

# Naval Submarine Medical Research Laboratory

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## **Impulse Peak Insertion Loss of the Honeywell Howard Leight™ MAX® Small Earplug**

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## 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 Honeywell Howard Leight™ MAX® Small Earplug (Howard Leight™ MAX® Small; Model: MAX-1S). 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. All samples were tested at the nominal levels of 160 and 170 decibel peak (dB<sub>P</sub>, 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 were rejected. The mean and standard deviation (SD) IPIL values for each nominal level were 52.7 (2.0) dB at 160 dB<sub>P</sub> and 53.5 (1.4) dB at 170 dB<sub>P</sub> (see Table 1). The Howard Leight™ MAX® Small (when properly fit and functional) will adequately protect (i.e., reduce exposure to less than 140 dB<sub>P</sub>) for impulses up to, but not including 180.0 dB<sub>P</sub>.

**Table 1.**

*Howard Leight™ MAX® Small mean (SD) IPIL value (in dB) for all test conditions.*

<b>160 dB<sub>P</sub></b>	<b>170 dB<sub>P</sub></b>
52.7 (2.0)	53.5 (1.4)

## Introduction

The Honeywell Howard Leight™ MAX® Small Single-Use Earplug (Howard Leight™ MAX® Small; Honeywell International Inc., Charlotte, NC) is an uncorded, passive bell-shaped plug made of polyurethane foam. Per manufacturer documentation, the Howard Leight™ MAX® Small is available in one universal size that is 20% smaller than its counterpart, the Howard Leight™ MAX® earplug, providing comfort for smaller ear canals (Honeywell International Inc., 2018). The Howard Leight™ MAX® Small is intended for single use and should be discarded if compromised.

This technical memorandum details the procedures followed to determine the impulse peak insertion loss (IPIL) value for the uncorded Howard Leight™ MAX® Small 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<sup>3</sup> anechoic chamber in order to minimize any effects of sound reflections.

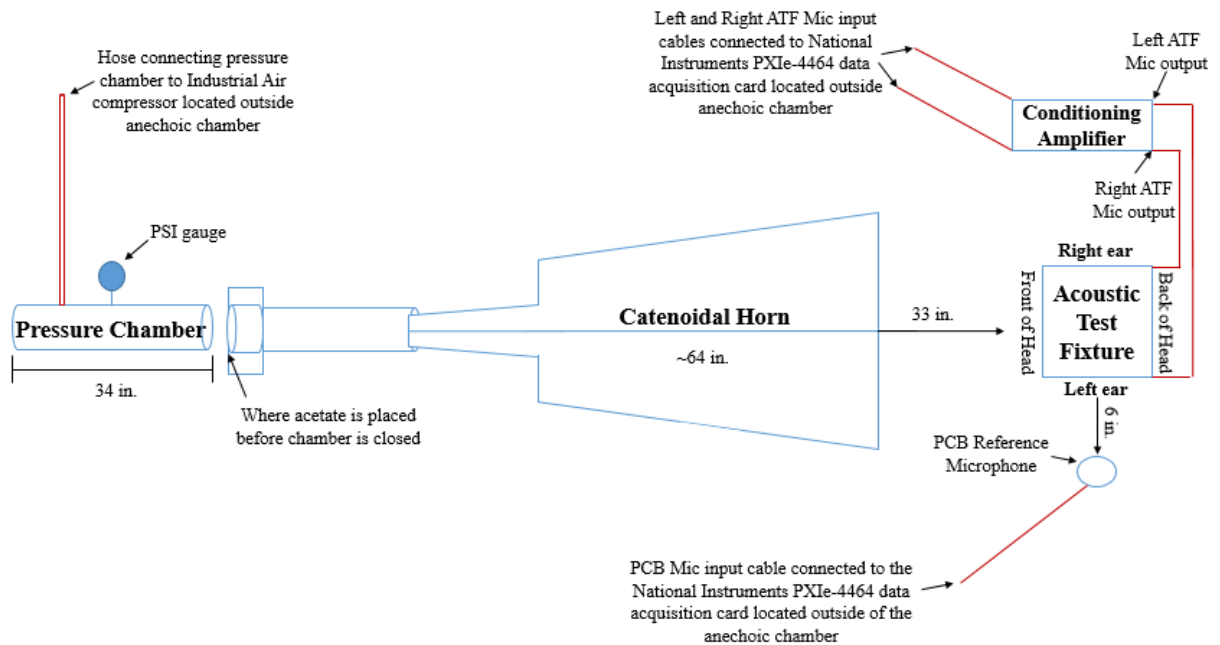
### Equipment

**Hardware.** Acoustic impulses were generated by NSMRL's 4 inch (in.) shock tube (B/C Precision, Inc., Greendale, IN). The shock tube pressure chamber is approximately 34 in. long, with an inner diameter of 4 in. A 64 in. 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 0.002 inches (2.0 millimeters) 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. 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. shock tube and test system can be seen in Figure 1.

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



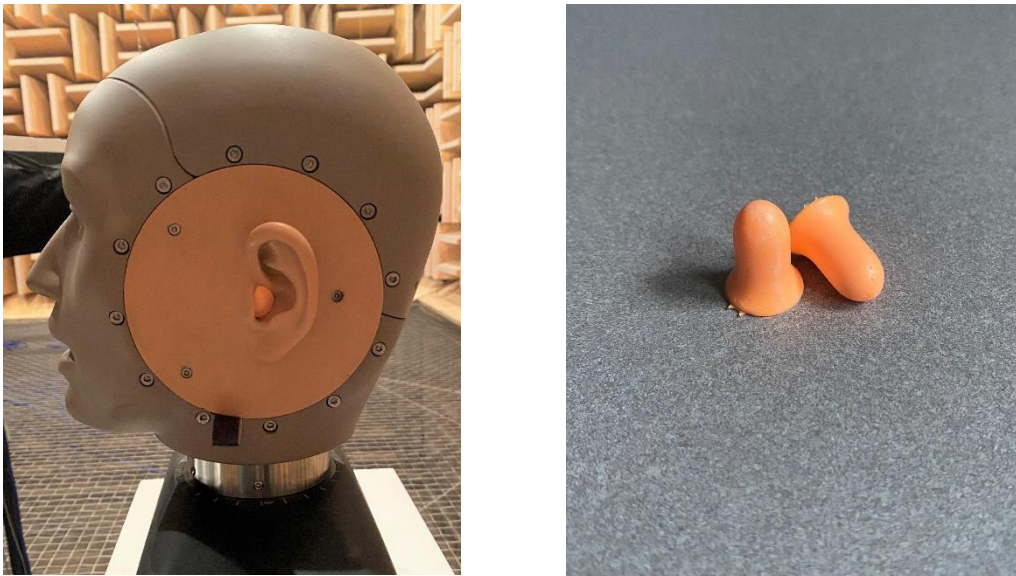
**Data Acquisition System.** The data acquisition system (NI chassis PXIe-1071 with NI PXIe-4460 and NI PXIe-4464; National Instruments Corp., Austin, TX) was controlled by a standalone laptop computer running project specific software (LabVIEW; National Instruments Corp., Austin, TX). The data acquisition 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. 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. 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 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 uncorded Honeywell Howard Leight™ MAX® Small Single-Use Earplugs (Manufacturer Product Number: MAX-1S) 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.**  
*Howard Leight™ MAX® Small 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, extreme hardness, or damage prior to use. Once inspected, each earplug was rolled down avoiding creases, inserted into the ear canal, and held in place for until fully expanded. Earplugs were given at least two minutes to fully expand in the ATF ear canal before impulse testing was performed.

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 4-in. 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 dB, six calibration impulses were generated at the 160 dB 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 dB. Calibrations were not completed at the 170 dB nominal level due to exposure limitations of the ATF right and left microphones.

A Butterworth filter (6<sup>th</sup> 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 dB 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 dB 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 dB 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 dB and 170 dB). Every waveform was plotted with time on the x-axis and pressure on the y-axis. The transfer functions were not plotted.

### **Results**

As shown in Table 2, the overall mean IPIL value was 52.7 dB at the 160 dB test condition and at 53.5 dB at the 170 dB test condition. Calculated IPIL values for all individual sample trials ranged between 49.4 and 57.0 dB at the 160 dB test condition and between 50.6 and 55.6 dB at the 170 dB test condition (see table 2). The waveforms for all trials with the uncorded Howard Leight™ MAX® Small are provided in Appendices A to F.

**Table 2.**

*Mean (SD) IPIL values (in dB) for Tested Howard Leight™ MAX® Small Samples.*

	<b>160 dBP</b>		<b>170 dBP</b>	
	<i>Right</i>	<i>Left</i>	<i>Right</i>	<i>Left</i>
HPD 1, Trial A	50.8	49.4	54.9	54.9
HPD 1, Trial B	52.4	49.8	55.2	55.1
HPD 2, Trial A	53.1	54.1	55.5	52.9
HPD 2, Trial B	52.0	52.2	55.6	52.1
HPD 3, Trial A	53.8	51.1	53.1	53.8
HPD 3, Trial B	53.7	52.5	53.2	52.1
HPD 4, Trial A	53.3	50.8	52.5	50.6
HPD 4, Trial B	54.0	52.1	52.5	51.5
HPD 5, Trial A	57.0	52.0	53.2	54.3
HPD 5, Trial B	57.0	52.0	53.2	54.2
<b>Ear Specific Mean (SD)</b>	53.7 (2.0)	51.6 (1.4)	53.9 (1.3)	53.2 (1.5)
<b>Level Overall Mean (SD)</b>	52.7 (2.0)		53.5 (1.4)	

## Discussion

The aim of this report was to document the measured attenuation provided by the Howard Leight™ MAX® Small to impulsive noises through testing IAW ANSI/ASA S12.42-2010. Across ears, the individual trial mean IPIL values were found to vary as much as 7.6 dB at 160 dBP and 5.0 dB at 170 dBP. This may be due to a combination of inherent variance within the impulse system and test-retest variability in the fit of each earplug. Results indicate that a greater variety of attenuation was present in the individual trials at the 160 dBP level compared to 170 dBP. This is noted with a larger SD at the 160 dBP (2.0 dB) nominal level compared to that at the 170 dBP (1.4 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 (6<sup>th</sup> 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 (6<sup>th</sup> 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, we omitted testing at the 130 dBP and 150 dBP nominal levels. 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 4-in. 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. It is important to note that these results do not guarantee similar Howard Leight™ MAX® Small 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**

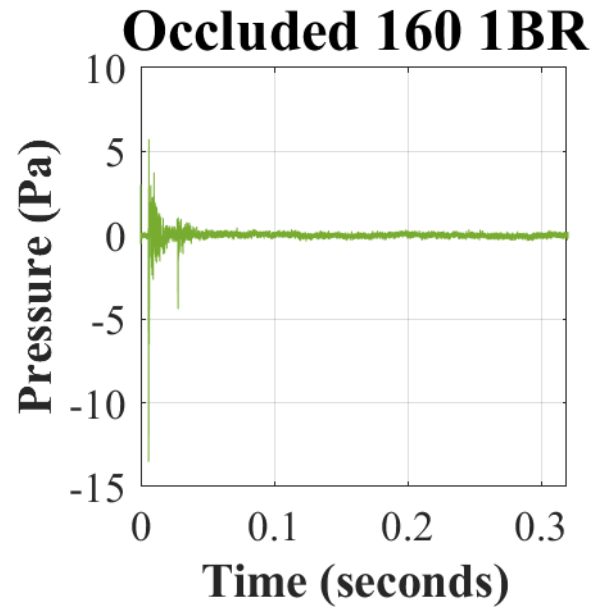
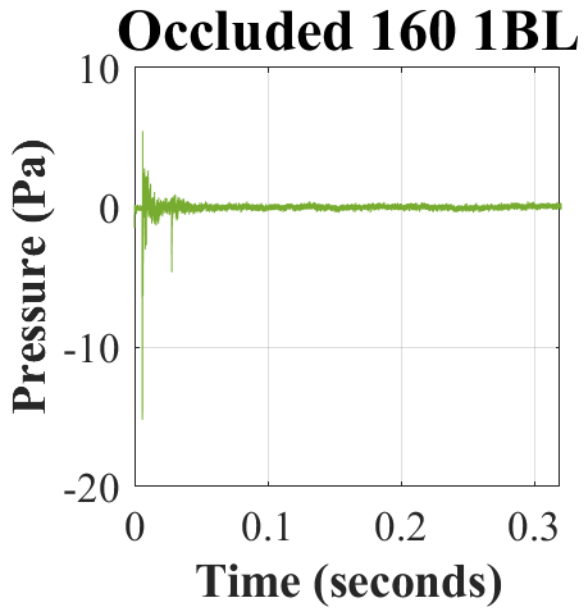
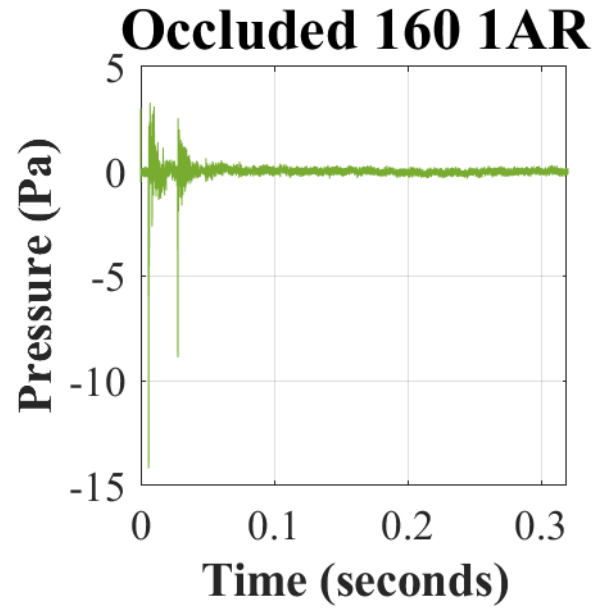
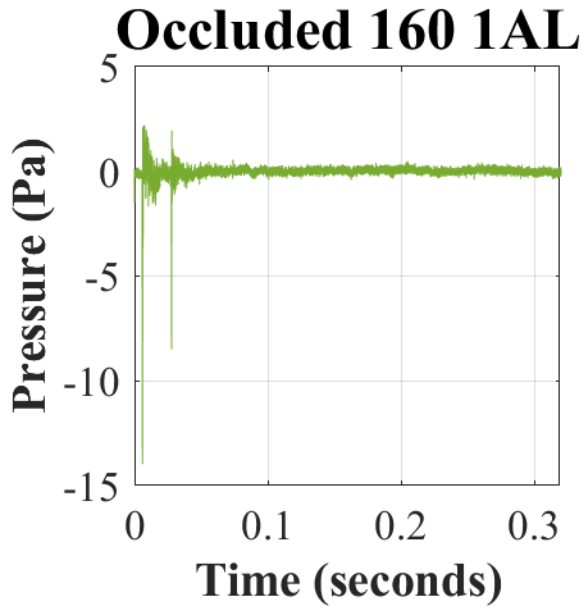
This report described the determination of the mean impulse peak insertion loss (IPIL) values provided by the uncorded Howard Leight™ MAX® Small Earplug at 160 dBP and 170 dBP nominal levels. The calculated overall mean (SD) impulse peak insertion loss (IPIL) values for the Howard Leight™ MAX® Small was found to be 52.7 (2.0) dB at 160 dBP and 53.5 (1.4) dB at 170 dBP.

