Naval Submarine Medical Research Laboratory

NSMRL/F1016,F2002/TM--2022-1393 March 18, 2022

Impulse Assessment of the ComTac™ V Hearing Defender Headset and the Oakley SI Ballistic M Frame® 2.0 Eyewear

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REPORT DOCUMENTATION PAGE

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
18-03-2022	Technical Memorandum	October 2021 - January 2022

4. TITLE AND SUBTITLE

Impulse Assessment of the ComTac™ V Hearing Defender Headset and the Oakley SI Ballistic M Frame® 2.0 Eyewear

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

F1016, F2002

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

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

8. PERFORMING ORGANIZATION REPORT NUMBER

NSMRL/F1016,F2002/TM--2022-1393

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

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

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

10. SPONSOR/MONITOR'S ACRONYM(S)

BUMED, ONR

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

12. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The impulse peak insertion loss (IPIL) is the standard measure of attenuation provided by hearing protection devices (HPDs) in response to an impulsive noise. This technical memorandum describes the IPIL testing conducted on a combined configuration that included the Oakley SI M Frame® 2.0 eyewear and the ComTac™ V Headset. Testing included two test modes for the ComTac™ V: passive and active. In all occluded conditions, the ComTac™ V and Oakley SI M Frame® 2.0 were donned. Testing was completed in accordance with the ANSI standard S12.42-2010. All device samples were tested at the nominal levels of 150, 160, and 170 decibel peak (dBP, re: 20 µPa). A total of five samples were fitted to an acoustic test fixture two times each for a total of 10 trials per test level in both the passive and active test modes. Results suggest that the ComTac™ V Headset, when functioning properly and fitted in combination with the Oakley SI M Frame® 2.0 can adequately protect against impulses below 155.6 dBP in both the passive and the active test modes.

15. SUBJECT TERMS

attenuation, impulse peak insertion loss, IPIL, blast, hearing protection device, HPD, active HPD, headset, double configuration, eyewear, eye protection

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			NAVSUBMEDRSCHLAB Commanding Officer
U	U	U	SAR	88	19b. TELEPHONE NUMBER *(Include area code)* 860-694-3263

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

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Acknowledgements

The authors would like to thank Ms. Rachael Maten for assistance in the collection of resource materials. The authors would also like to thank Mr. Jake See for assistance in data collection.

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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 a combined configuration that included the Oakley Standard Issue Ballistic M Frame® 2.0 Strike – ANSI Z87.1 Stamped eyewear (Oakley SI M Frame® 2.0; Model: 11-139) and the 3M™ PELTOR™ ComTac™ V Hearing Defender Headset (ComTac™ V; Model: MT20H682FB-09 CY). Testing included two test modes for the ComTac™ V: passive (i.e., turned OFF) and active (i.e., turned on and output level set to MAX). In all occluded conditions, the ComTac™ V and Oakley SI M Frame® 2.0 were donned. Testing was completed in accordance with the American National Standards Institute (ANSI) standard S12.42-2010, "Methods for the Measurement of Insertion Loss of Hearing Protection Devices in Continuous or Impulsive Noise Using Microphone-in-Real-Ear or Acoustic Test Fixture Procedures." All device samples were tested at the nominal levels of 150, 160, and 170 decibel peak (dBP, re: 20 µPa). A total of five samples (one headset plus eyewear) were fitted to an acoustic test fixture two times each for a total of 10 trials per test level in both the passive and active test modes. No samples of either product were rejected. As seen in Table 1, the mean and standard deviation (SD) IPIL values at 150 dBP were 15.6 (2.2) dB SPL for the passive (i.e., OFF) mode, and 15.6 (2.4) dB SPL for the active (i.e., MAX) mode. Results obtained at the 160 dBP presentation level showed mean (SD) IPIL values of 18.1 (2.4) dB SPL for the passive mode, and 18.3 (2.3) dB SPL for the active mode. Results obtained at the 170 dBP presentation level showed mean (SD) IPIL values of 20.5 (2.5) dB SPL for the passive mode, and 20.4 (2.5) dB SPL for the active mode. These results suggest that the ComTac™ V Hearing Defender Headset, when functioning properly and fitted in combination with the Oakley SI M Frame® 2.0 can adequately protect (i.e., reduce exposure to less than 140 dBP) against impulses below 155.6 dBP in both the passive (OFF) and the active (on and set to MAX) test modes.

