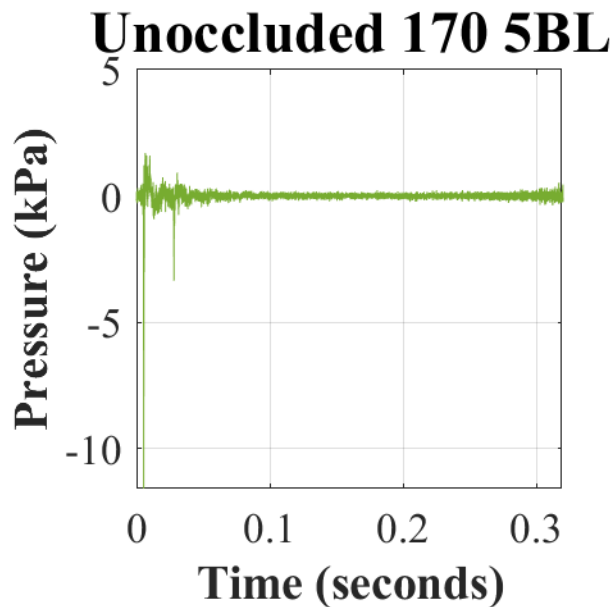
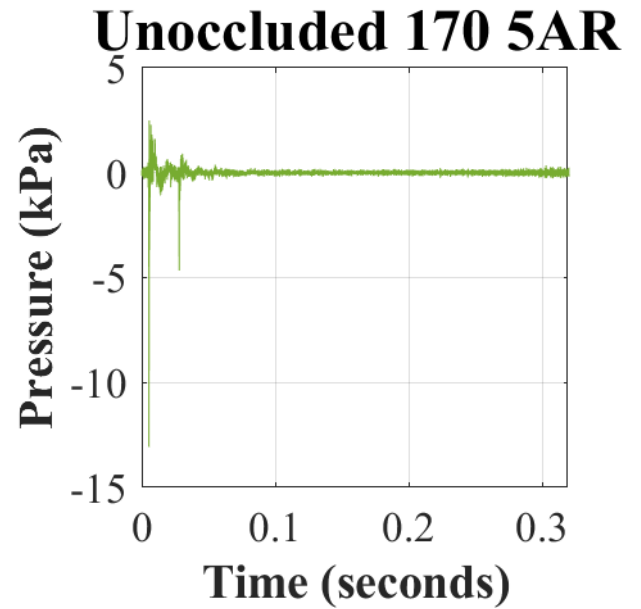
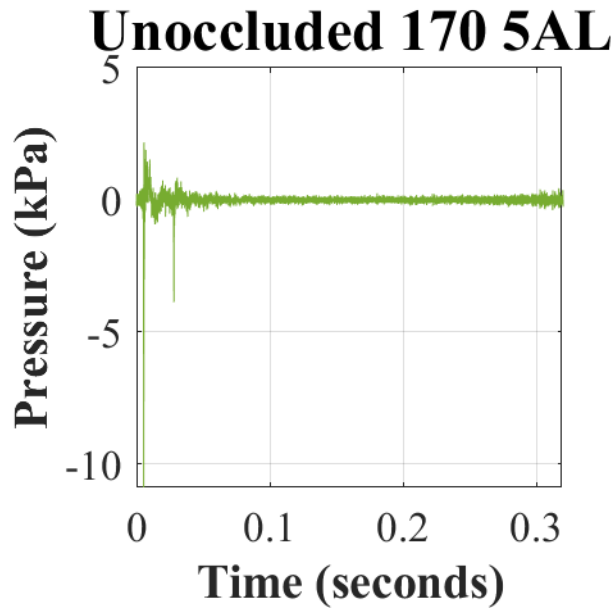
Unoccluded 170 3BL