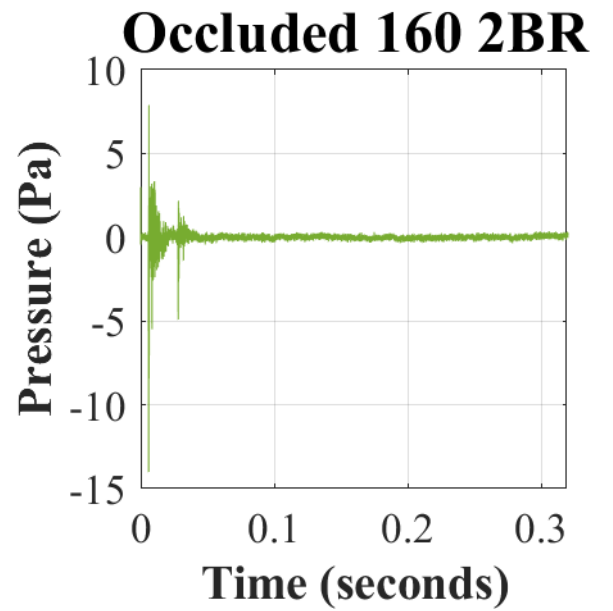
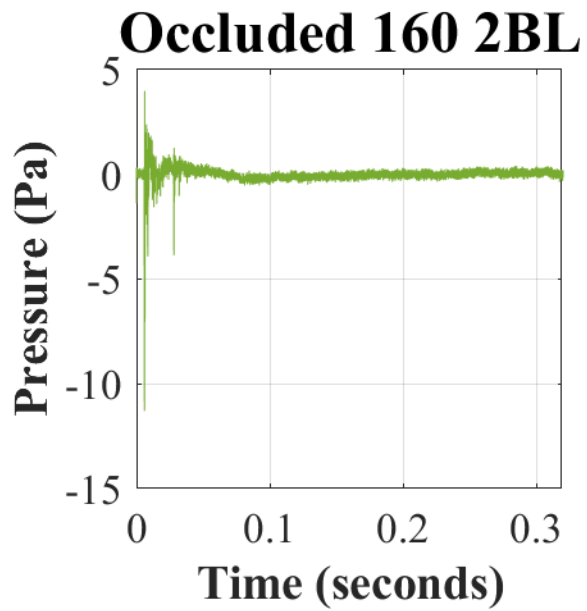
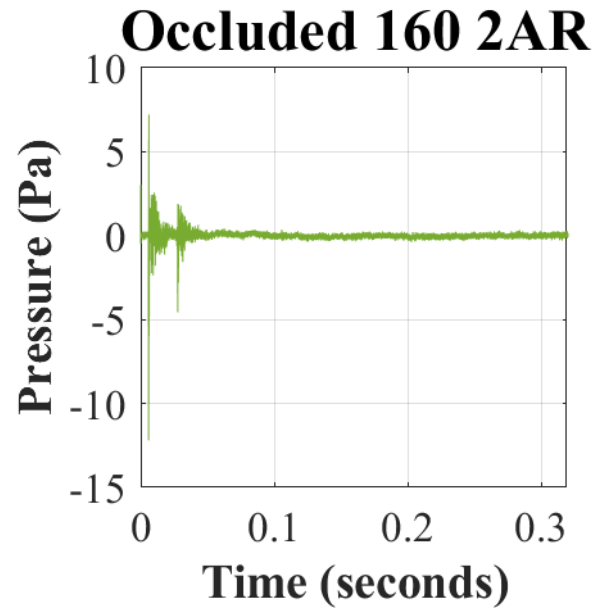
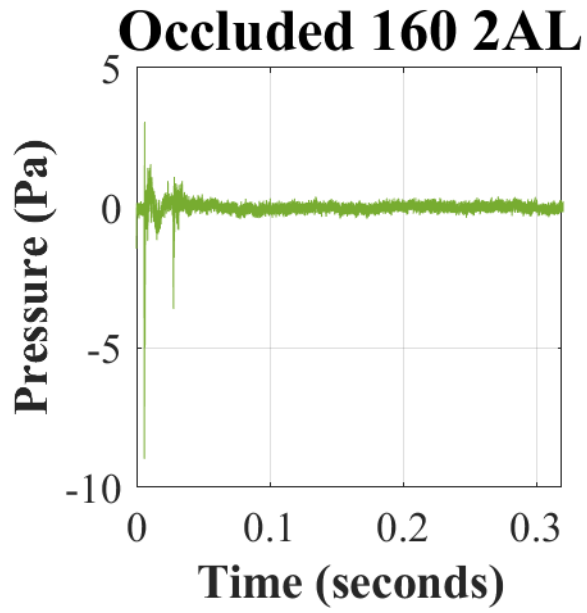
Within the Department of Defense (DoD), the exposure limit for impulse noise is 140 dBP (Office of the Under Secretary of Defense for Personnel and Readiness, 2019, Department of Defense, 2015). At exposure levels equal to and/or exceeding 140 dBP, hearing conservation efforts must be put into place. One such measure is the use of an HPD such as an earplug or earmuff to reduce the impulse below the 140 dBP threshold. The Howard Leight™ MAX® Small Earplug (when properly fit and functional) will adequately protect the user from impulses up to, but not including 180 dBP.

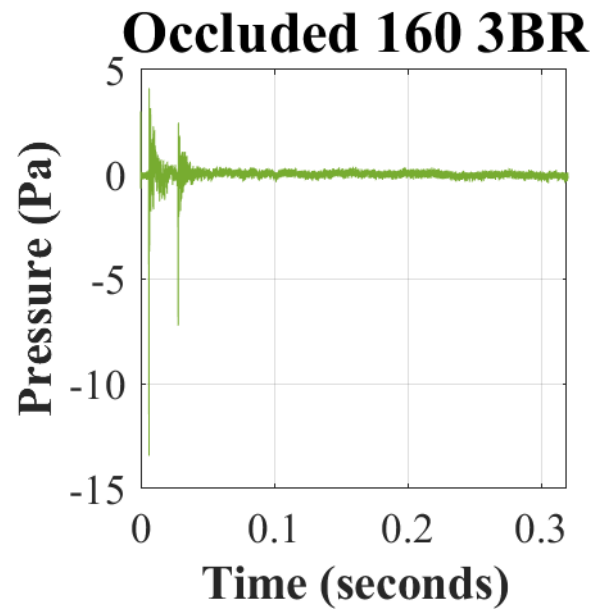
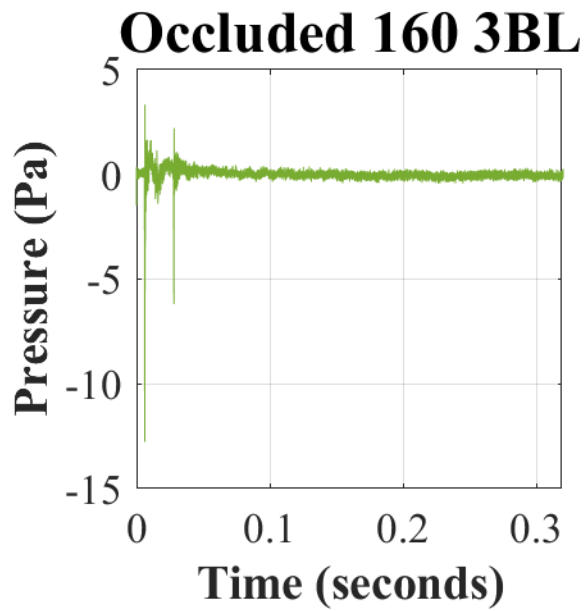
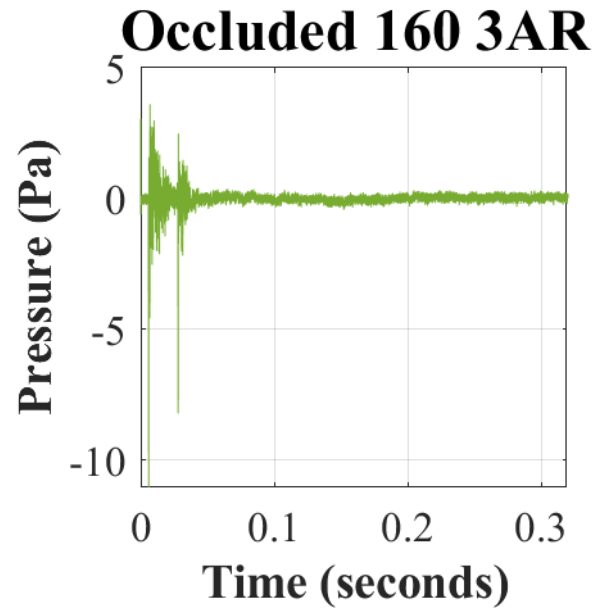
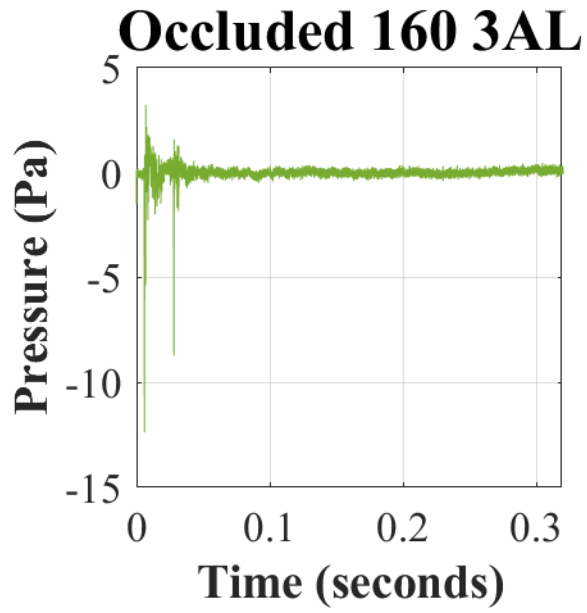
## References

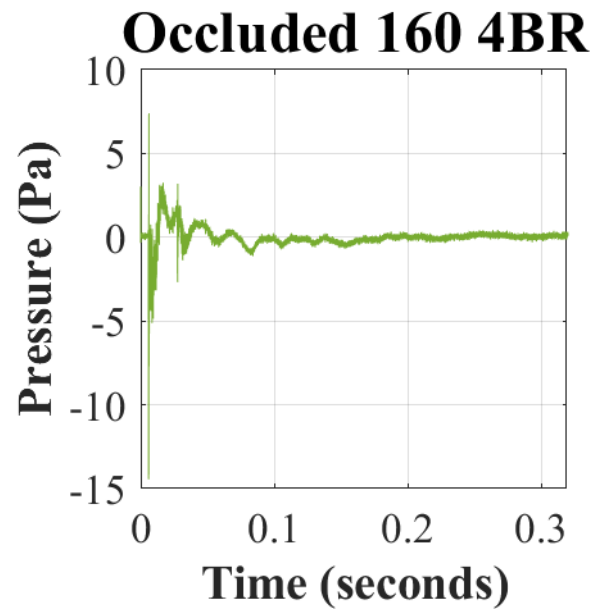
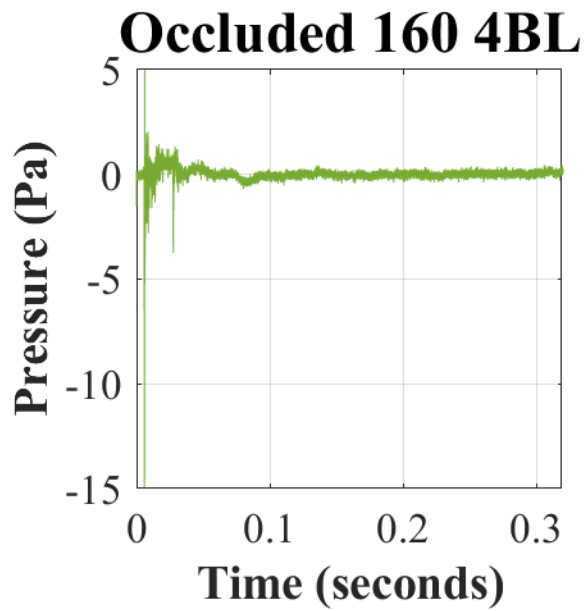
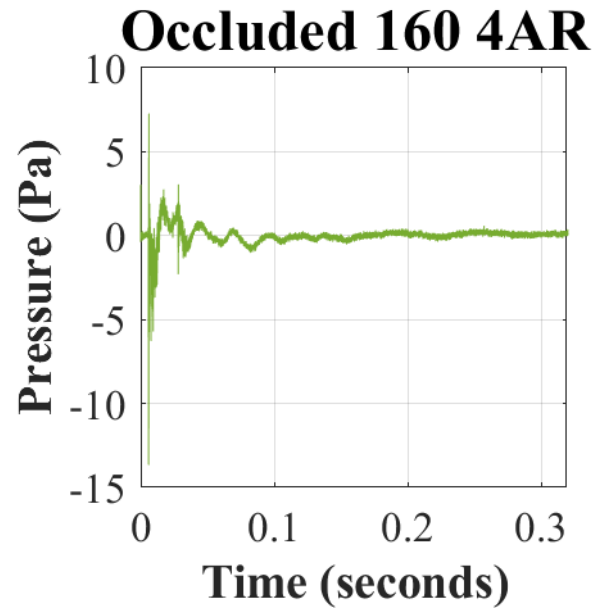
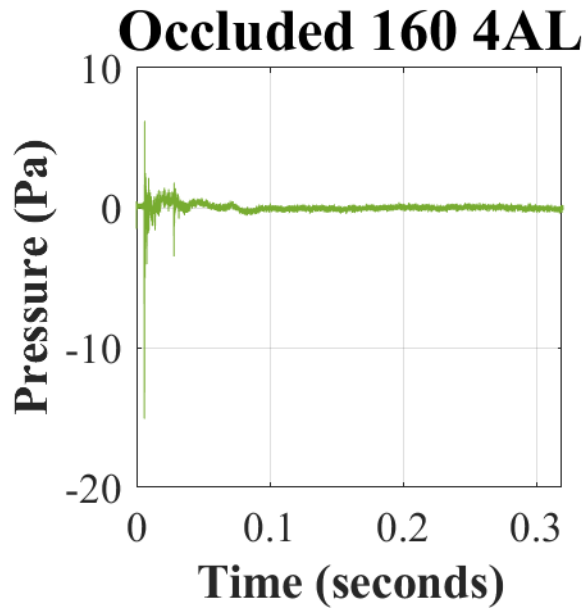
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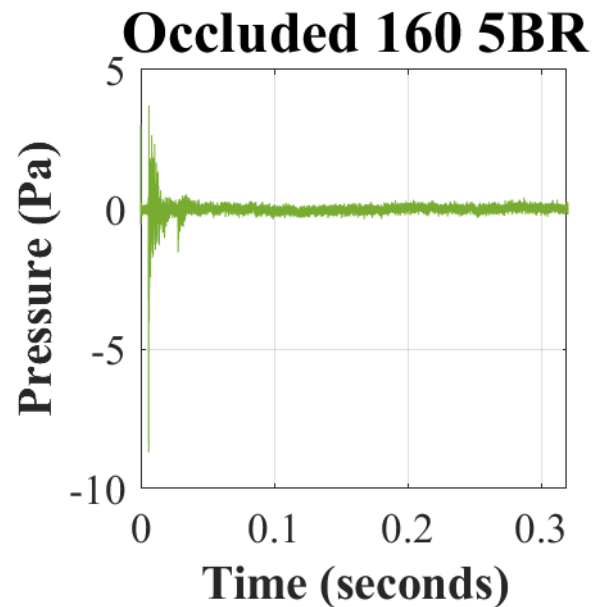
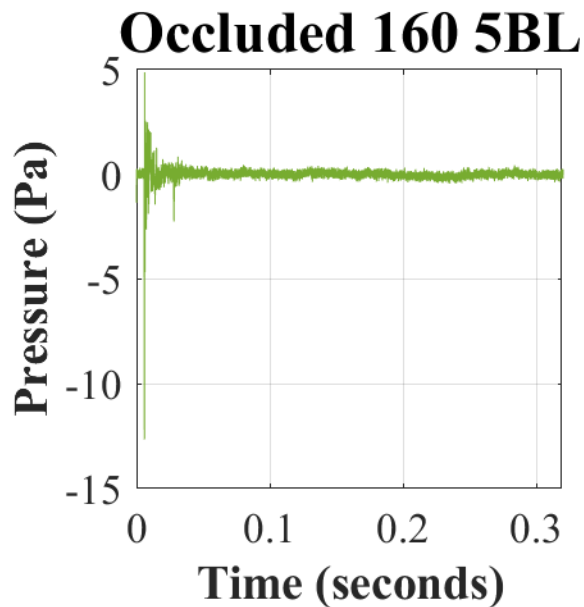
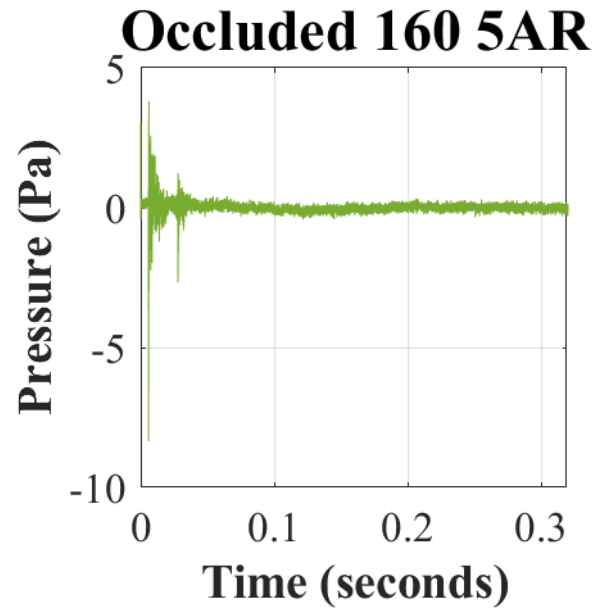
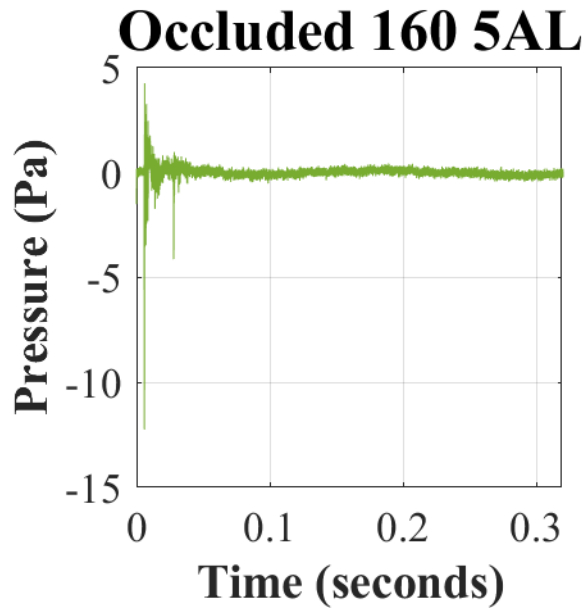
**Appendix A.** Recorded occluded (closed-ear) waveforms in response to 160 dBp with the Howard Leight™ MAX® Small earplugs.





