

# Naval Submarine Medical Research Laboratory

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## **Impulse Assessment of the 3M™ PELTOR™ ComTac™ V Hearing Defender Headset**

Natalie Silvia, AuD <sup>1,2</sup>  
Alexa H. Kolias, AuD <sup>1,2</sup>  
Derek W. Schwaller, BS <sup>1</sup>  
Stephanie J. Karch, AuD, PhD <sup>1</sup>  
Jeremy S. Federman, PhD <sup>1</sup>

<sup>1</sup> Naval Submarine Medical Research Laboratory, Groton, CT, United States

<sup>2</sup> Leidos, Inc., Reston, VA, United States

**Approved and Released by:  
K. K. Shobe, CAPT, MSC, USN  
Commanding Officer  
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<sup>2</sup> 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

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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 on the 3M™ PELTOR™ ComTac™ V Hearing Defender (headband model) Headset (ComTac™ V; Model: MT20H682FB-09 CY) in two test modes: passive (i.e., turned OFF) and active (i.e., turned on and set to MAX). 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. A total of five samples were fitted to an acoustic test fixture two times each for a total of 10 trials per test level in both the passive (i.e., OFF) and active (i.e., on and set to MAX) test modes. No samples of the HPD were rejected. All samples were tested at the nominal levels of 160 and 170 decibel peak (dBp, re: 20 µPa). As shown in Table 1, the results revealed mean IPIL values within 1.0 dB of each other for the passive (i.e., OFF) and active (i.e., MAX) test modes at both 160 and 170 dBp. Greater mean IPIL values were measured for the 170 dBp test condition compared to 160 dBp for both the passive (OFF) and active (MAX) test modes. These results suggest that when properly fit and functional, the ComTac™ V Hearing Defender will adequately protect (i.e., reduce exposure to less than 140 dBp) impulses below 167.5 dBp in the passive (OFF) mode and below 168.5 dBp in the active (on at MAX) mode.

**Table 1.**  
*ComTac™ V mean (SD) IPIL value (in dB) for all test conditions.*

	<b>160 dBp</b>	<b>170 dBp</b>
OFF	25.2 (1.5)	27.5 (1.0)
MAX	26.1 (1.7)	28.5 (1.0)

## Introduction

The 3M™ PELTOR™ ComTac™ V Hearing Defender Headset (ComTac™ V; 3M, St. Paul, MN) is a non-communication active earmuff that is currently fielded by the U.S. Navy and U.S. Marine Corps. The ComTac™ V Hearing Defender has two ear-level omni-directional microphones, along with level dependent hearing protection that is powered by two AAA batteries. The active-volume function amplifies low level sounds (e.g., speech), while loud impulsive noises (i.e., blasts, artillery firing) are attenuated via compression (3M Personal Safety Division, n.d.). Additionally, the ear-level circuitry is designed to automatically turn off the amplifier when the signal exceeds 82 dB A-weighted (dBA) (3M Personal Safety Division, 2015). It is available as either a headband or neckband model, and can also be mounted on a helmet rail system when used with the 3M™ PELTOR Accessory Rail Connector (ARC) attachment.

Per the Department of Defense Instruction 6055.12 (2015), the exposure limit for impulse noise is 140 peak decibels (dBP). Therefore, should an impulse noise meet or exceed 140 dBP (e.g., artillery fire, grenade, small arm weapon fire, large caliber weapon fire), hearing conservation efforts must be put into place. One conservation measure used to reduce the noise hazard below the 140 dBP limit at the user level are hearing protection devices (HPDs) like that of an earplug or earmuff.

To determine if the issued HPD will reduce the noise exposure below the 140 dBP limit, the impulse peak insertion loss (IPIL) value of the issued and/or used HPD should be subtracted from the impulse noise level (Department of Defense, 2015). The IPIL value is the standard metric (ANSI/ASA S12.42) used to determine the amount of protection afforded by a HPD in response to impulse noise. At present, the IPIL value of the ComTac™ V Hearing Defender at 168 dBP is reported to be 32.6 dB (3M Personal Safety Division, 2021). The current effort determined the IPIL value for the ComTac™ V Hearing Defender Headset in both the passive (i.e., OFF) and active (i.e., turned on and set to MAX) test modes. 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., 10.2 centimeters (cm)) shock tube (B/C Precision, Inc., Greendale, IN). The shock tube pressure chamber is approximately 34 in. (86.4 cm) long, with an inner diameter of 4 in. (10.2 cm). A 64 in. (162.6 cm) long catenoidal tube horn consisting of four welded steel flat-projection sheets forming a square cross section was connected to the shock tube using a PVC 4.5 in. (11.4 cm) coupler. An industrial air compressor (ILA#1883054; Industrial Air Corporation, Memphis, TN) supplied pressurized air

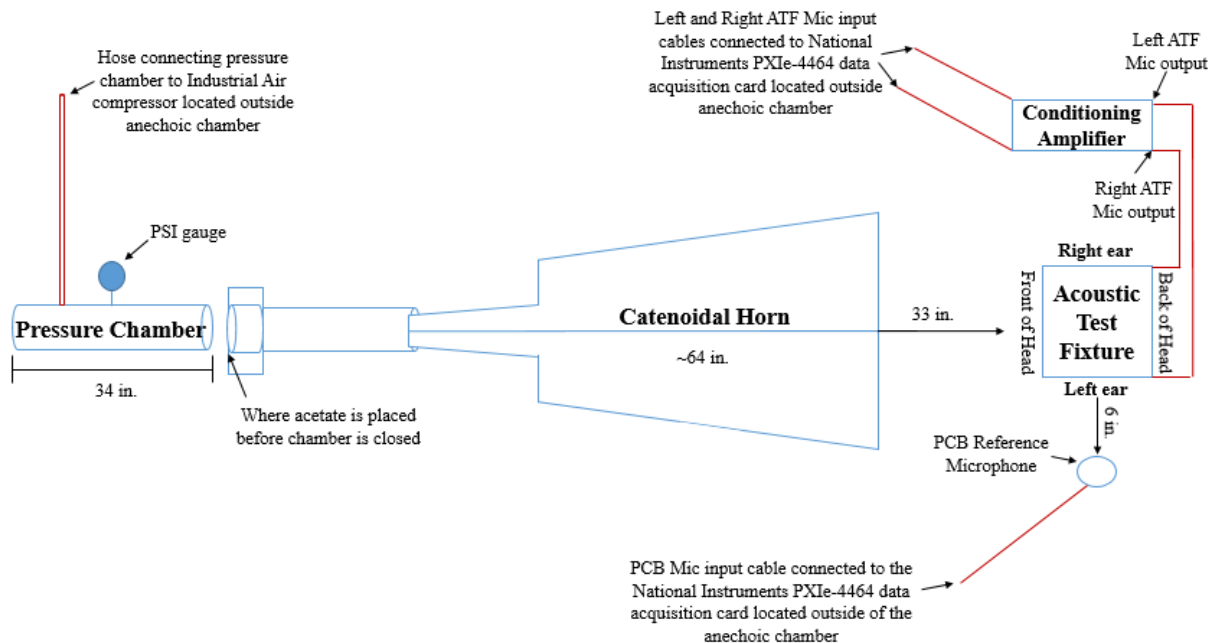
(900 kilopascal) to the shock tube. For each trial, a 7 in. (17.8 cm) by 7 in. (17.8 cm), acetate sheet (Grafix Plastic, Maple Heights, OH) was used as a membrane between the pressurized chamber and the catenoidal tube horn to enable pressurization of the air chamber. Each acetate sheet was 0.002 in. (2 mil) thick.

All waveforms were recorded with the ANSI/ASA S12.42 (2010) compliant GRAS 45CB-S2 acoustic test fixture (ATF) along with GRAS RA0045-S9 Ear Simulators (GRAS Sound and Vibration, Twinsburg, OH). Additionally, the ATF was connected to a conditioning amplifier which served as the power supply (GRAS Type 12AA; GRAS Sound and Vibration, Twinsburg, OH). As required by ANSI/ASA S12.42/2010, the ATF was placed to front-face (i.e., nose facing) the catenoidal tube horn at 0° elevation and 0° azimuth.

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

**Figure 1.**

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



**Data Acquisition System.** The data acquisition system (NI chassis PXIe-1071 with NI PXIe-4460 and NI PXIe-4464; National Instruments Corp., Austin, TX) was controlled by a standalone laptop computer running project specific software (LabVIEW; National Instruments Corp., Austin, TX). The data acquisition system was connected to the laptop using an MXI cord and host interface card (NI PXIe-8360). The

software controlled the acquisition of waveforms from the three source microphones (left ATF microphone, right ATF microphone, and a reference microphone) at a sampling rate of 204.8 k samples/second during each impulse recording. Pre-trigger settings were 1024 samples per 0.005 seconds, with a trigger level of 110 dB SPL. Each recording was 0.3 seconds in duration.

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

The custom-written software program saved all recorded waveforms as files (.tdms), which were exported 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).

**Hearing Protection Device Samples.** Five samples of the ComTac™ V Hearing Defender Headset (Manufacturer Product Number: MT20H682FB-09 CY) with foam ear cushions and headband were tested IAW ANSI/ASA S12.42-2010. Each sample (i.e., one headset) was randomly assigned and labeled with a number 1 through 5.

**Figure 2.**

*ComTac™ V Hearing Defender Headset (Headband Model).*



## Procedure

Since the ComTac™ V employs active technology, this device was tested in both the passive (OFF) and active modes (i.e., the headset turned on and the equipment volume set at its maximum limit (MAX)). Per ANSI/ASA S12.42, each sampled HPD was fitted to the ATF twice, resulting in two trials (trials A and B) per sample, and 10 total trials per nominal level test condition (160 and 170 dBp) for each HPD mode. No samples of the HPD were rejected. To achieve an appropriate fit that would provide maximum attenuation, each sample was expertly fitted to the ATF following the instructions provided on the device packaging. The manufacturer fitting guidelines stated that all samples should be inspected for any wear, cracks, or damage prior to use. Once inspected, earmuffs were placed over the ears to encompass the pinnae, and the headband adjusted to just rest on the head of the ATF.

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

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

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

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

## Data Analysis

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

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

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

## Results

As shown in Table 2, the calculated overall mean (standard deviation (SD)) IPIL value of the ComTac™ V at 160 dBP was 25.2 (1.5) in the passive (i.e., OFF) test mode and 26.1 (1.7) dB in the active (i.e., MAX) test mode. At 170 dBP, the calculated overall mean (SD) IPIL value was 27.5 (1.0) in the OFF mode and 28.5 (1.0) dB in the MAX mode. Calculated IPIL values for all sample trials in the OFF mode ranged between 21.9 to 27.6 dB at 160 dBP and 25.5 to 29.1 dB at 170 dBP, while all tested sample trials in the MAX mode ranged between 22.8 to 28.1 dB at 160 dBP and between 26.3 to 29.8 dB at 170 dBP.

**Table 2.***Mean (SD) IPIL values (in dB) for Tested ComTac™ V Samples.*

	160 dBP				170 dBP			
	OFF		MAX		OFF		MAX	
	Right	Left	Right	Left	Right	Left	Right	Left
HPD 1, Trial A	24.7	24.6	25.3	28.0	28.0	28.1	27.4	28.6
HPD 1, Trial B	23.8	23.9	27.7	27.2	27.4	27.0	29.4	28.8
HPD 2, Trial A	26.1	23.5	25.0	23.8	28.5	26.8	26.9	26.3
HPD 2, Trial B	26.7	24.9	26.9	24.7	29.1	27.1	29.7	27.8
HPD 3, Trial A	24.4	24.0	23.7	24.6	28.5	28.2	28.3	29.3
HPD 3, Trial B	24.7	25.1	27.9	26.4	28.4	28.6	29.5	28.3
HPD 4, Trial A	27.3	25.4	26.9	27.9	27.9	26.8	28.1	28.9
HPD 4, Trial B	24.3	21.9	28.1	27.2	27.6	25.5	29.2	28.2
HPD 5, Trial A	26.7	27.6	27.0	25.5	26.4	27.1	29.7	28.0
HPD 5, Trial B	27.3	26.1	24.4	22.8	27.1	25.7	29.8	28.0
<b>Ear Specific Mean (SD)</b>	25.6 (1.4)	24.7 (1.6)	26.3 (1.6)	25.8 (1.8)	27.9 (0.8)	27.1 (1.0)	28.8 (1.1)	28.2 (0.8)
<b>Level Overall Mean (SD)</b>	25.2 (1.5)		26.1 (1.7)		27.5 (1.0)		28.5 (1.0)	

As shown in Table 3, the measured clamping force of the ComTac™ V (headband model) ranged from 2.6 to 2.8 lbf, with a mean (SD) of 2.7 (0.1) lbf.

**Table 3.***Mean (SD) Band Force (lbf) for Tested ComTac™ V Samples.*

	Band Force
HPD 1	2.8
HPD 2	2.8
HPD 3	2.6
HPD 4	2.6
HPD 5	2.7
<b>MEAN (SD)</b>	2.7 (0.1)

The waveforms for all trials for the passive (i.e., OFF) test mode of the ComTac™ V are provided in Appendices A to F and are color-coded green. While the waveforms for all trials for the active (i.e., MAX) test mode are provided in Appendices G to L and are color-coded orange.

## Discussion

As required by ANSI/ASA S12.42-2010, when measuring the IPIL of an active HPD, the ComTac™ V Hearing Defender was tested in both the passive and active modes. The ComTac™ V utilizes an external microphone, an amplifier, a limiting circuit, and an internal loudspeaker to pass low-level sounds through the HPD. When a

signal exceeds 82 dB A-weighted (dBA), the limiting circuit will automatically turn off the amplifier (3M Personal Safety Division, 2015). Once the amplifier is turned off, the headset acts as a passive HPD, attenuating all incoming noise above 82 dBA.

Therefore, when the active technology is functional and the ear cups are fitted properly, it is anticipated that the passive (i.e., OFF) and active (i.e., MAX) test modes will perform similarly. A possible mode of failure is the limiting circuit not turning off fast enough, allowing some of the impulse noise to be amplified and actively passed through the device. To test for this possibility, the ComTac™ V Hearing Defender Headset was tested both powered off and with the unit powered on and volume set to its maximum setting.

As anticipated, the calculated mean IPIL values were greater at the 170 dBP nominal level than at the 160 dBP nominal level for both tested HPD modes. Results revealed overall mean IPILs across nominal test levels (160 to 170 dBP) within 1.0 dB of each other for both test modes (i.e., OFF, MAX). The NSMRL calculated overall mean IPIL values (i.e., OFF, MAX) at the nominal level of 170 dBP were found to be less than the manufacturer reported 32.6 dB (3M Personal Safety Division, 2021). While a difference of 5.1 dB was noted at the 170 dBP nominal level between the manufacturer and NSMRL data, determining the rationale for why the discrepancy exists is beyond the scope of the current memorandum. However, Navy and Marine Corps Public Health Center Technical Manual 6260.51.99-3 (2020) states that attenuation measures obtained from government labs (such as NSMRL) can be relied upon for HPD selection.

Across ears, the individual trial mean IPIL values were found to vary as much as 5.7 dB at 160 dBP and 3.6 dB at 170 dBP in the OFF test mode, while all individual trial mean IPILs in the MAX test mode varied as much as 5.3 dB at 160 dBP and 3.5 dB at 170 dBP. This may be due to a combination of inherent variance within the impulse system and/or variability in fit as a result of each HPD sample being fit twice. Results indicate that a greater variety of attenuation was present in the individual trials at the 160 dBP level compared to 170 dBP. This is noted with larger SDs at the 160 dBP (1.5 dB OFF, 1.7 dB MAX) nominal level compared to those at the 170 dBP (1.0 dB OFF, 1.0 dB MAX) nominal level.

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

## **Conclusions**

This report described the determination of the mean impulse peak insertion loss (IPIL) values provided by the ComTac™ V Hearing Defender Headset at the nominal levels of 160 dBP and 170 dBP. The calculated overall mean (SD) impulse peak insertion loss (IPIL) value for the ComTac™ V Hearing Defender in the passive (OFF) mode at 160 dBP was found to be 25.2 (1.5) dB and 27.5 (1.0) dB at 170 dBP. When the ComTac™ V was in the active (turned on with the volume set to MAX) mode, the

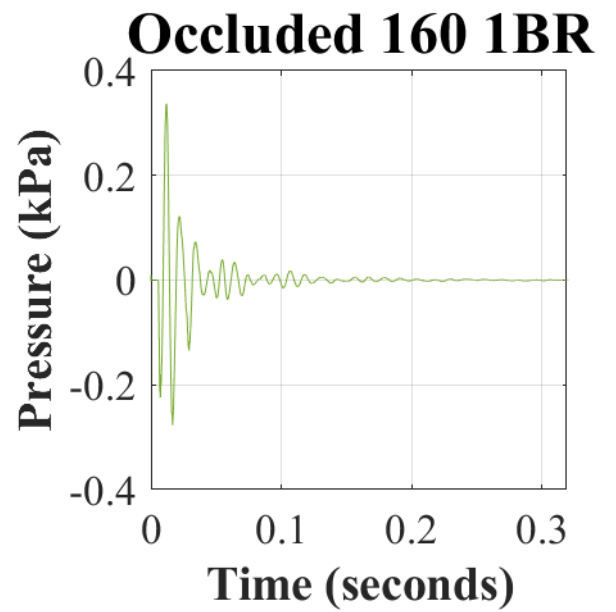
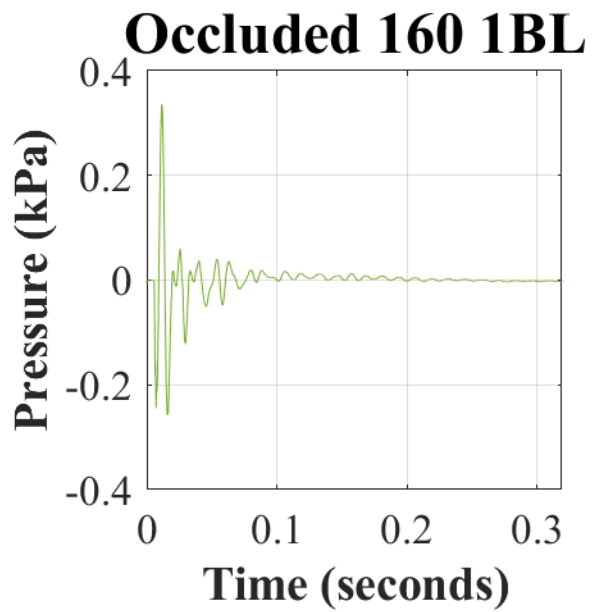
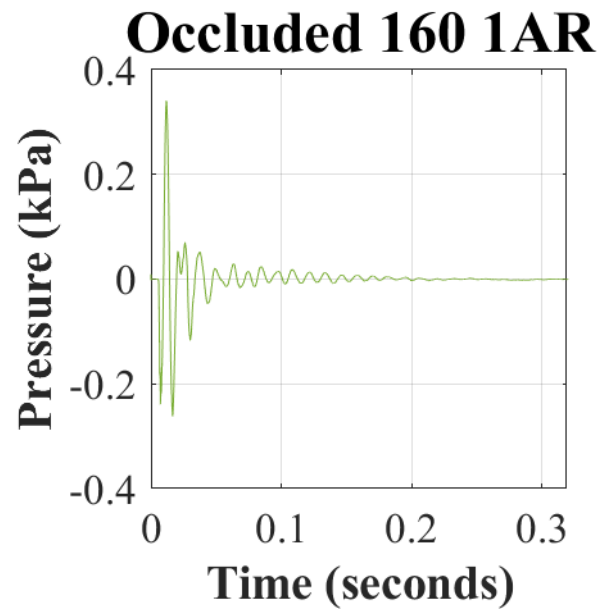
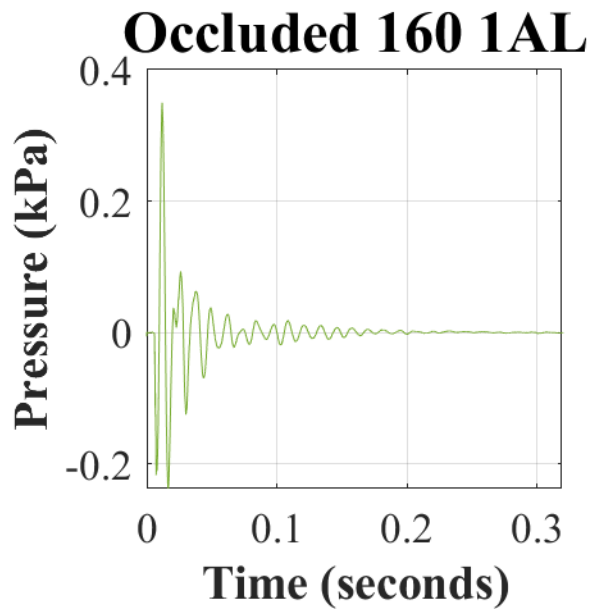
calculated overall mean (SD) IPIL value at 160 dBP was 26.1 (1.7) dB and at 170 dBP it was 28.5 (1.0) dB.

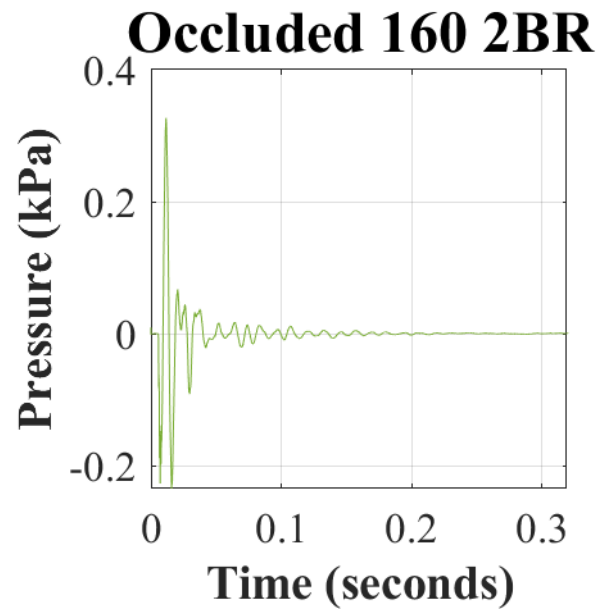
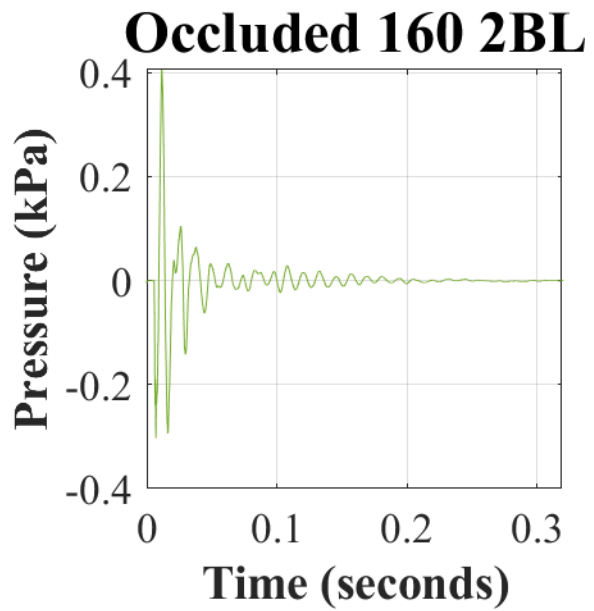
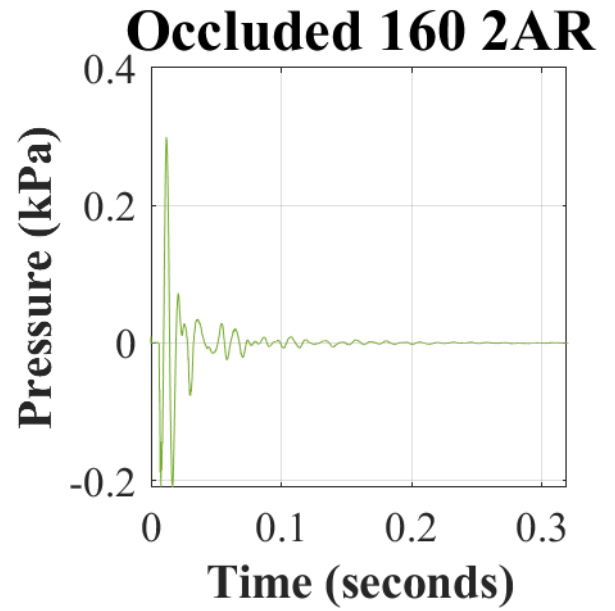
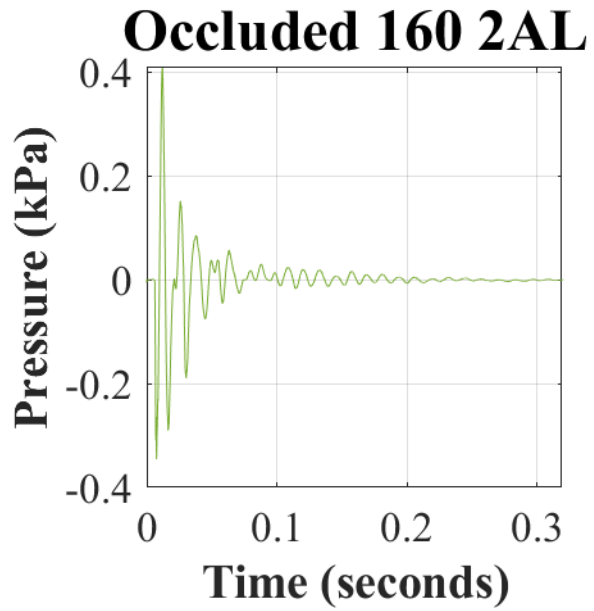
These results imply that when properly fit and functional, the ComTac™ V Hearing Defender Headset will adequately protect impulses (i.e., reduce the exposure level below 140 dBP) below 167.5 dBP in the passive (i.e., OFF) mode and below 168.5 in the active (i.e., MAX) mode.

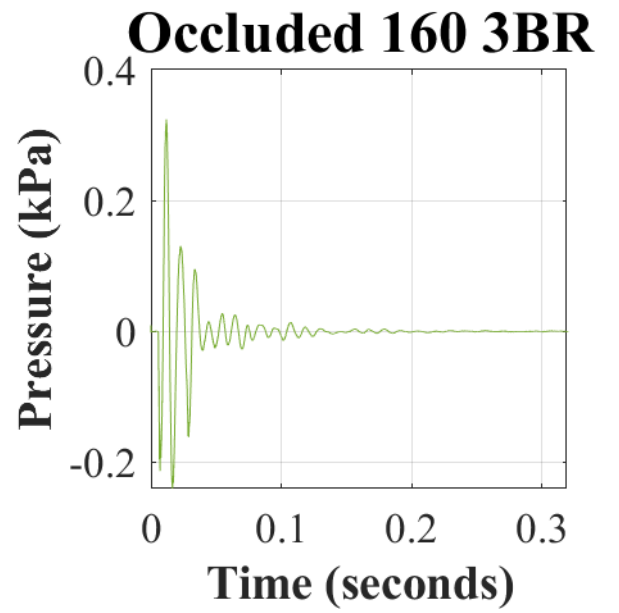
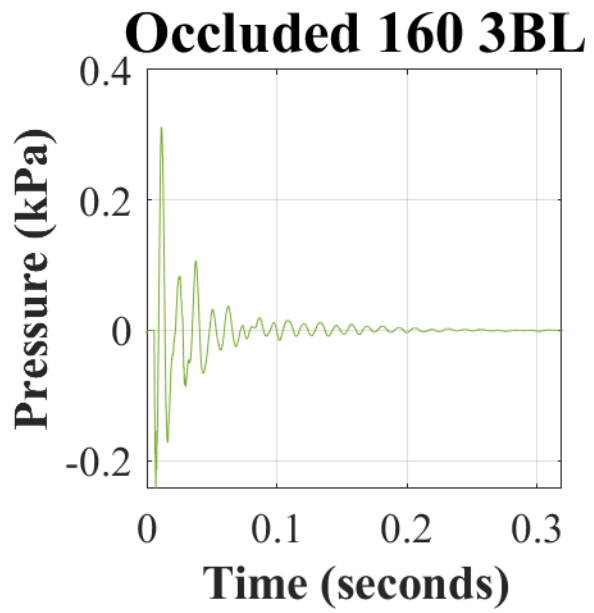
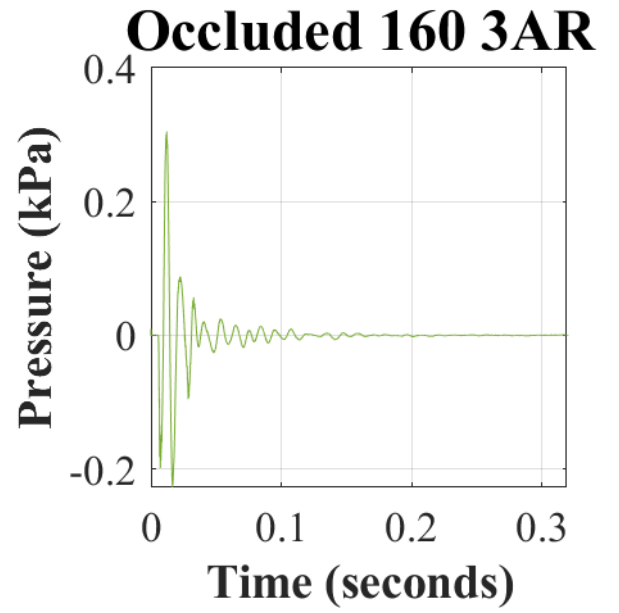
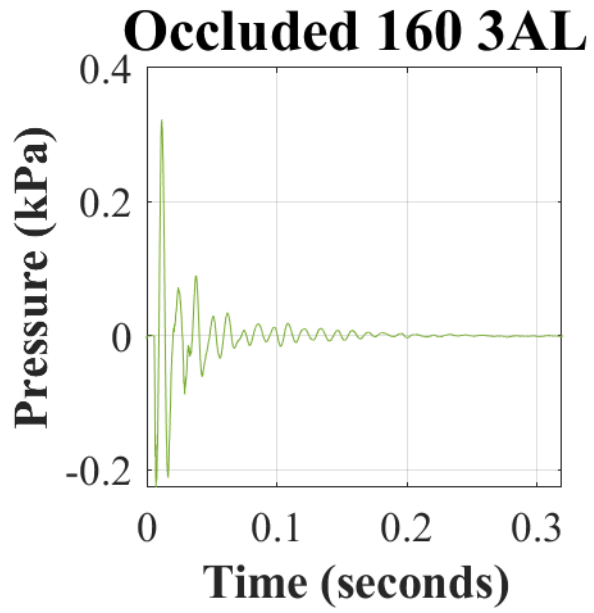
## References

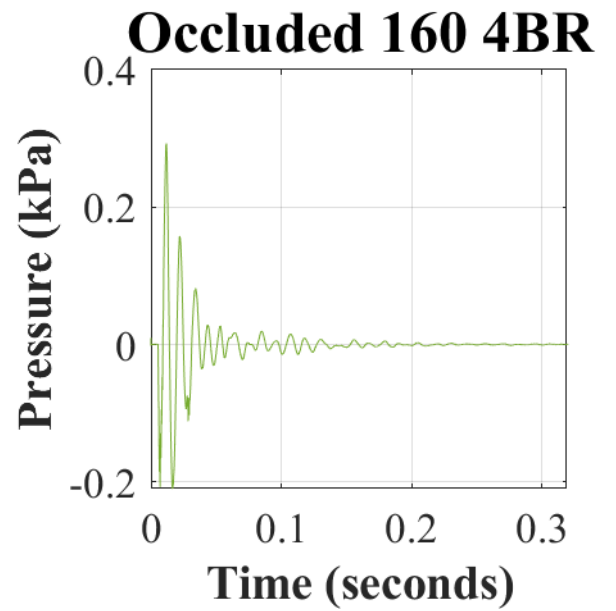
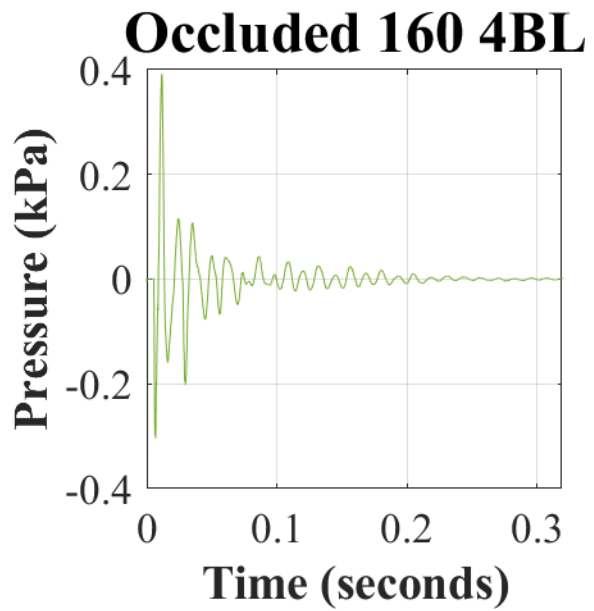
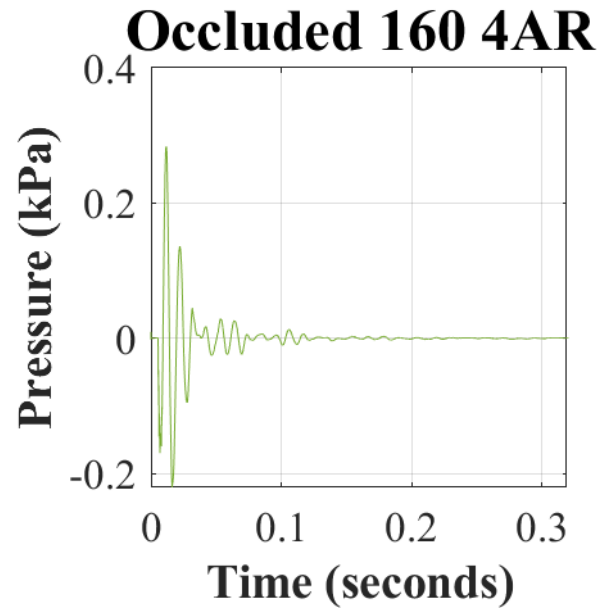
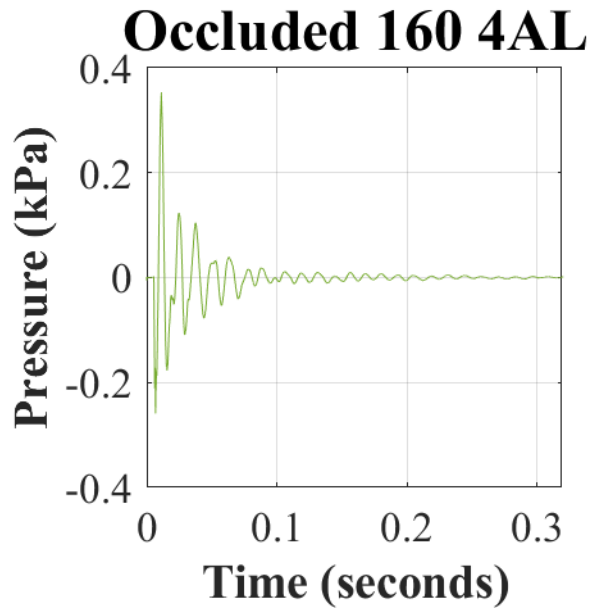
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**Appendix A.** Recorded occluded (earmuff donned) waveforms in response to 160 dBp with the ComTac™ V (OFF).