Unoccluded 170 3BR

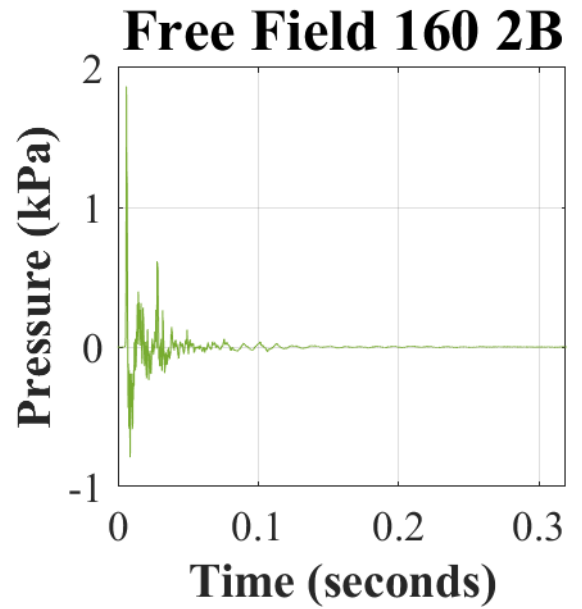
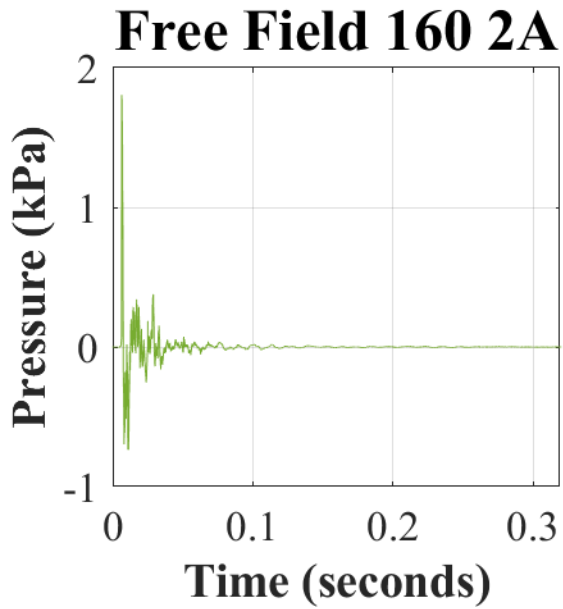
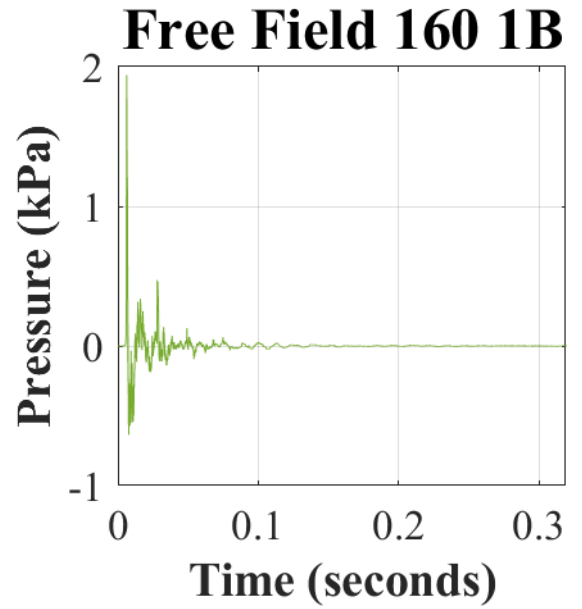
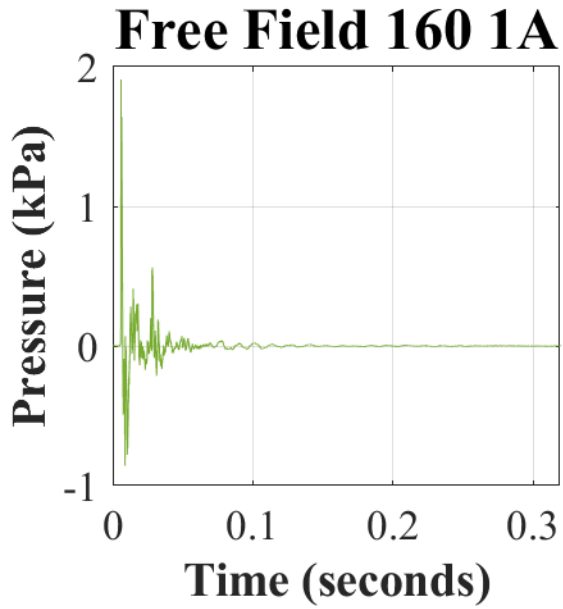