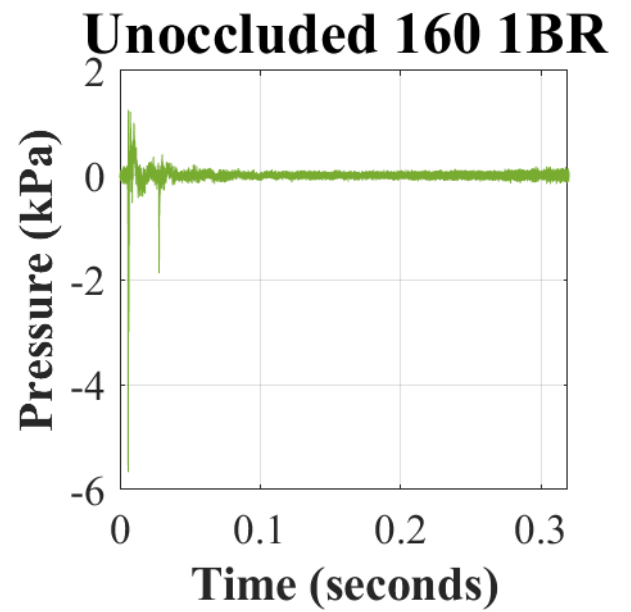
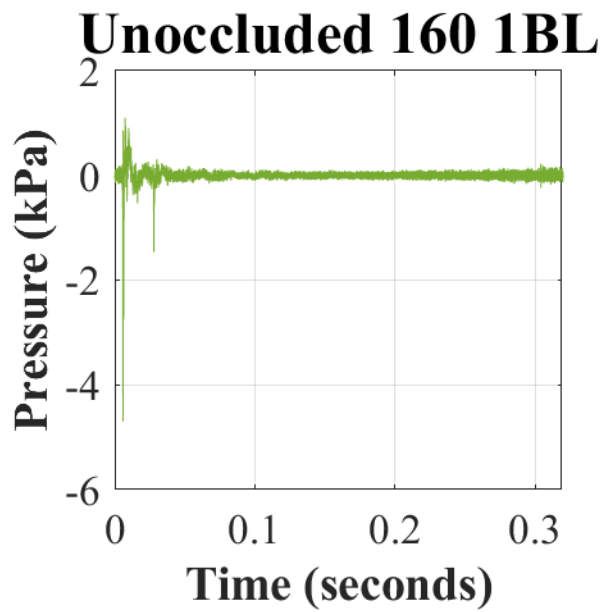
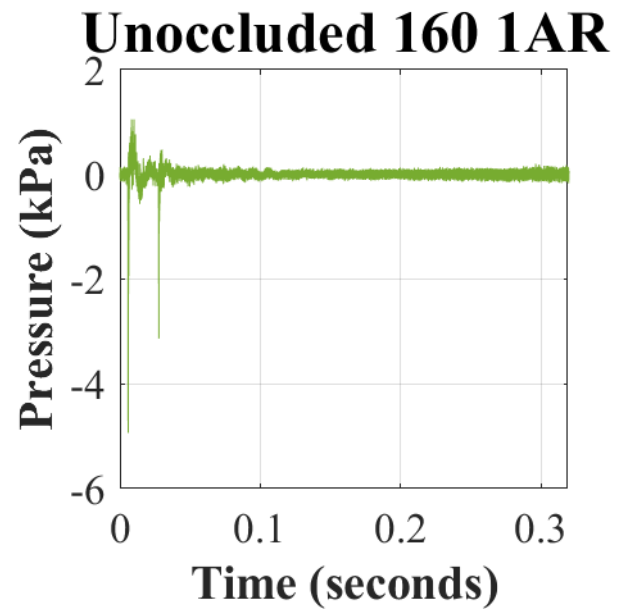
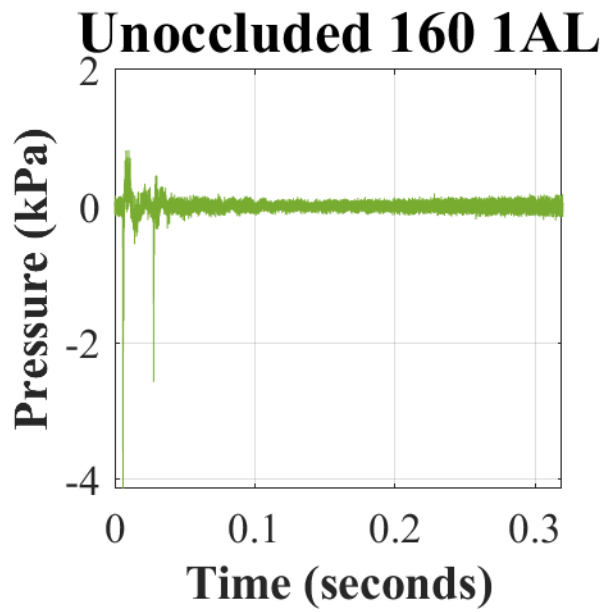


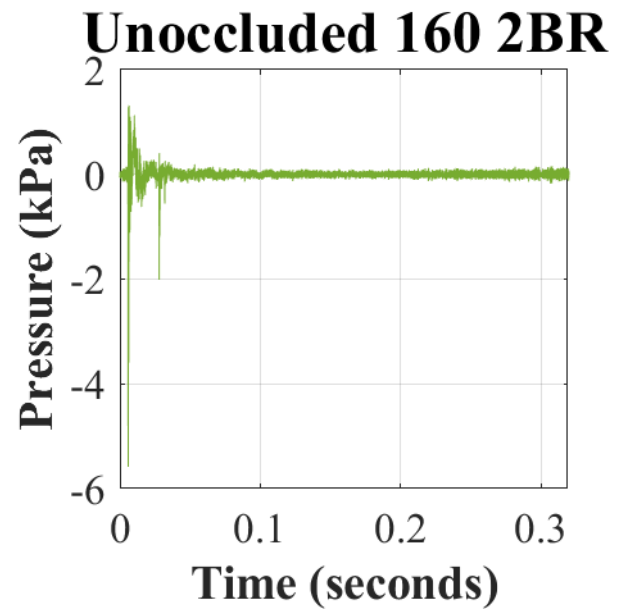
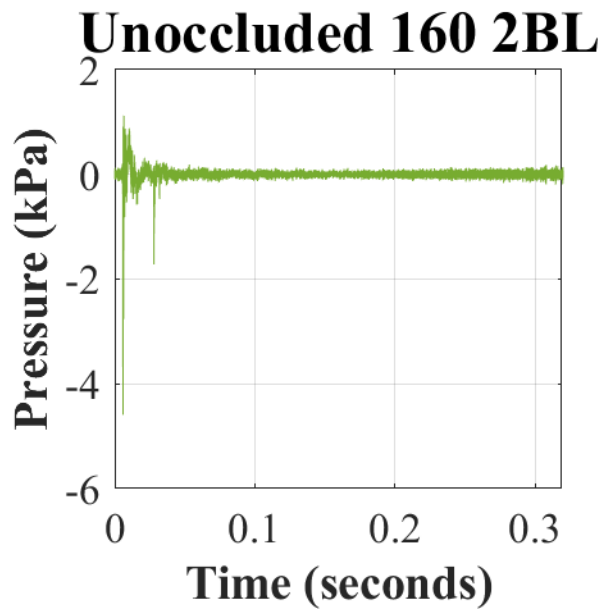
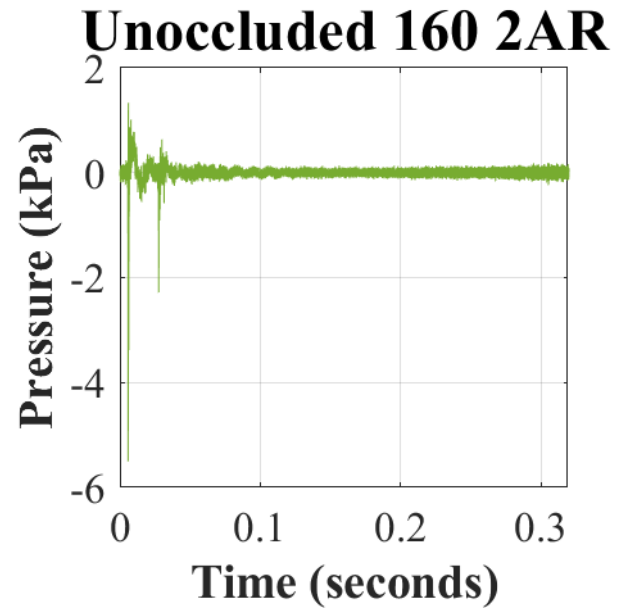
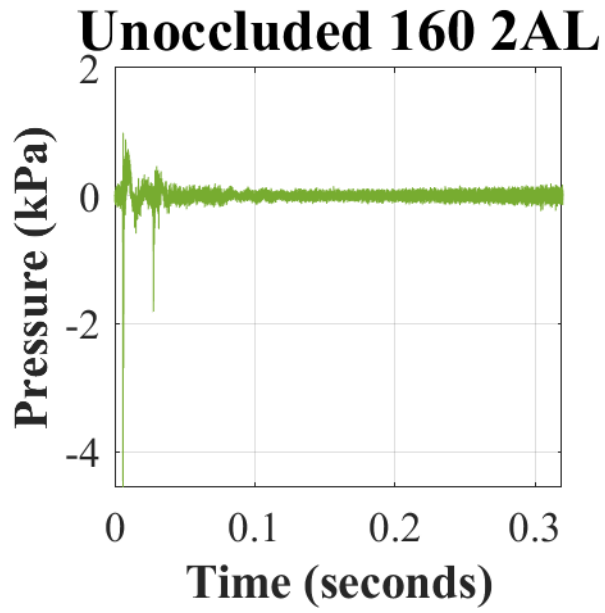


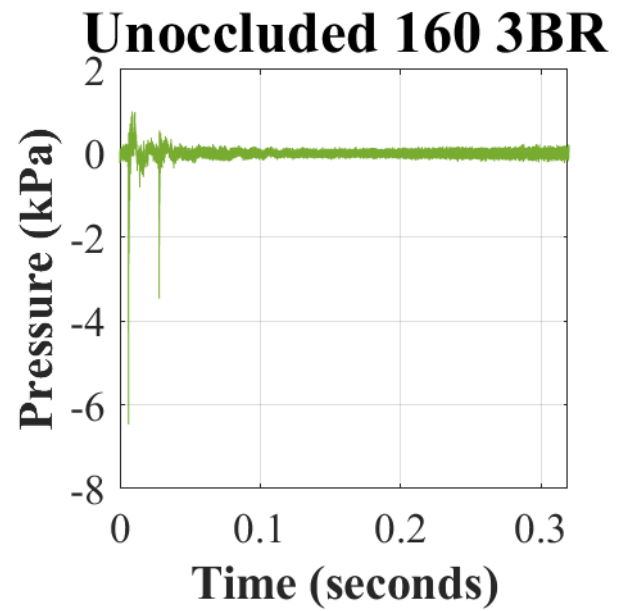
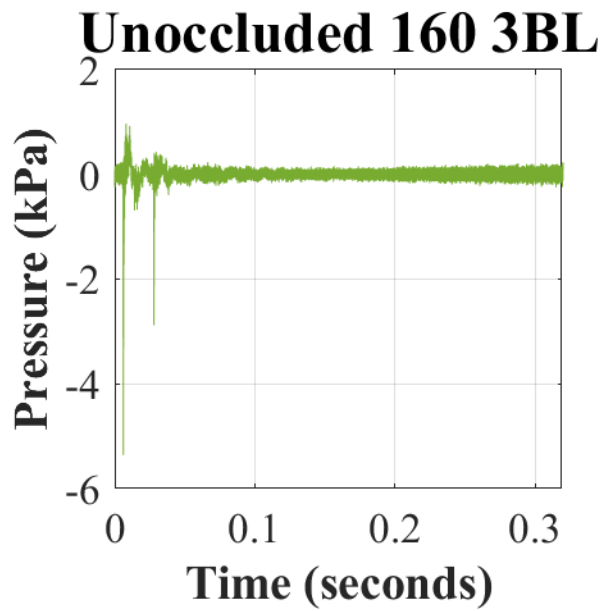
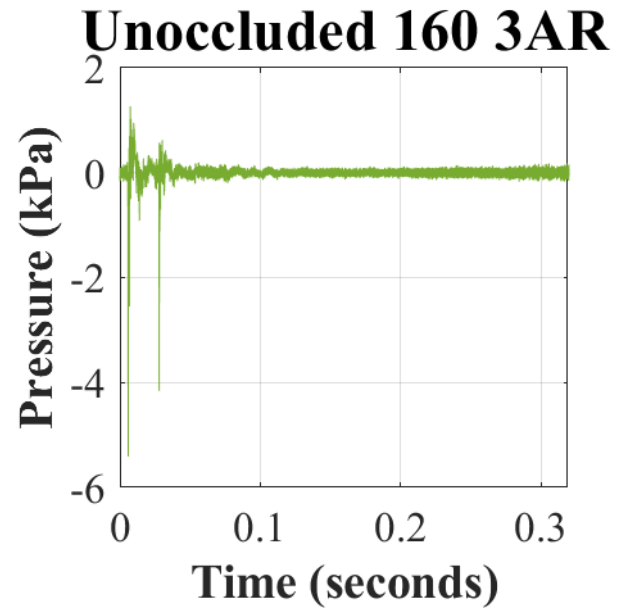
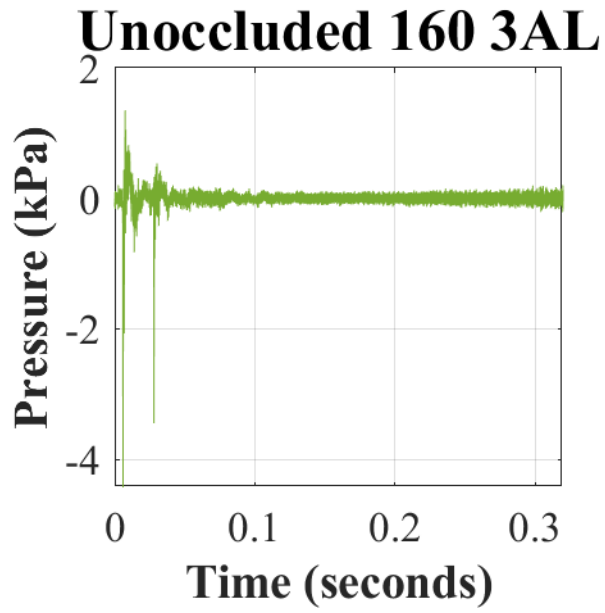