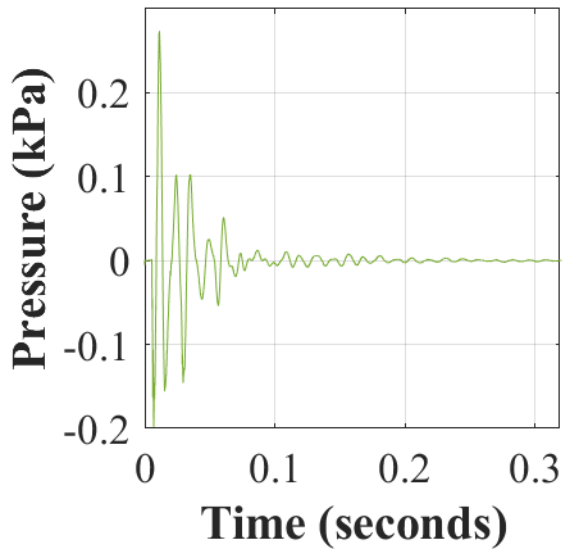




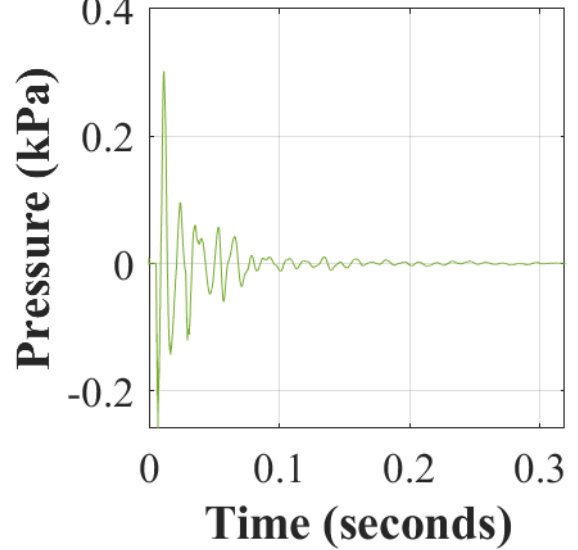




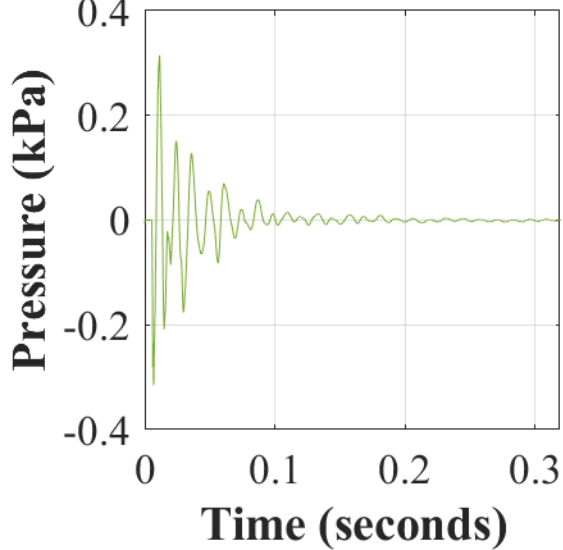
**Occluded 160 5AL**



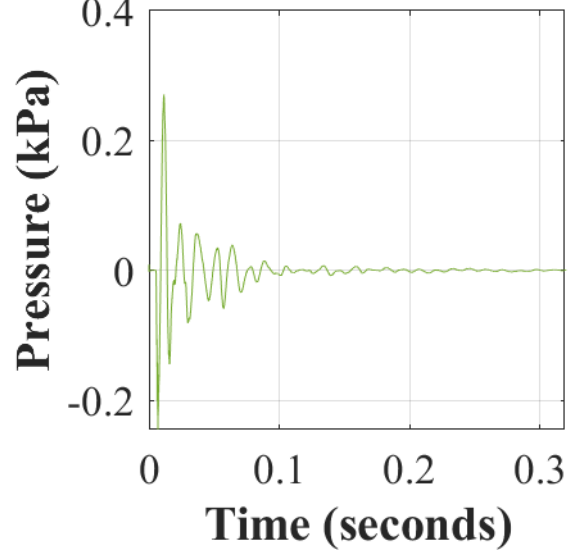
**Occluded 160 5AR**



**Occluded 160 5BL**

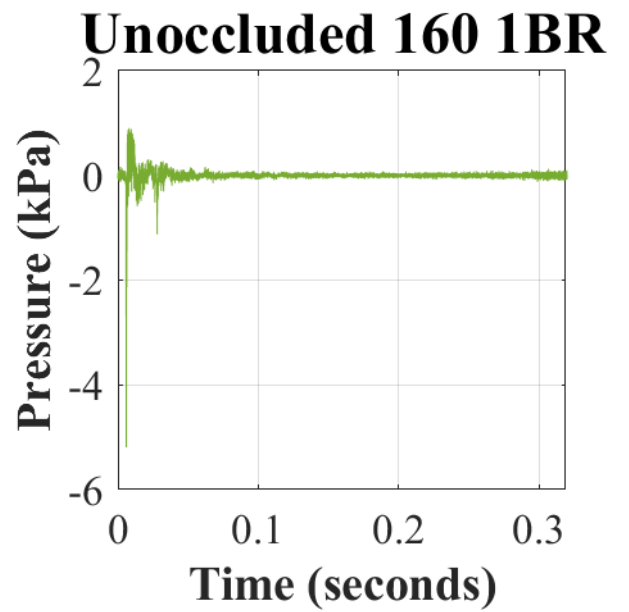
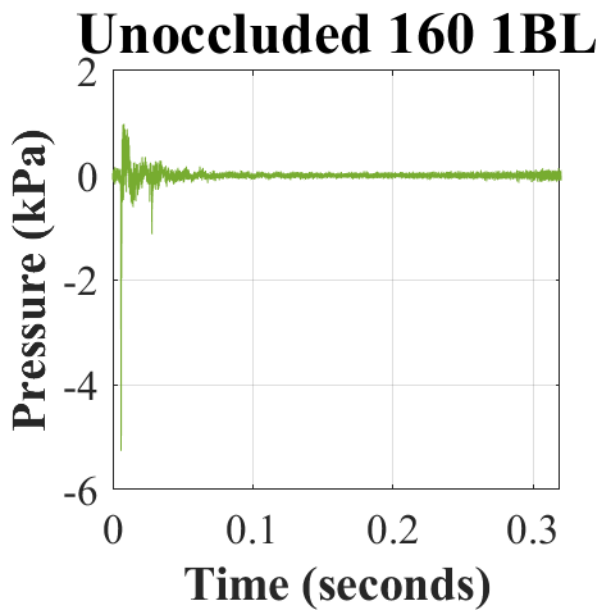
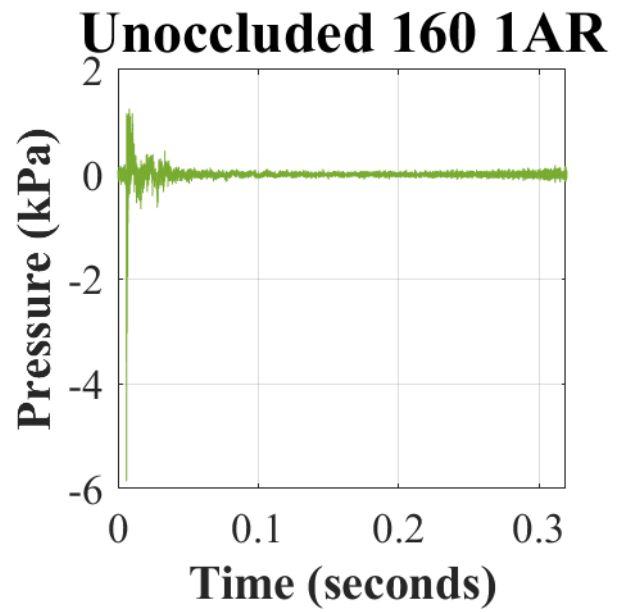
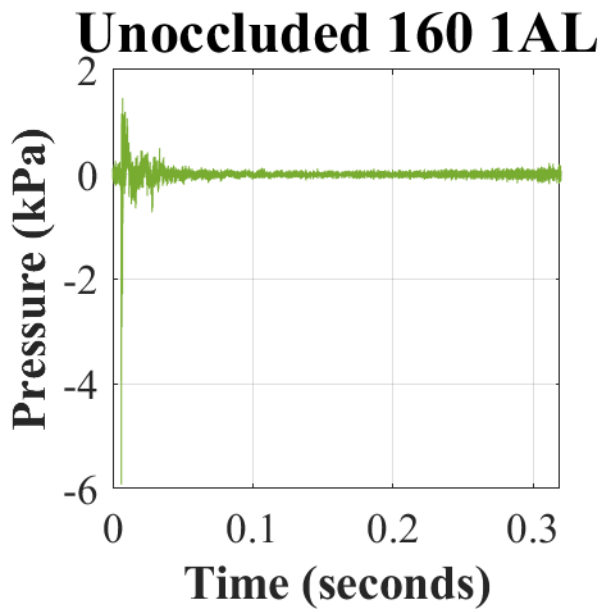


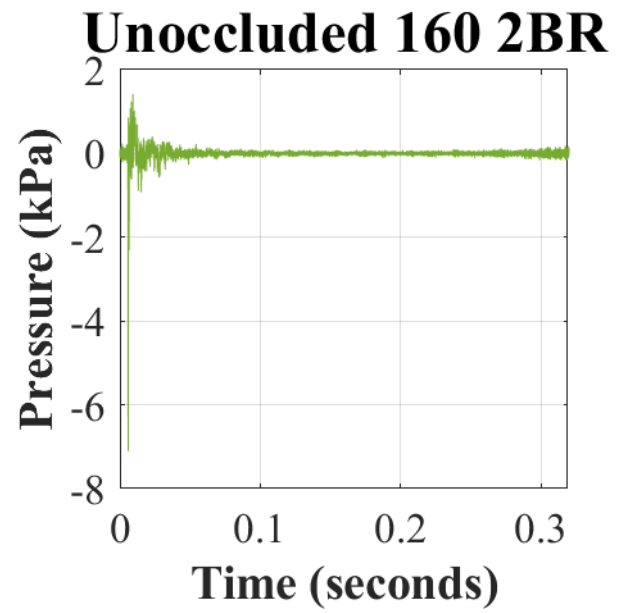
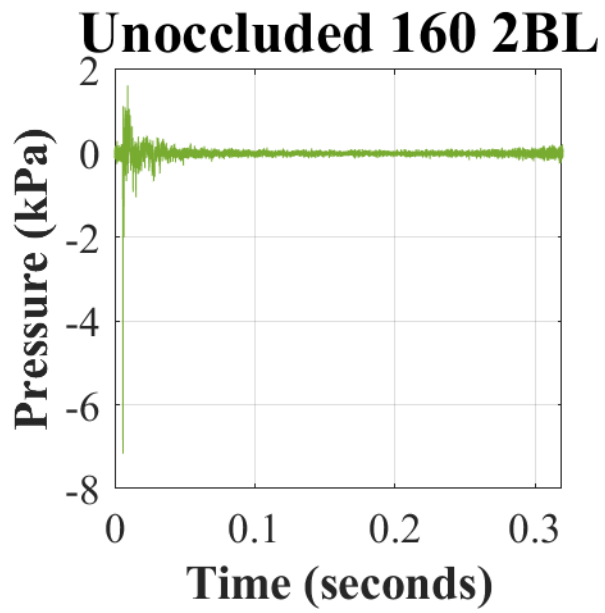
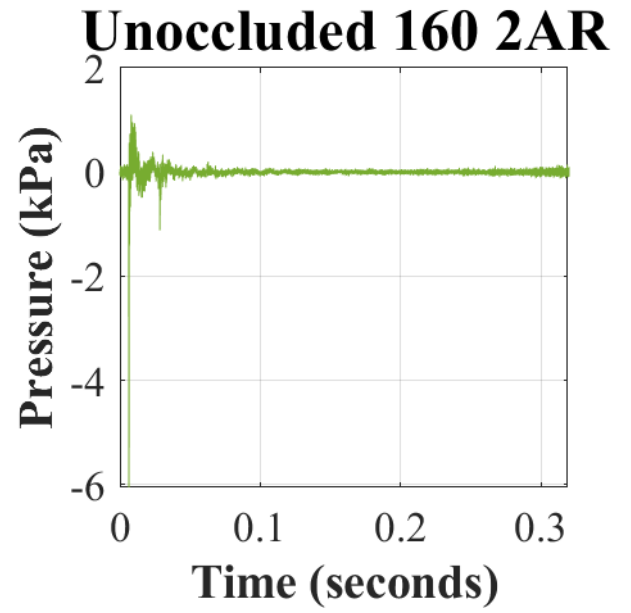
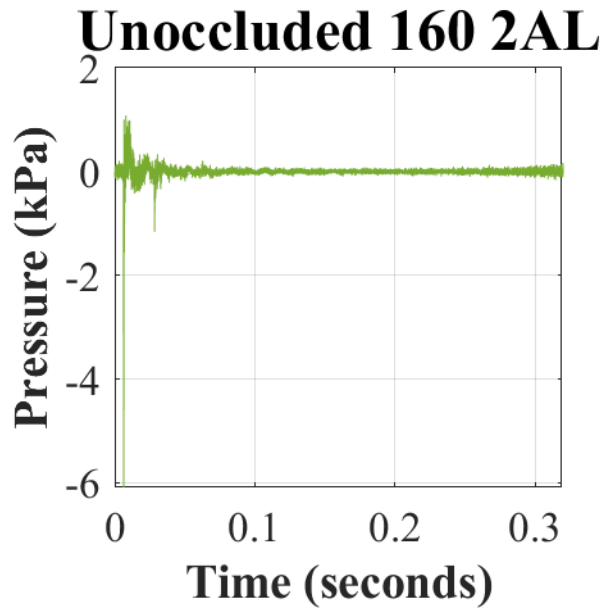
**Occluded 160 5BR**

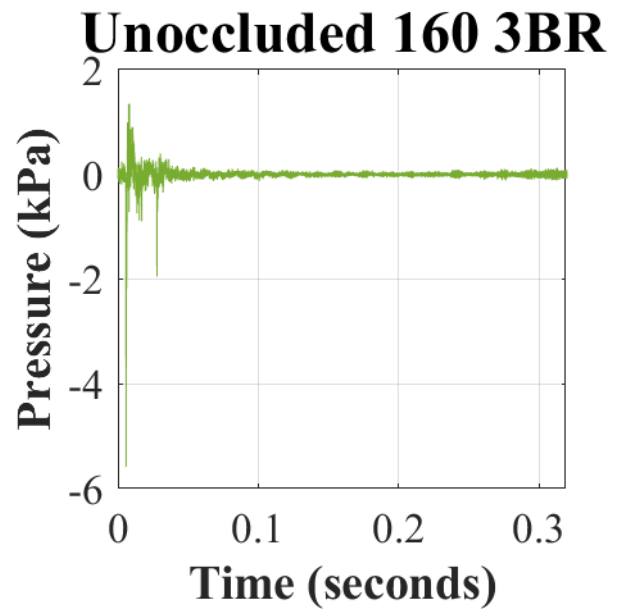
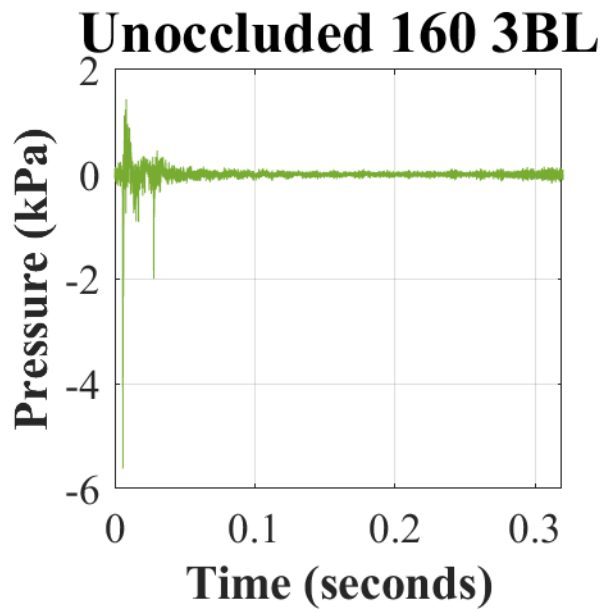
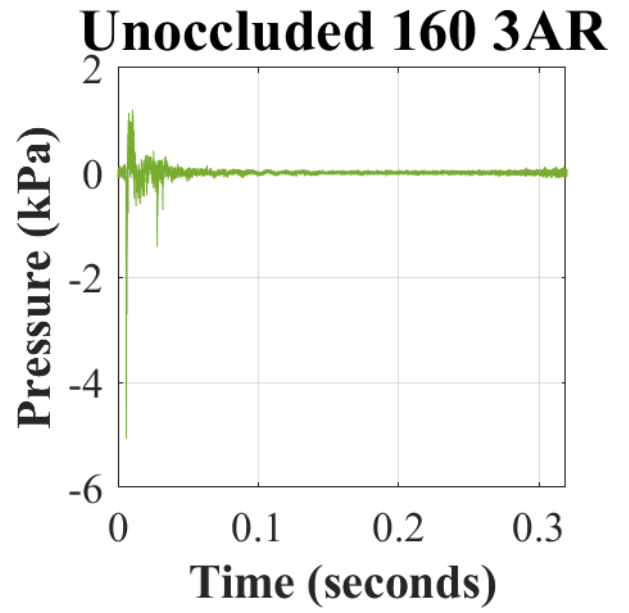
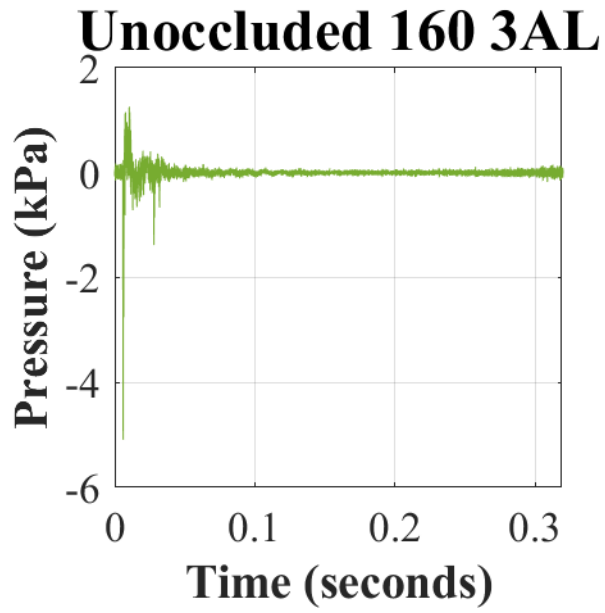


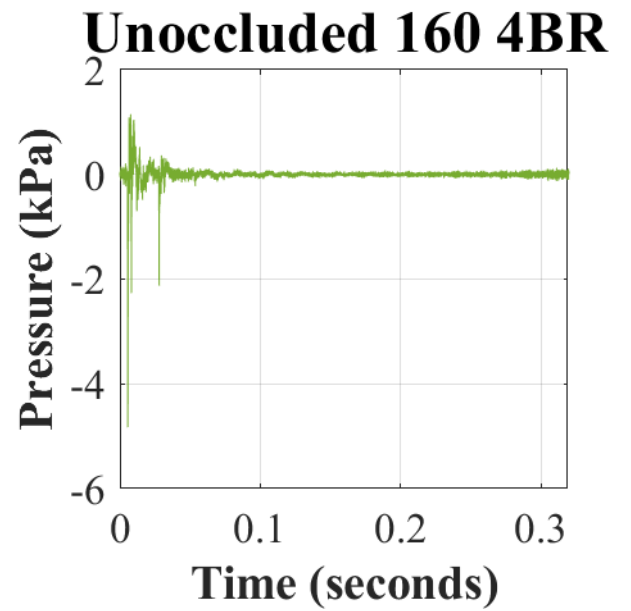
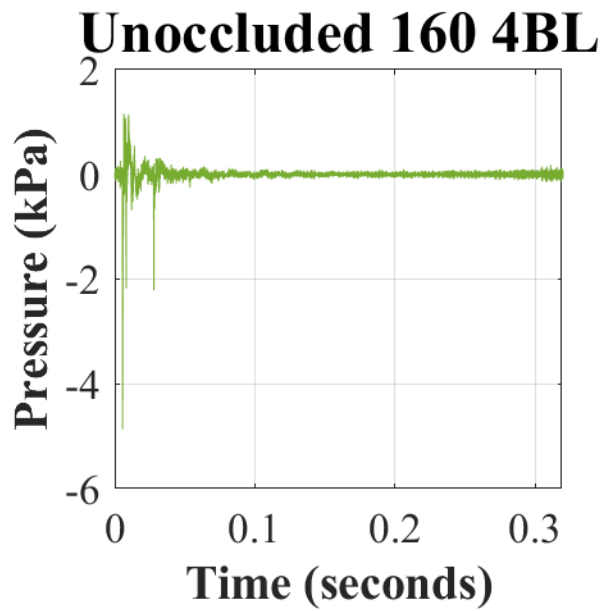
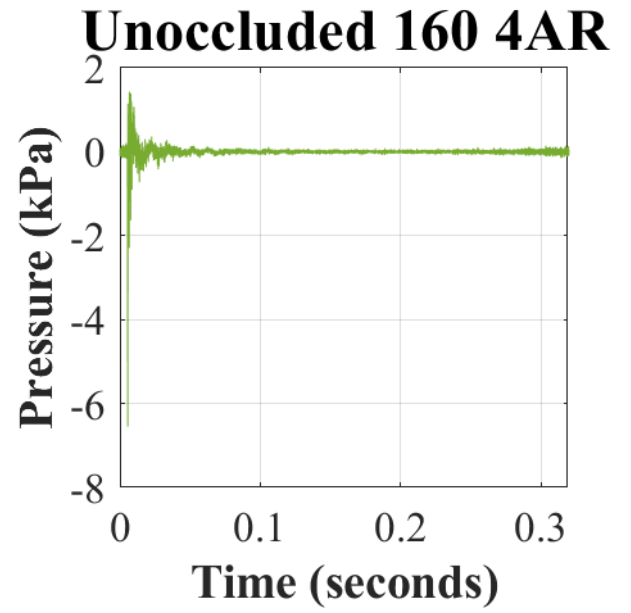
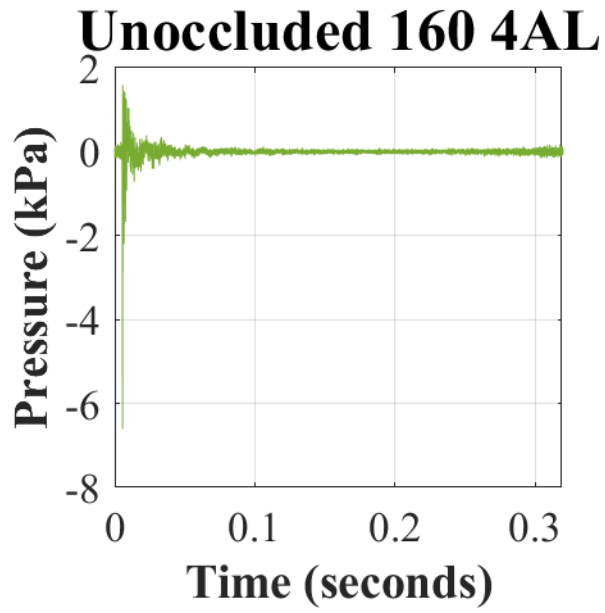
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the earmuff donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B)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

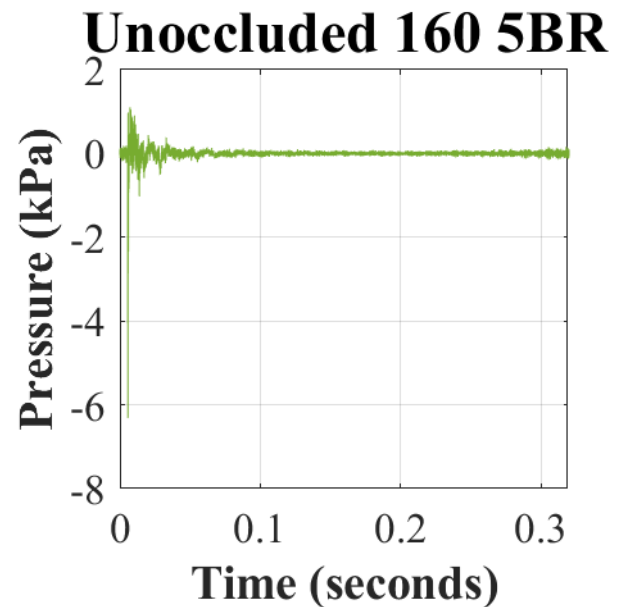
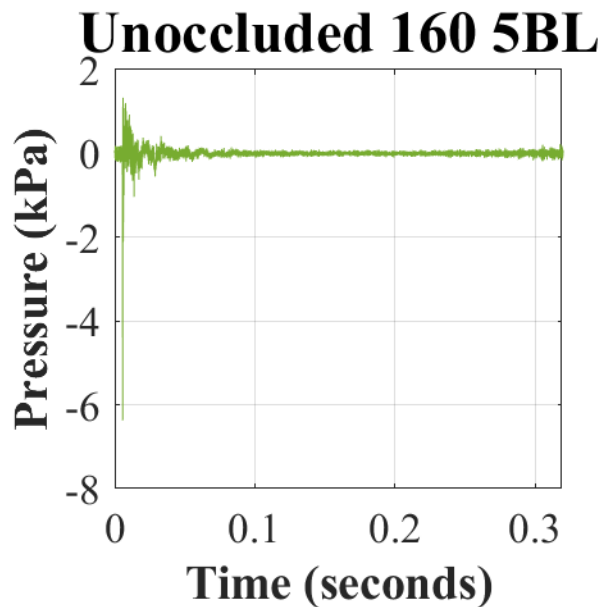
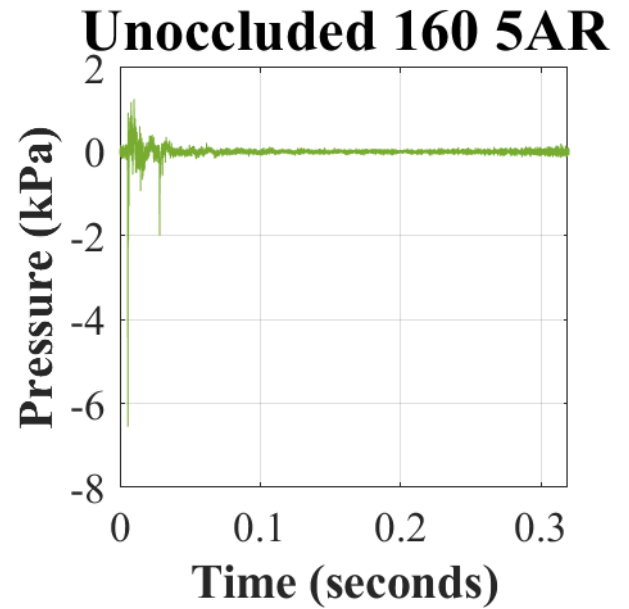
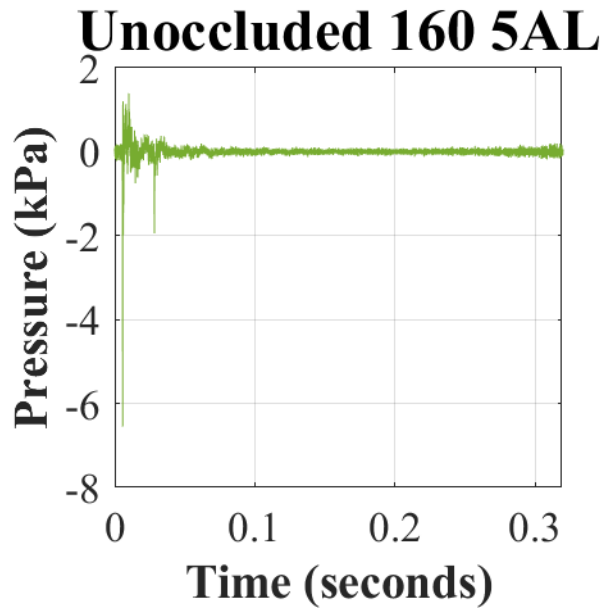
**Appendix B.** Estimated unoccluded (earmuff doffed) waveforms in response to 160 dBp with the ComTac™ V (OFF).