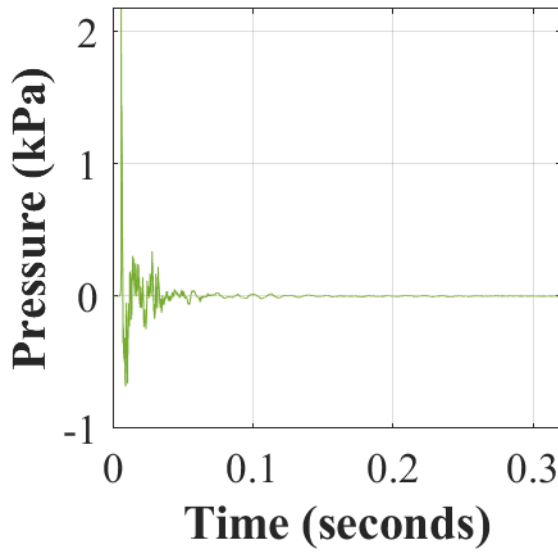


Note. The naming convention for all occluded waveforms is “Unoccluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the HPD doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B)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

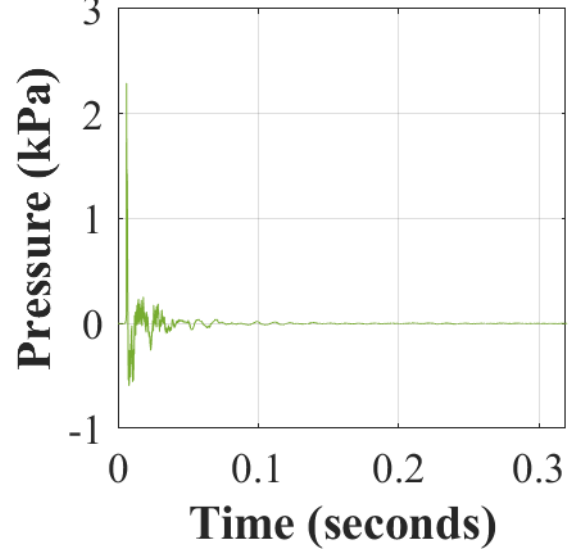
Appendix E. Recorded waveform of the impulse measured with the free-field probe at 160 dBp and the Quattro™ earplugs donned.