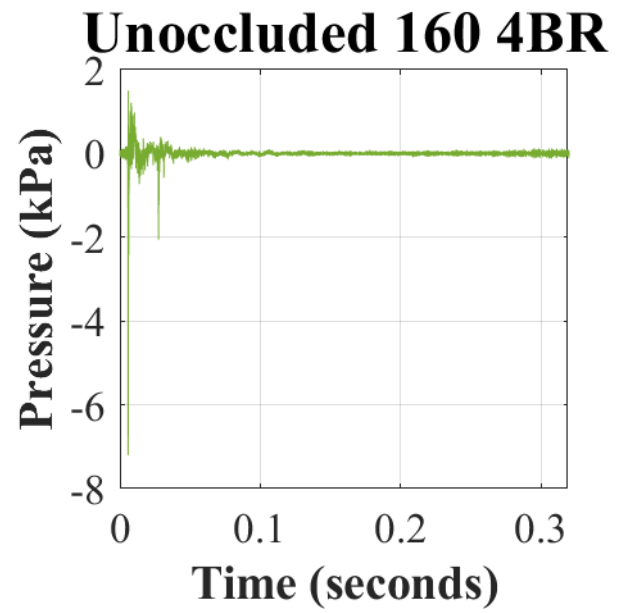
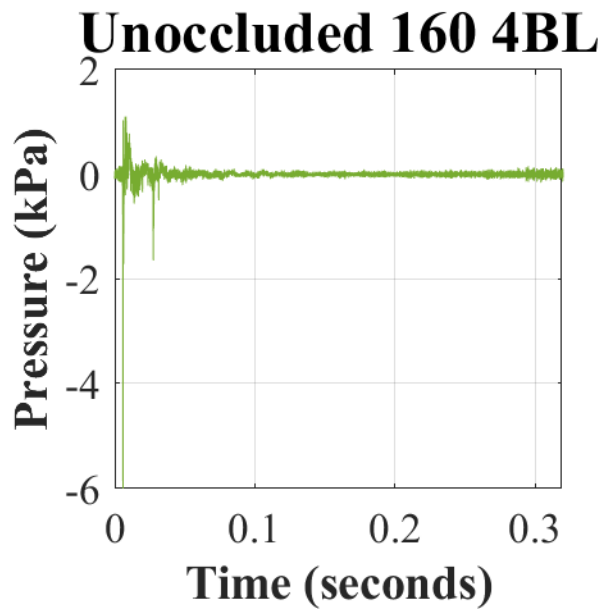
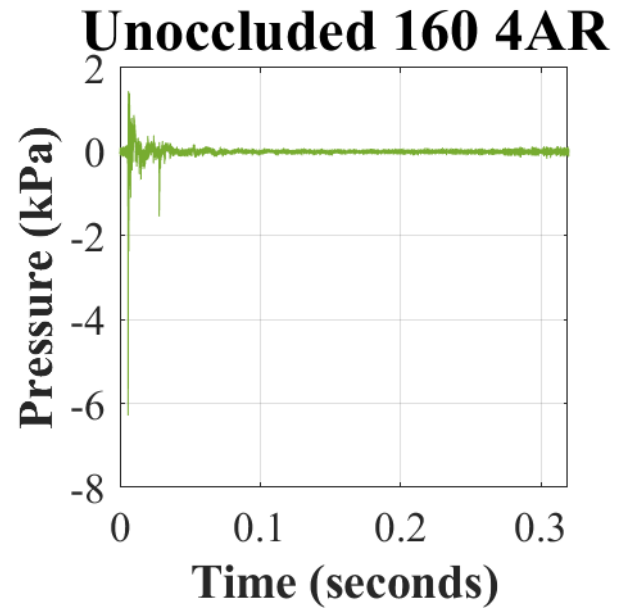
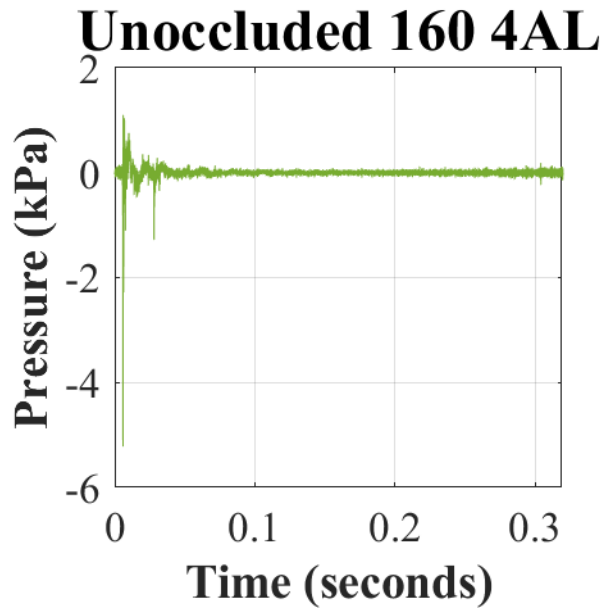
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating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

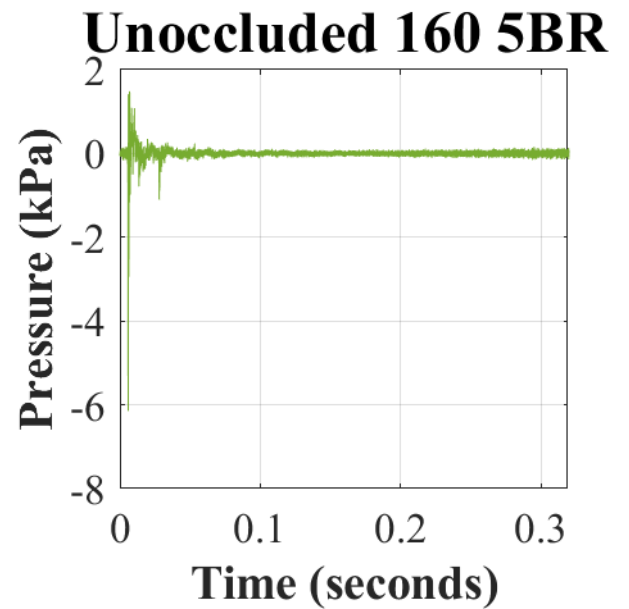
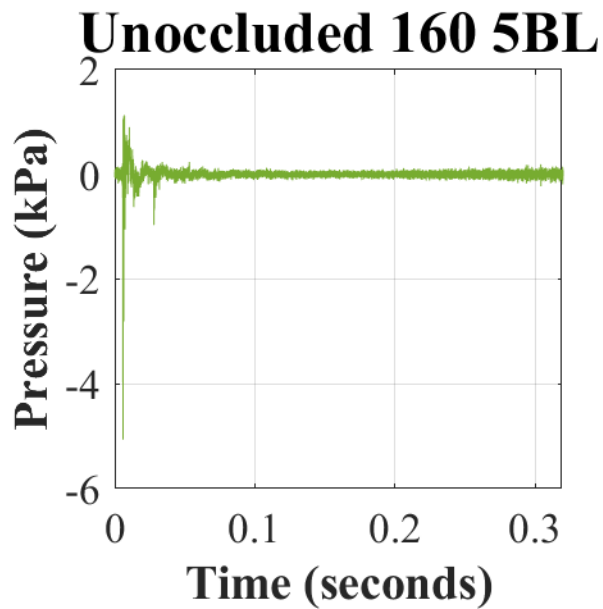
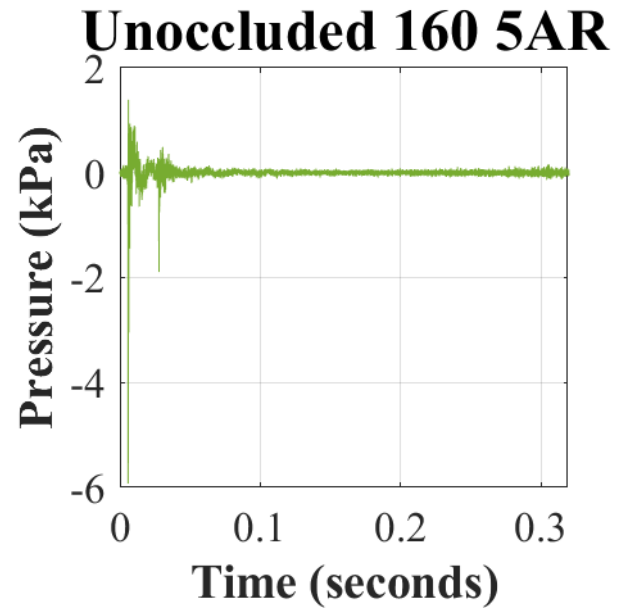
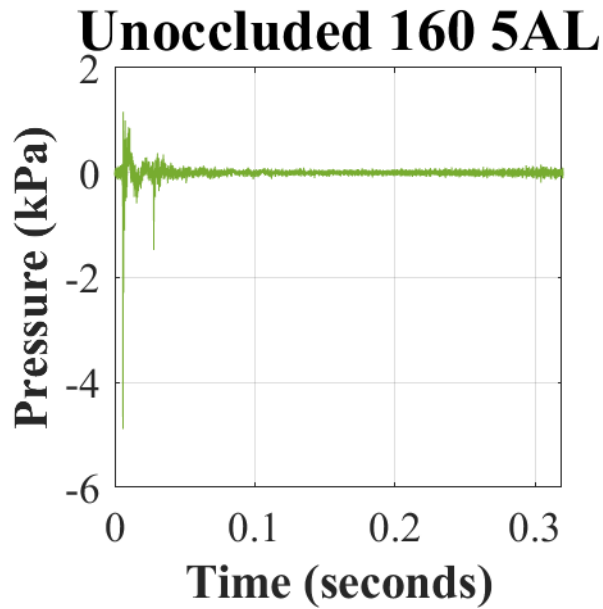
**Appendix B.** Estimated unoccluded (open-ear) waveforms in response to 160 dBp with the Howard Leight™ MAX® Small earplugs.





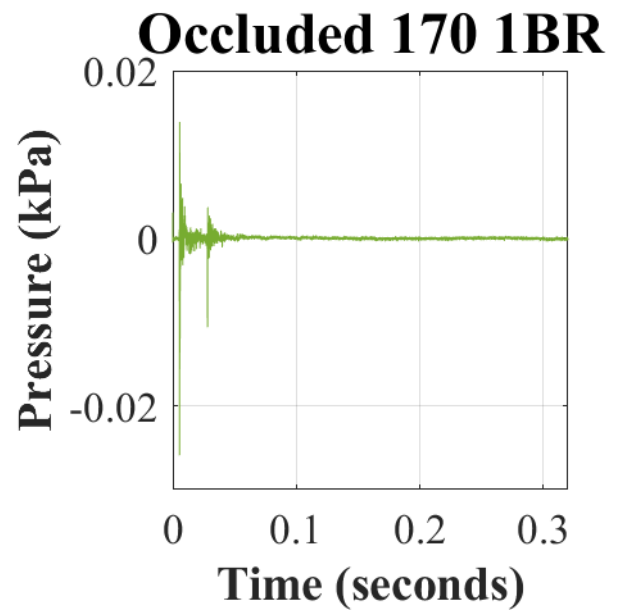
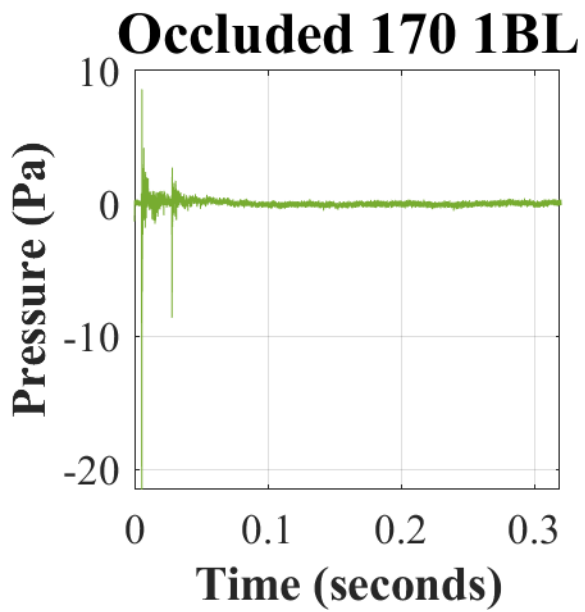
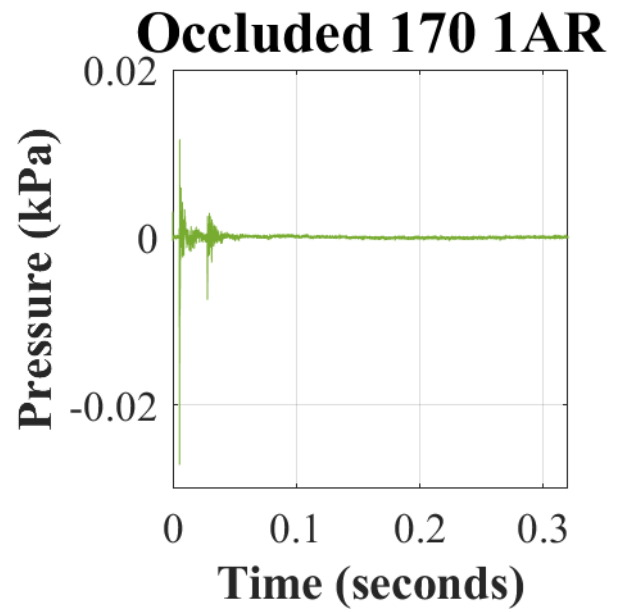
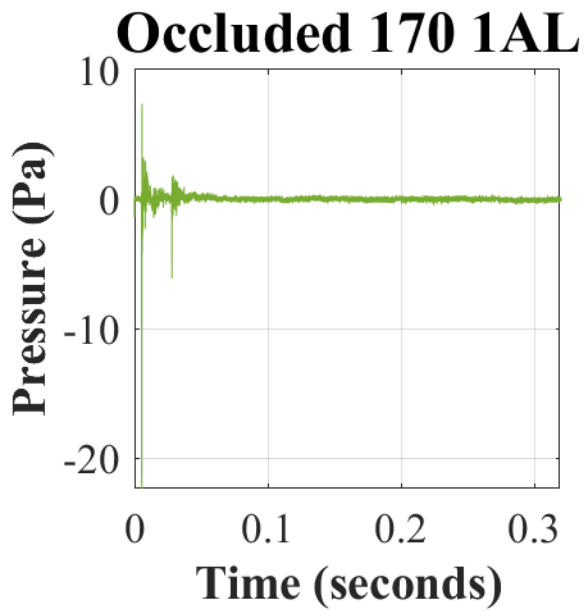