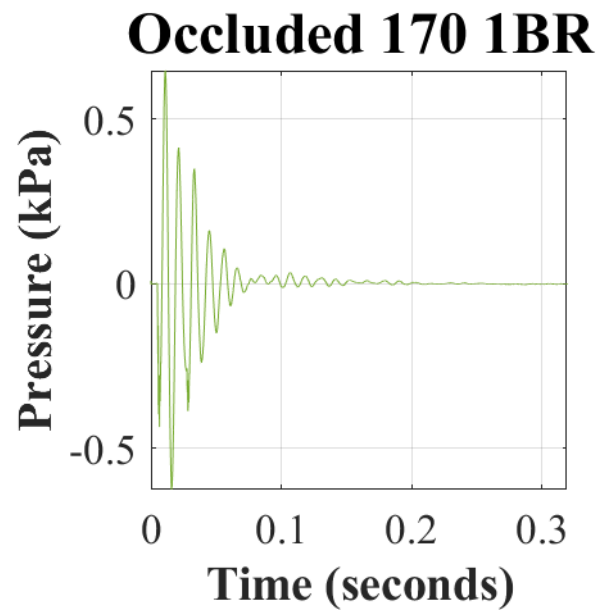
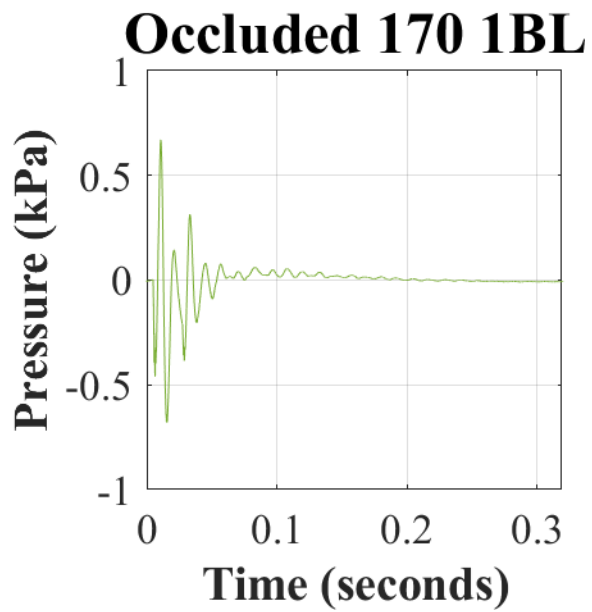
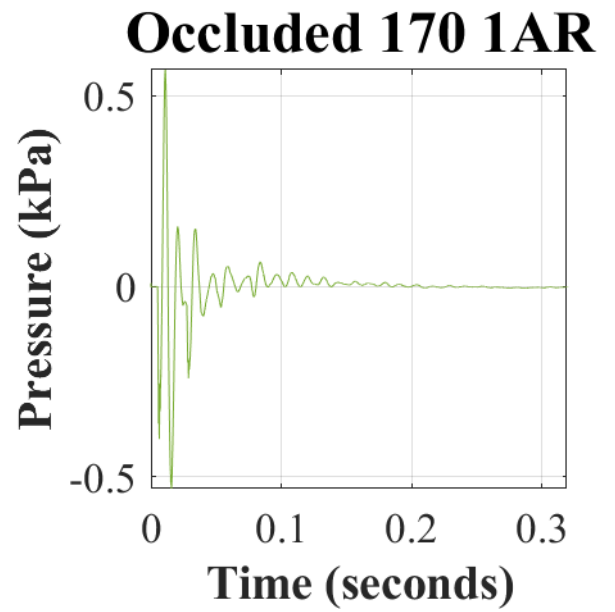
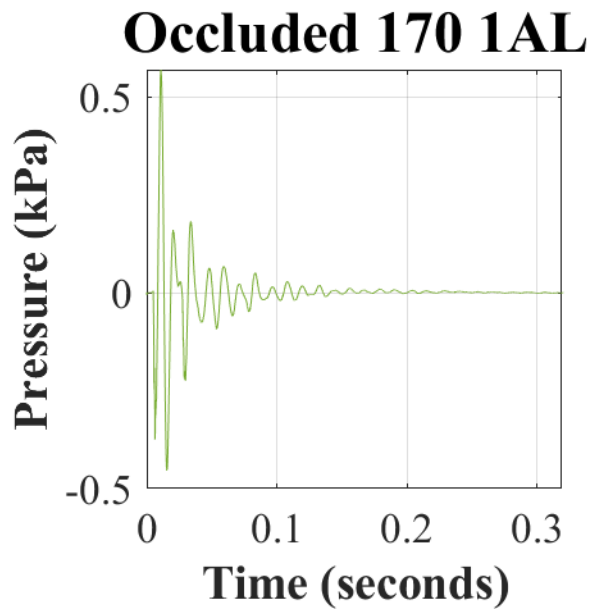


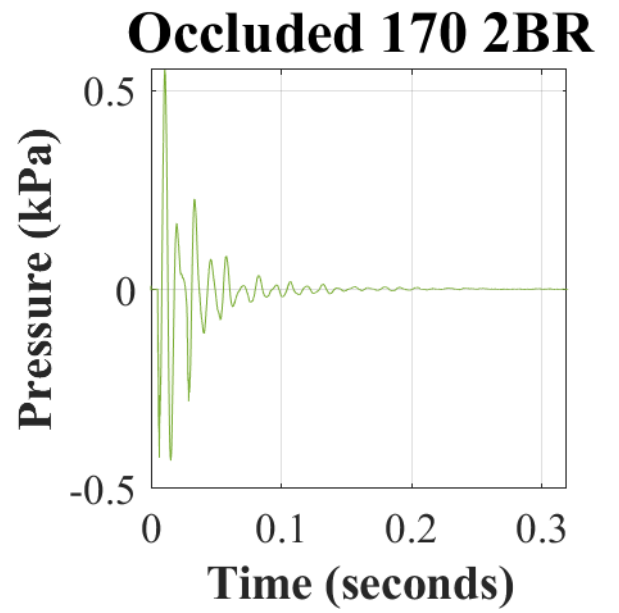
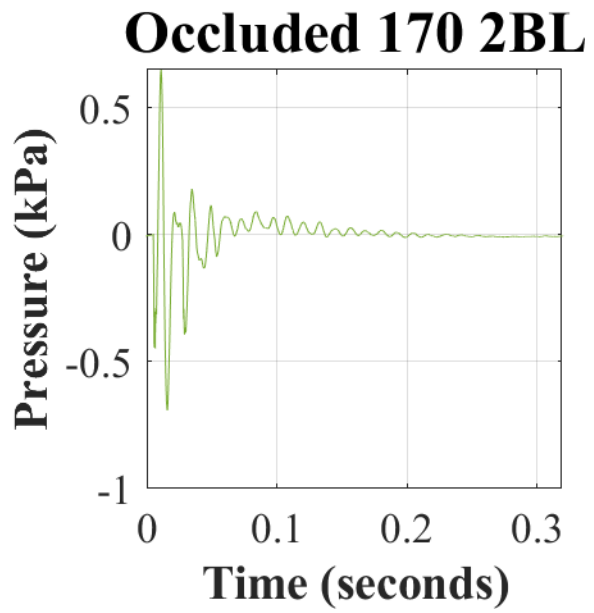
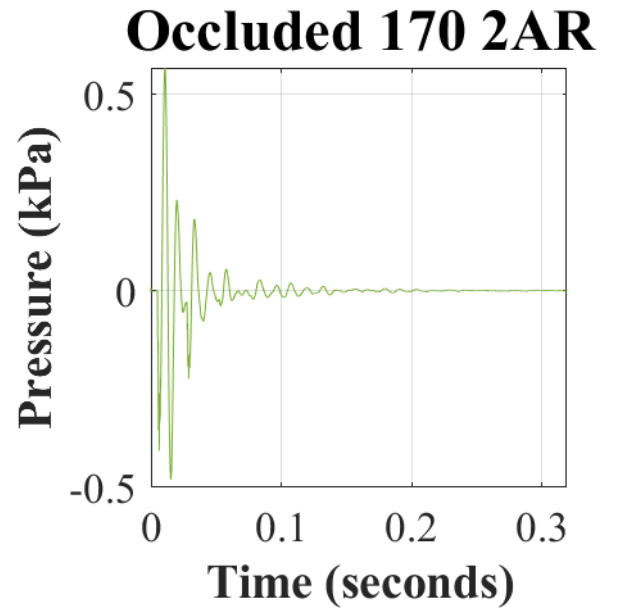
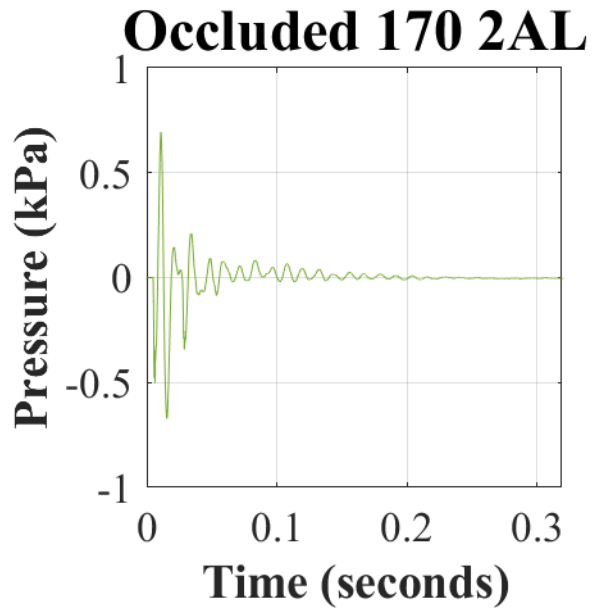




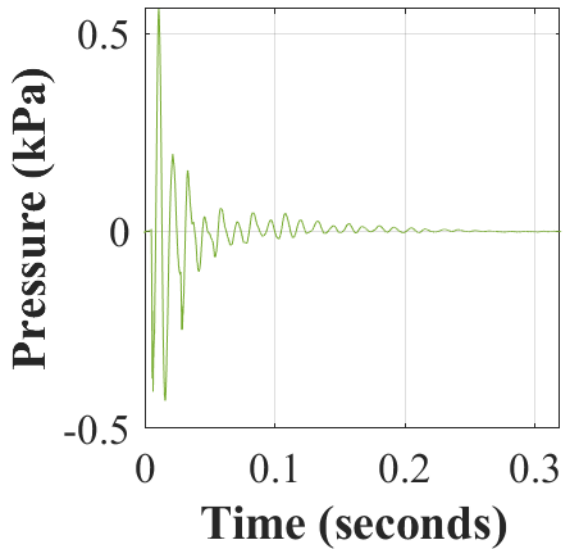
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the earmuff doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or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

**Appendix C.** Recorded occluded (earmuff donned) waveforms in response to 170 dBp with the ComTac™ V (OFF).

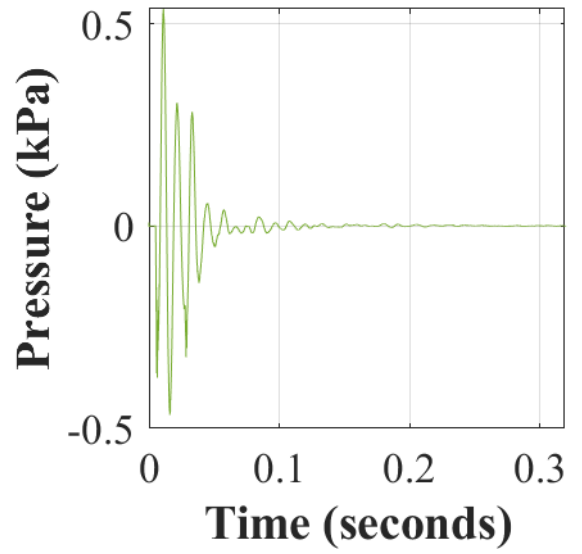




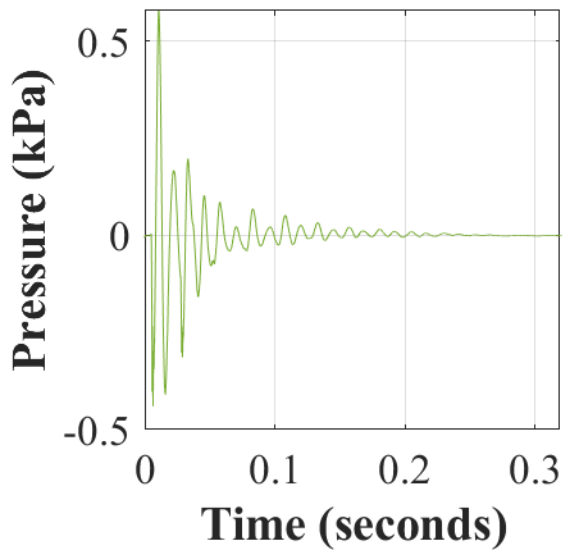
**Occluded 170 3AL**



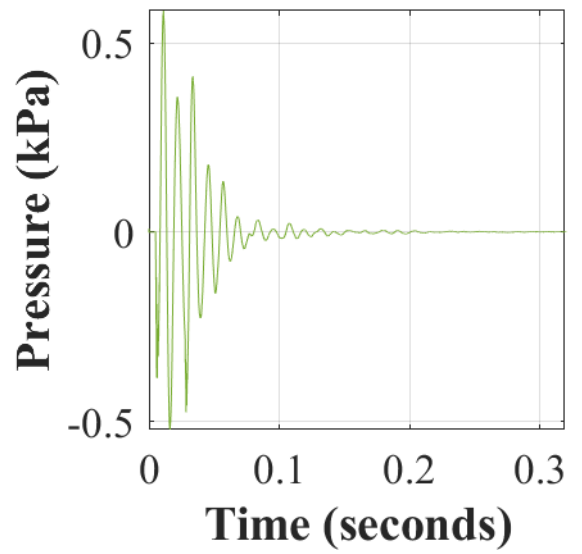
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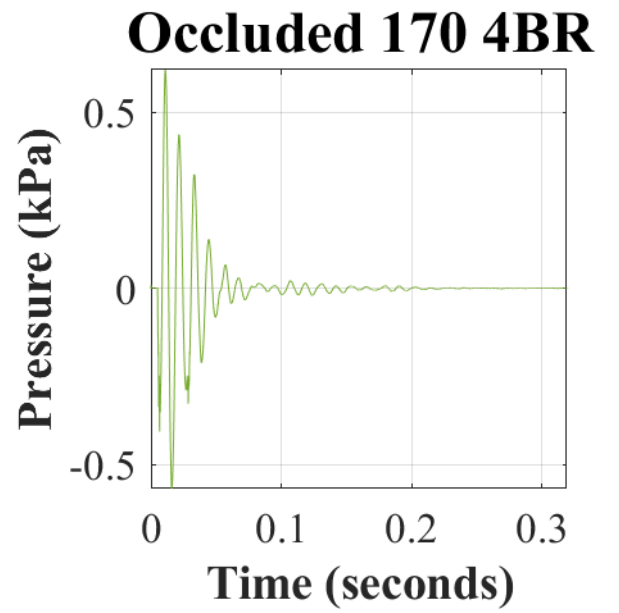
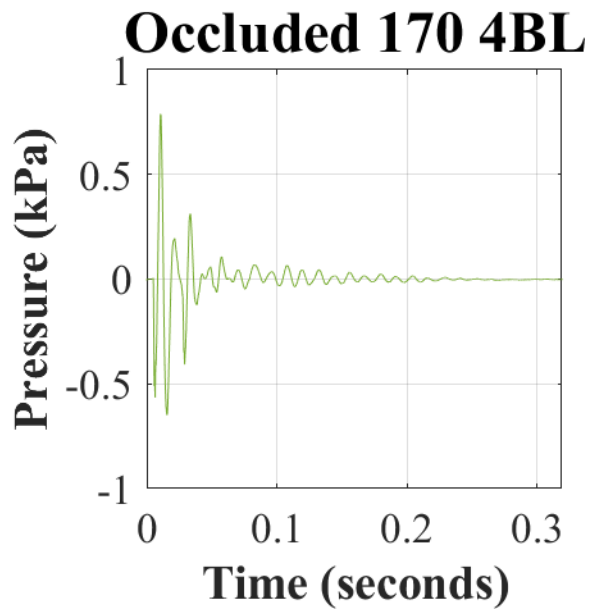
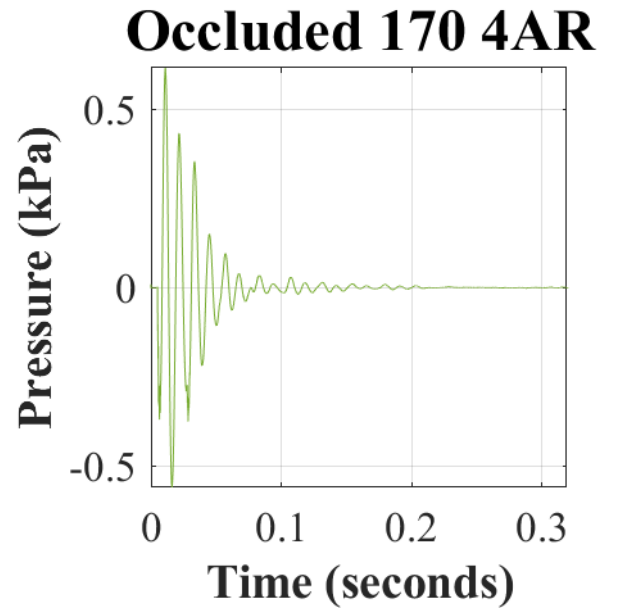
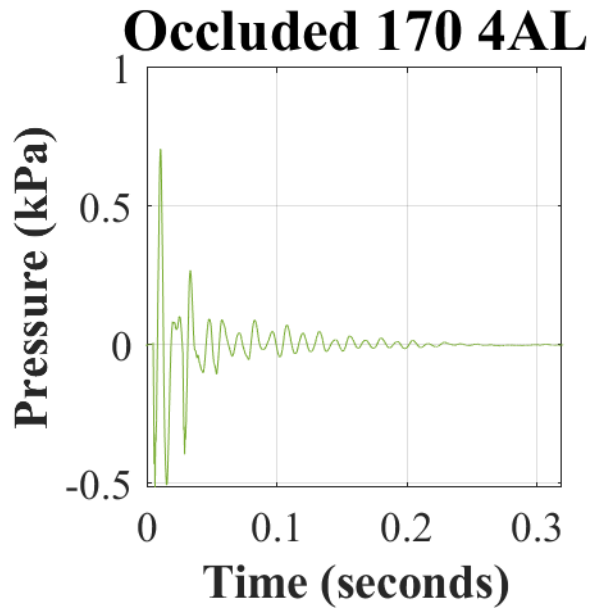


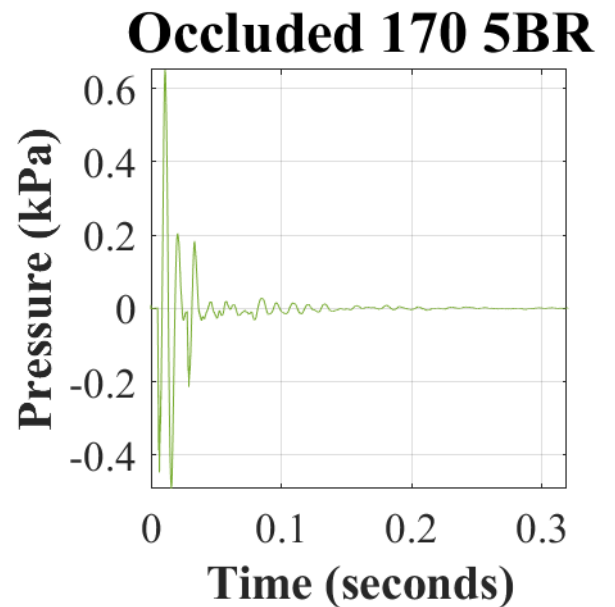
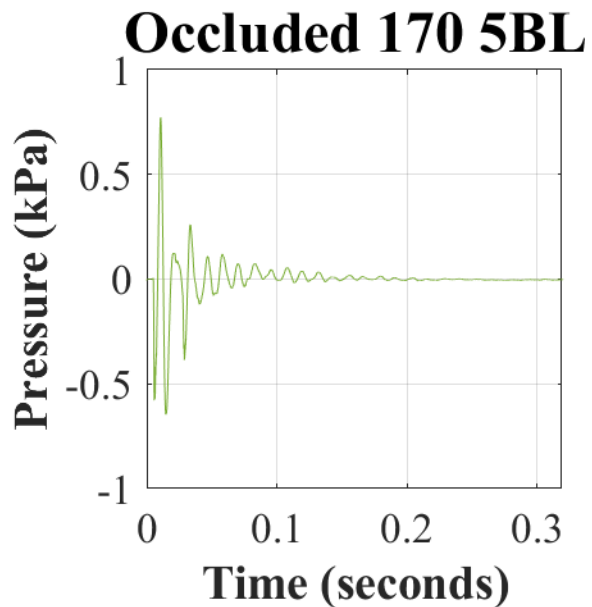
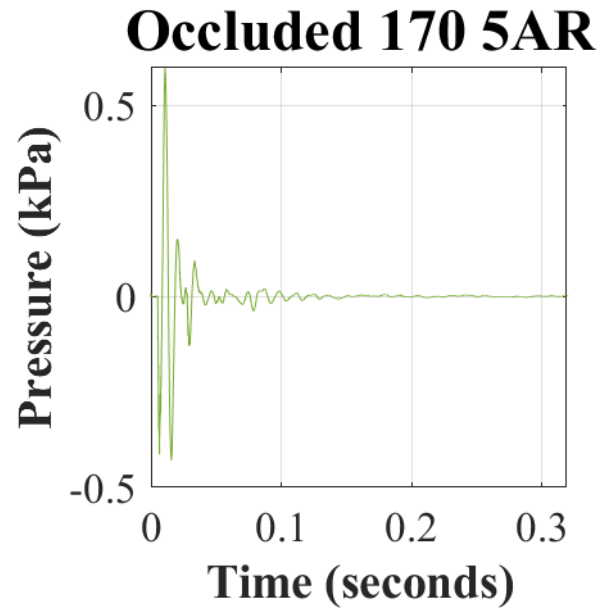
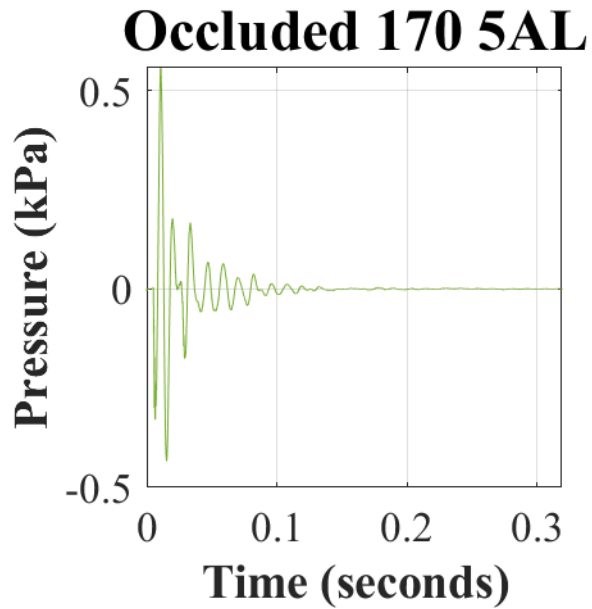
**Occluded 170 3BL**



**Occluded 170 3BR**

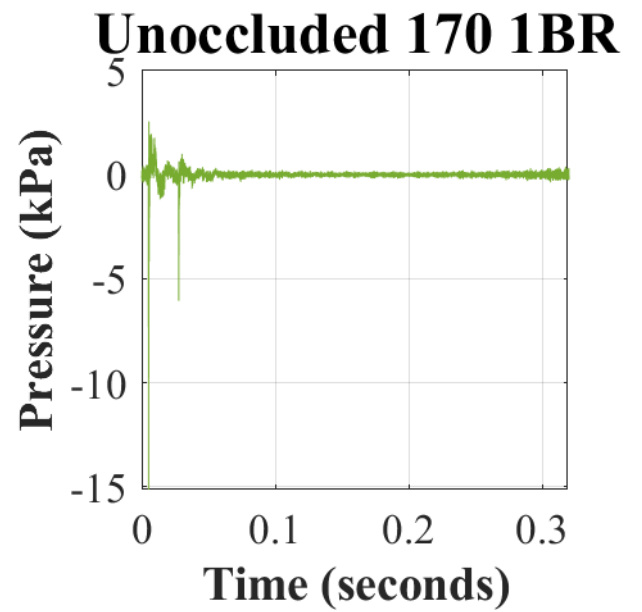
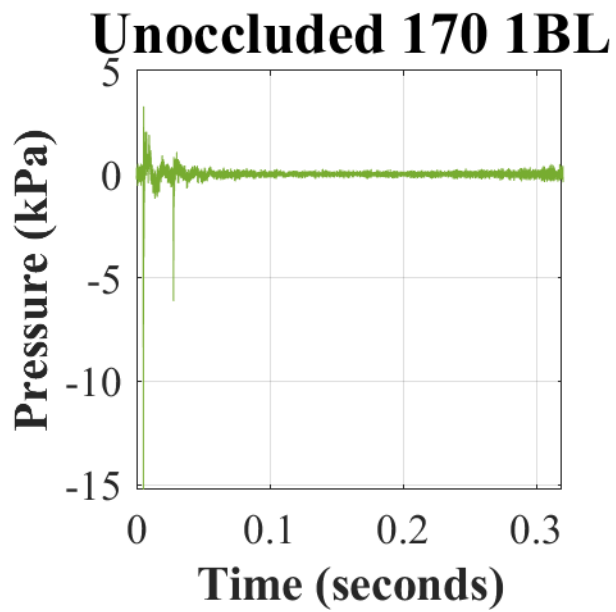
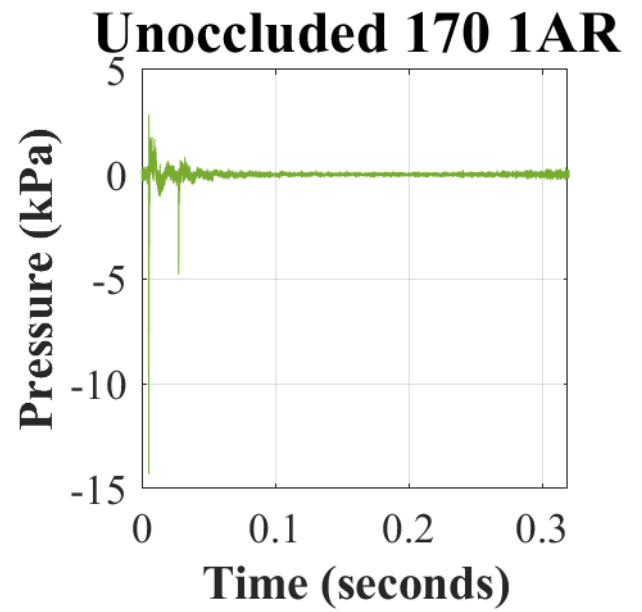
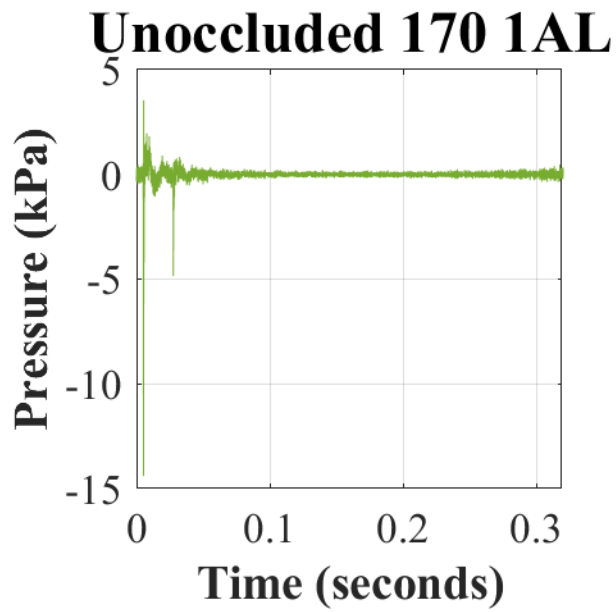