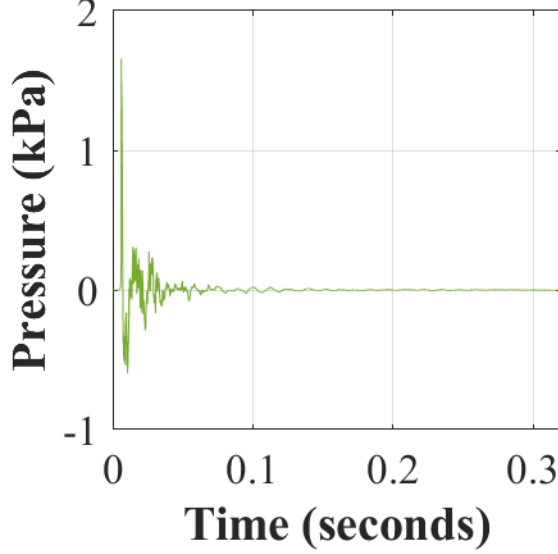
Free Field 160 3A



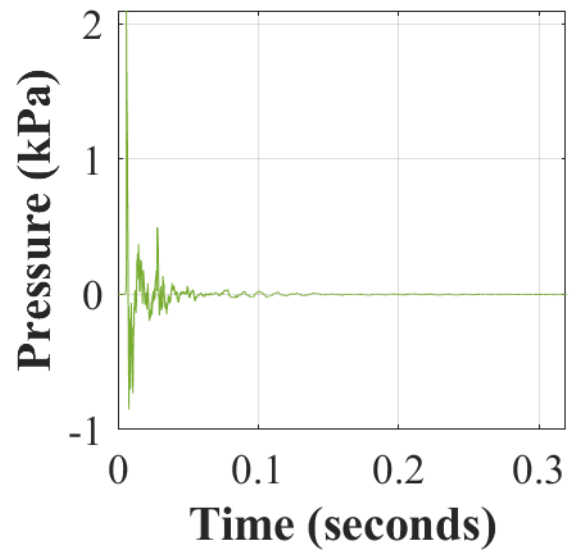
Free Field 160 3B

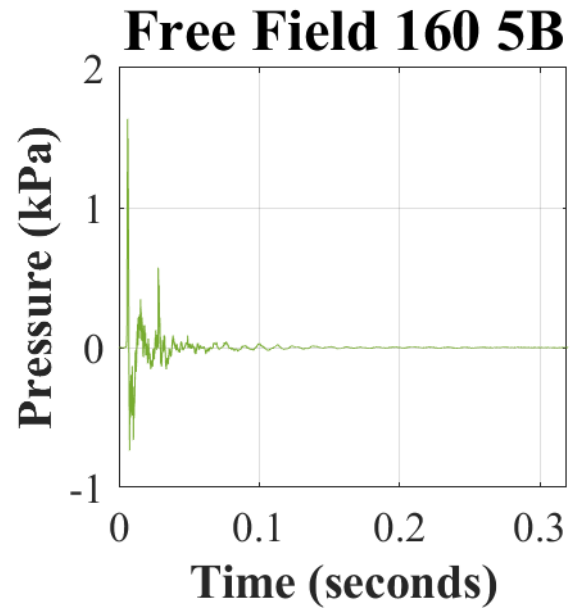
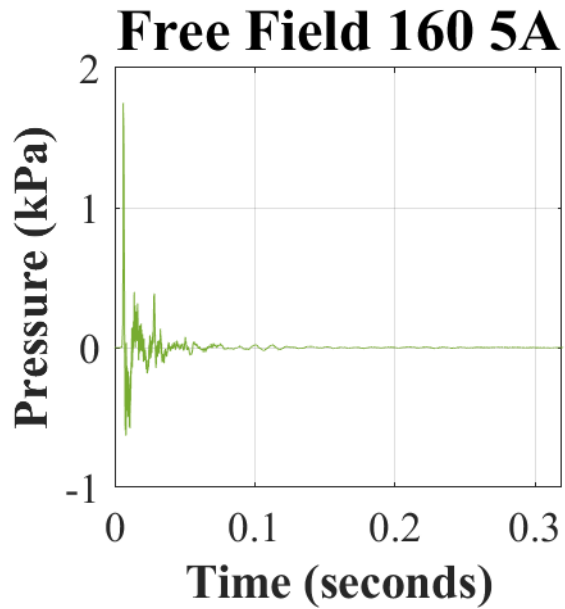