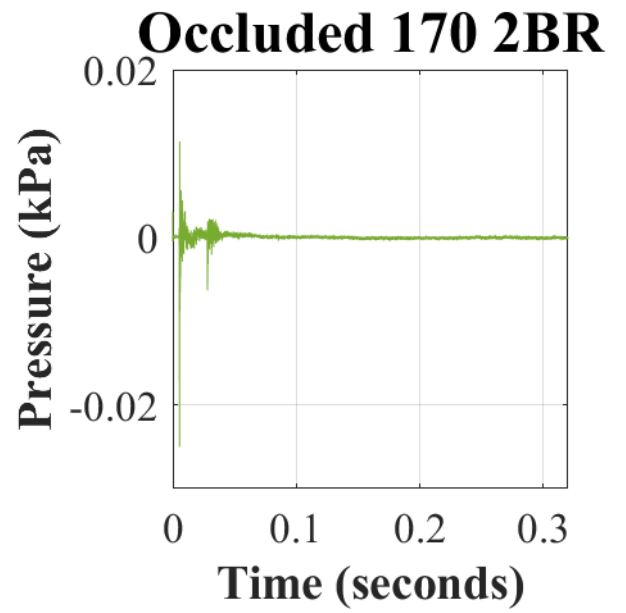
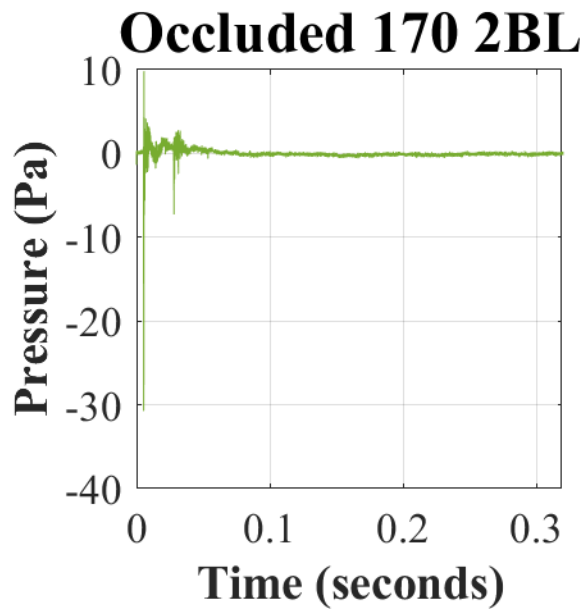
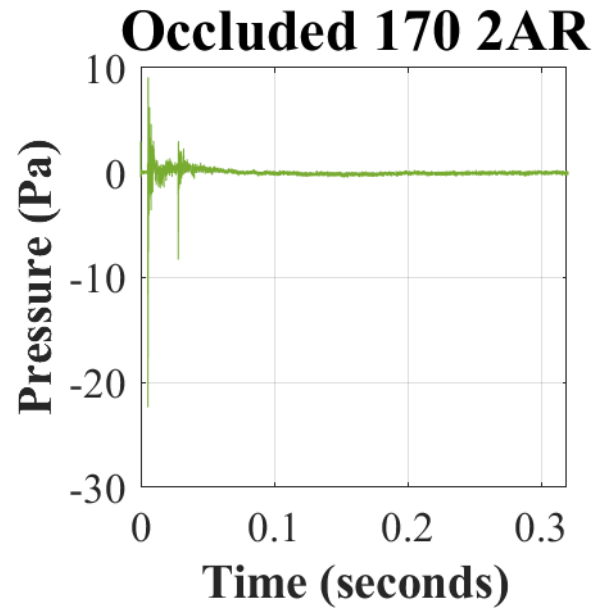
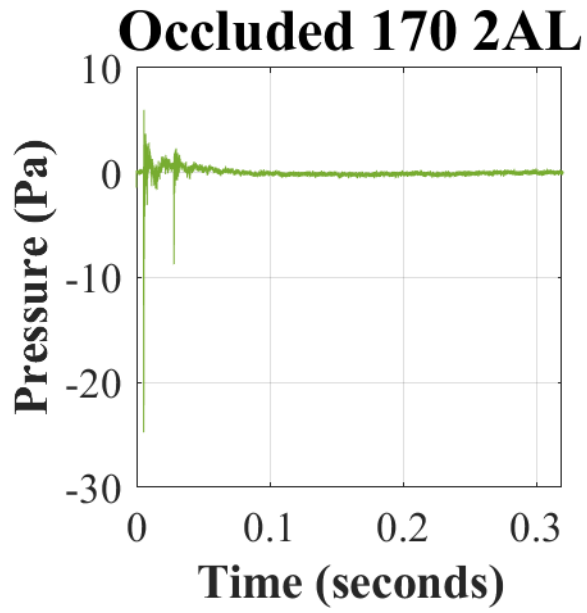


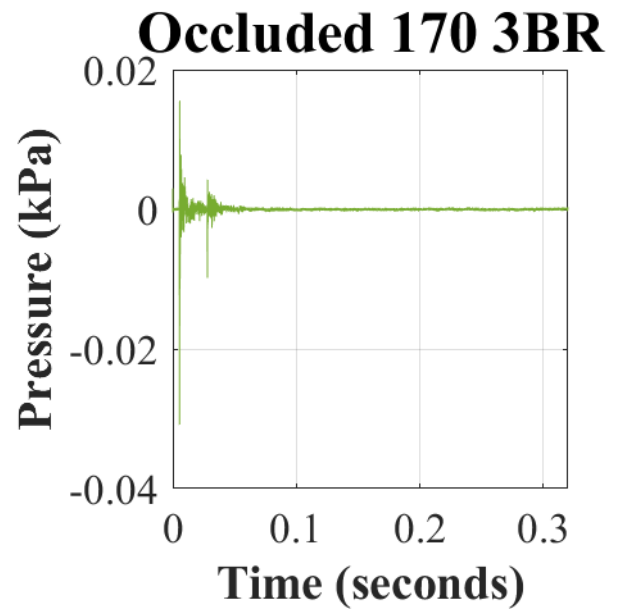
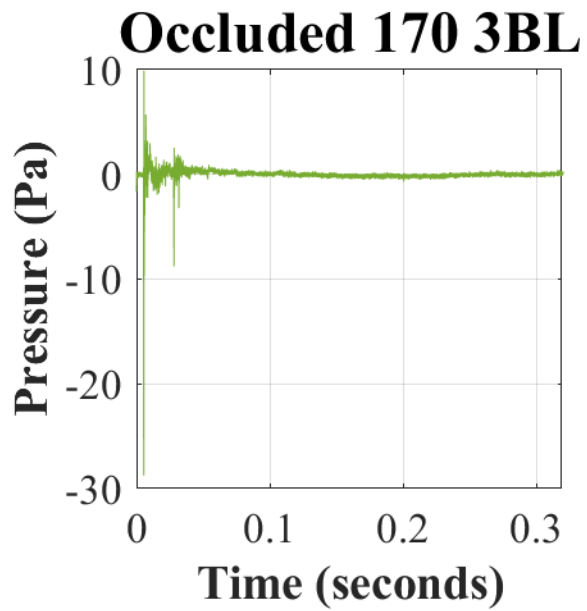
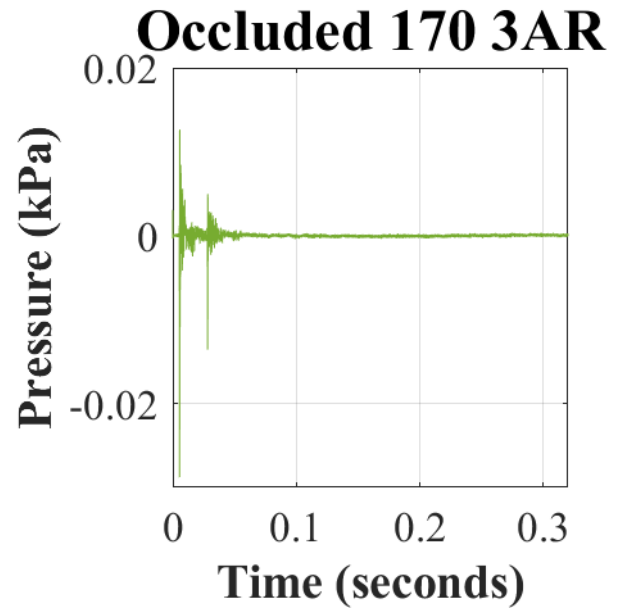
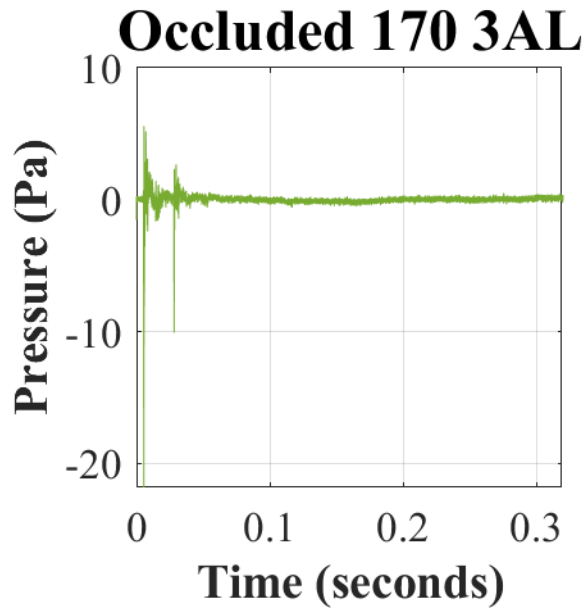


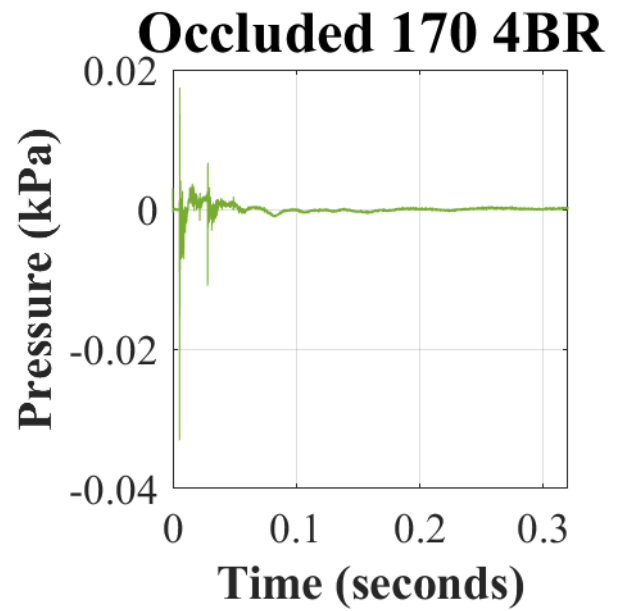
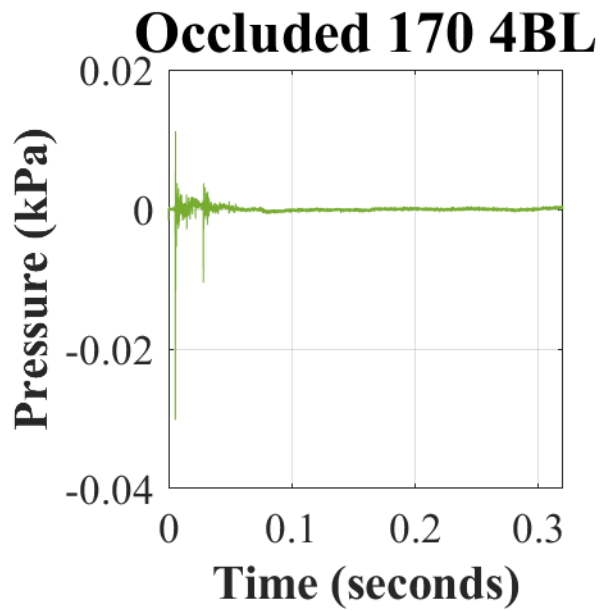
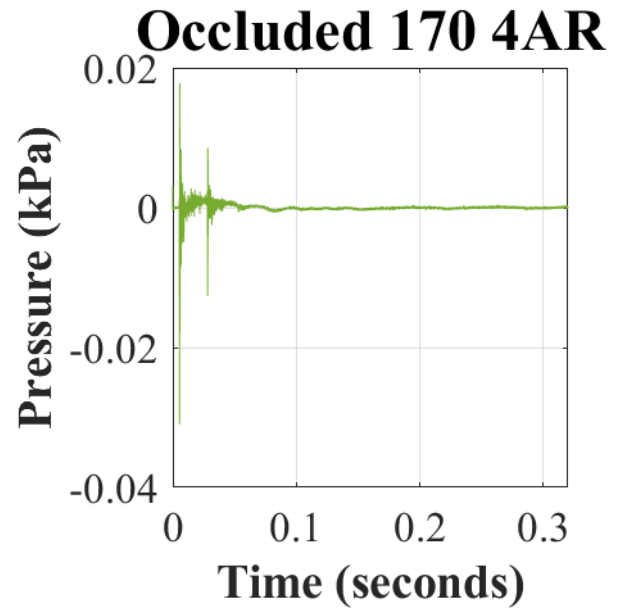
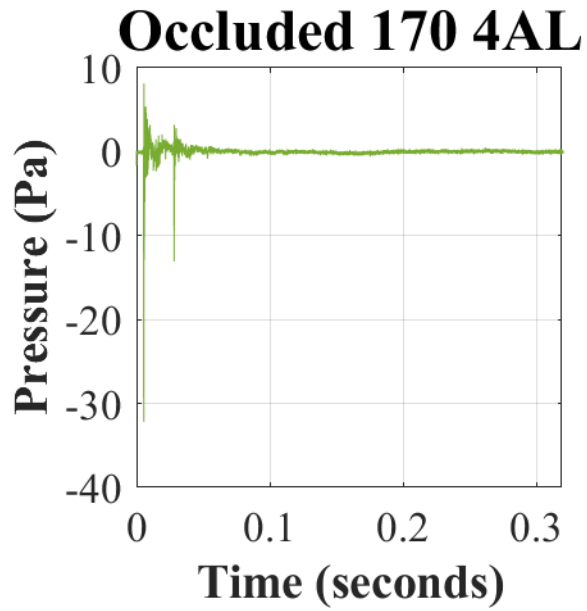
Note. The naming convention for all occluded waveforms is “Unoccluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the HPD doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B)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

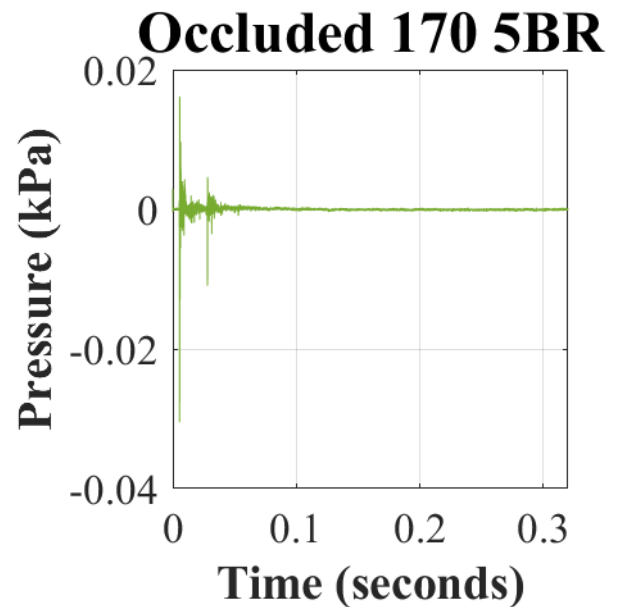
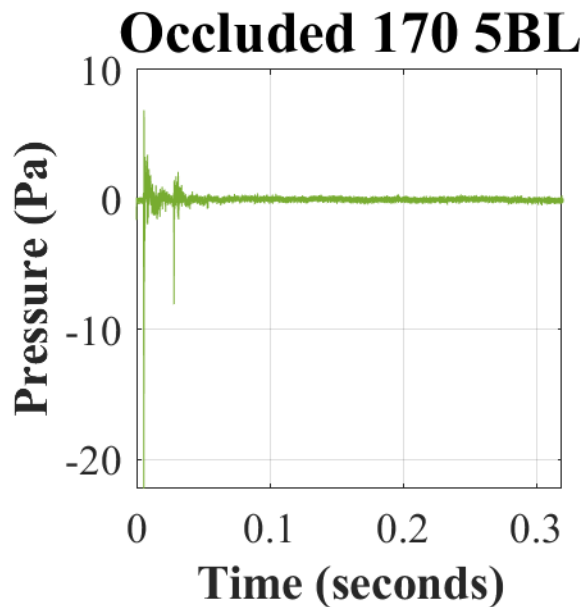
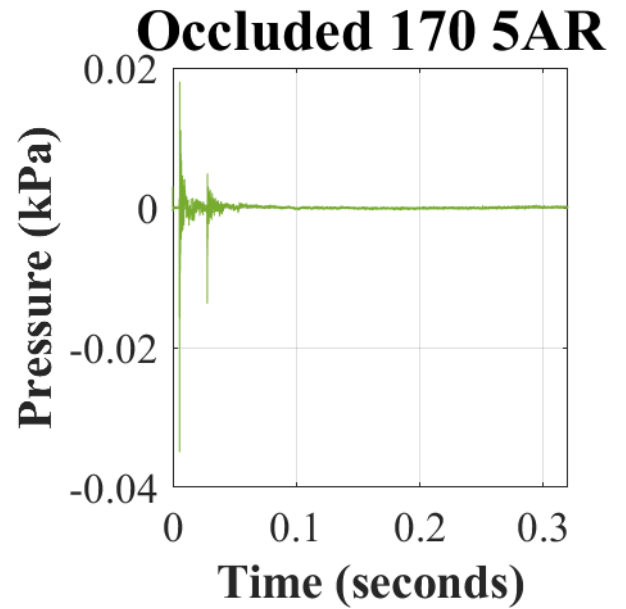
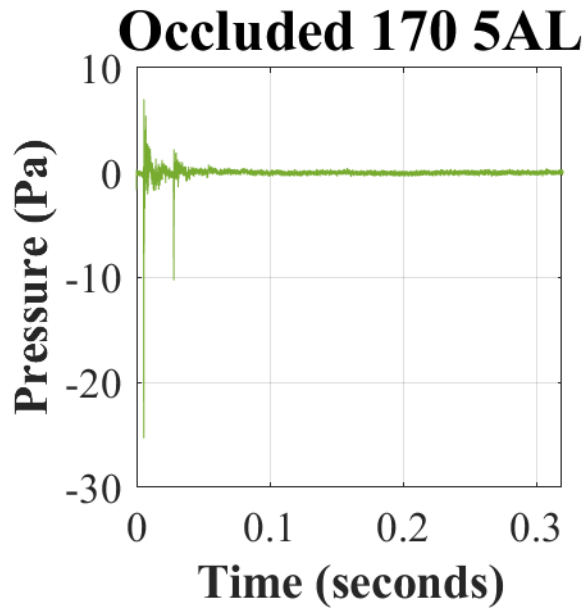
**Appendix C.** Recorded occluded (closed-ear) waveforms in response to 170 dBp with the Howard Leight™ MAX® Small earplugs.