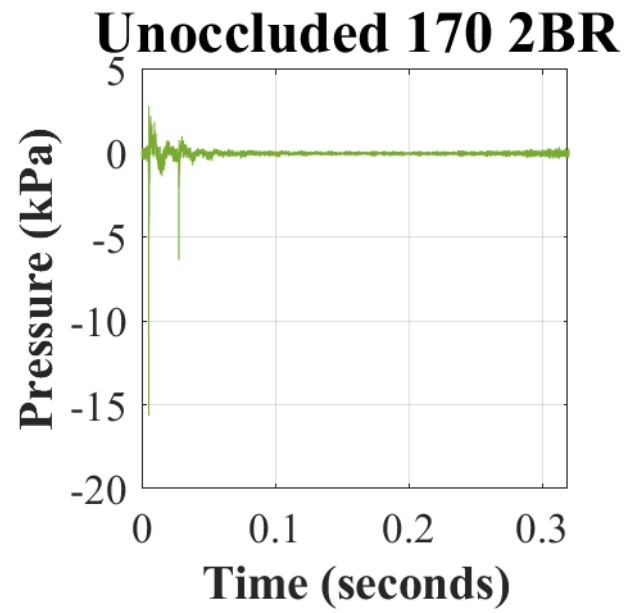
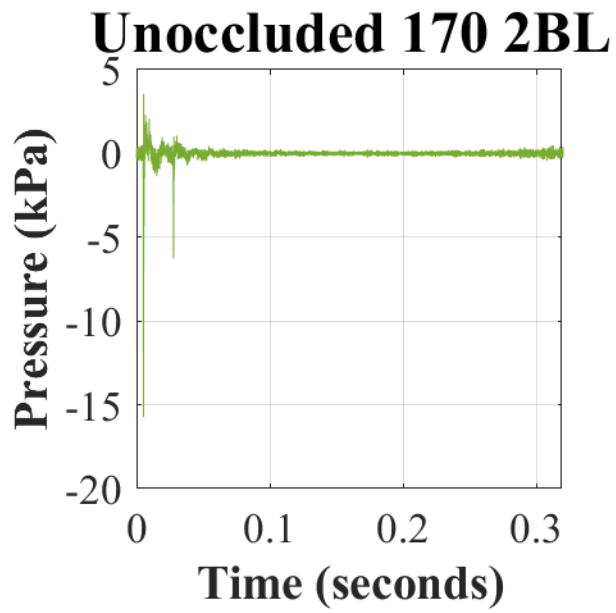
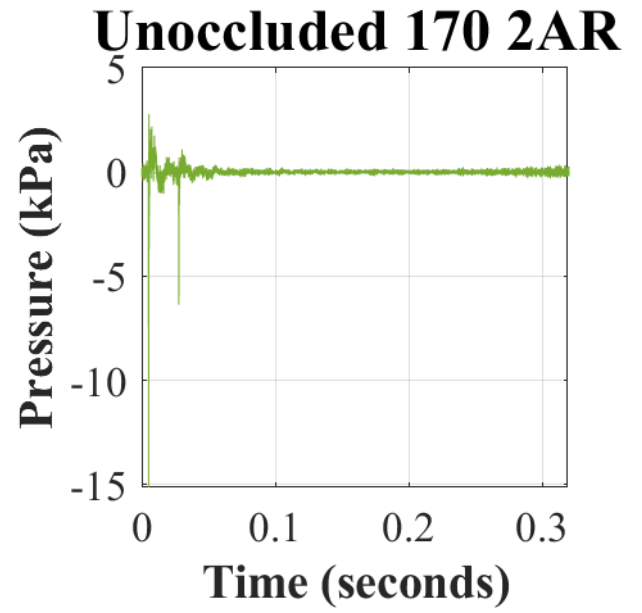
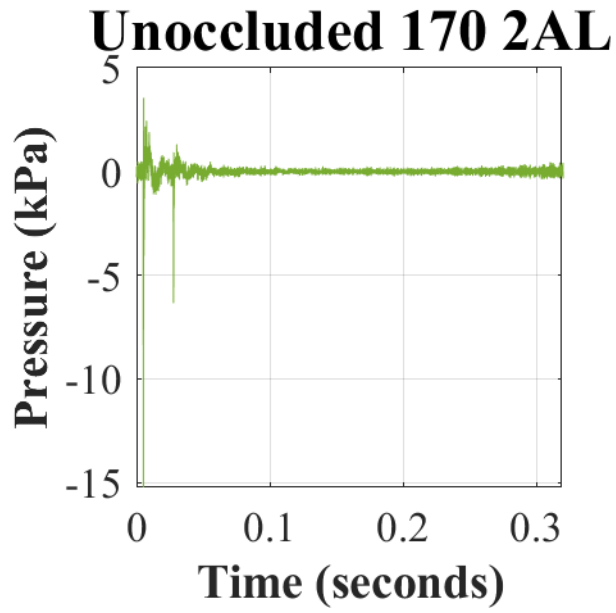


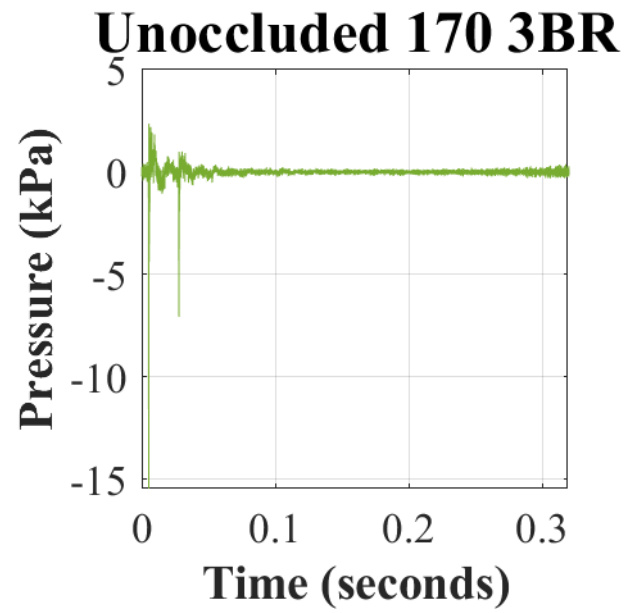
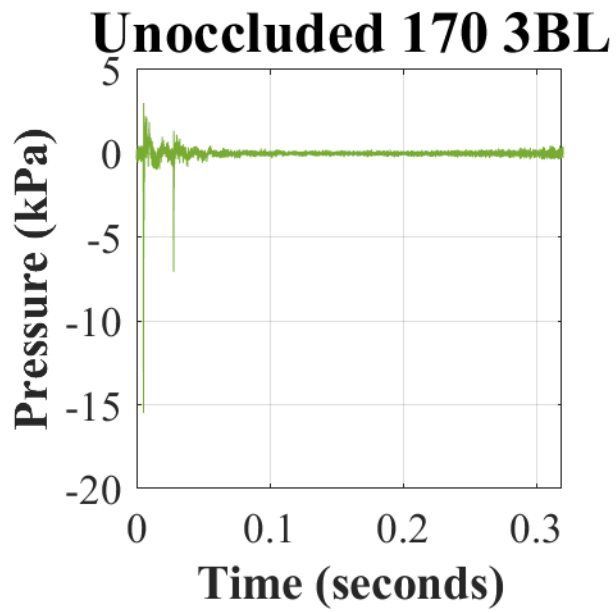
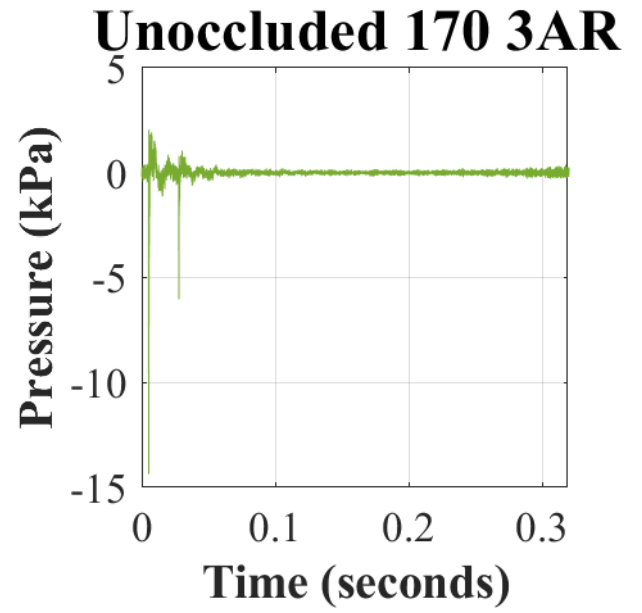
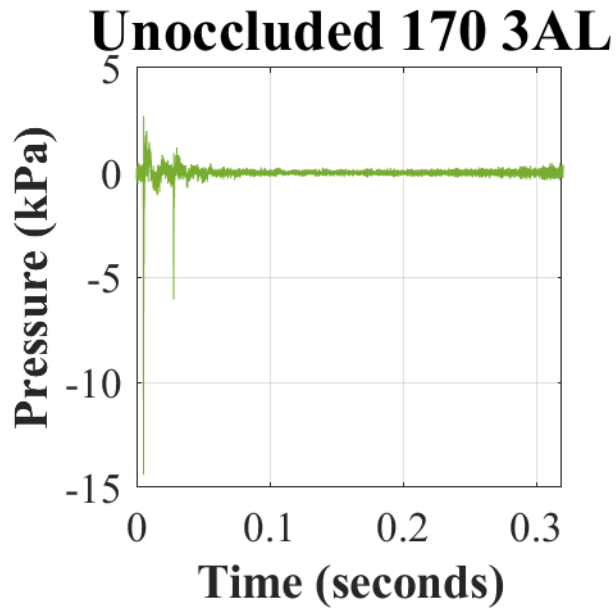


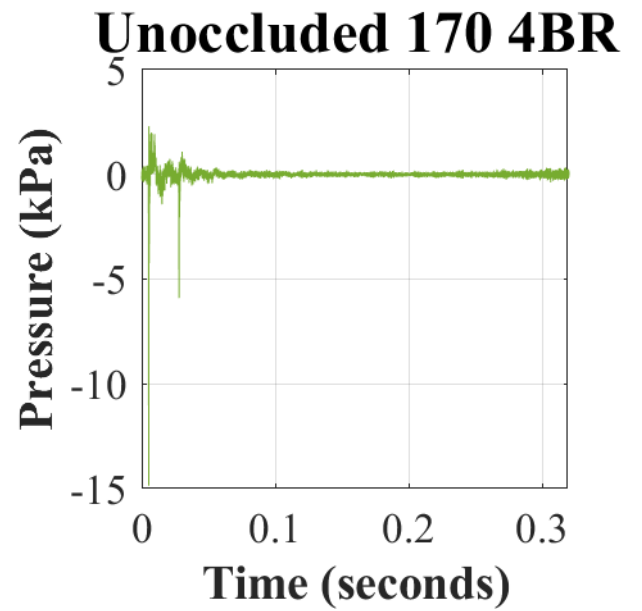
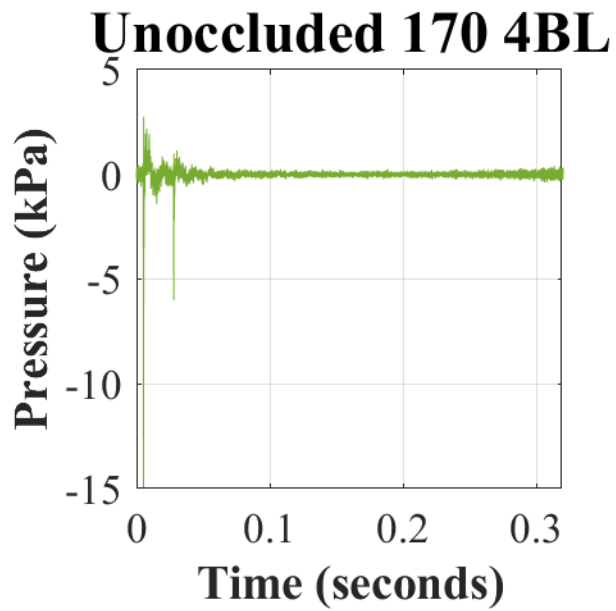
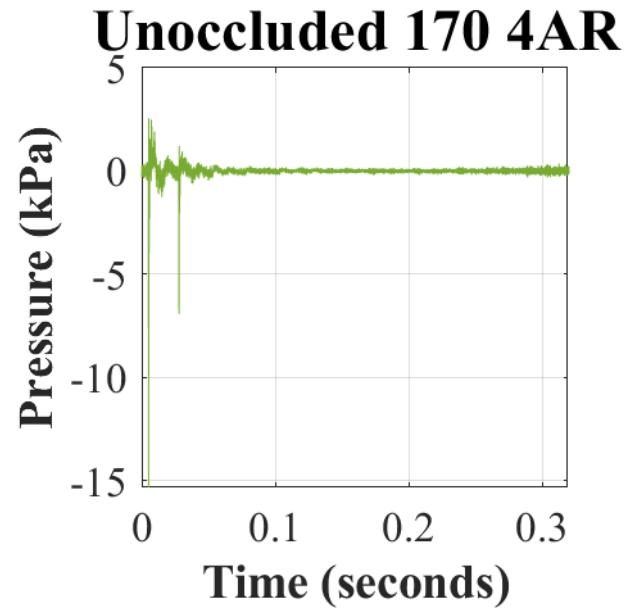
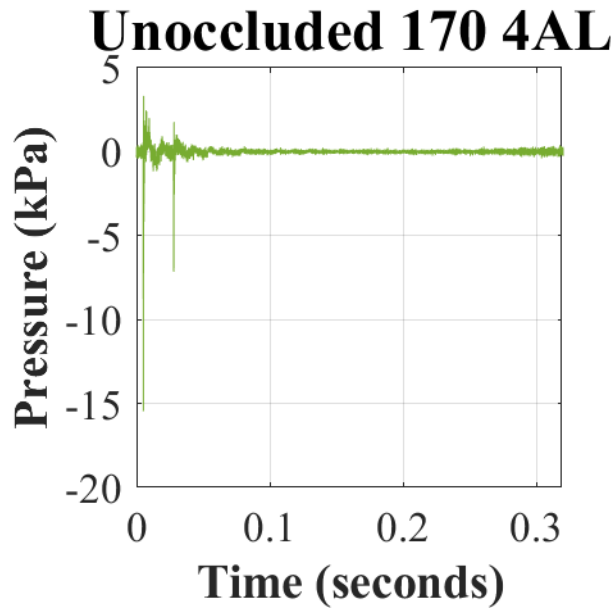
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the earmuff donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B)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

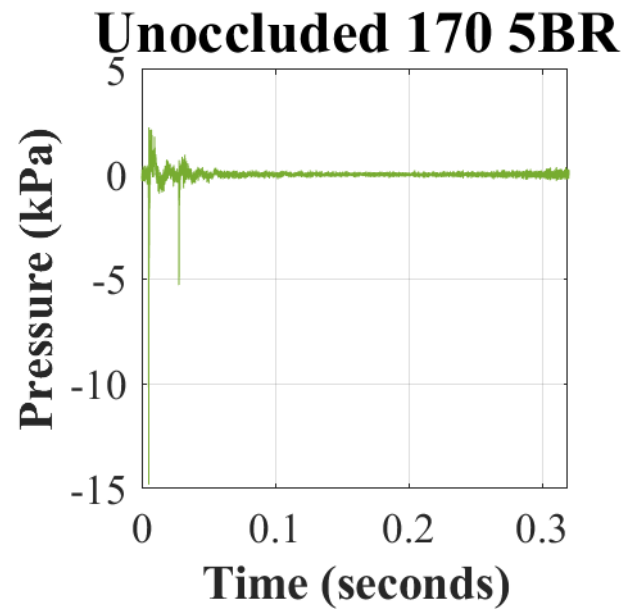
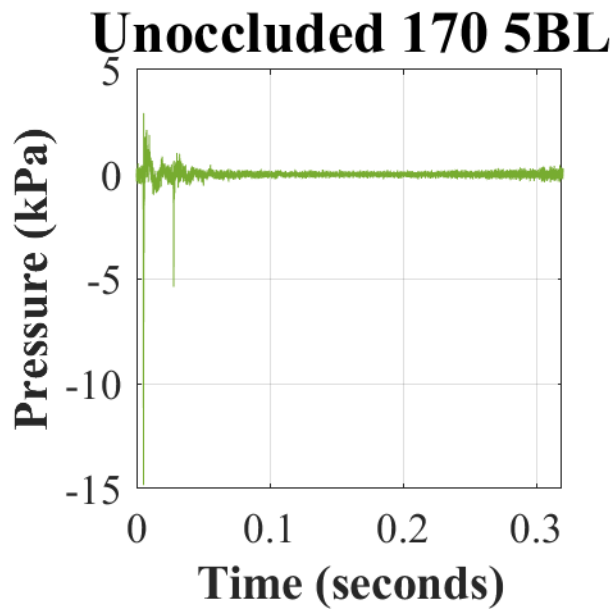
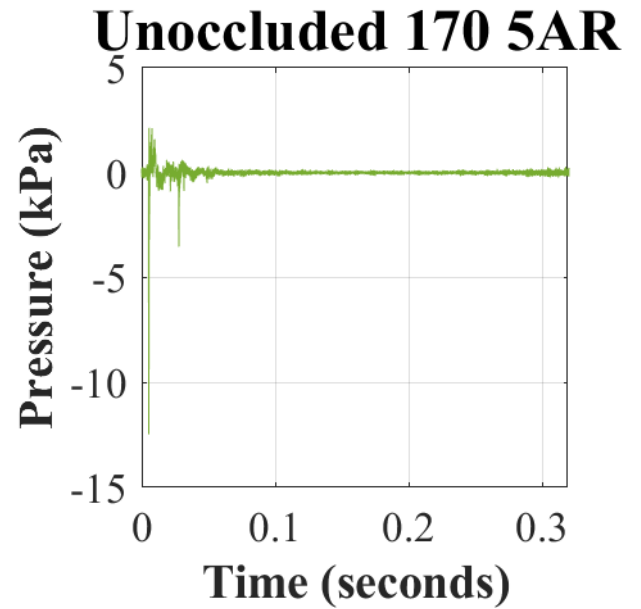
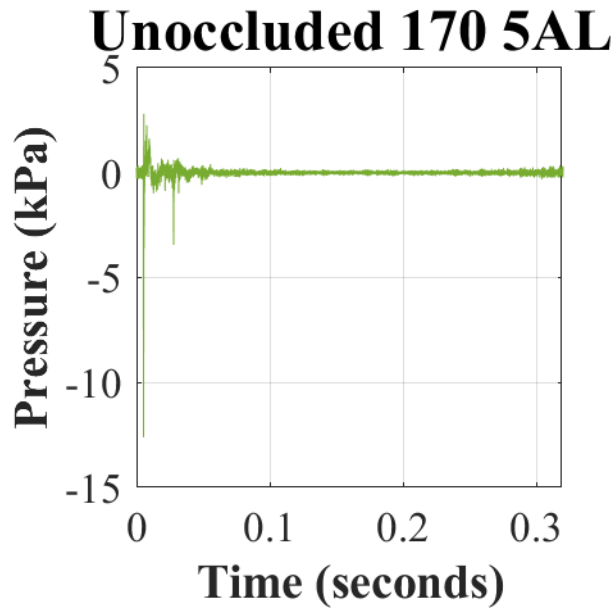
**Appendix D.** Estimated unoccluded (earmuff doffed) waveforms in response to 170 dBp with the ComTac™ V (OFF).





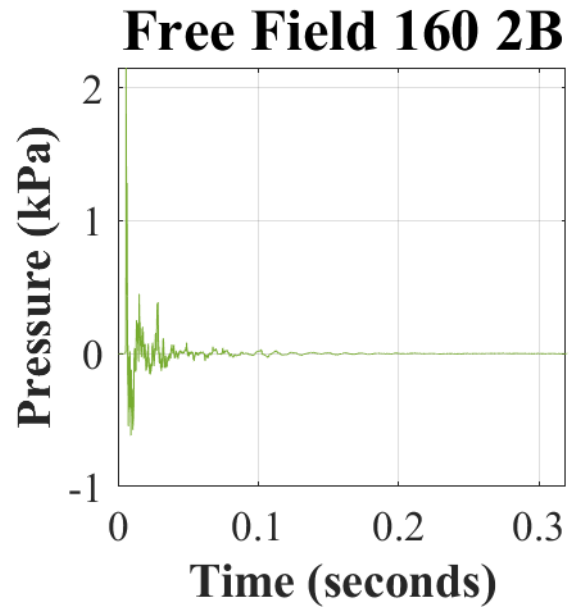
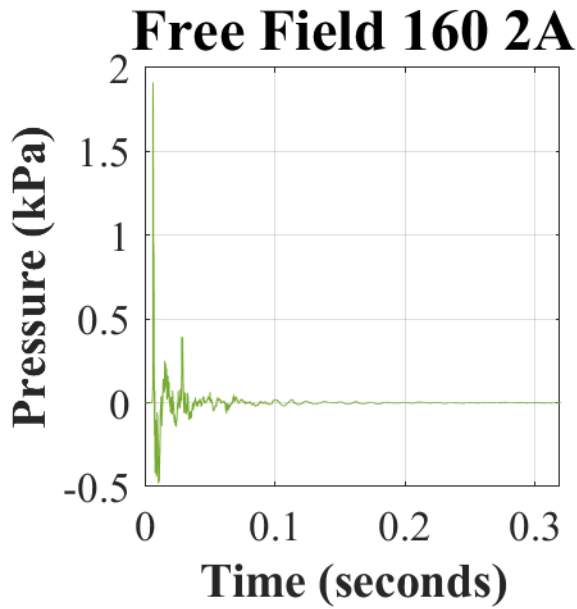
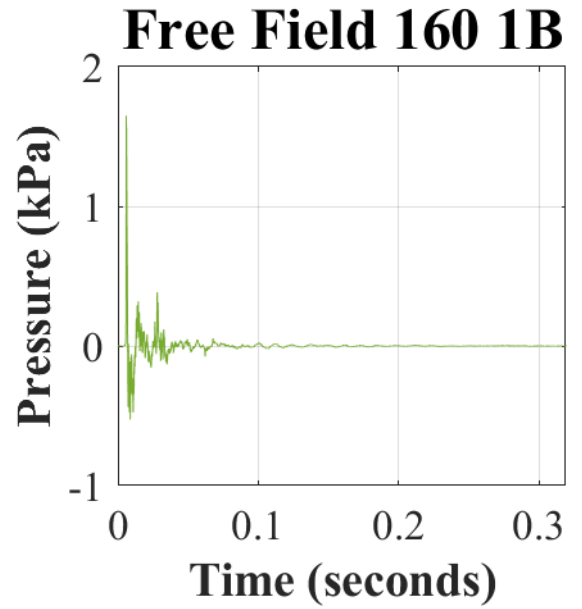
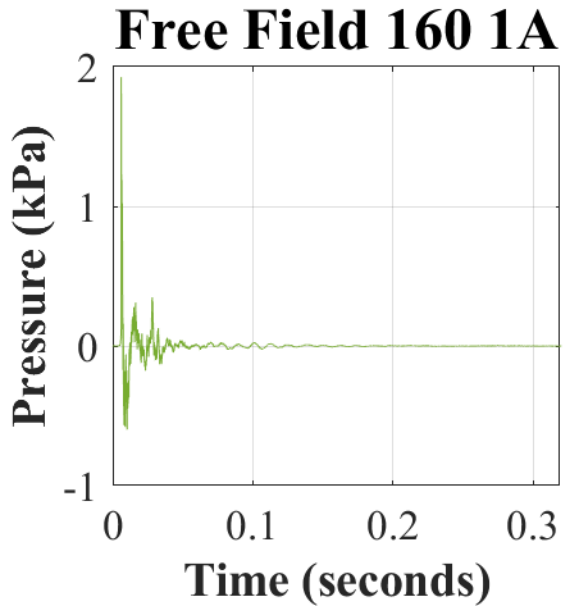


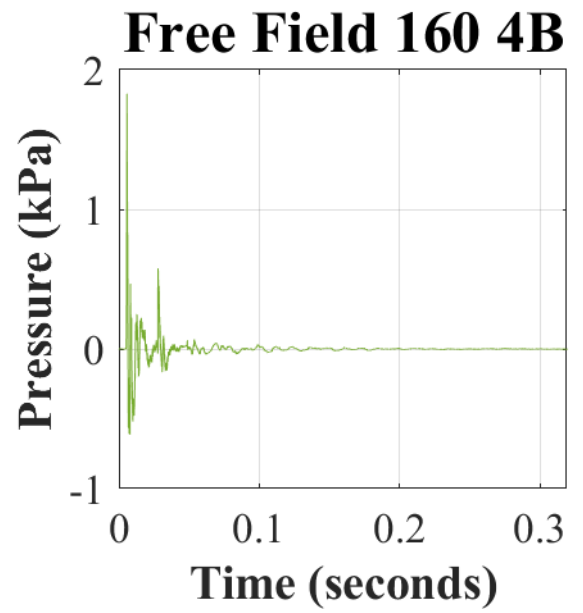
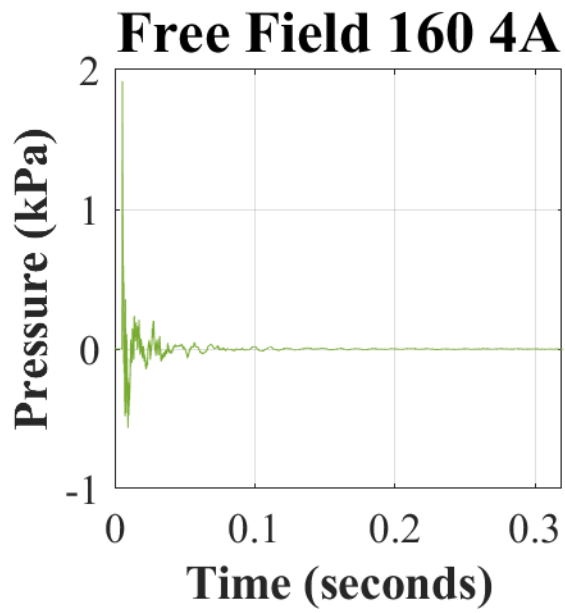
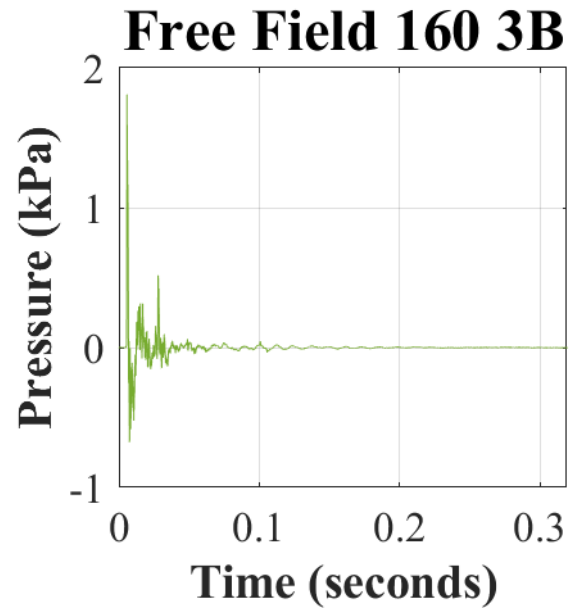
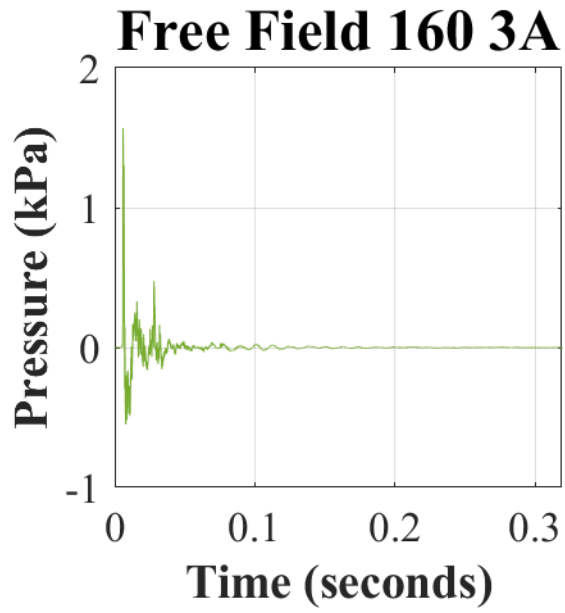


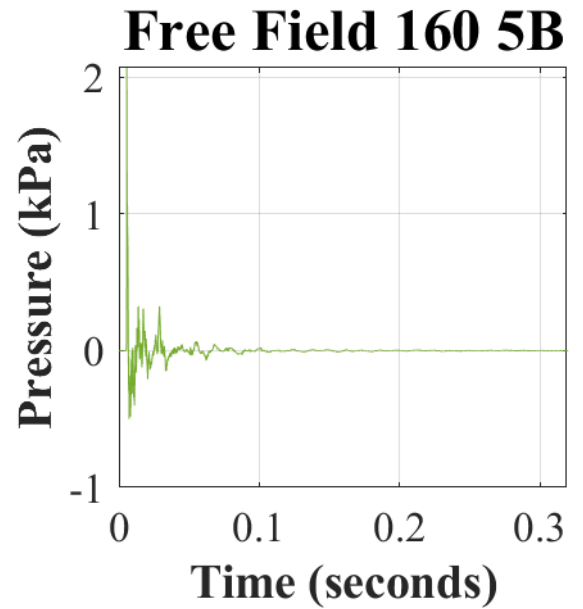
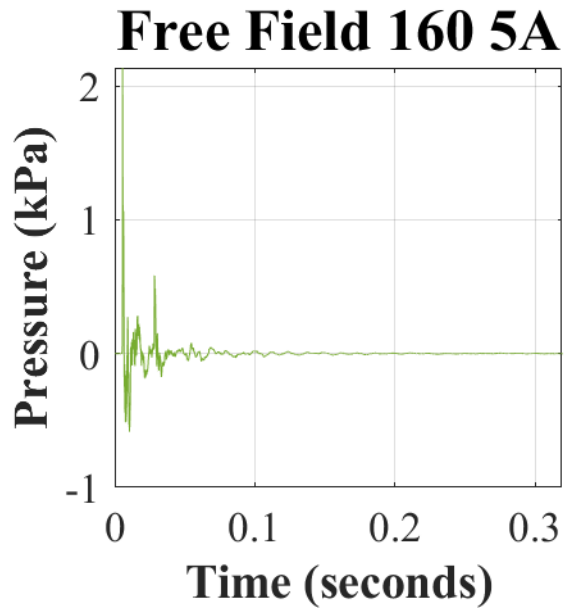


Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the earmuff doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or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

**Appendix E.** Recorded waveform of the impulse measured with the free-field probe at 160 dBp and the ComTac™ V (OFF) donned.