Free Field 160 4A



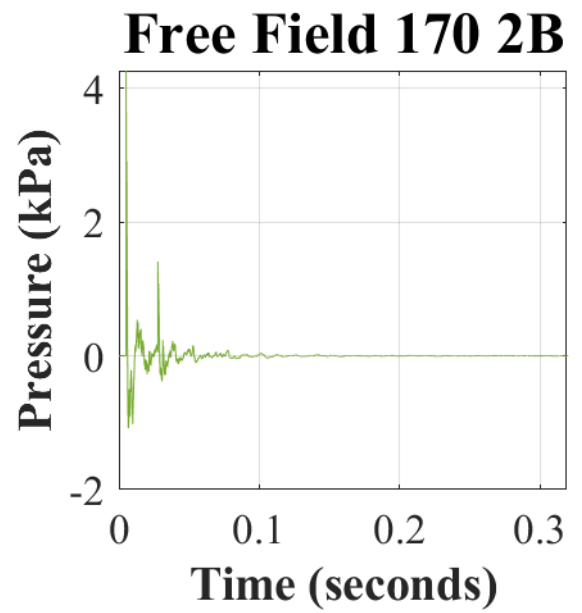
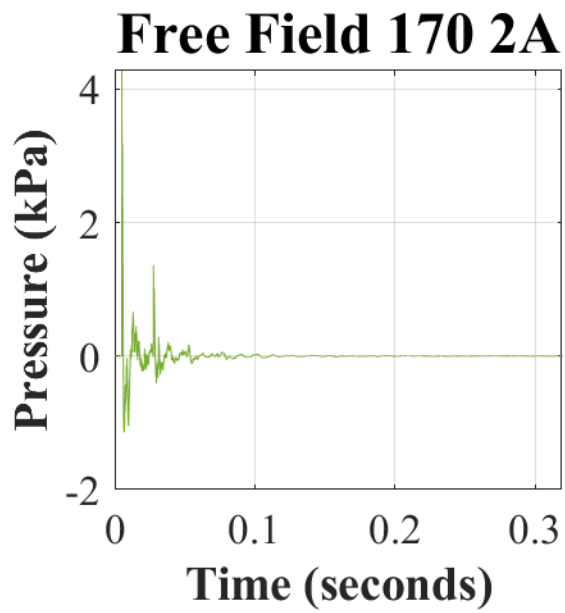
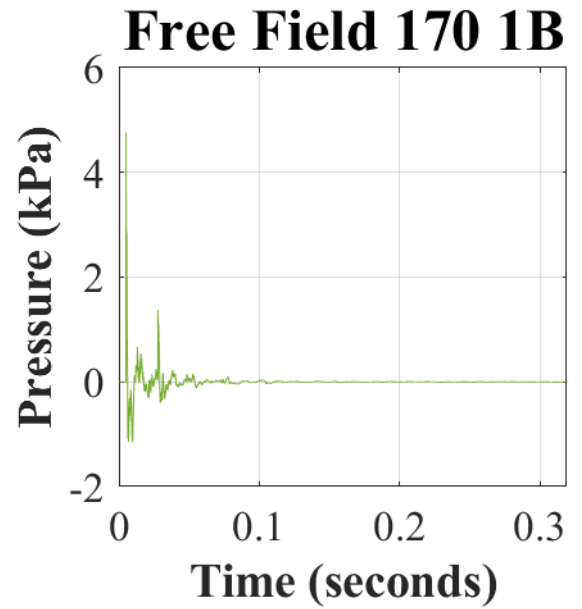
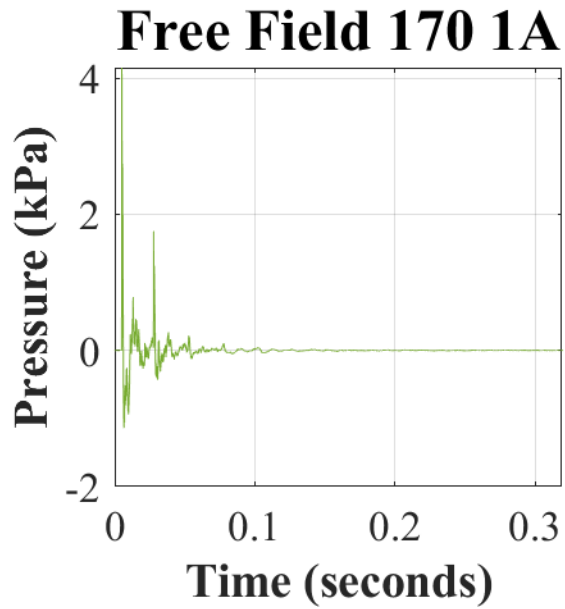
Free Field 160 4B