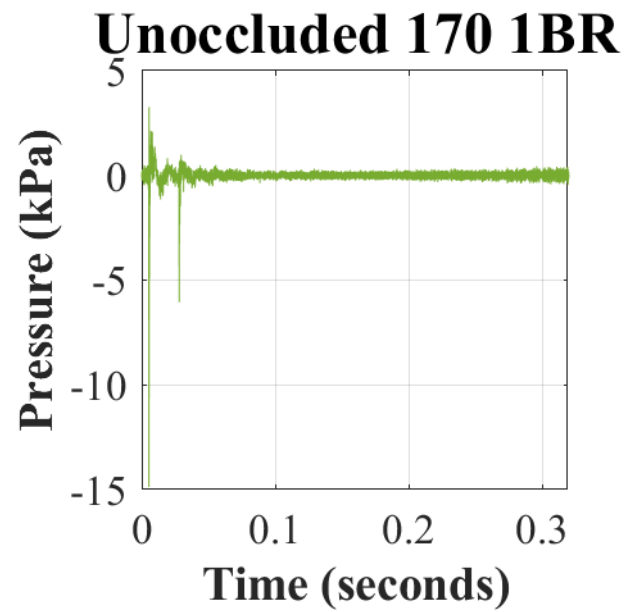
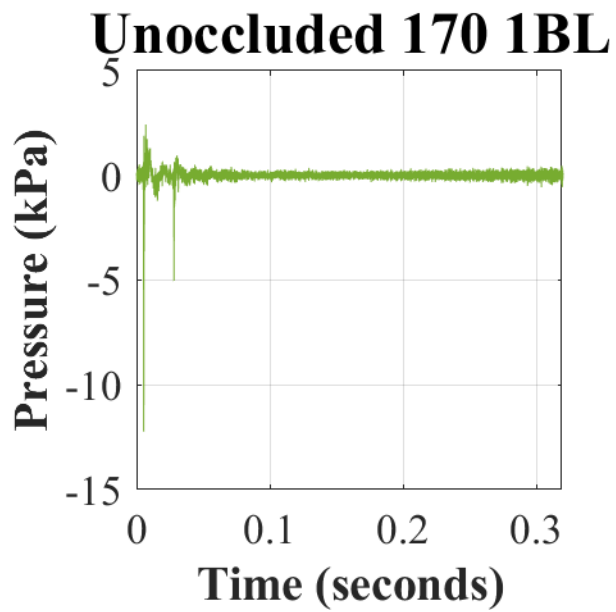
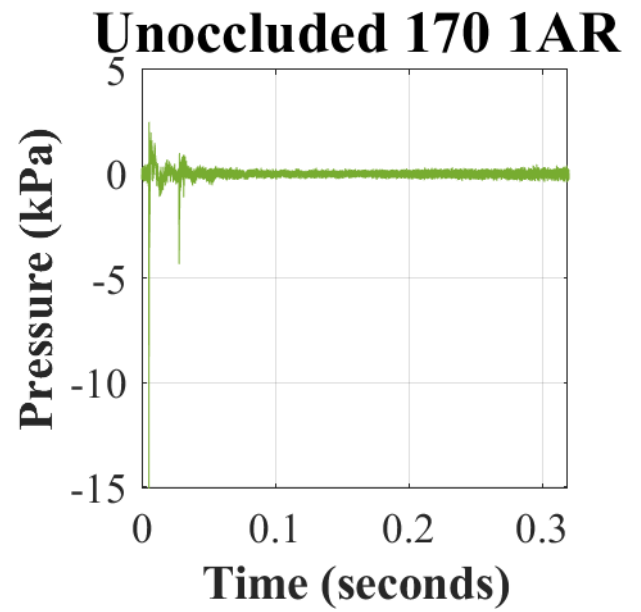
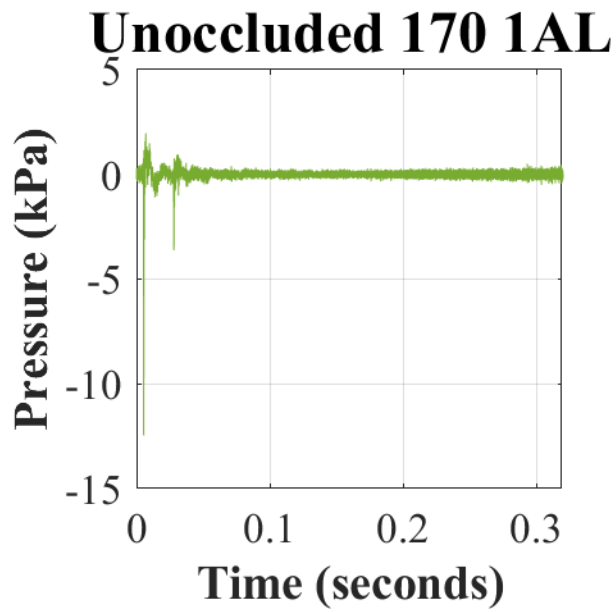


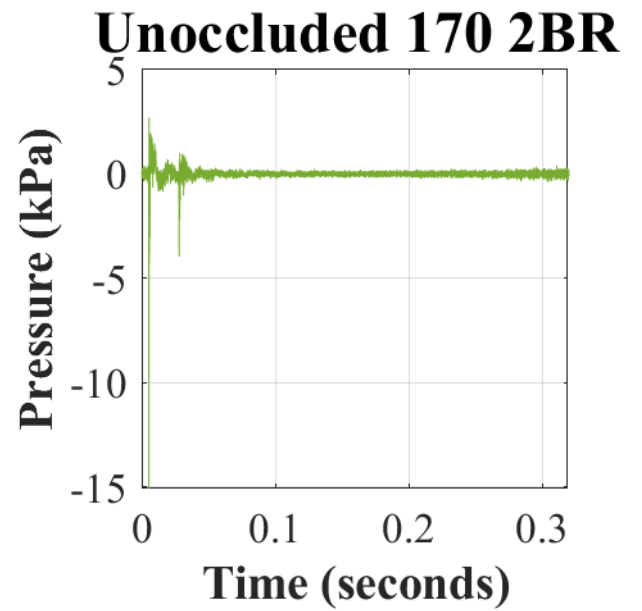
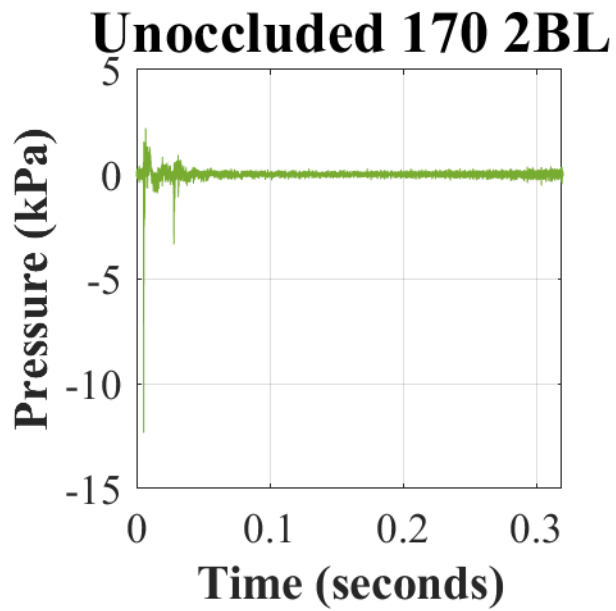
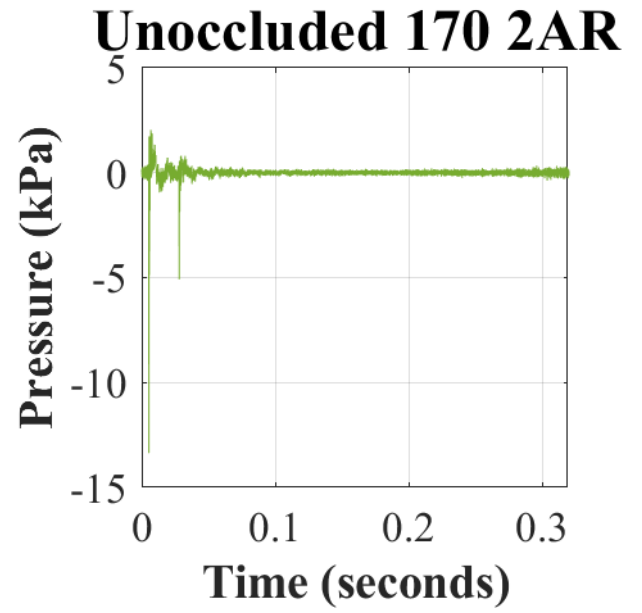
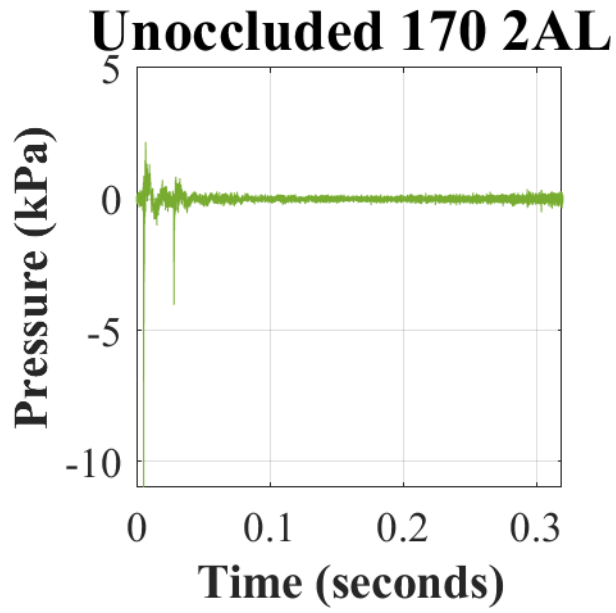


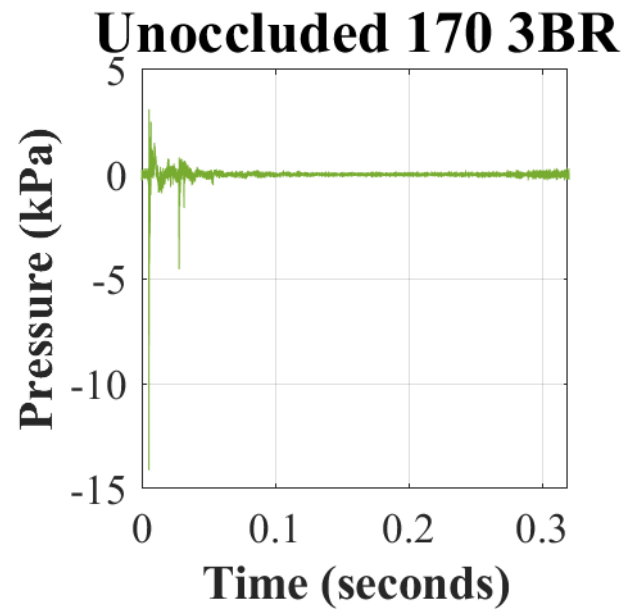
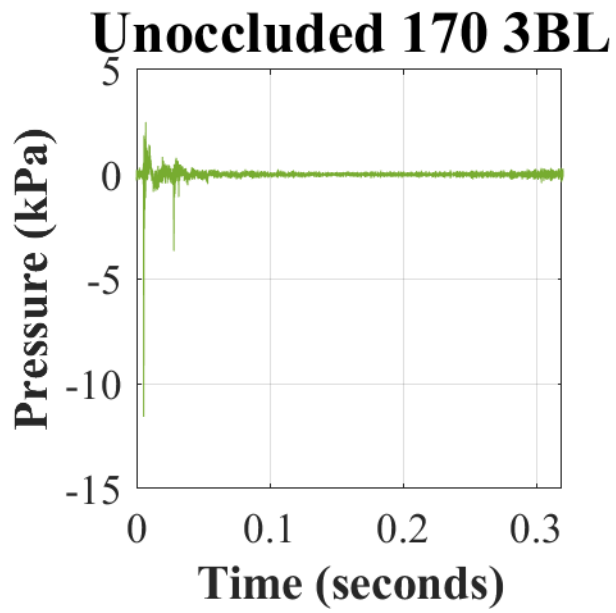
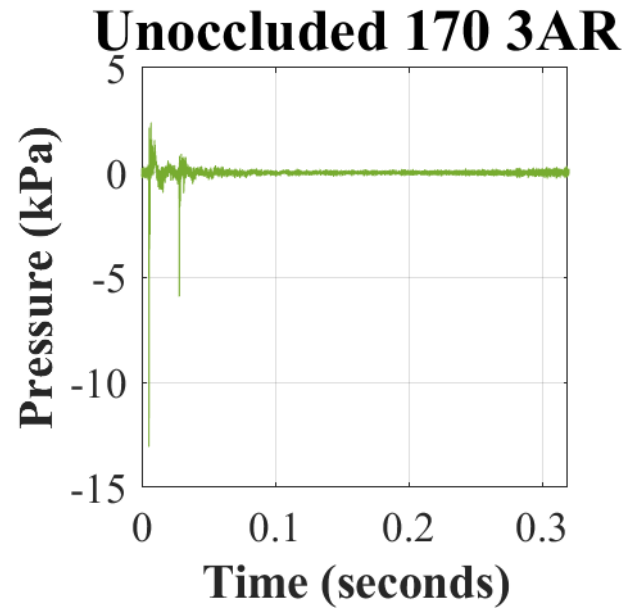
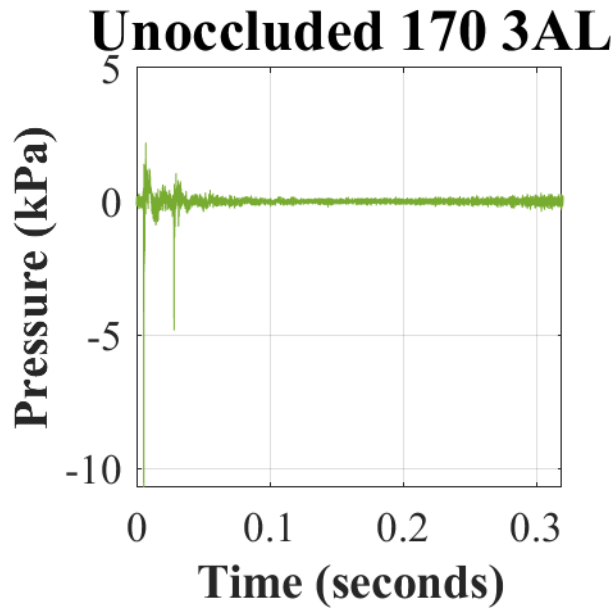