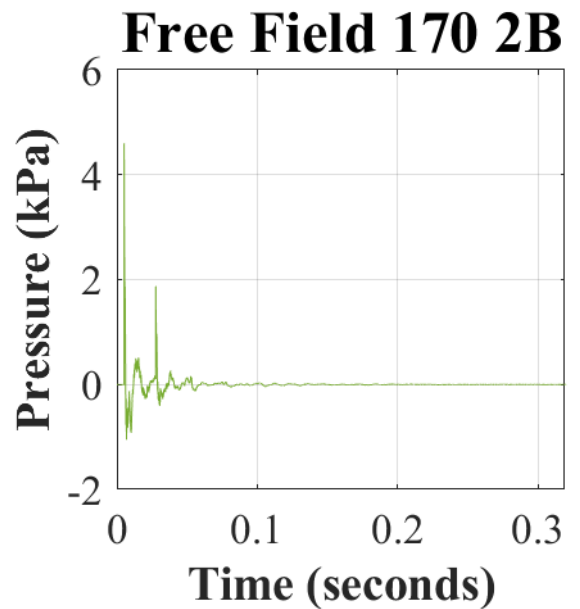
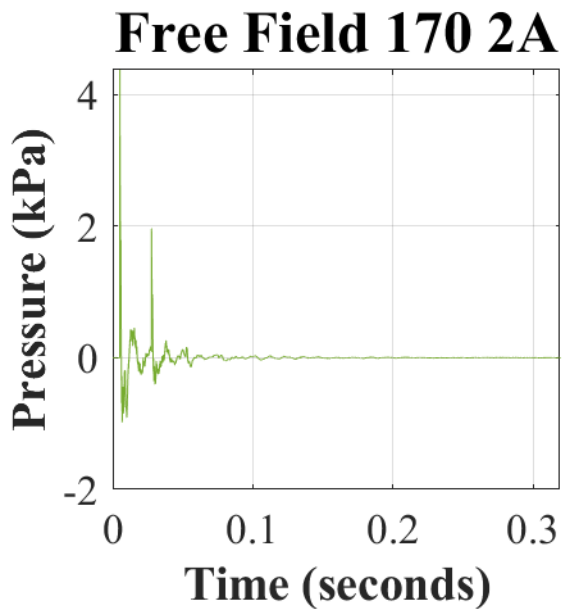
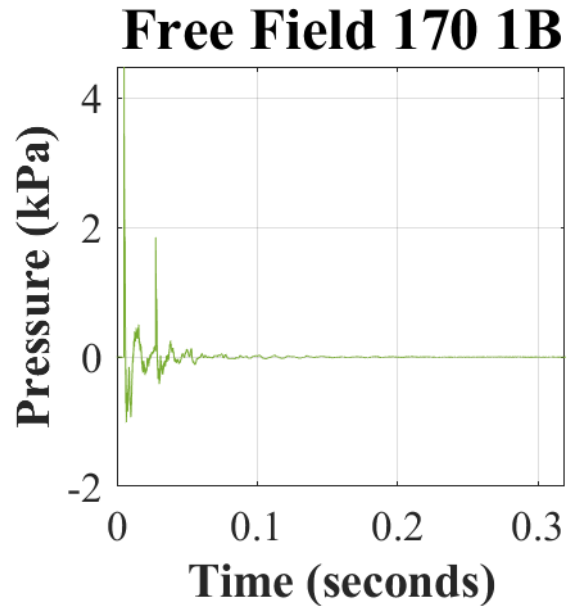
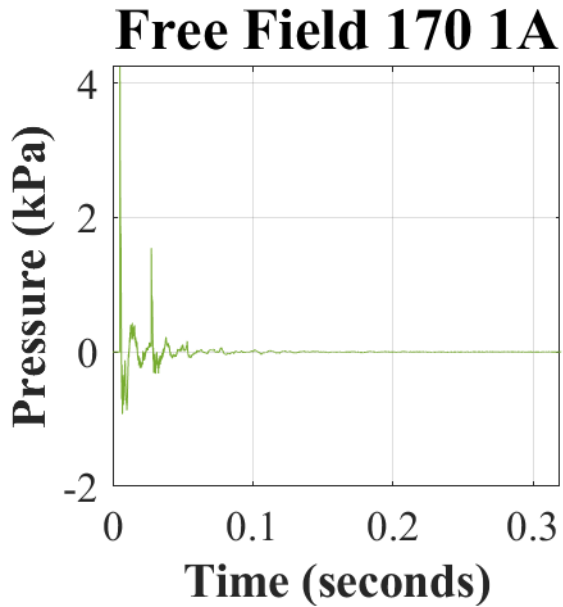


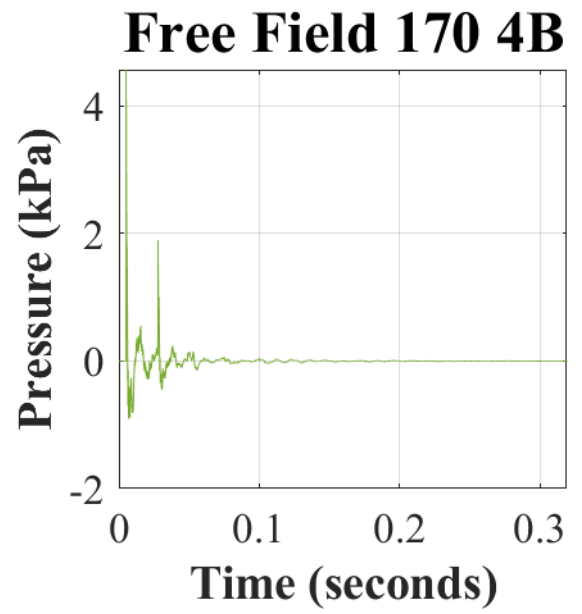
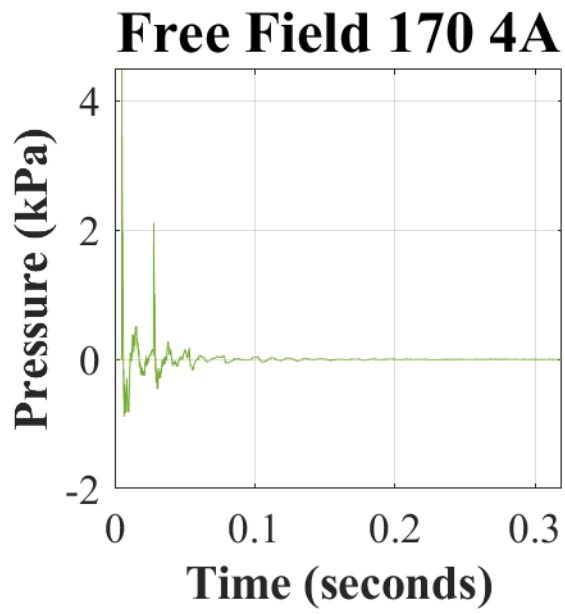
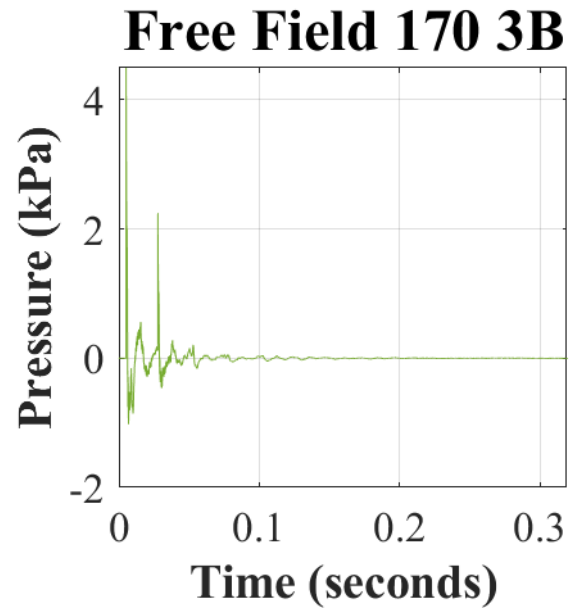
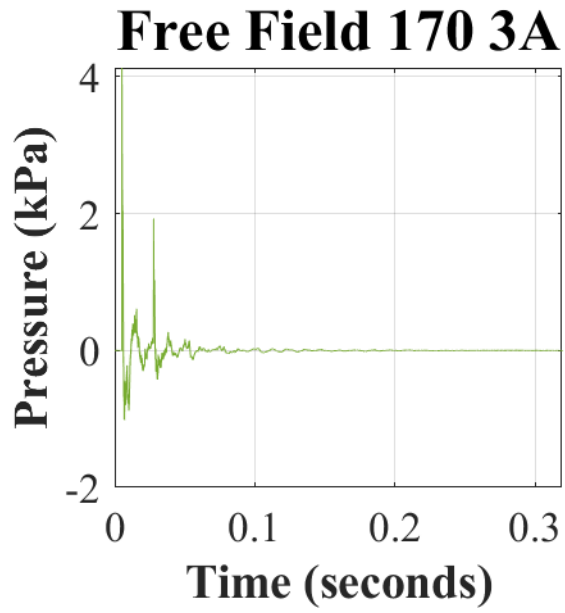


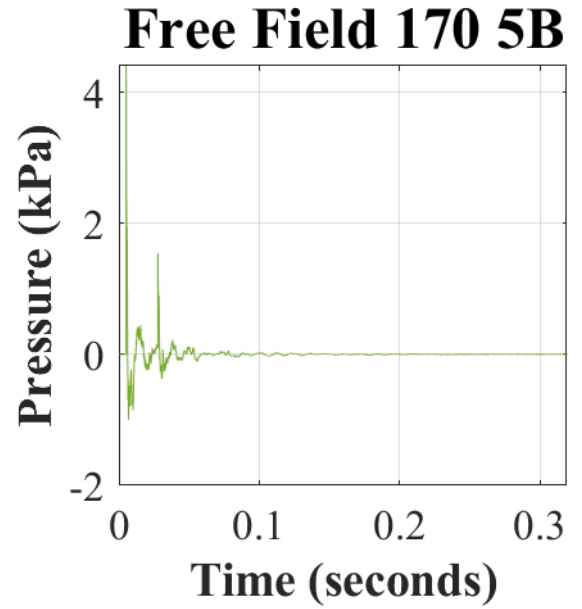
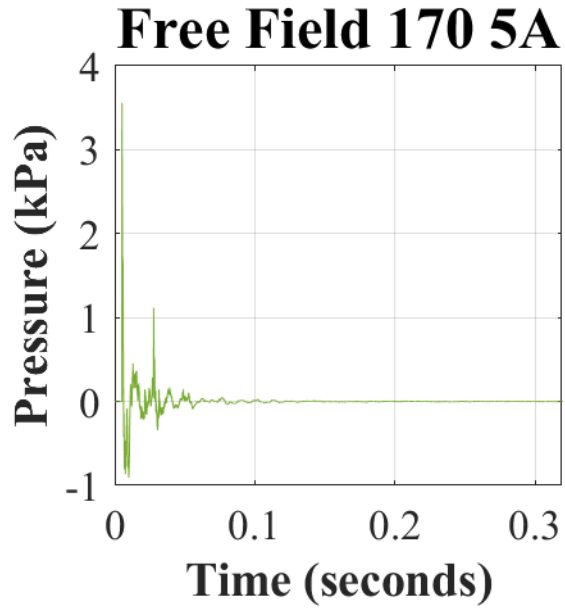


Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (170 dBp), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

**Appendix F.** Recorded waveform of the impulse measured with the free-field probe at 170 dBp and the ComTac™ V (OFF) donned.

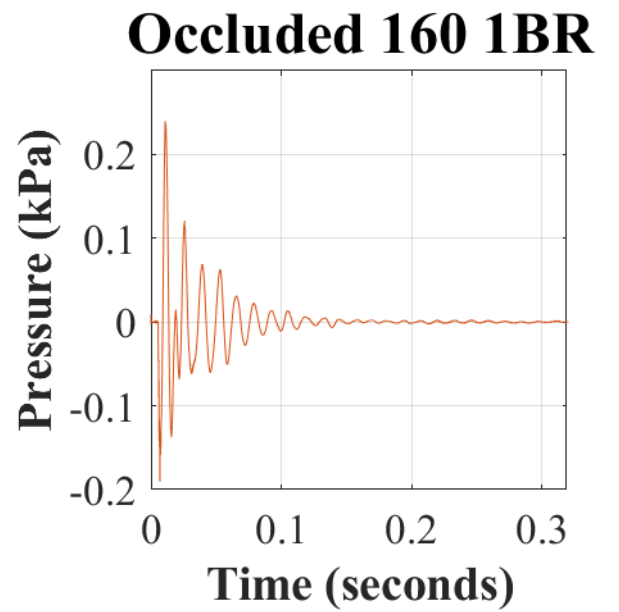
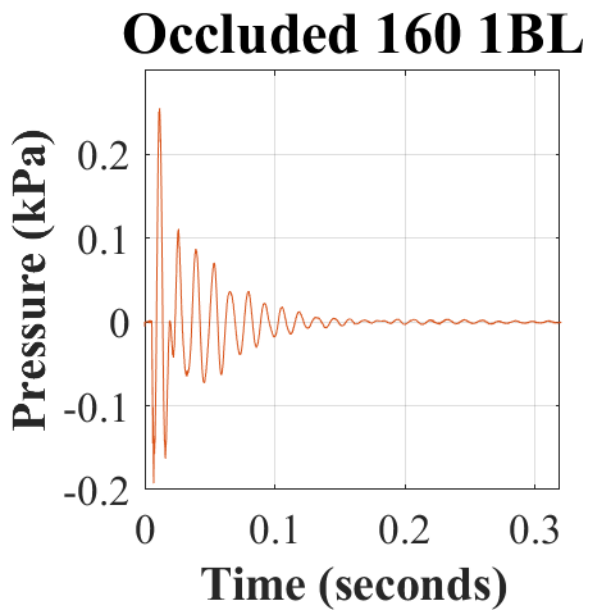
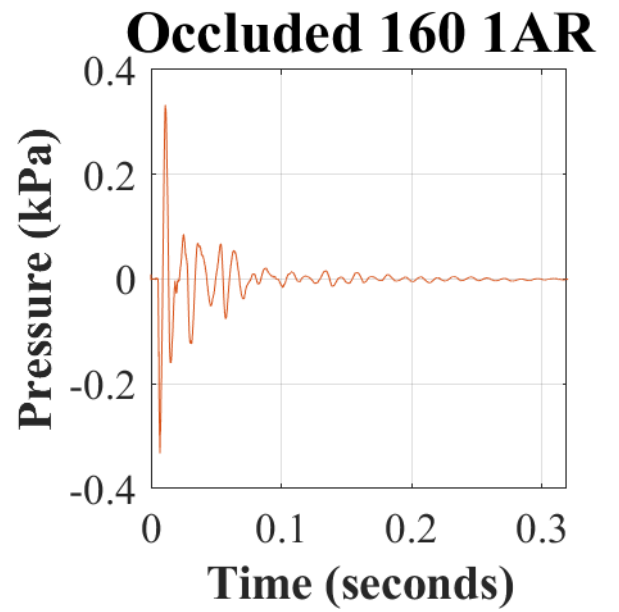
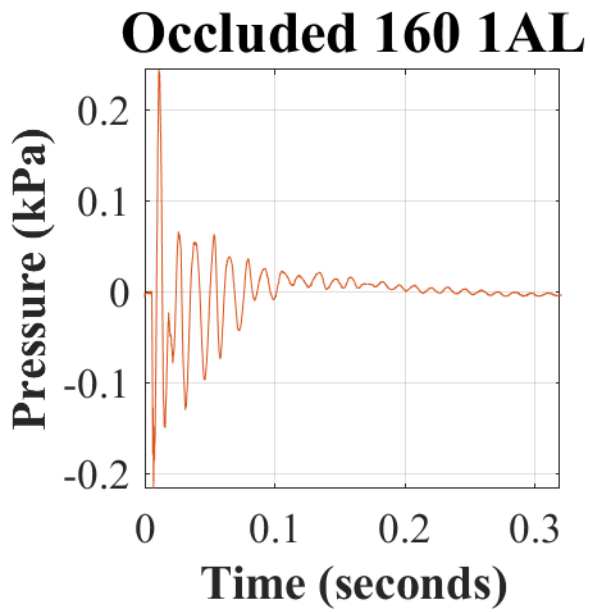




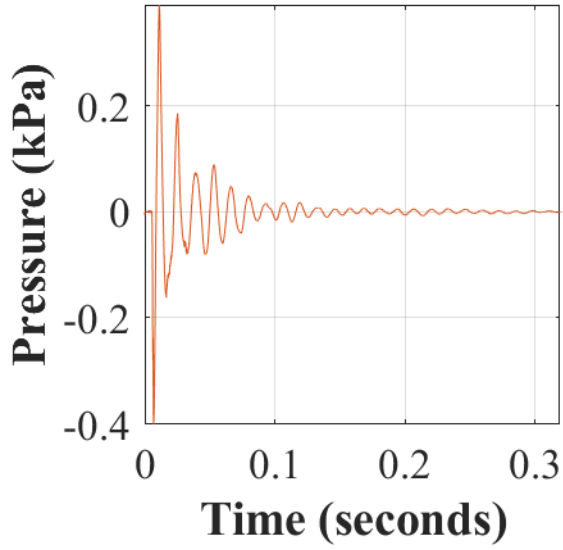


Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (170 dBp), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

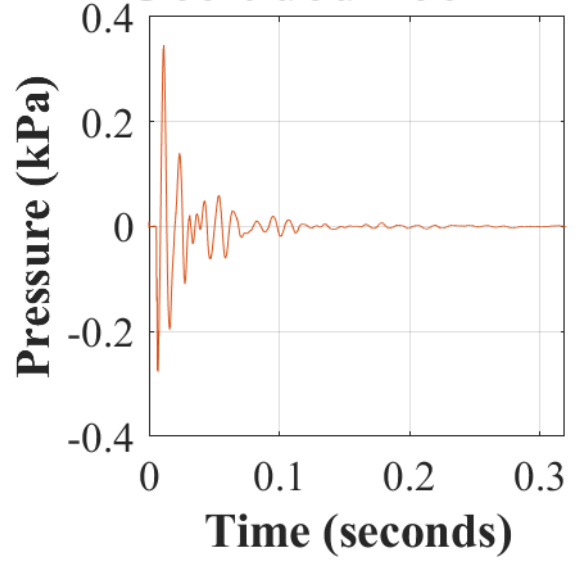
**Appendix G.** Recorded occluded (earmuff donned) waveforms in response to 160 dBp with the ComTac™ V (MAX).



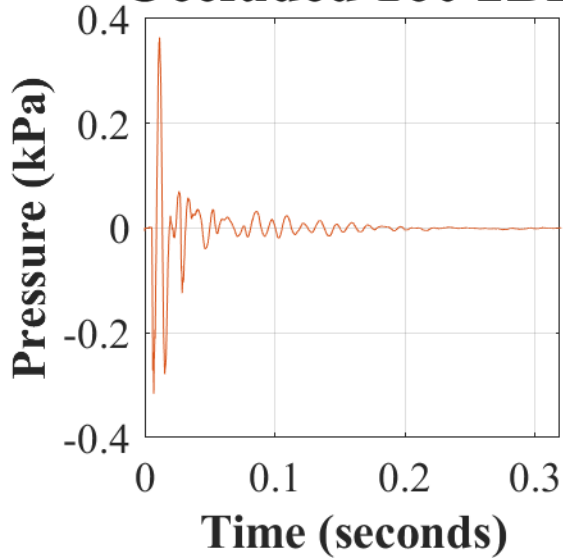
**Occluded 160 2AL**



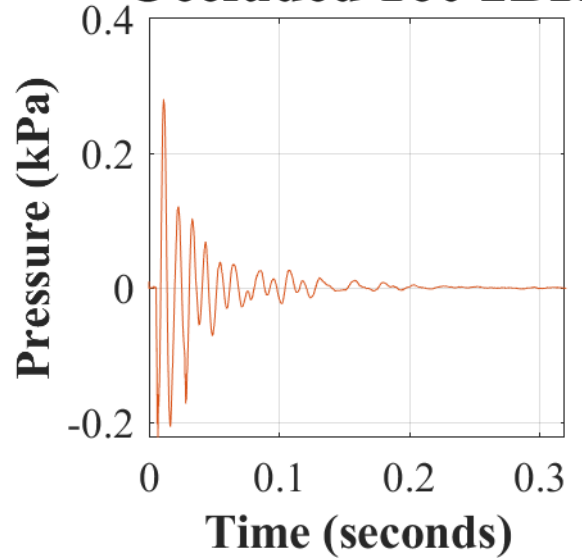
**Occluded 160 2AR**

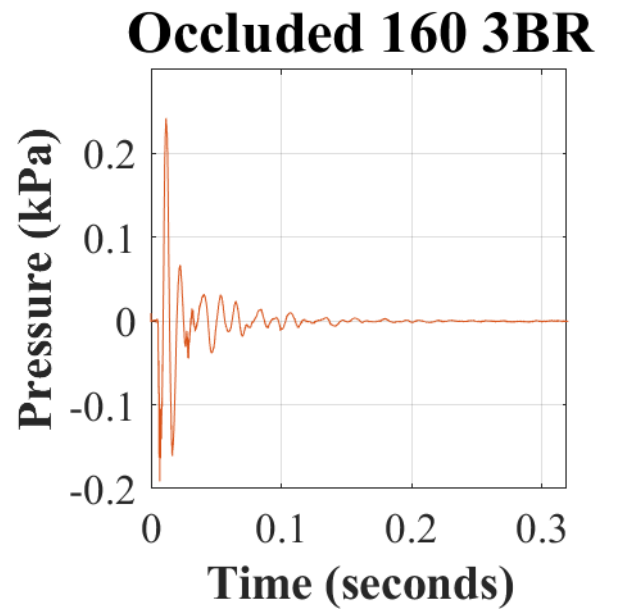
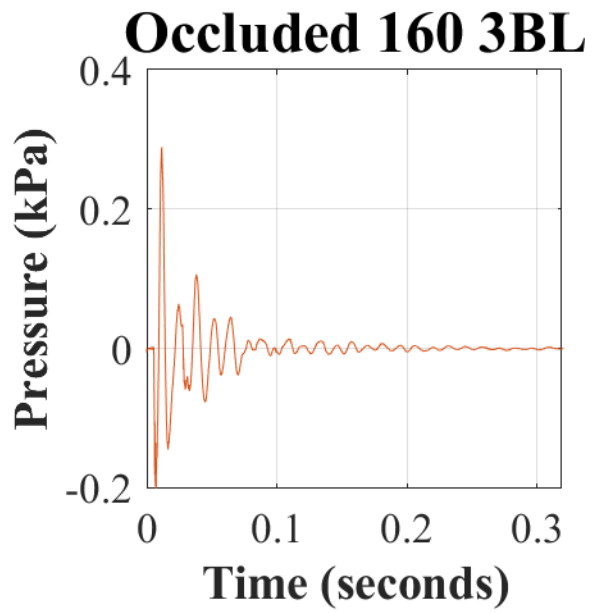
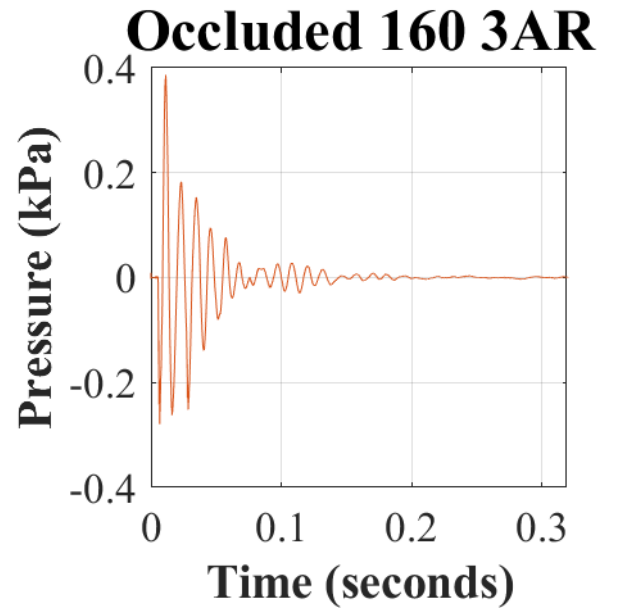
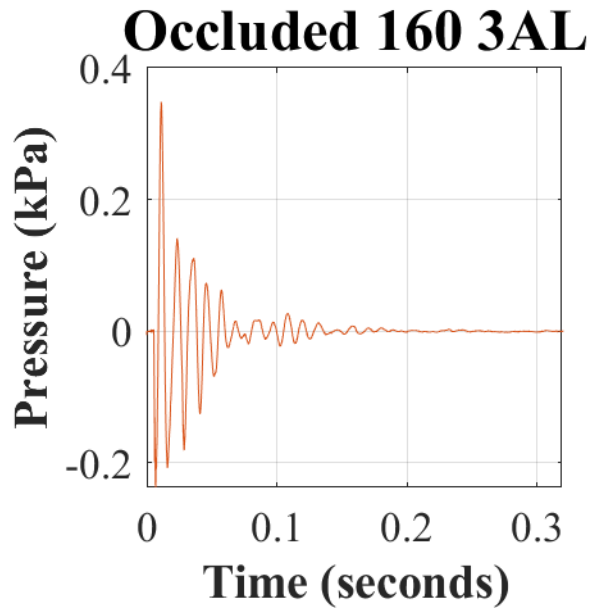


**Occluded 160 2BL**

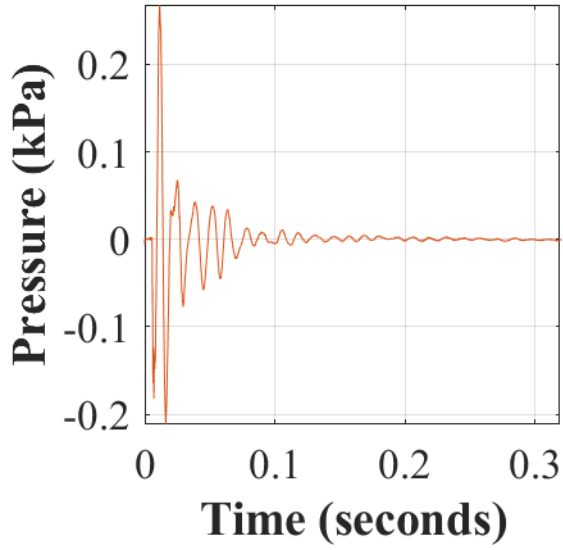


**Occluded 160 2BR**

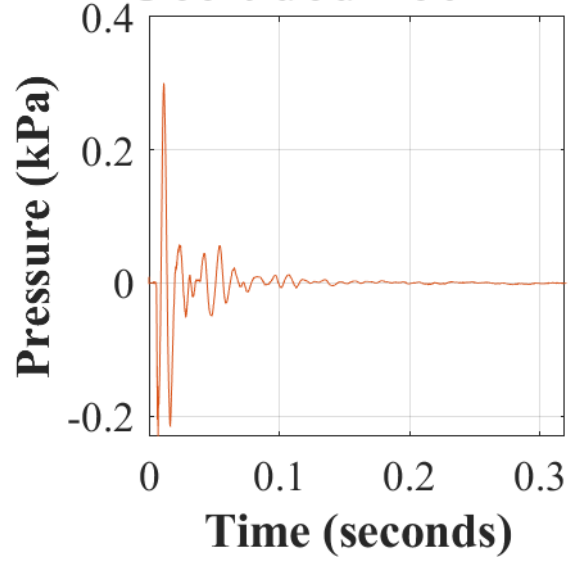




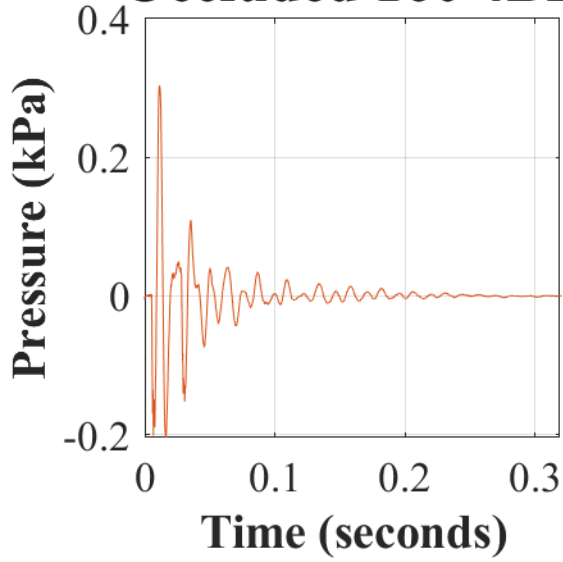
**Occluded 160 4AL**



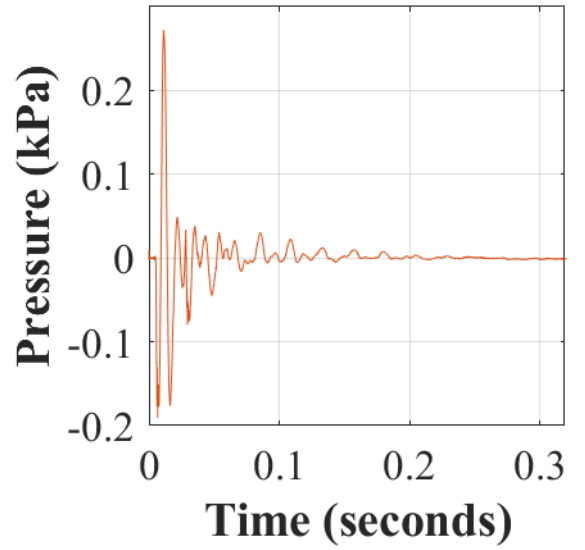
**Occluded 160 4AR**

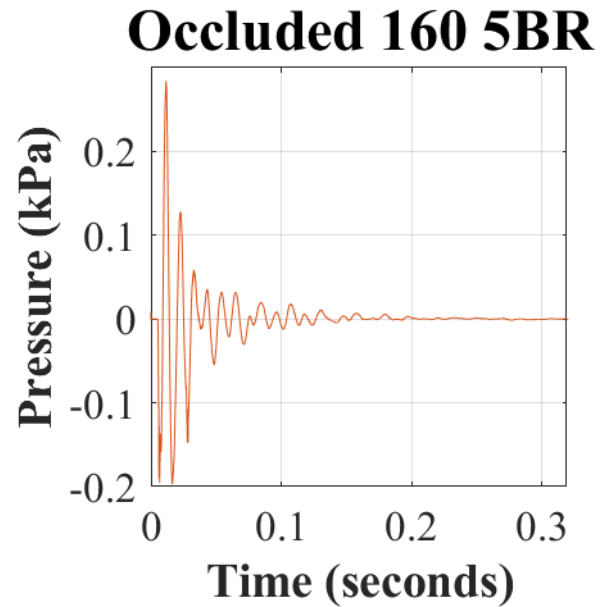
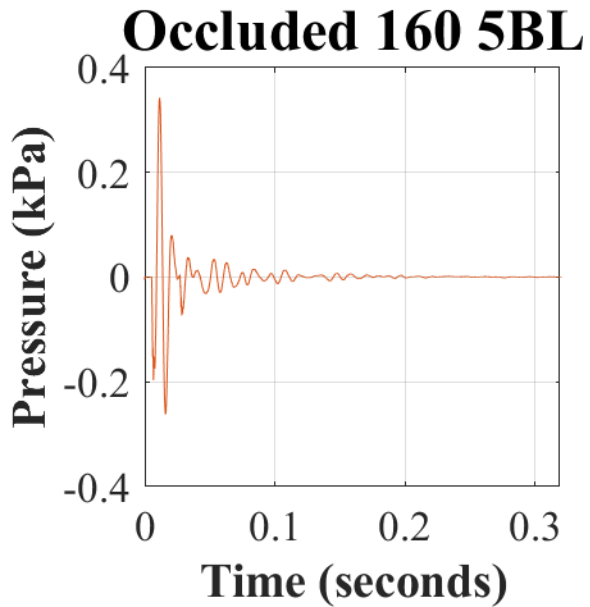
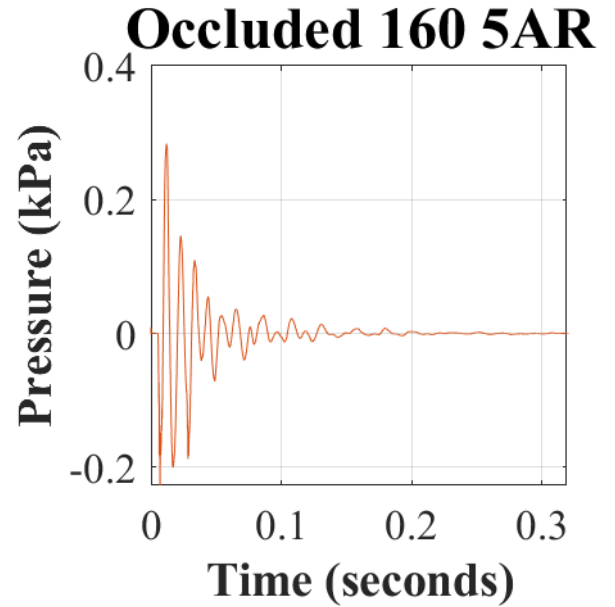
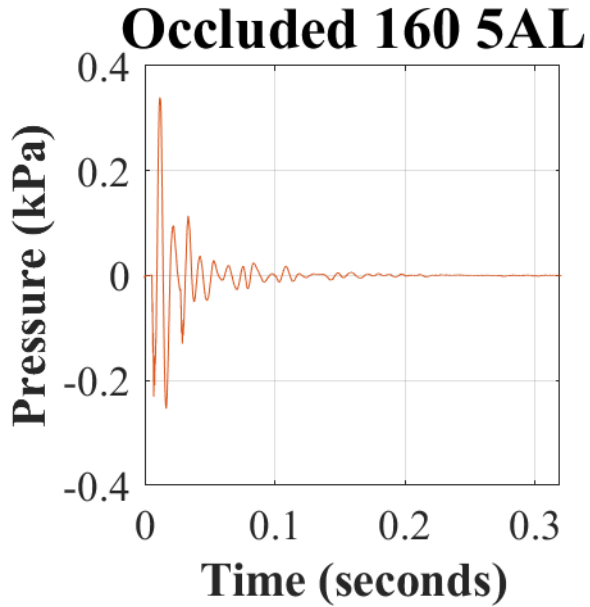