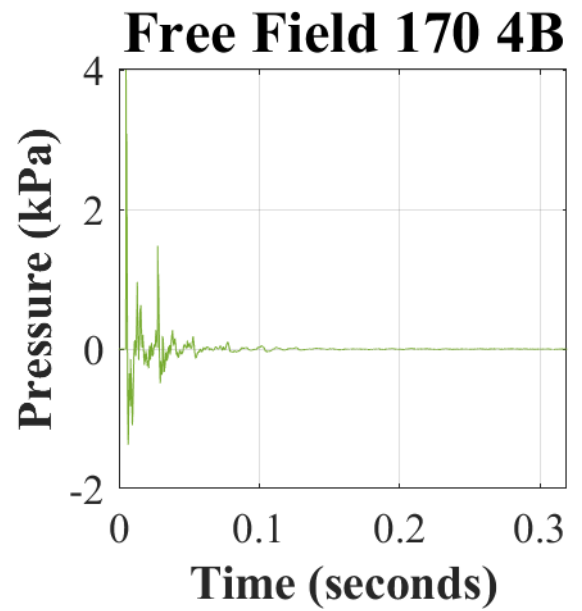
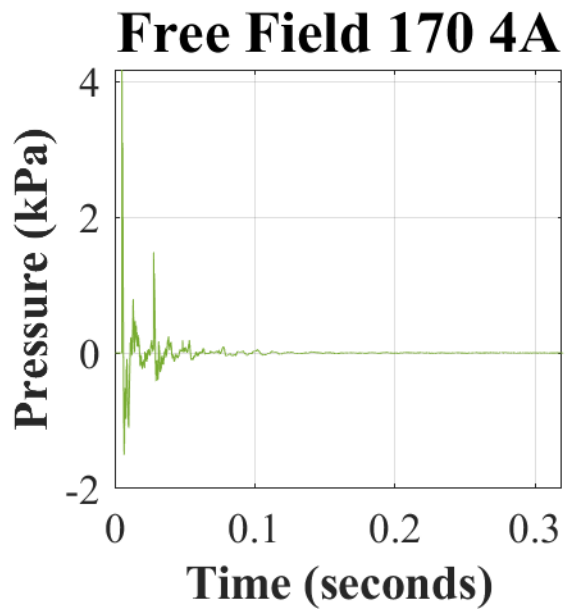
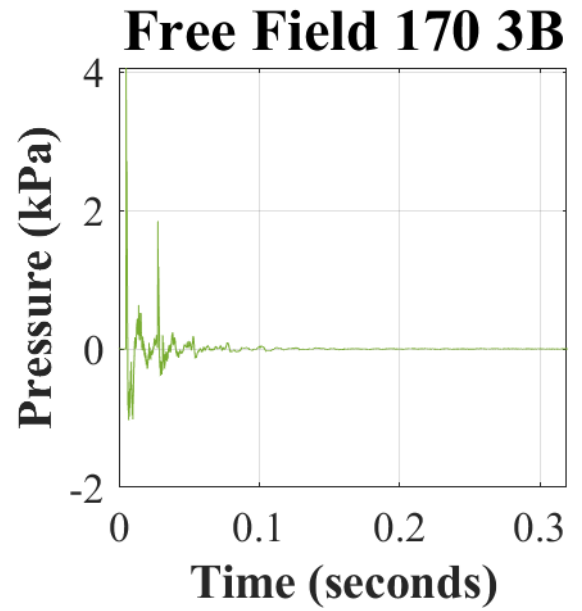
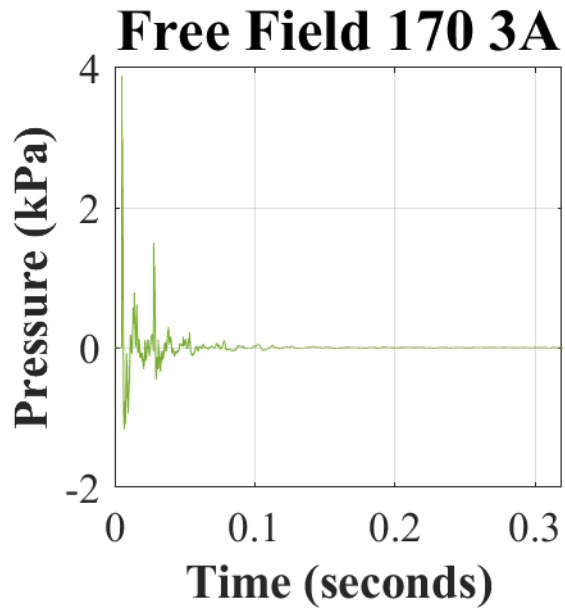