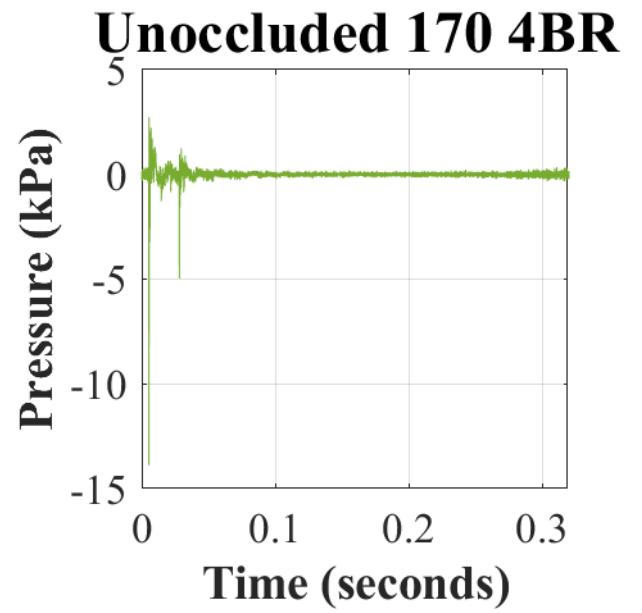
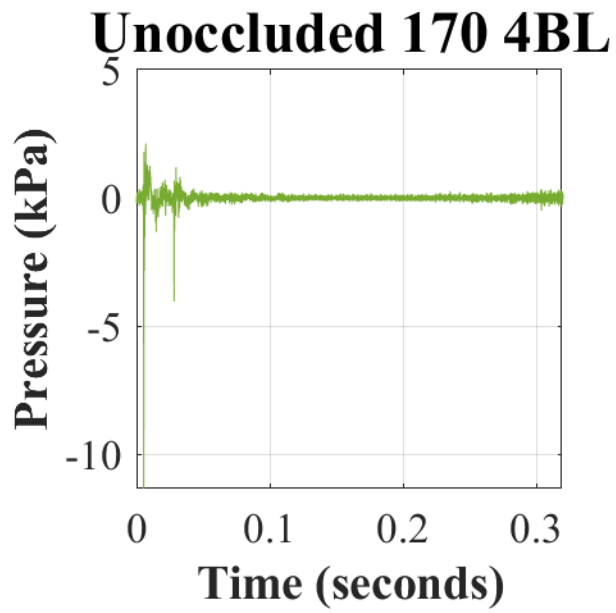
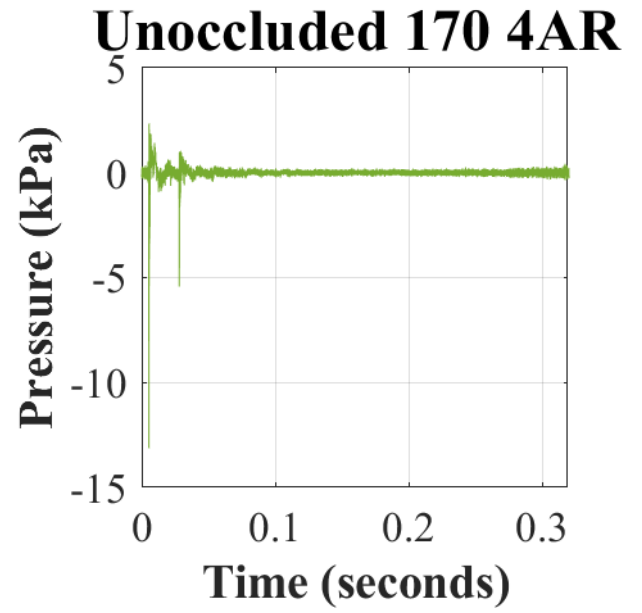
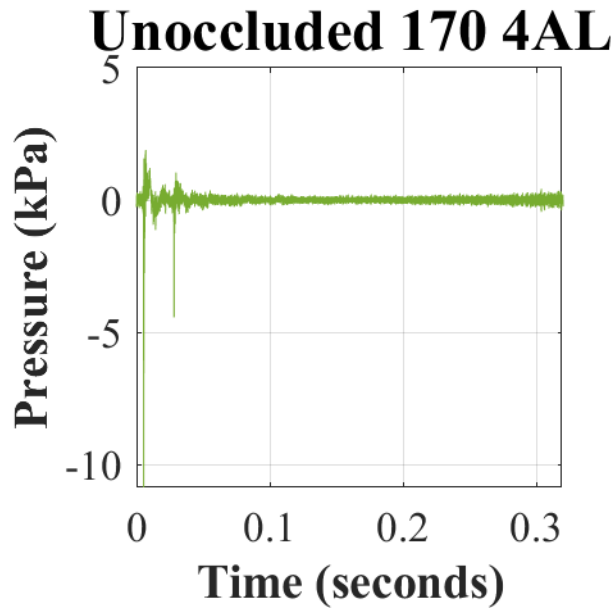
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating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

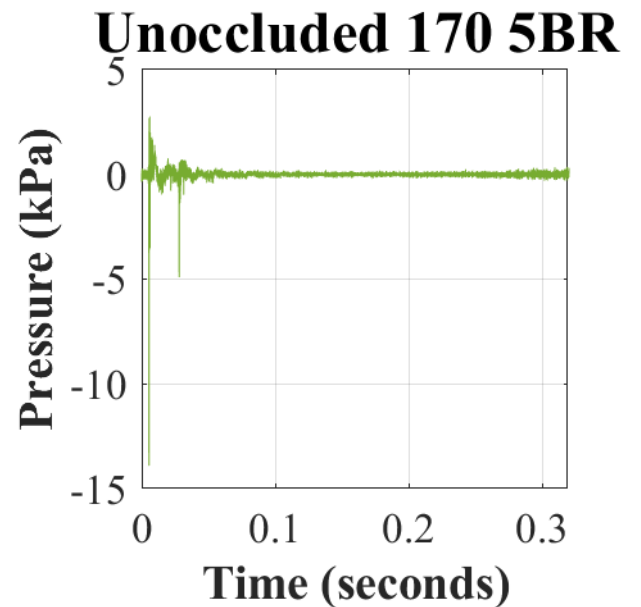
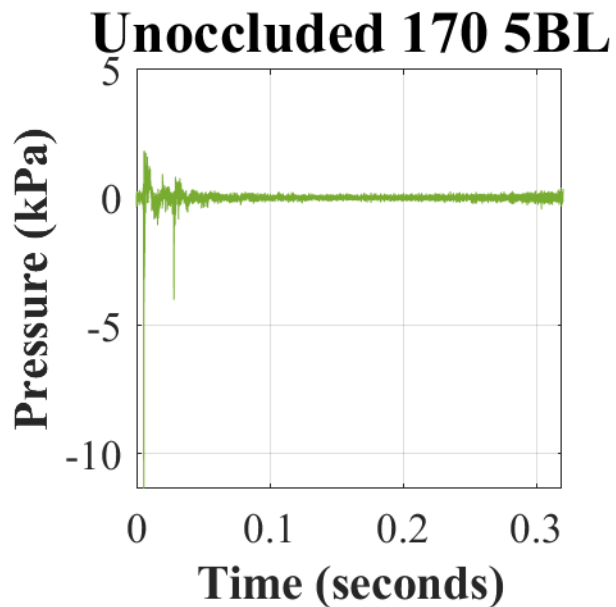
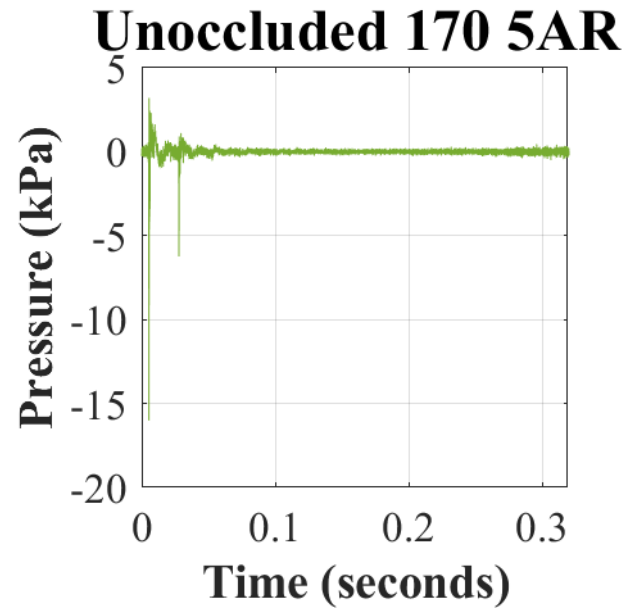
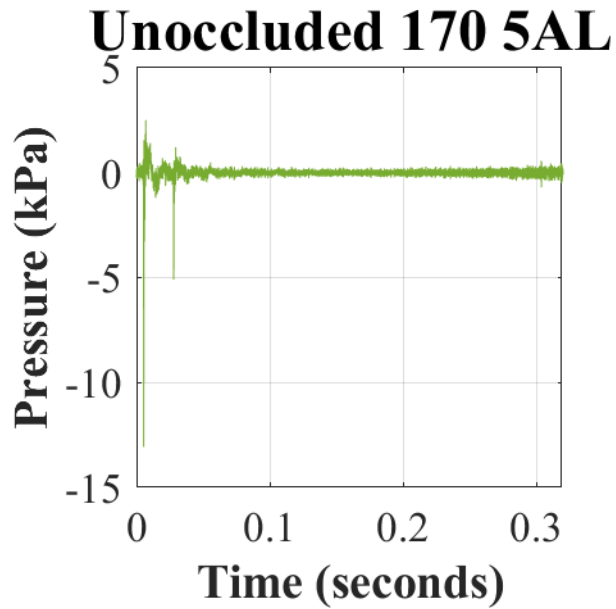
**Appendix D.** Estimated unoccluded (open-ear) waveforms in response to 170 dBp with the Howard Leight™ MAX® Small earplugs.





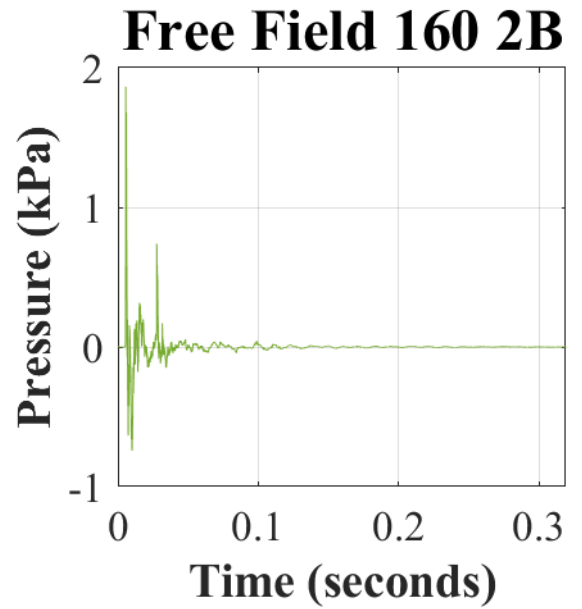
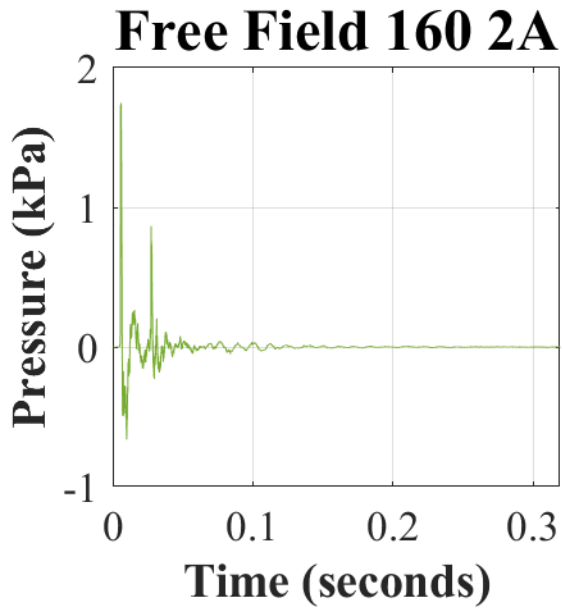
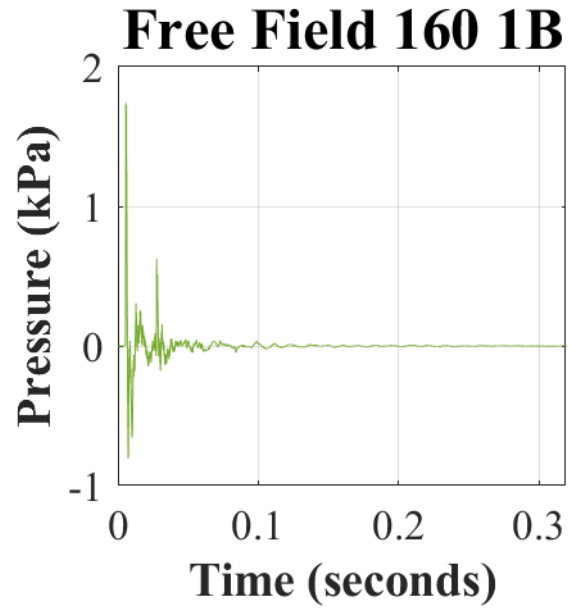
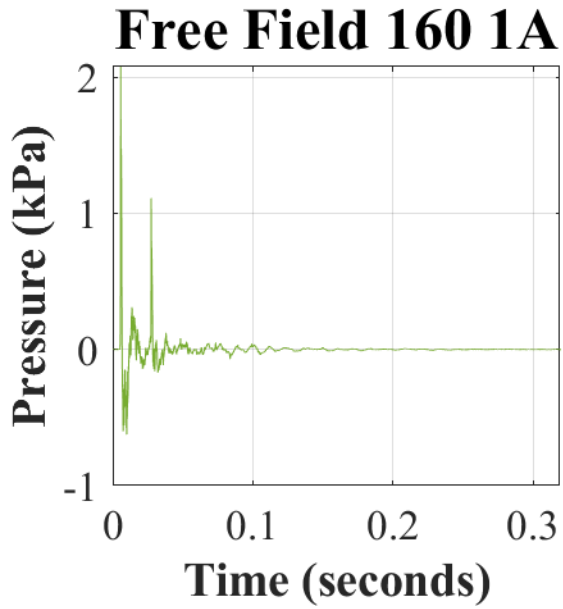