**Occluded 160 4BL**



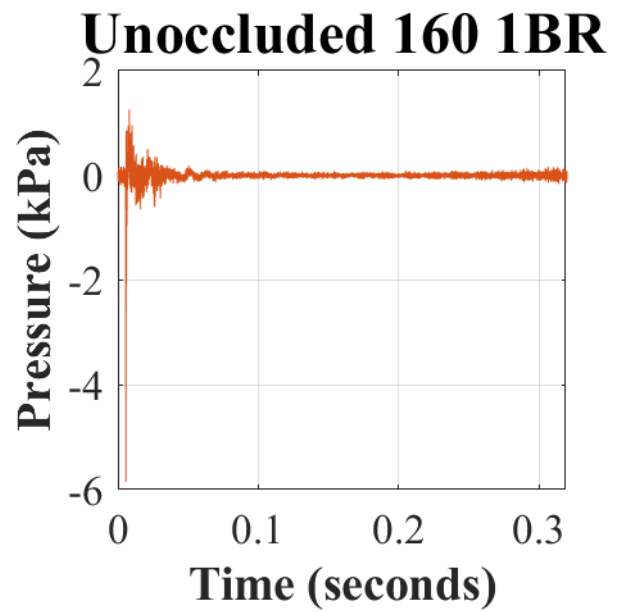
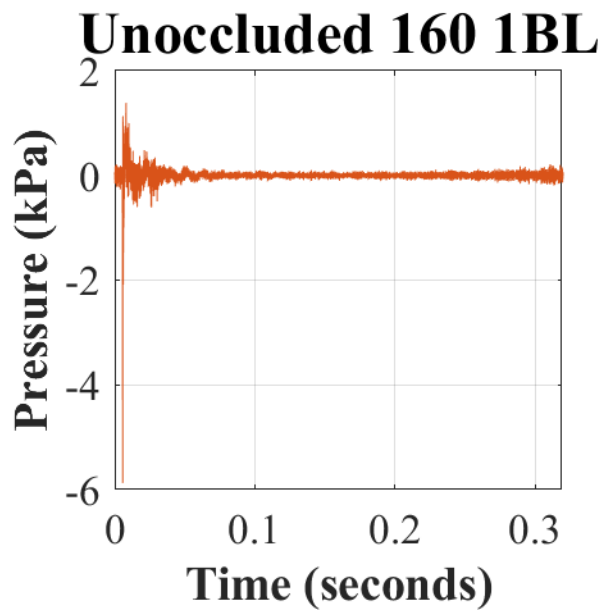
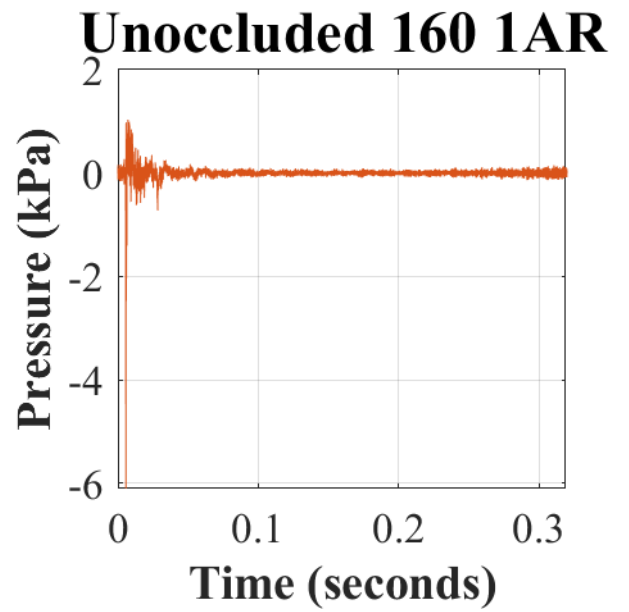
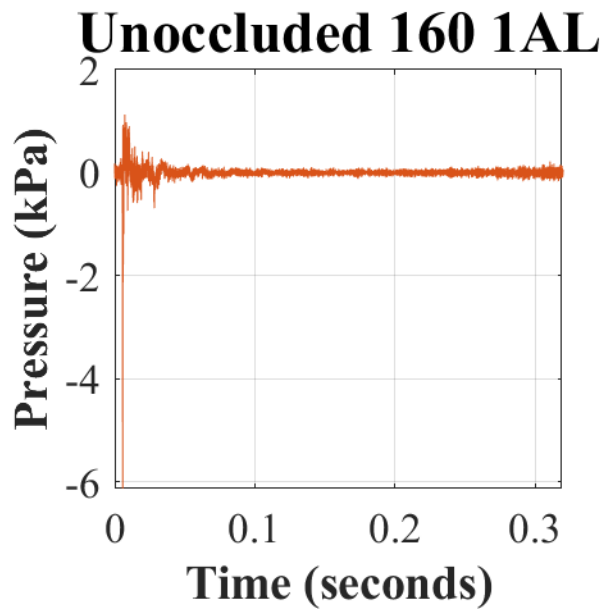
**Occluded 160 4BR**

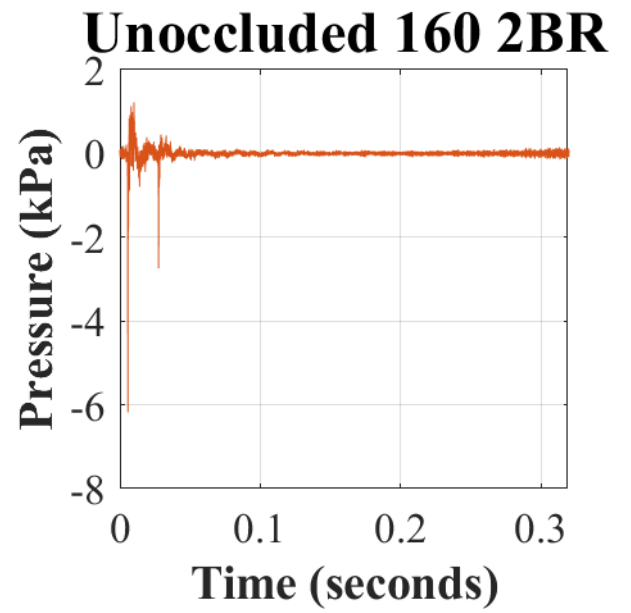
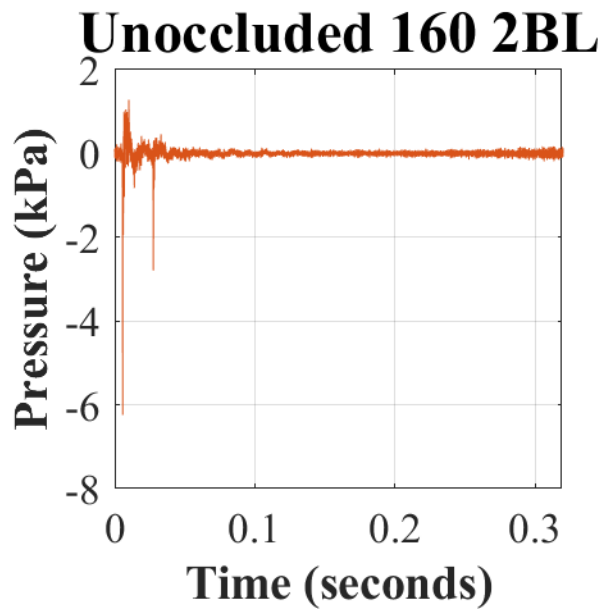
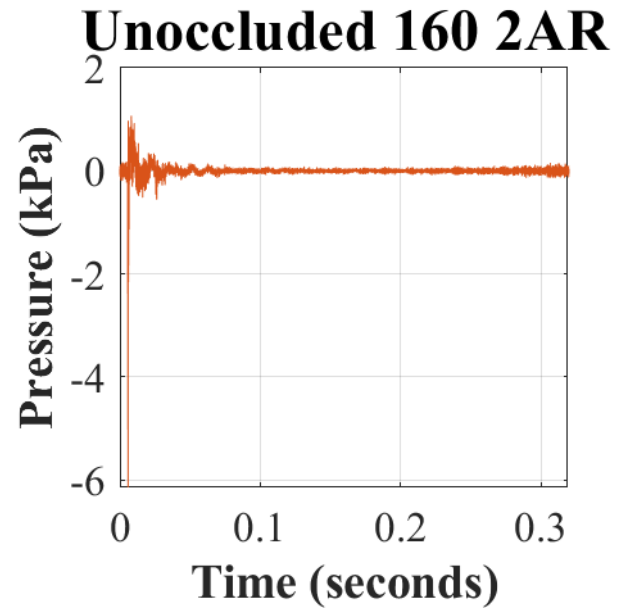
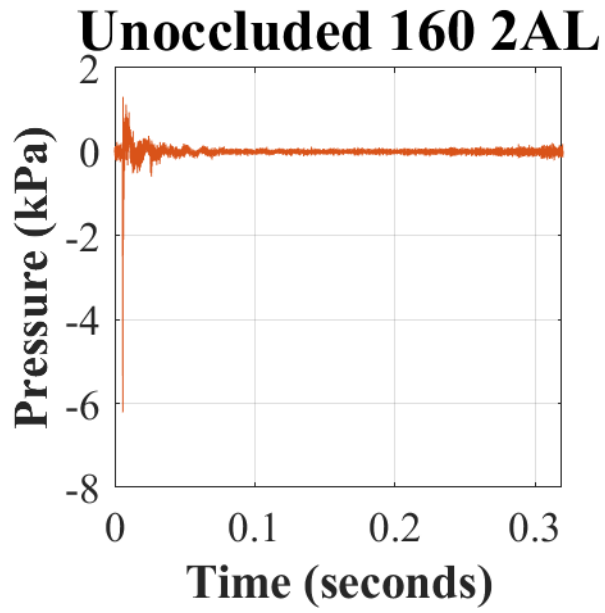


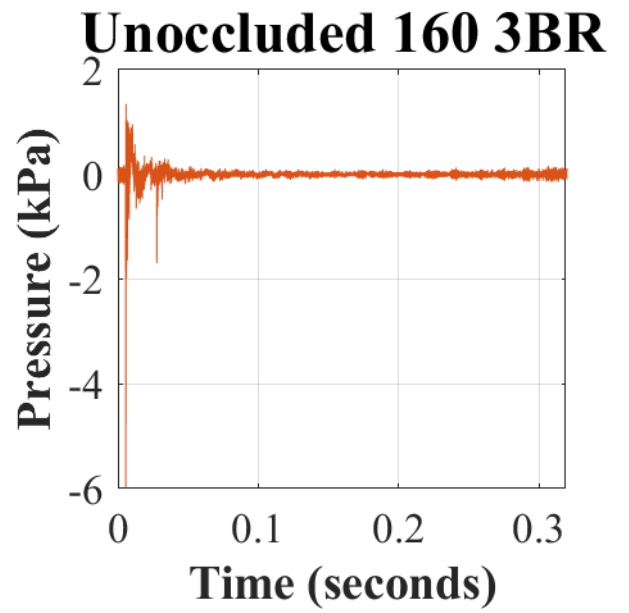
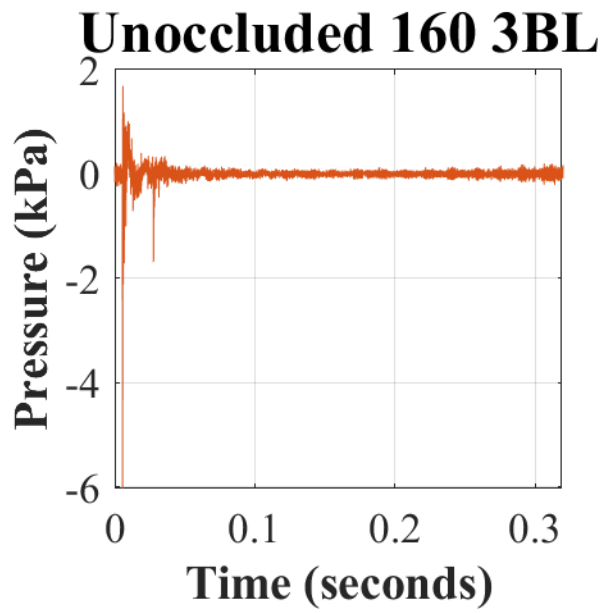
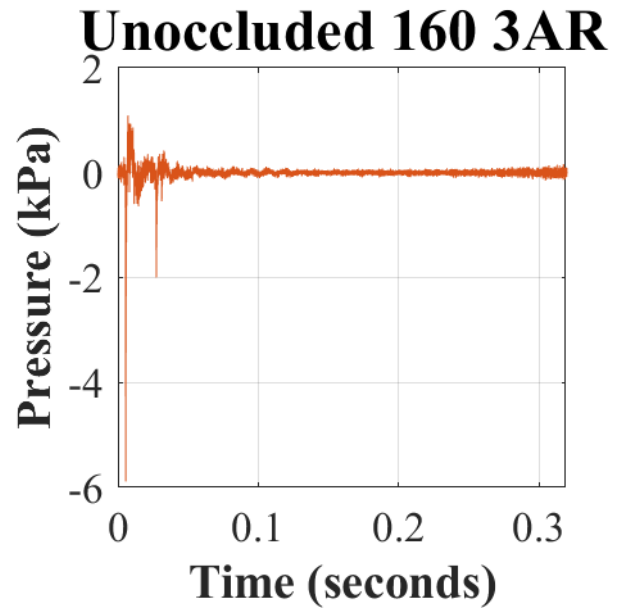
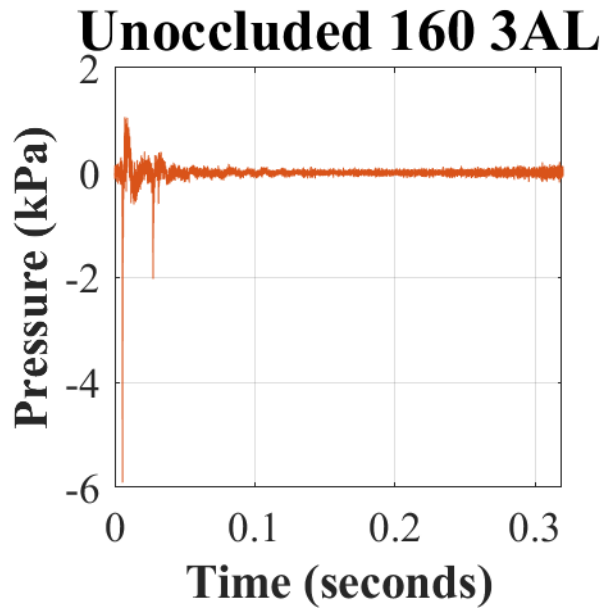


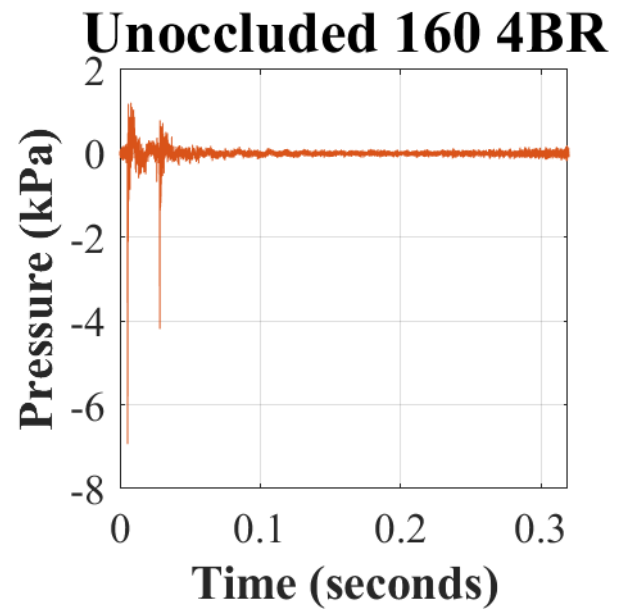
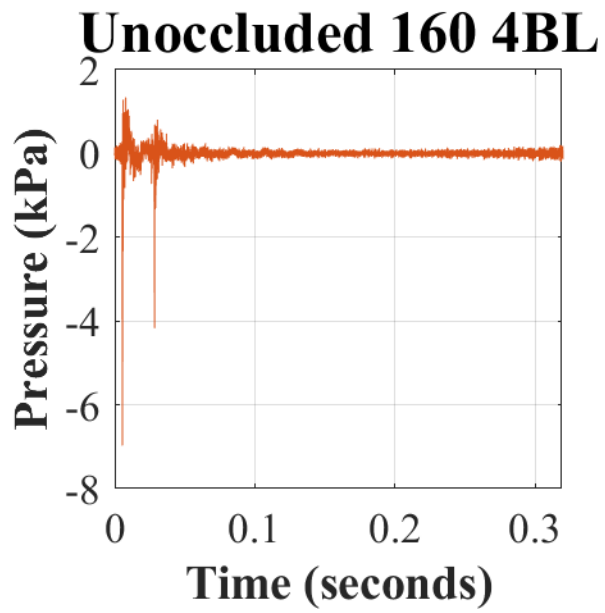
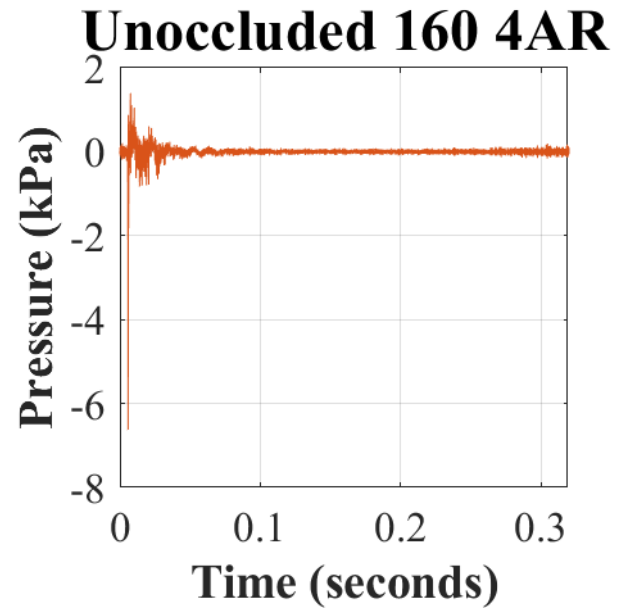
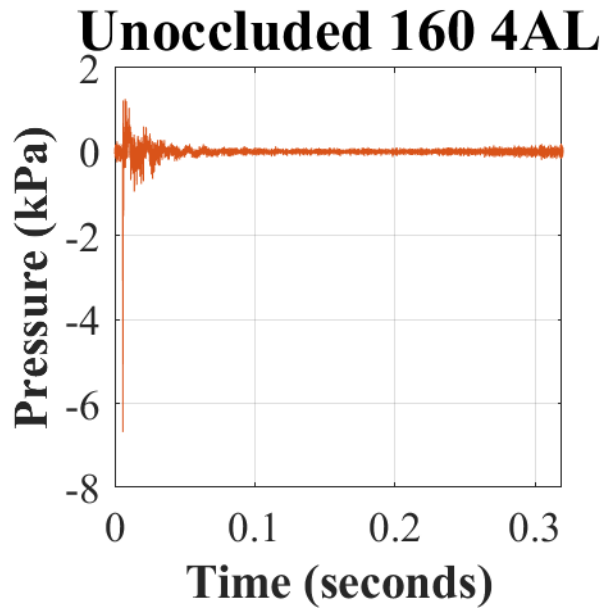
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the earmuff donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B)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

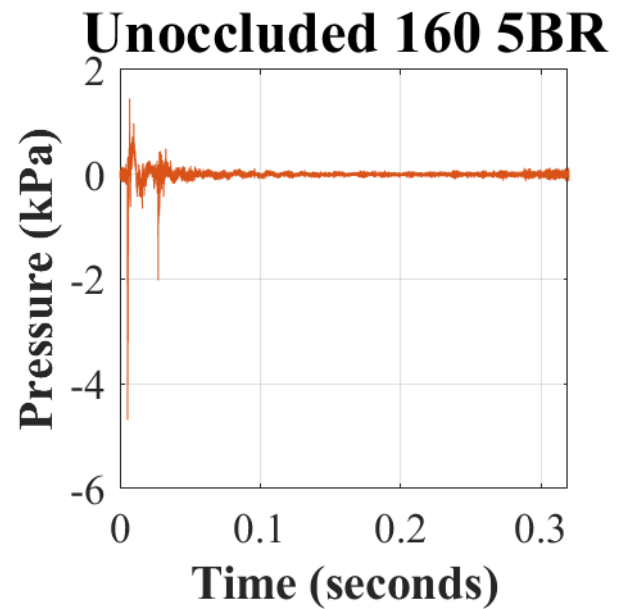
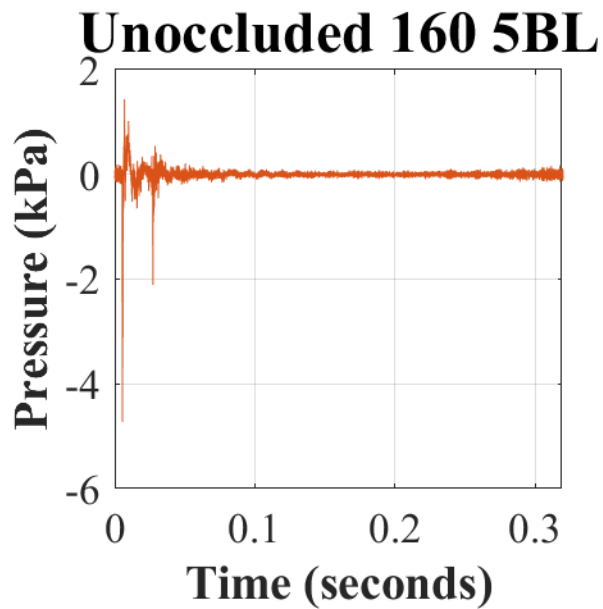
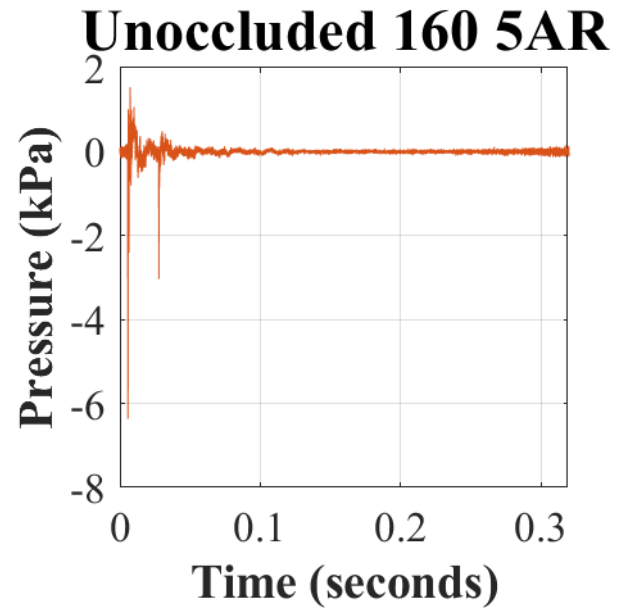
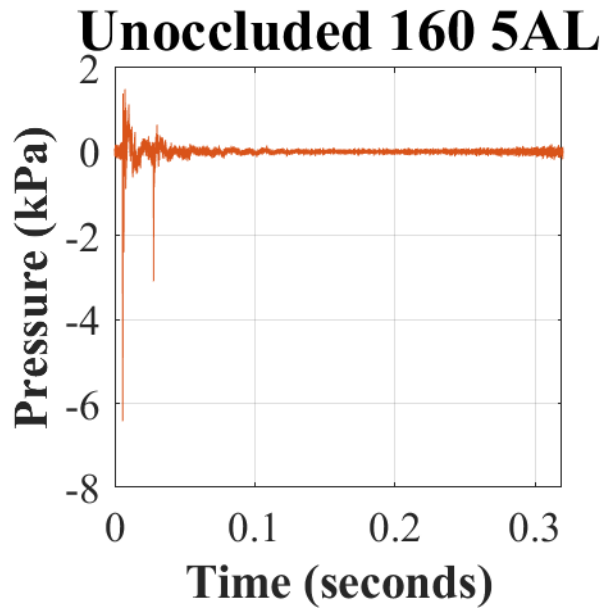
**Appendix H.** Estimated unoccluded (earmuff doffed) waveforms in response to 160 dBp with the ComTac™ V (MAX).







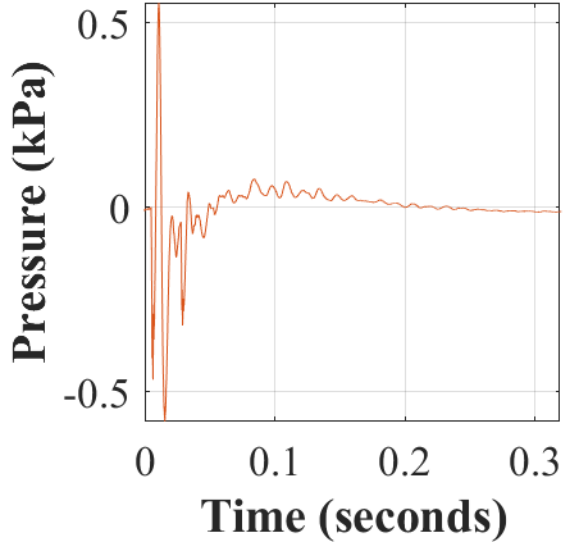




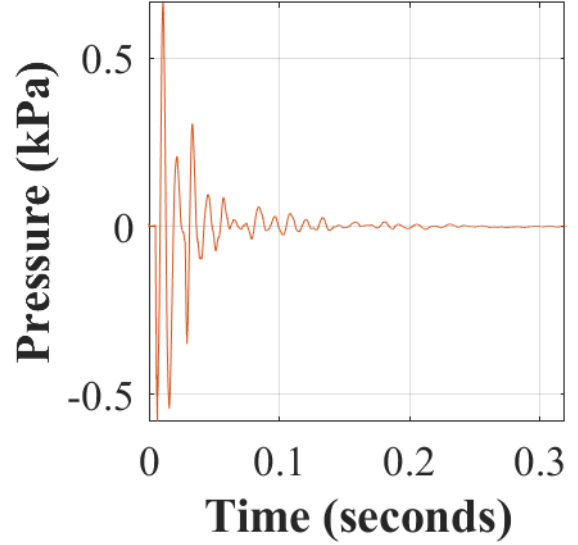
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the earmuff doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or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

**Appendix I.** Recorded occluded (earmuff donned) waveforms in response to 170 dBp with the ComTac™ V (MAX).

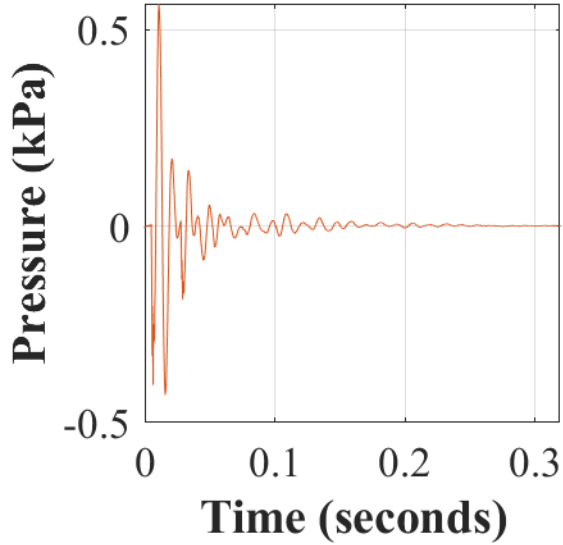
**Occluded 170 1AL**



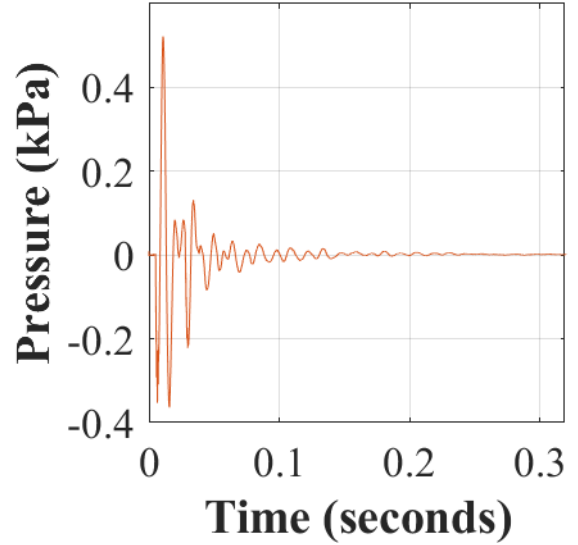
**Occluded 170 1AR**

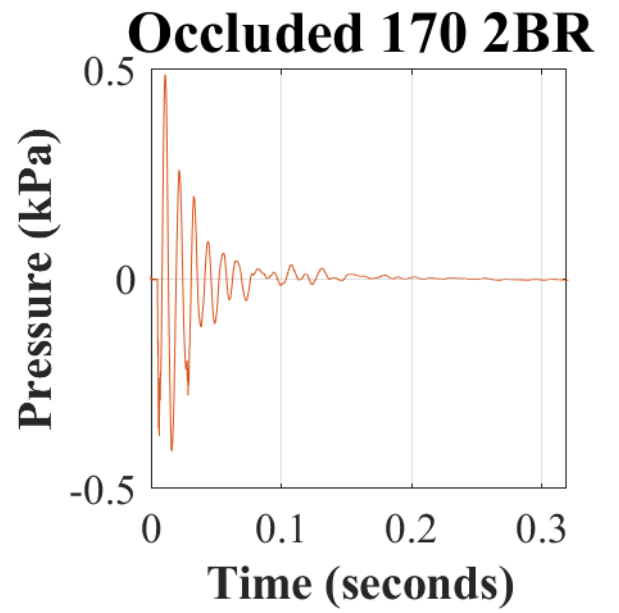
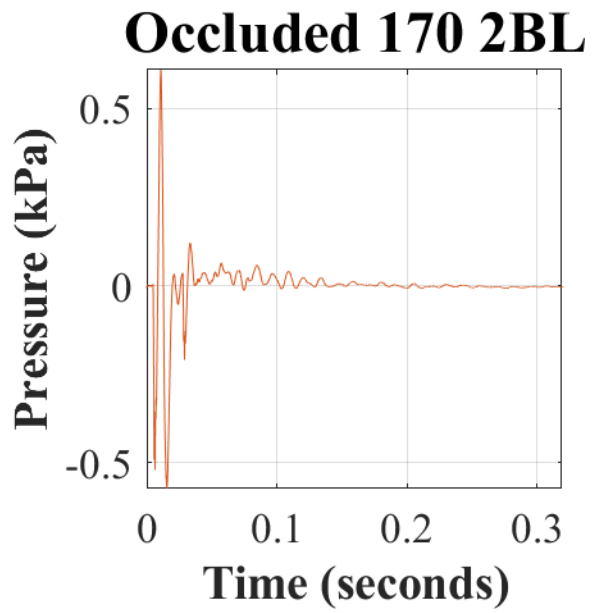
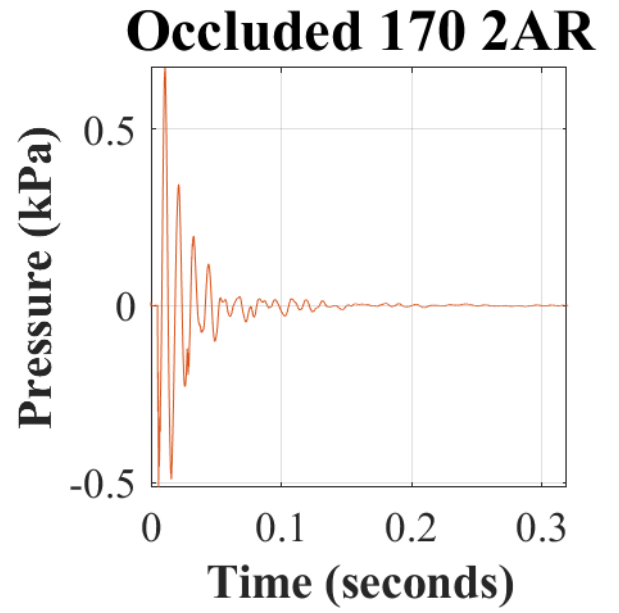
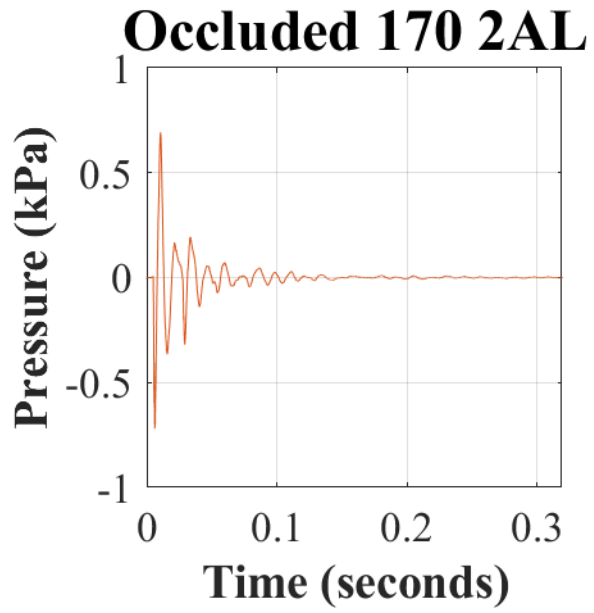