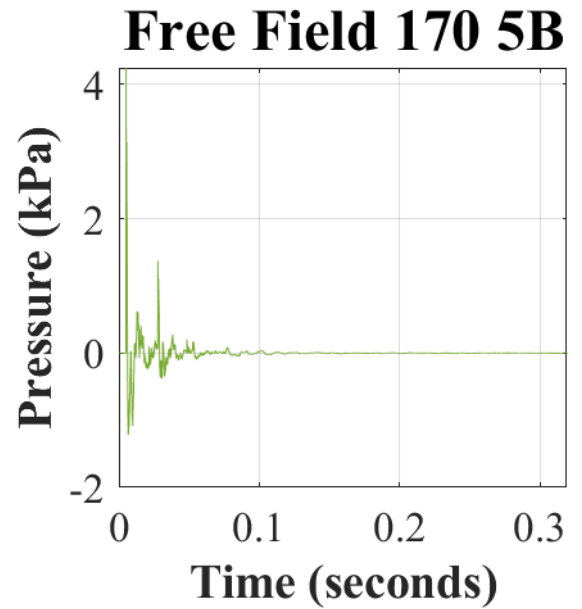
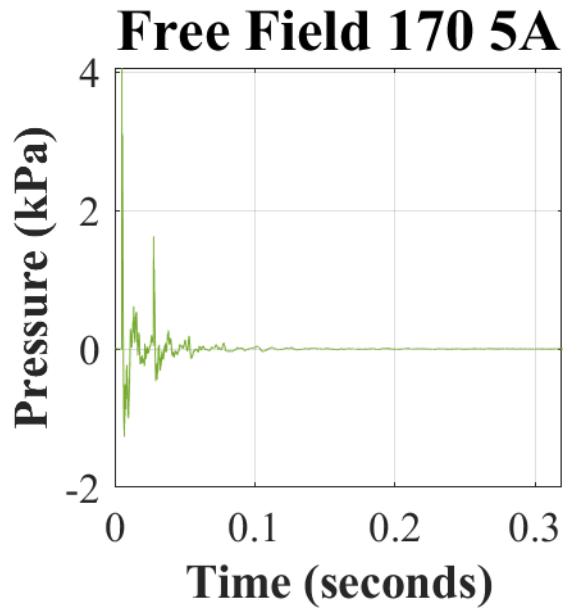


Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (170 dBp), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

Appendix F. Recorded waveform of the impulse measured with the free-field probe at 170 dBp and the Quattro™ earplugs donned.







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 dB), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or B).