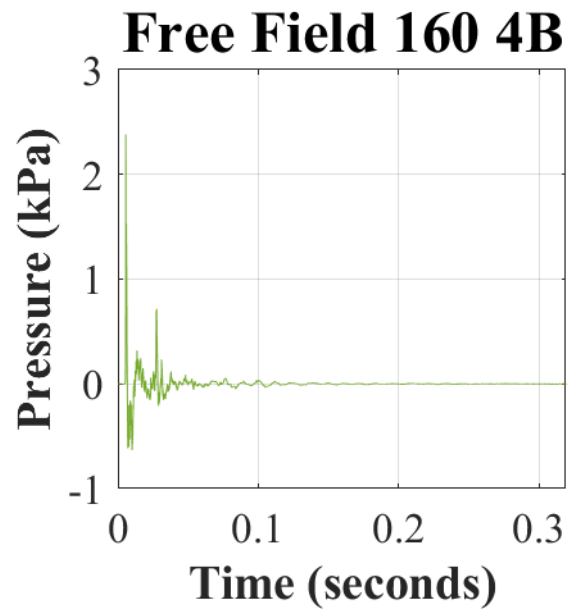
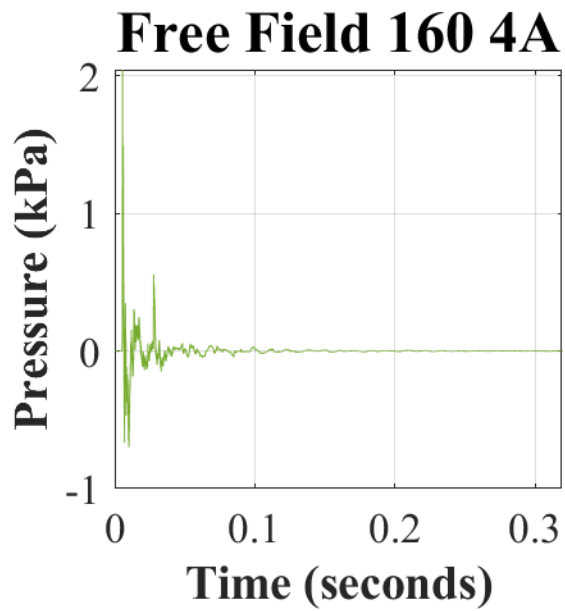
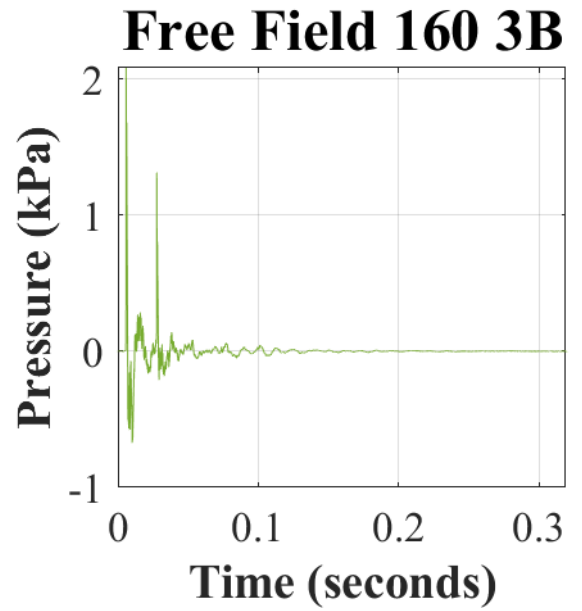
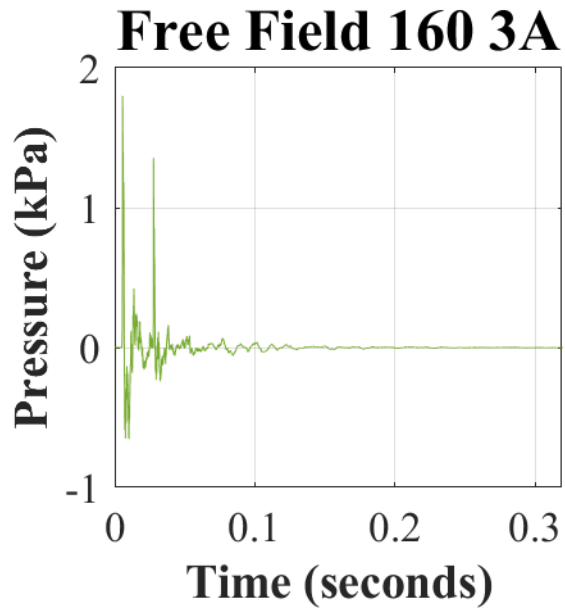


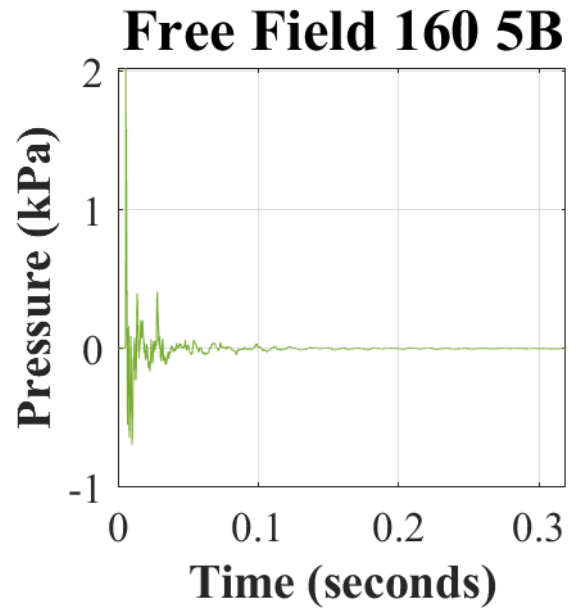
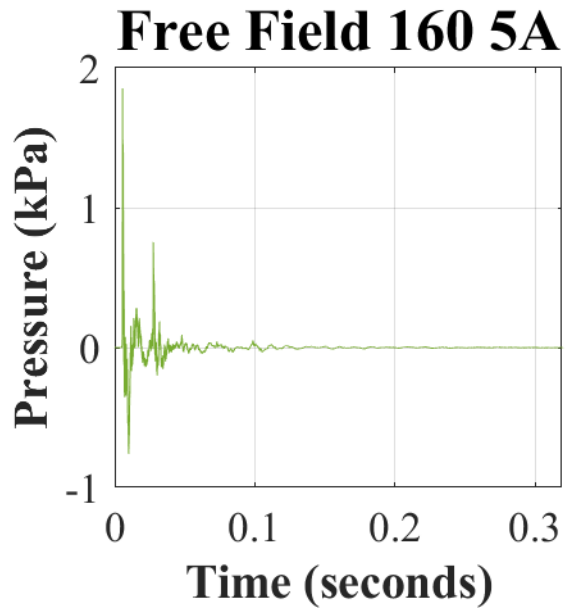


Note. The naming convention for all occluded waveforms is “Unoccluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the HPD doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) 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 E.** Recorded waveform of the impulse measured with the free-field probe at 160 dBp and the Howard Leight™ MAX® Small earplugs donned.

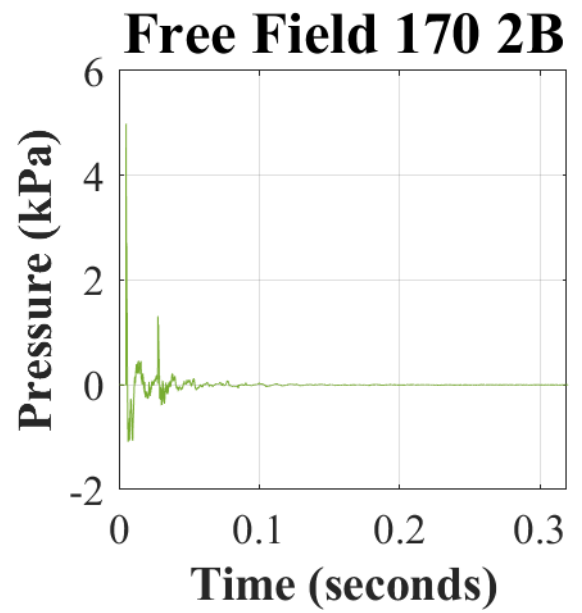
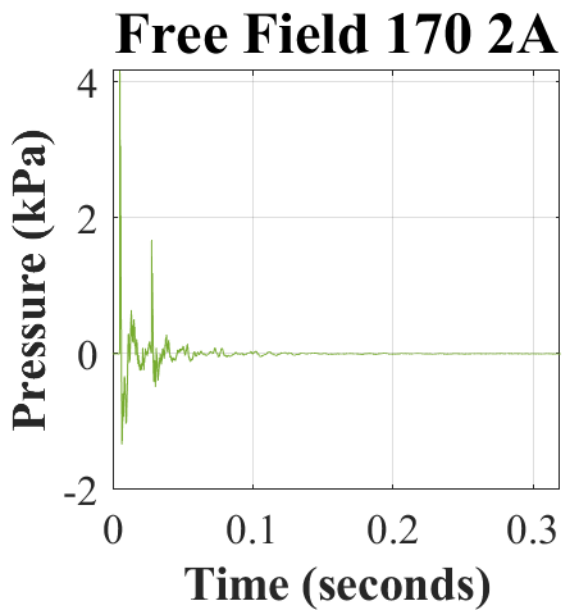
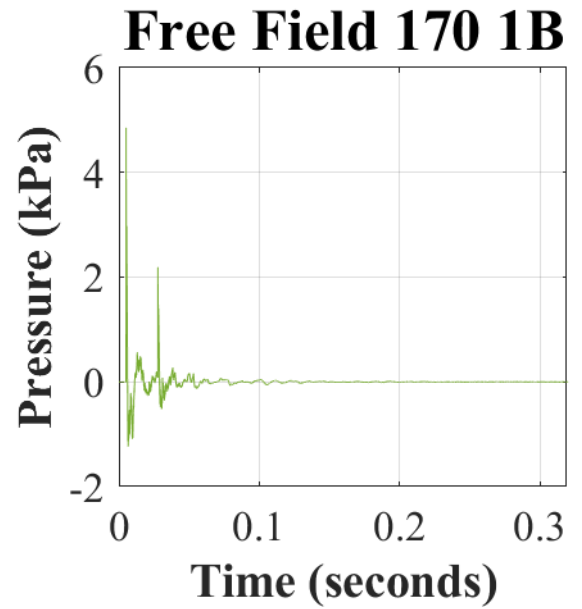
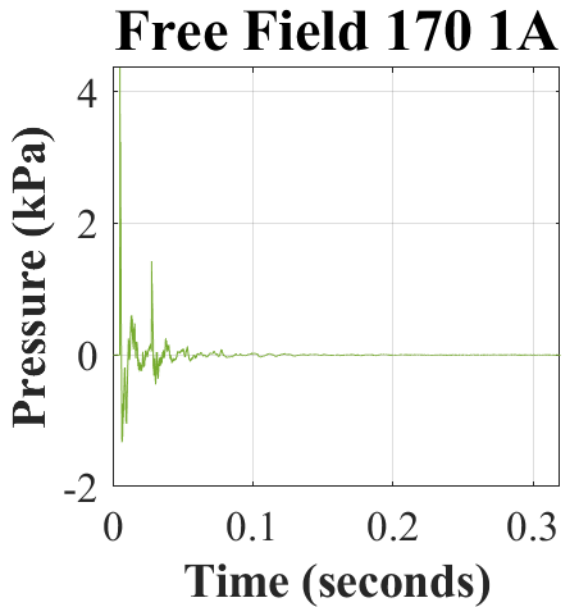


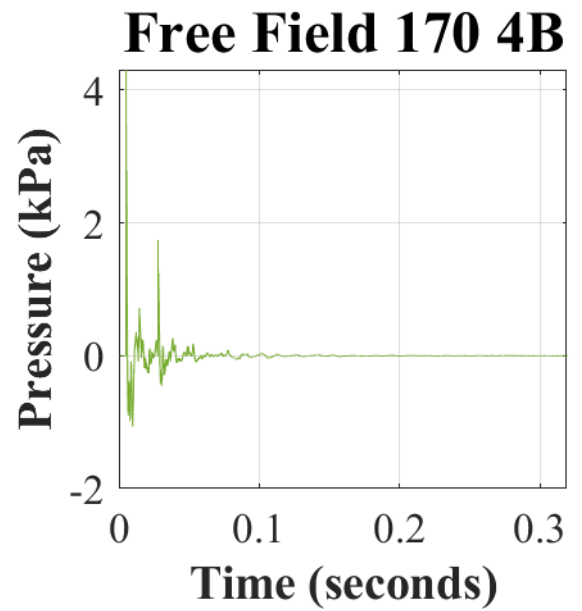
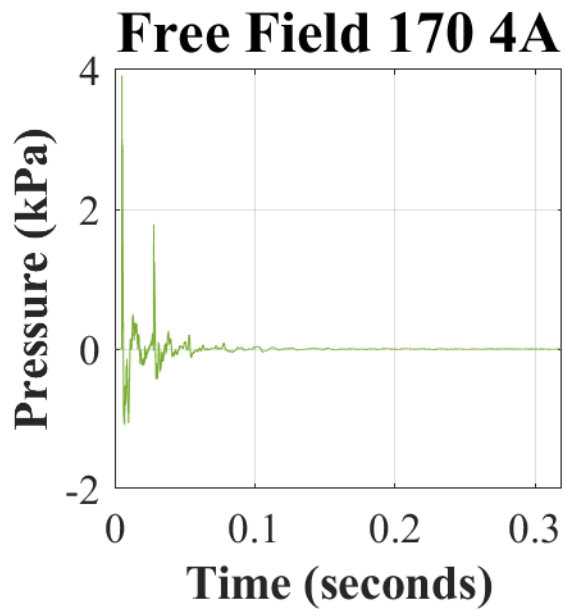
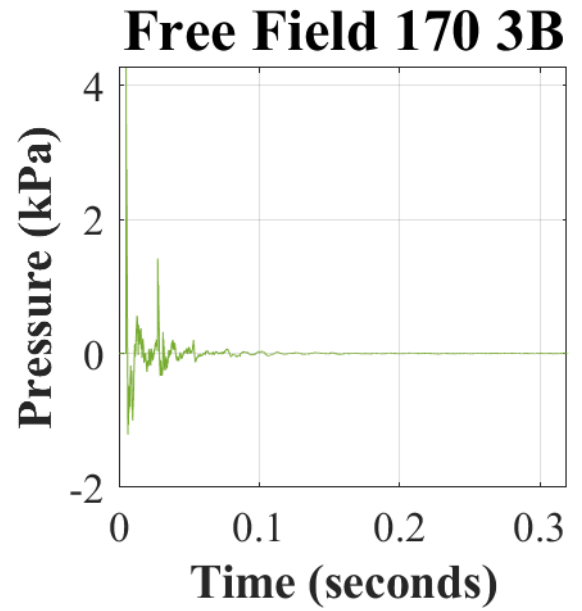
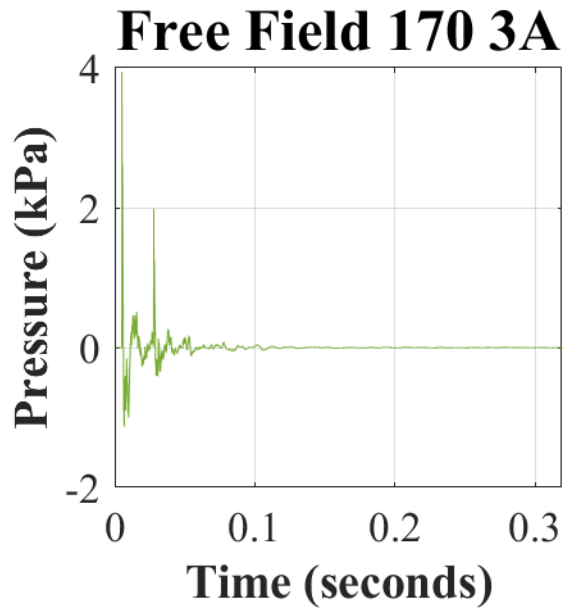


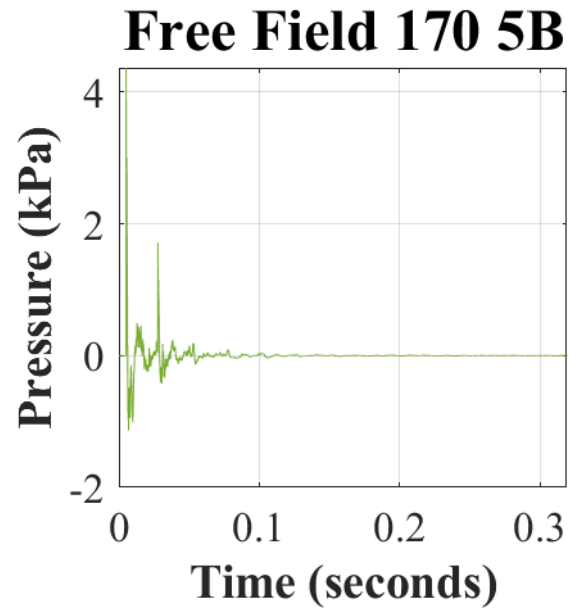
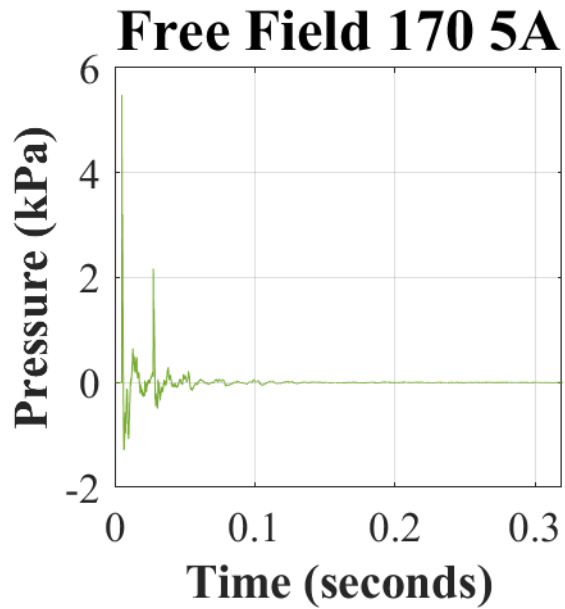


Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (170 dBp), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

**Appendix F.** Recorded waveform of the impulse measured with the free-field probe at 170 dBp and the Howard Leight™ MAX® Small 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 dBp), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or B).