**Occluded 170 1BL**

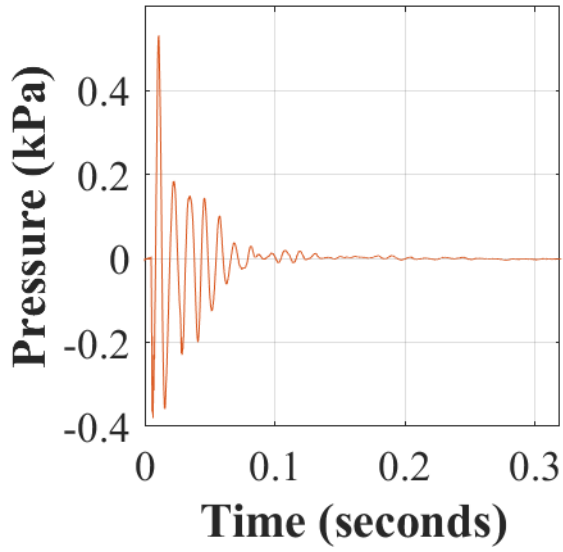


**Occluded 170 1BR**

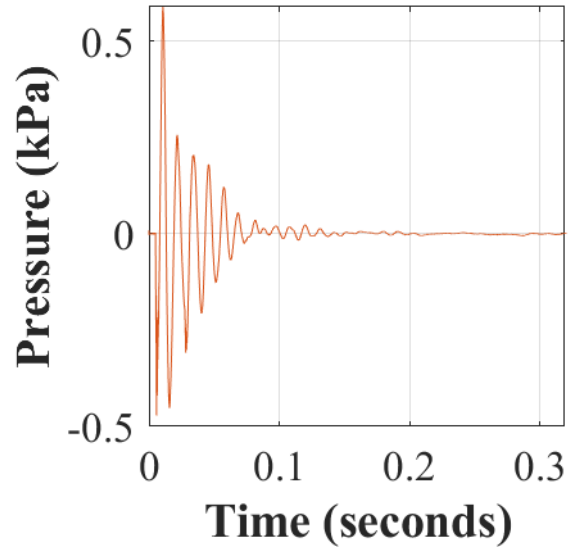




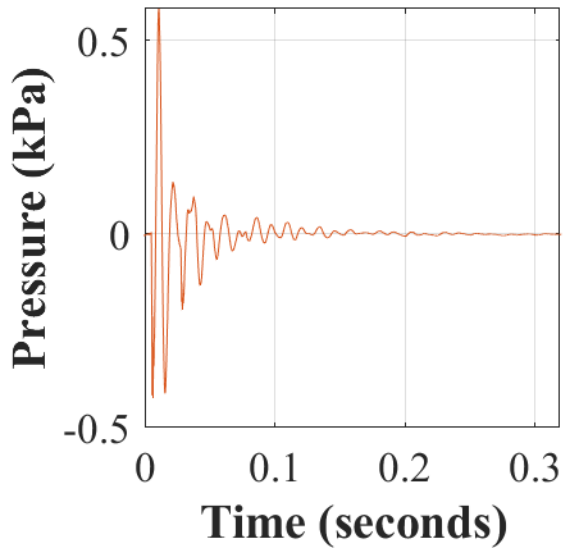
**Occluded 170 3AL**



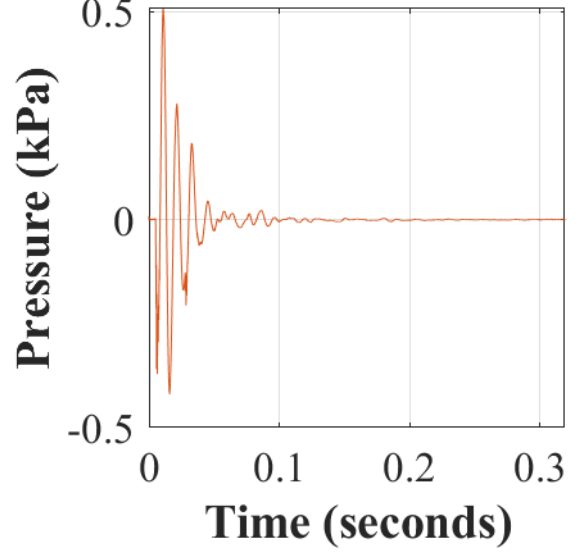
**Occluded 170 3AR**

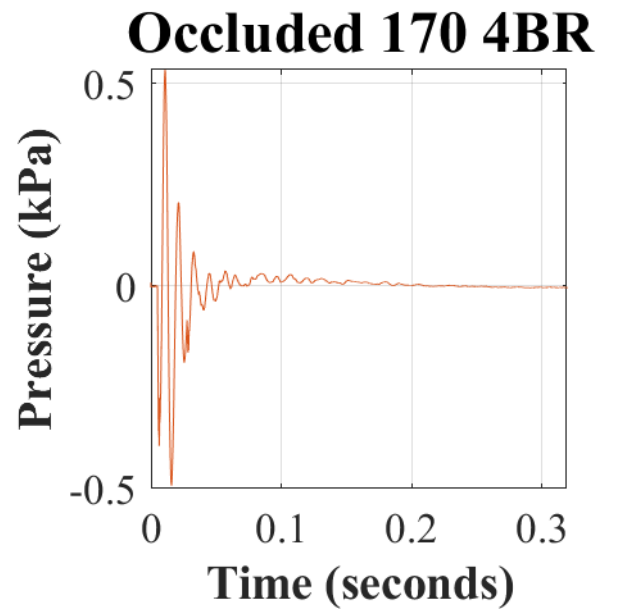
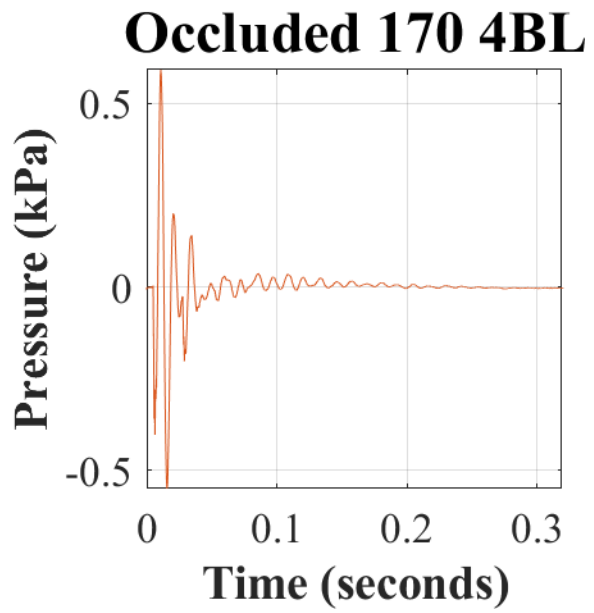
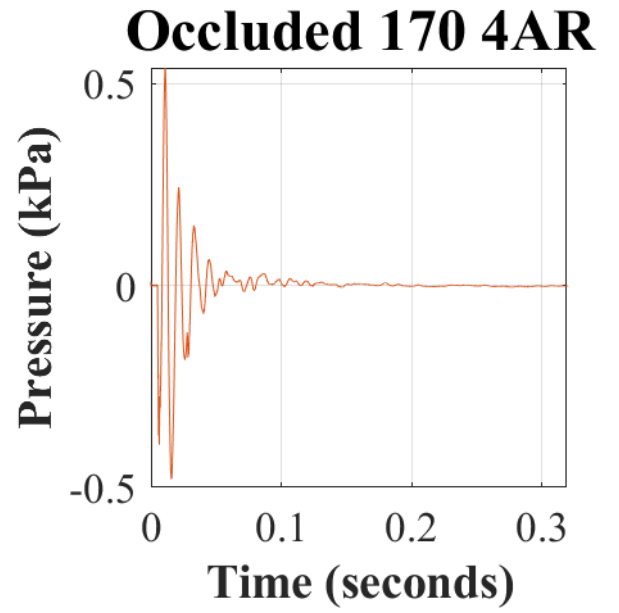
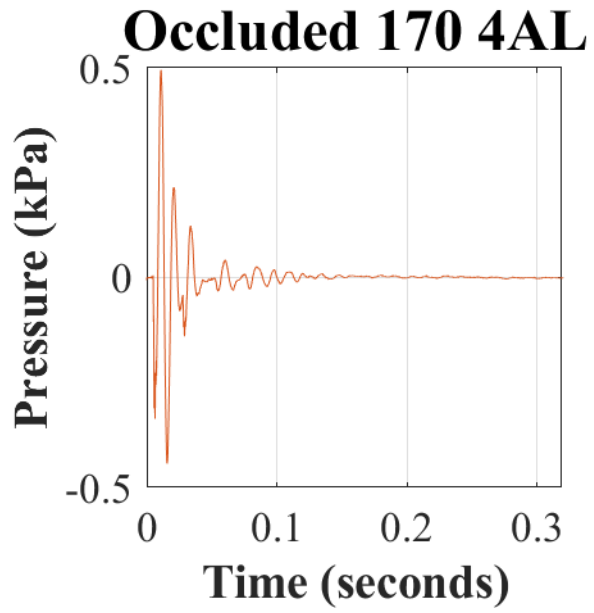


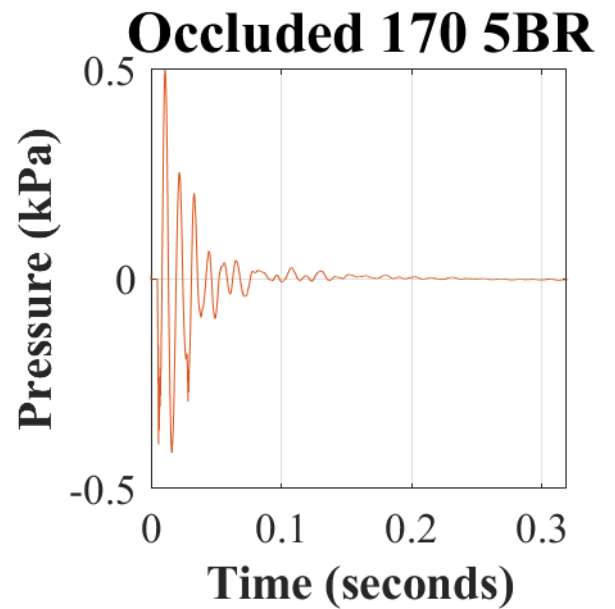
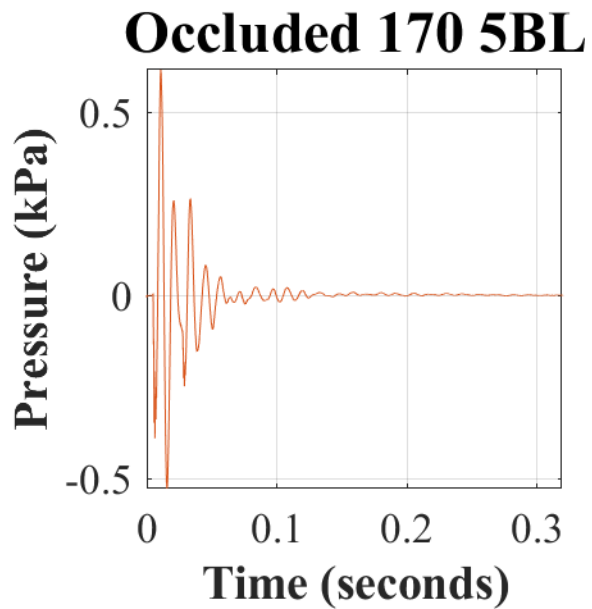
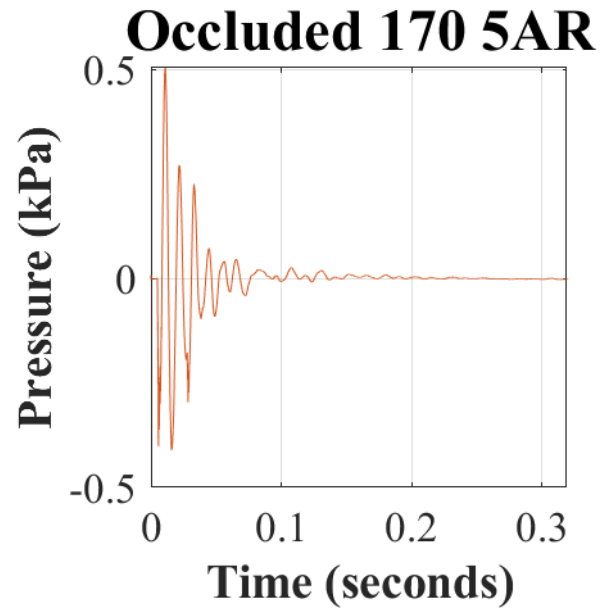
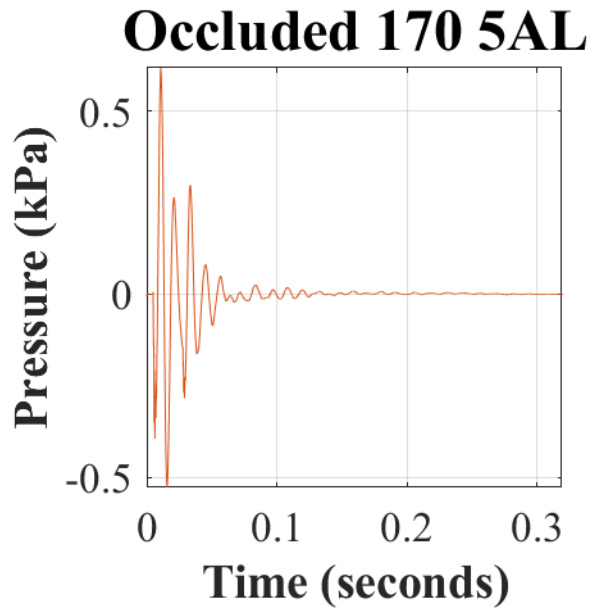
**Occluded 170 3BL**



**Occluded 170 3BR**

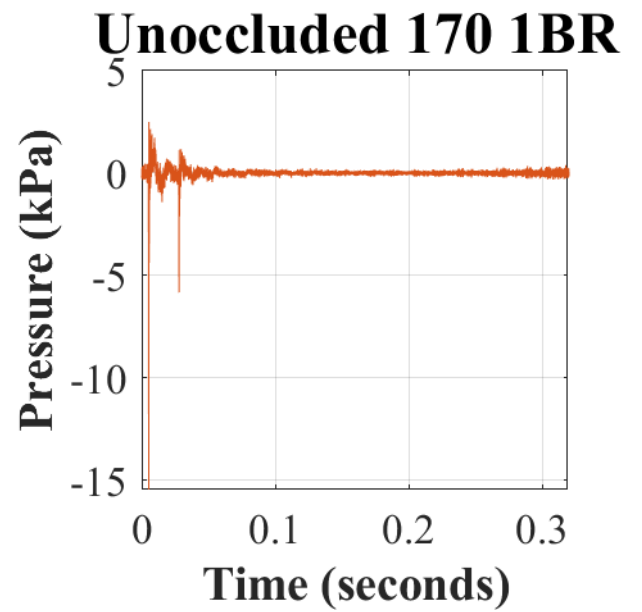
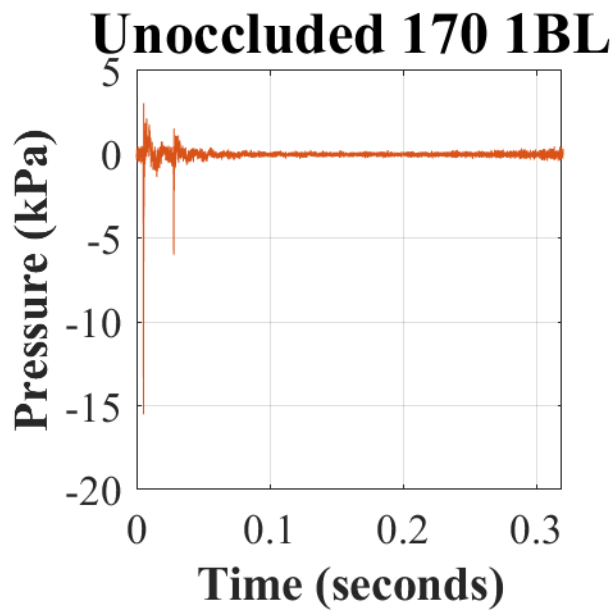
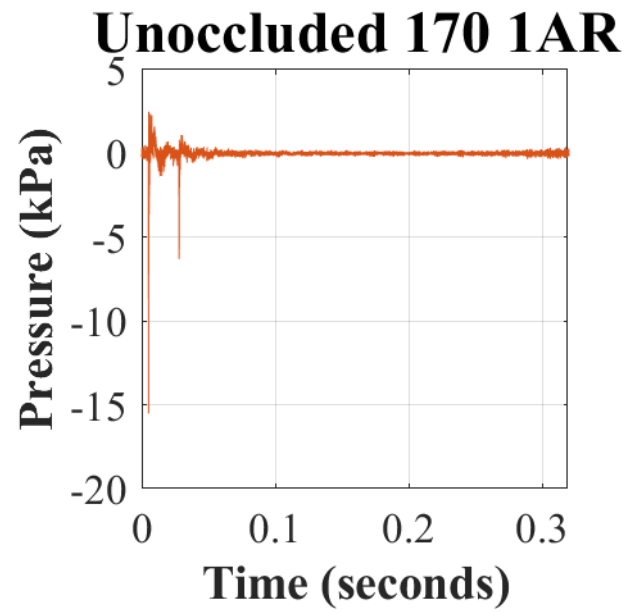
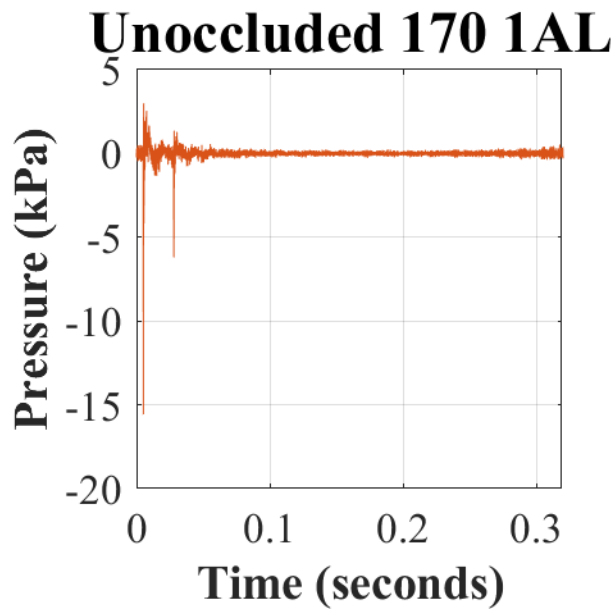


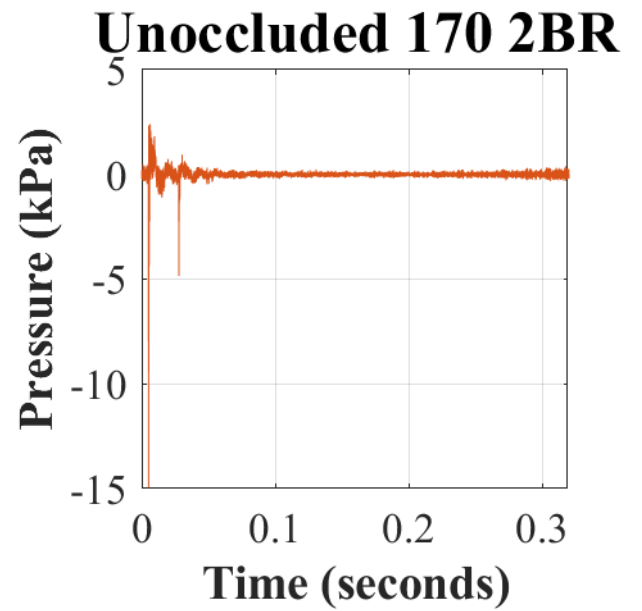
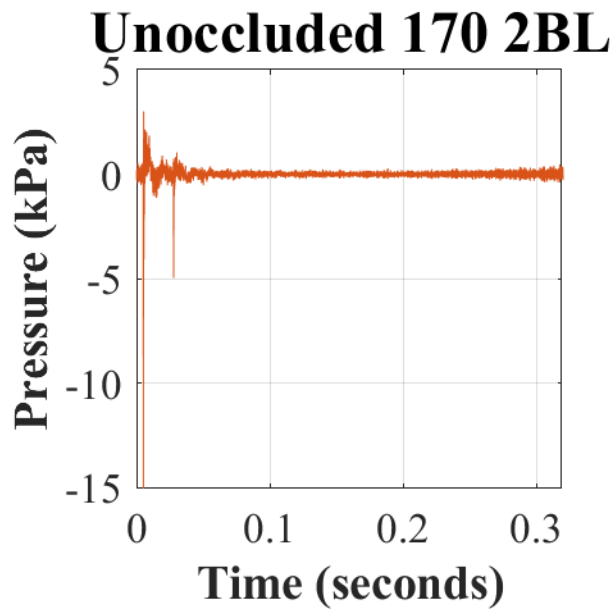
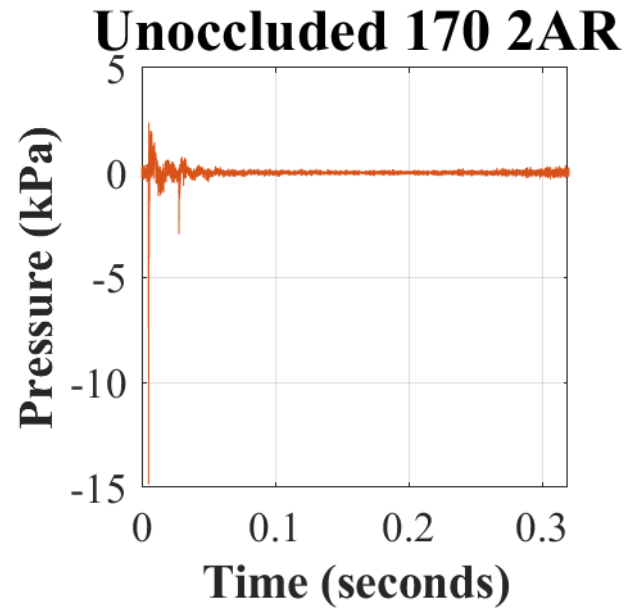
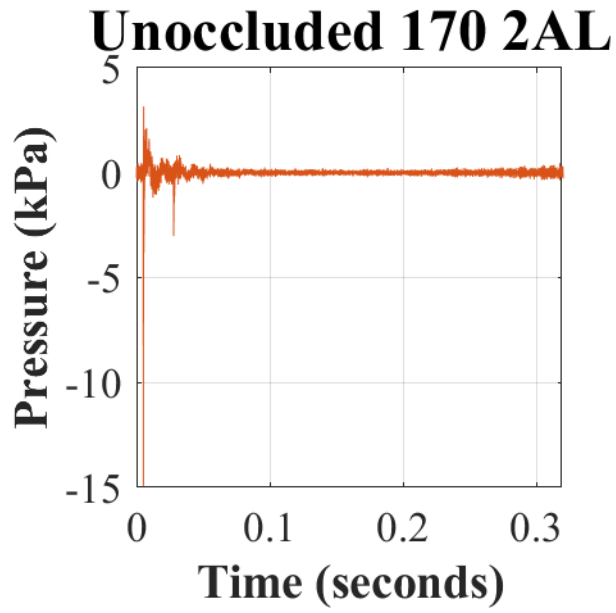


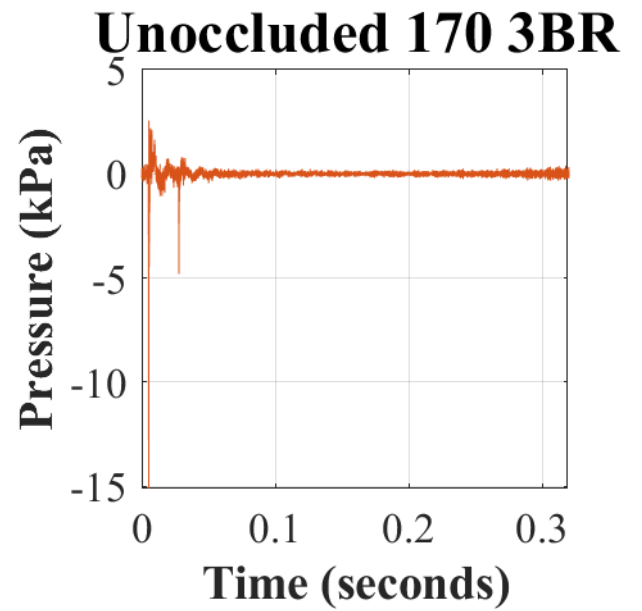
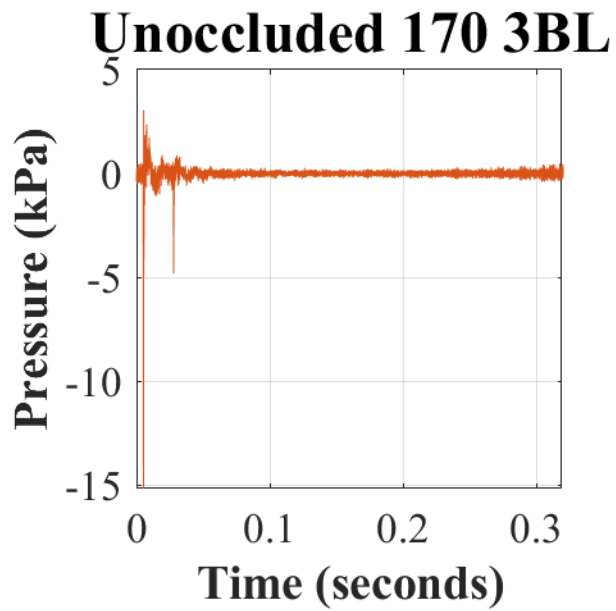
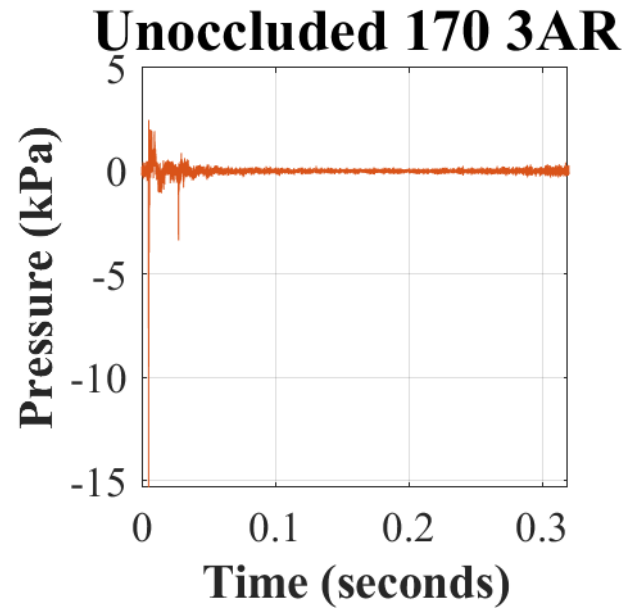
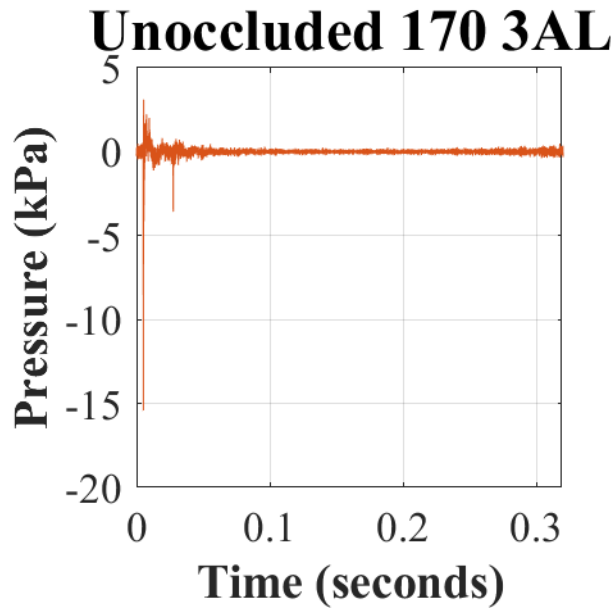


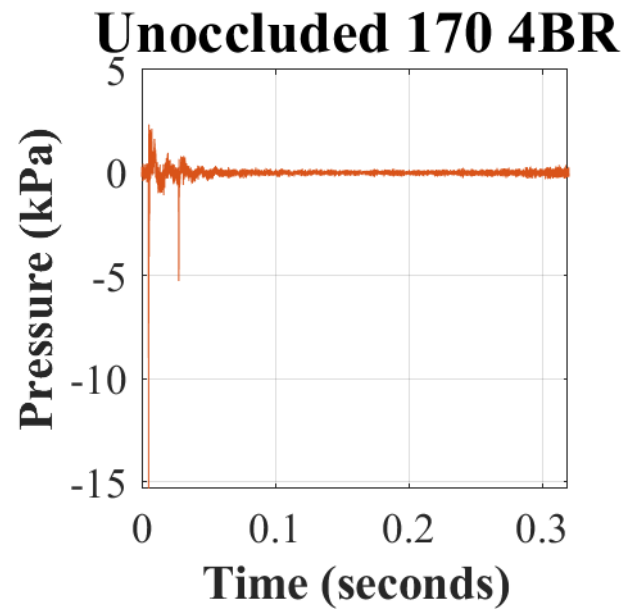
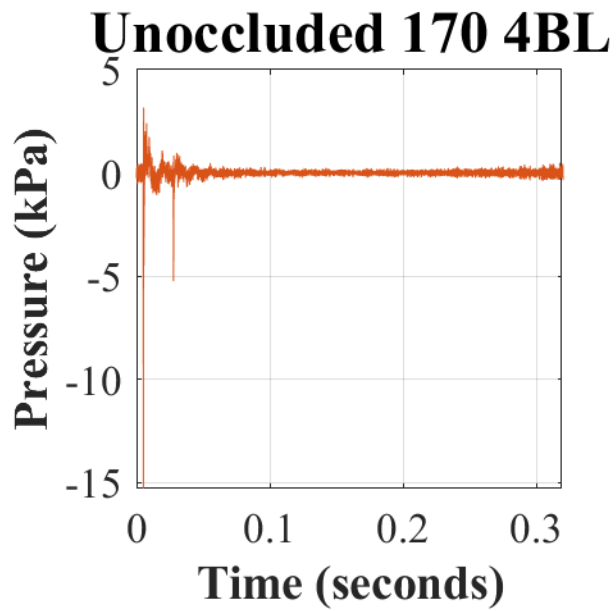
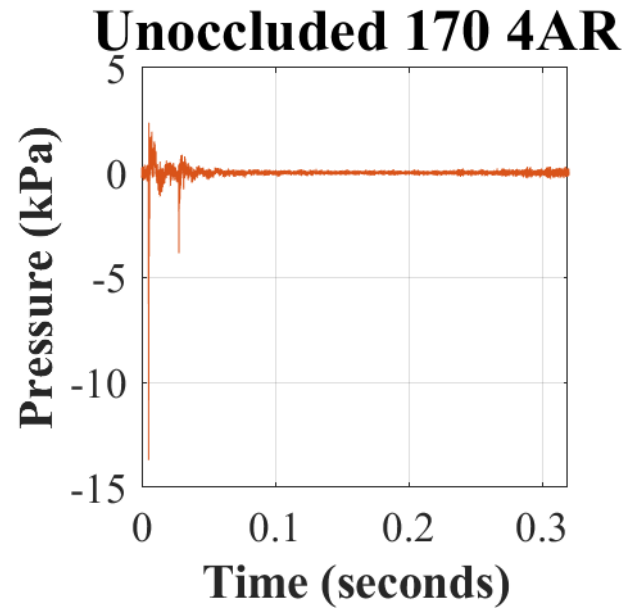
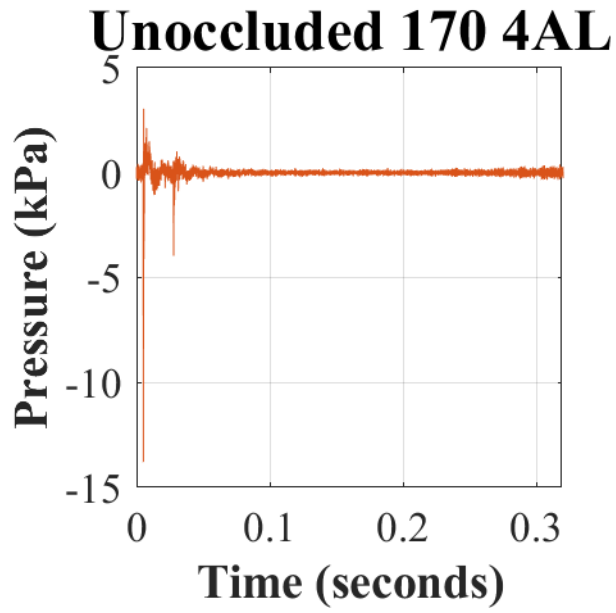
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the earmuff donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B)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

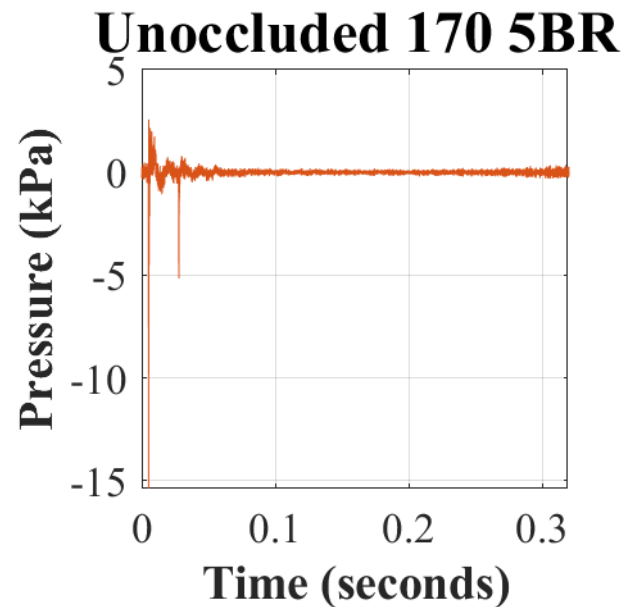
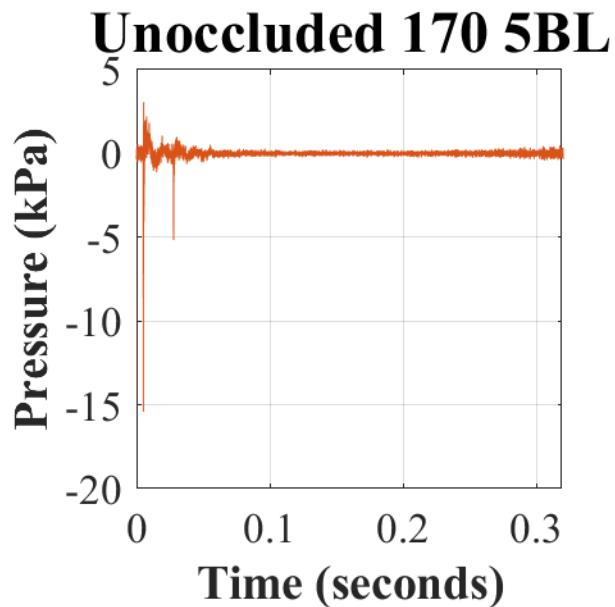
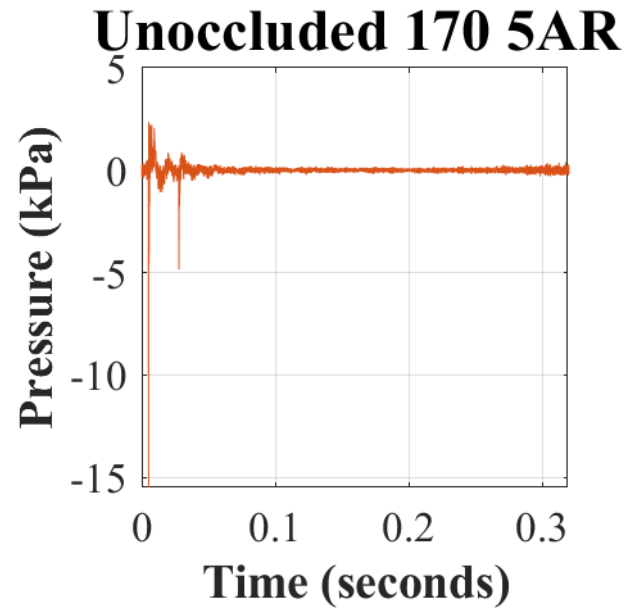
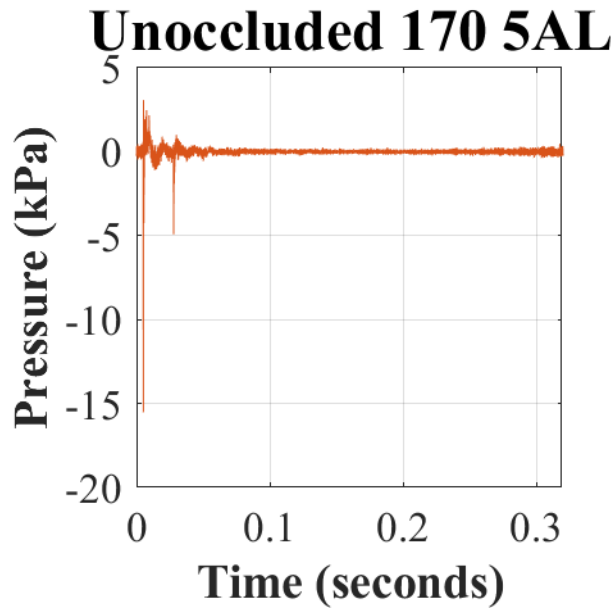
**Appendix J.** Estimated unoccluded (earmuff doffed) waveforms in response to 170 dBP with the ComTac™ V (MAX).





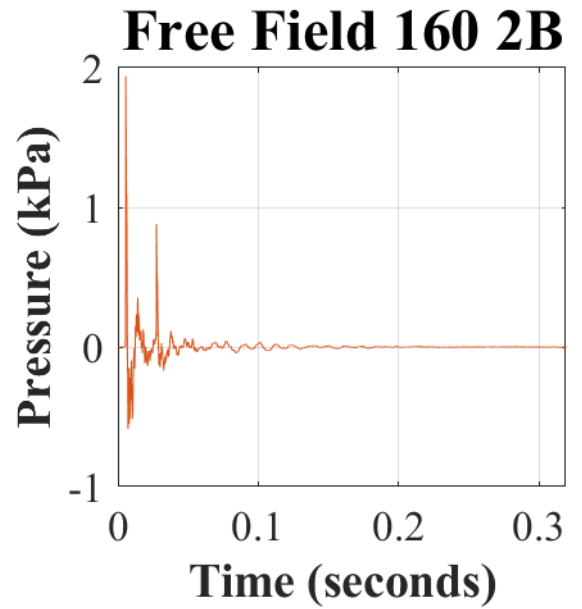
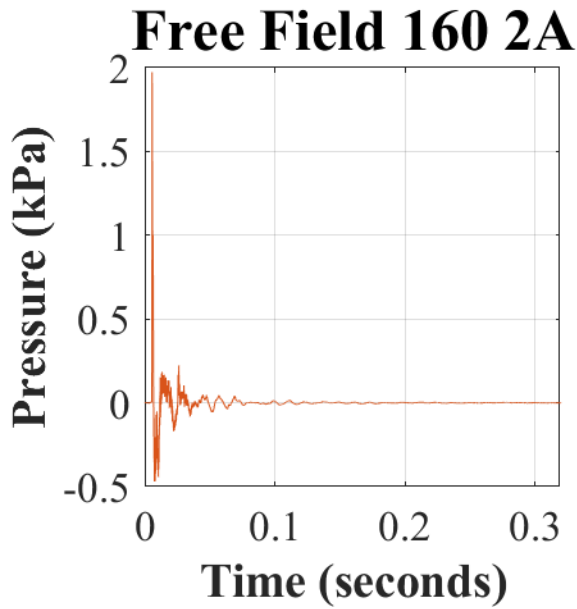
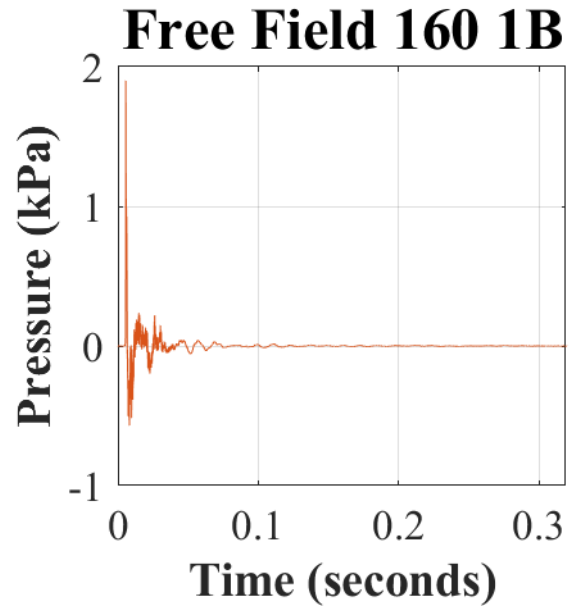
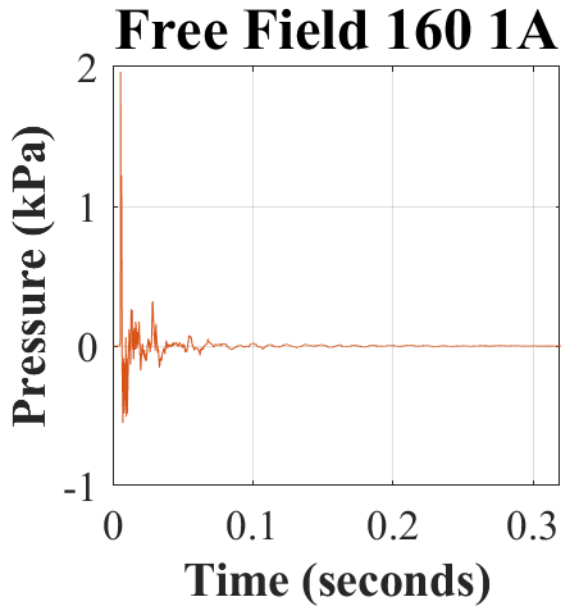


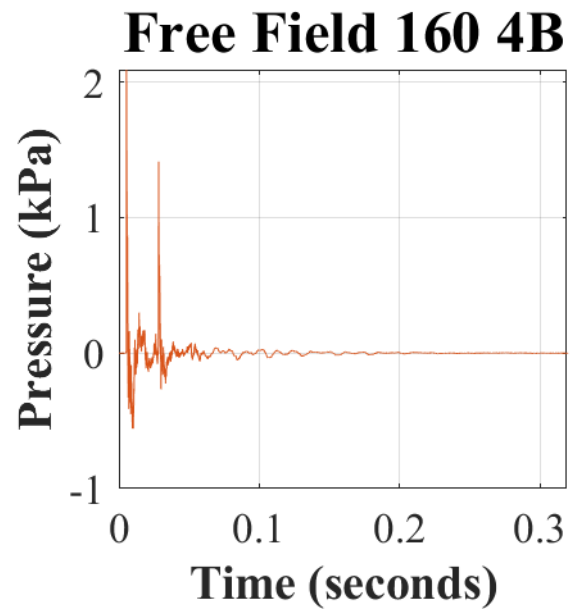
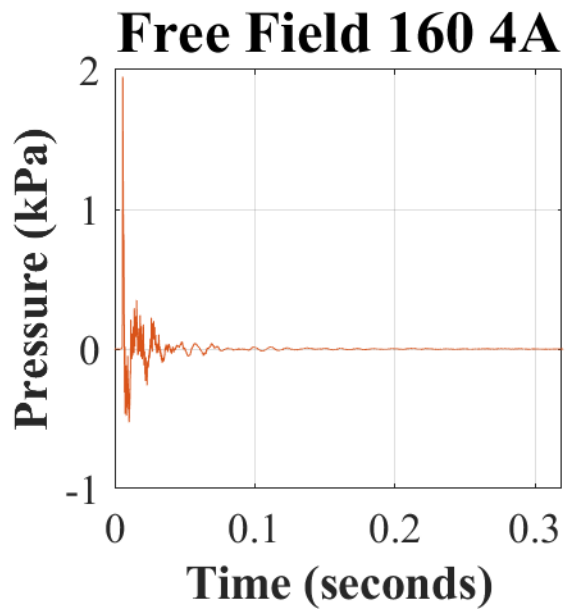
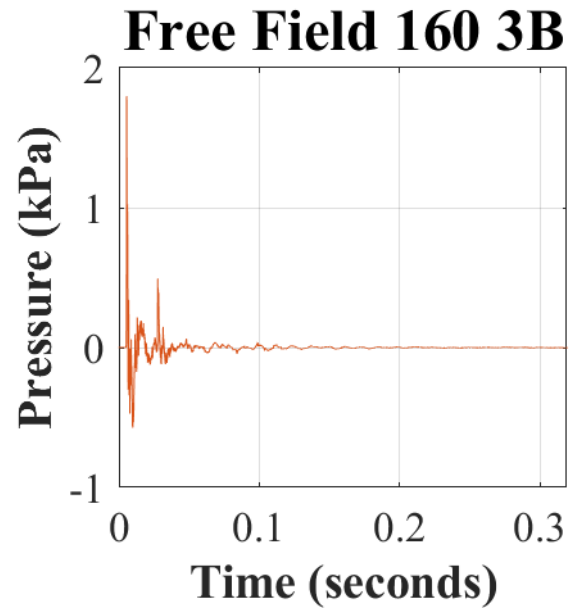
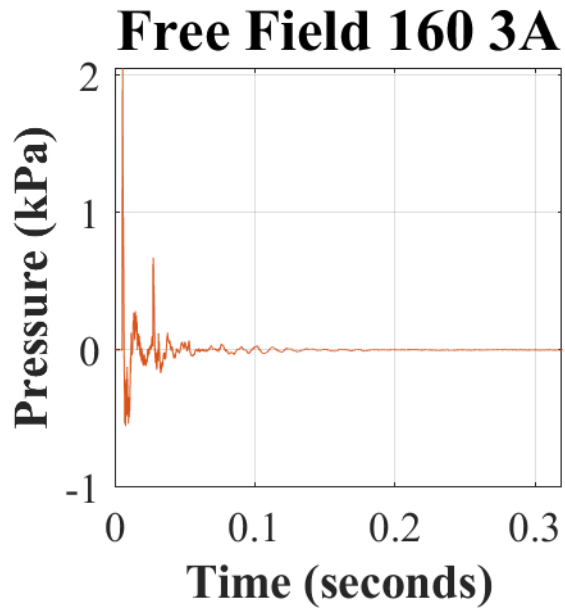


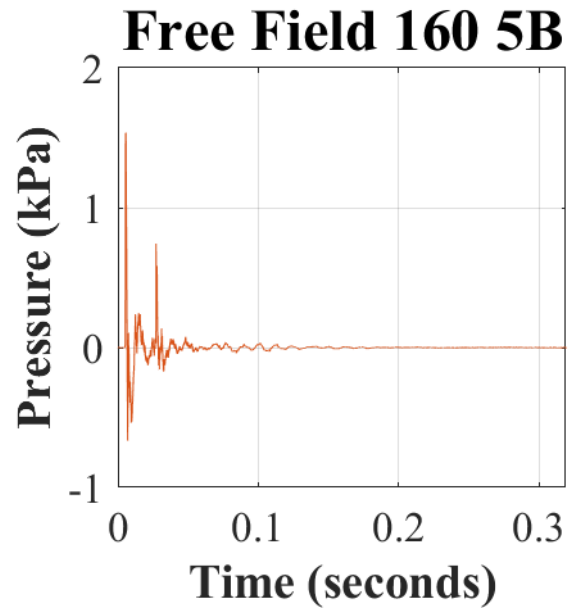
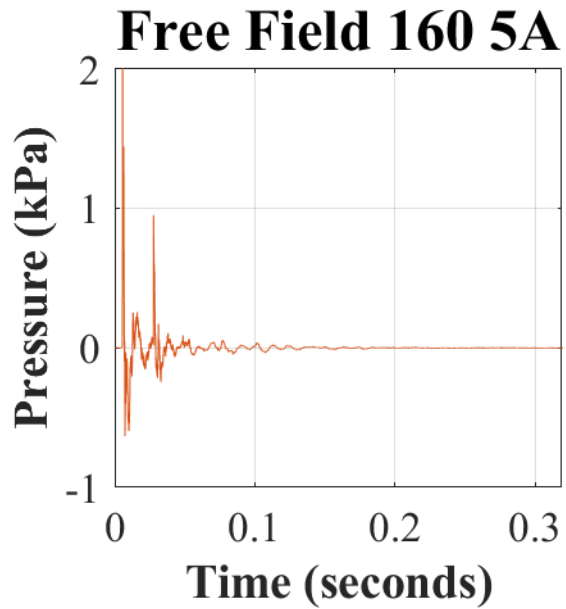


Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the earmuff doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or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

**Appendix J.** Recorded waveform of the impulse measured with the free-field probe at 160 dBp and the ComTac™ V (MAX) donned.

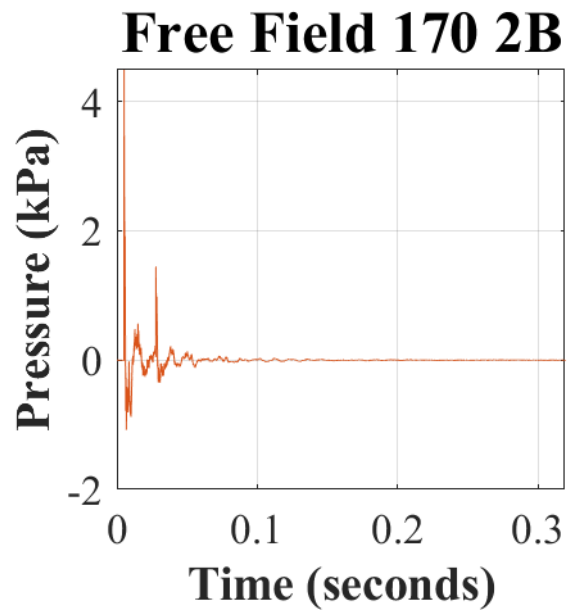
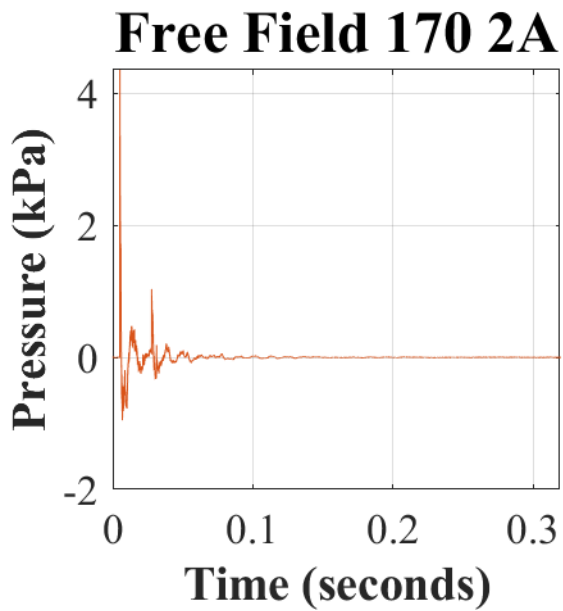
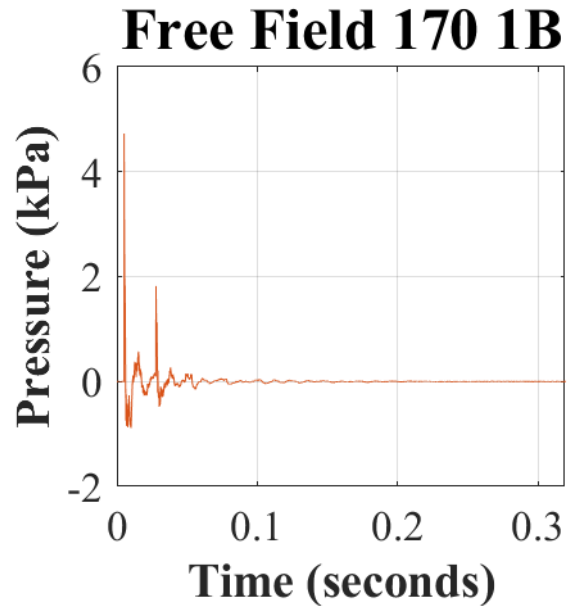
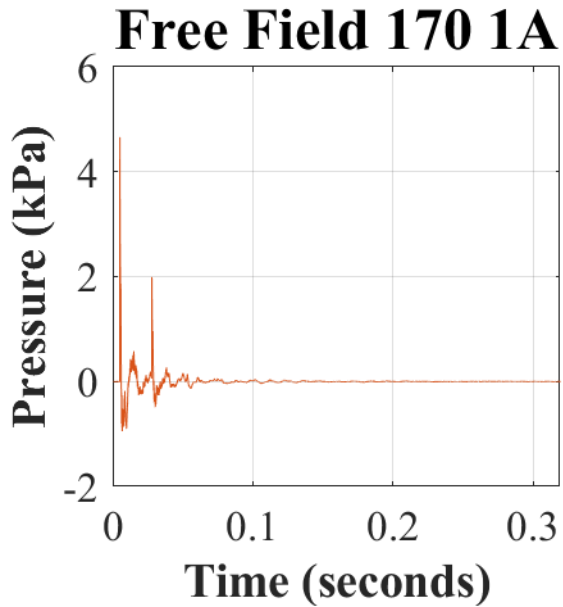


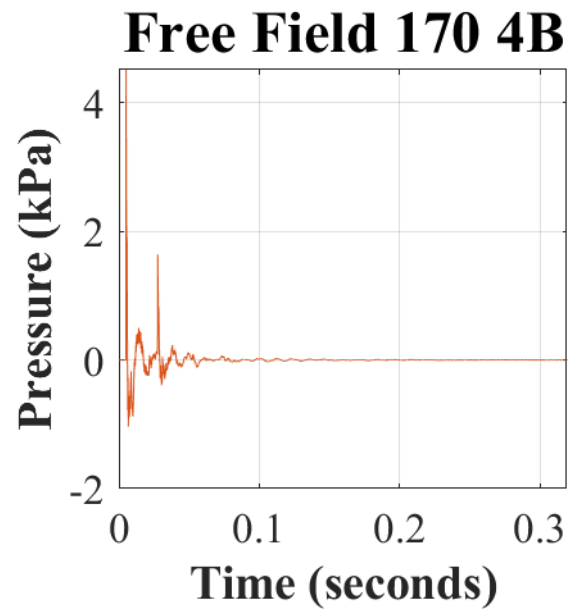
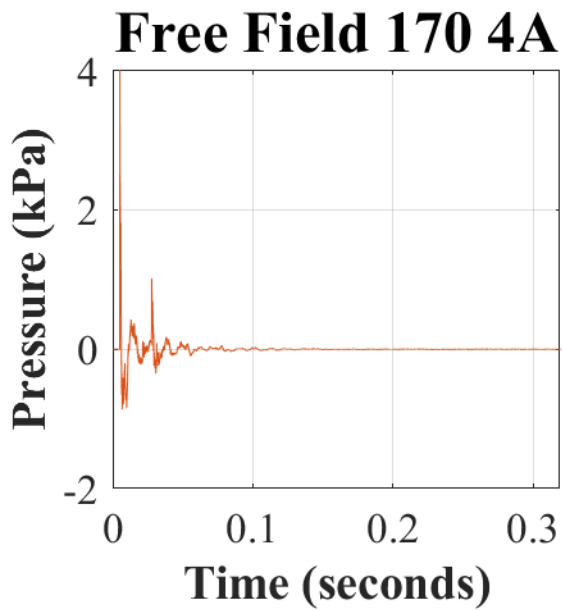
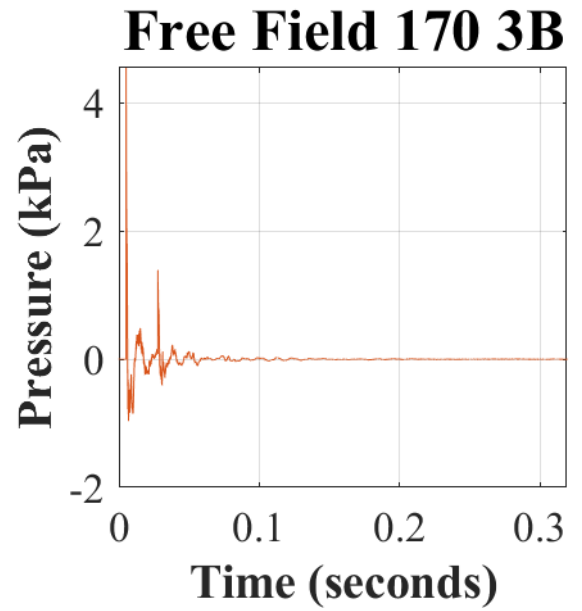
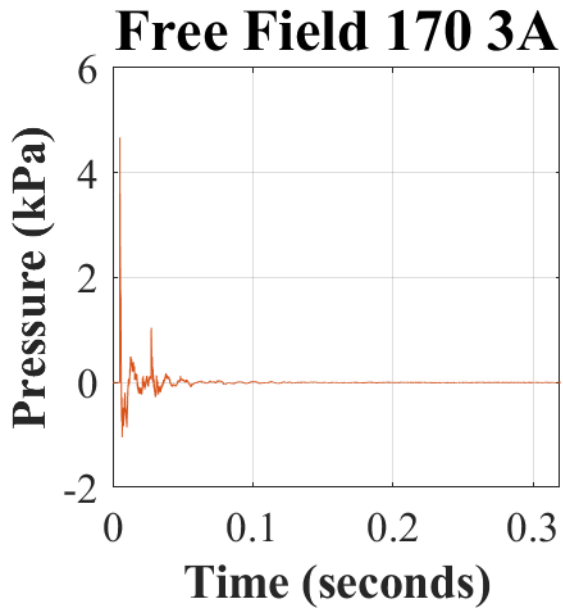


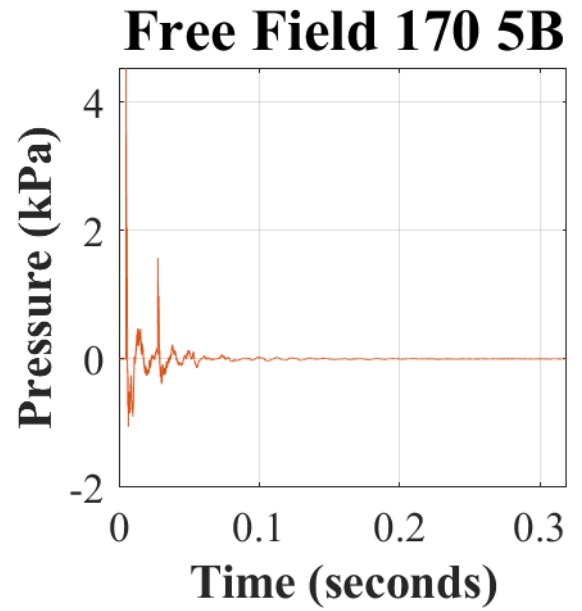
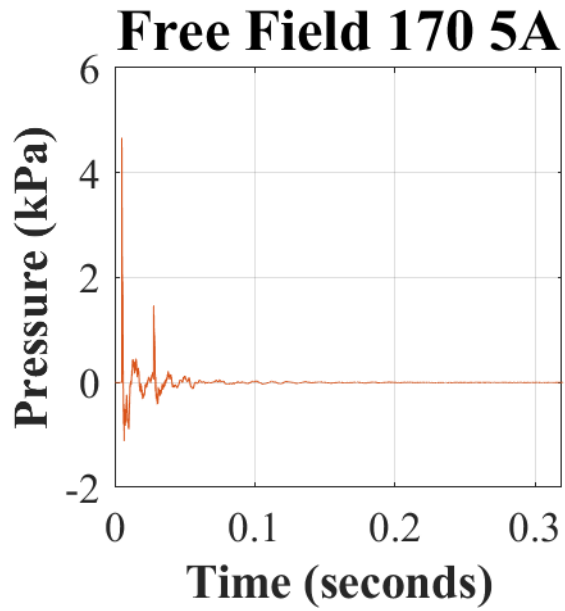


Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (170 dBp), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

**Appendix L.** Recorded waveform of the impulse measured with the free-field probe at 170 dBp and the ComTac™ V (MAX) 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).