Table 1.
ComTac™ V with Oakley SI M Frame® 2.0 mean (SD) IPIL value (in dB) for all test conditions.

	150 dBP	**160 dBP**	**170 dBP**
OFF	15.6 (2.2)	18.1 (2.4)	20.5 (2.5)
MAX	15.6 (2.4)	18.3 (2.3)	20.4 (2.5)

Introduction

The 3M™ PELTOR™ ComTac™ V Hearing Defender Headset (ComTac™ V; 3M, St. Paul, MN) is an active earmuff-style communications headset currently fielded by the U.S. Navy and U.S. Marine Corps. The ComTac™ V Hearing Defender has two ear-level, omni-directional microphones and a level dependent, electronic hearing protection signal processor powered by two AAA batteries. The signal processor function amplifies low level sounds (e.g., speech), and attenuates loud, continuous (e.g., vehicle engines, air compressors) and impulsive noises (e.g., weapon fire; 3M Personal Safety Division, n.d.). The headset is available as either a headband or neckband model, but can also be mounted on a helmet rail system when used with the 3M™ PELTOR Accessory Rail Connector (ARC) attachment. The ComTac™ V Hearing Defender Headset described herein is intended for face-to-face communications, and not radio communications. As it is common to don a pair of earmuffs combined with eyewear, the amount of protection provided to users when the ComTac™ V is worn in combination with eye protection was tested. Separate calculated impulse peak insertion loss (IPIL) values for the ComTac™ V have been previously reported by the Naval Submarine Medical Research Laboratory (NSMRL; Silvia et al., 2021).

The eyewear selected for the testing described herein was the Oakley Standard Issue Ballistic M Frame® 2.0 Strike – ANSI Z87.1 Stamped eyewear (Oakley SI M Frame® 2.0; Oakley SI, Foothill Ranch, CA). Per the manufacturer, Oakley SI M Frame® 2.0 eyewear meets high mass and high velocity impact requirements outlined in ANSI Z87.1-2003/2010 "American National Standard for Occupational and Educational Personal Eye and Face Protection Devices" along with meeting the ballistic fragmentation impact standards outlined in MIL PRF-31013 clause 3.5.1.1 (Oakley Standard Issue, n.d.). The Oakley SI M Frame® 2.0 comes equipped with proprietary Plutonite® lenses to offer high level optical clarity and thin stem frames to enable compatibility with earmuffs and other over-the-ear communication systems (Oakley Standard Issue, n.d.).

The Department of Defense Instruction 6055.12 (2019) "Hearing Conservation Program (HCP)" limits impulse noise exposure to 140 peak decibels (dBP). Therefore, should an impulse noise meet or exceed 140 dBP, hearing conservation efforts to prevent hearing loss resulting from occupational and operational illness and injury are mandated. One conservation measure used to reduce impulse noise hazards below the 140 dBP limit is hearing protection devices (HPDs; e.g., earplug or earmuff).

To calculate whether an issued HPD or HPD combination will reduce the impulse noise exposure to below the 140 dBP limit, the impulse peak insertion loss (IPIL) value of the HPD is subtracted from the impulse noise level (Department of Defense, 2015). The IPIL value is the standard metric (ANSI/ASA S12.42) used to determine the amount of protection afforded by an HPD in response to impulse noise. At the time of this writing, the IPIL values of the Oakley SI M Frame® 2.0 combined with the ComTac™ V at 150, 160, and 170 dBP were unknown. This report describes the methods used to determine the IPIL value for the Oakley SI M Frame® 2.0 used in combination with 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 and reports the results.

Specifically, both an overall device IPIL and ear-specific IPILs are reported for the tested nominal levels.

Methods

Facility

IPIL testing described herein was completed in the NSMRL 1000 m^3 anechoic chamber in order to minimize any effects of sound reflections.

Equipment

Hardware. NSMRL's 4 inch (in., 10.2 centimeters [cm]) shock tube (B/C Precision, Inc., Greendale, IN) generated all acoustic impulses. The shock tube pressure chamber is approximately 34 in. (86.4 cm) long, with an inner diameter of 4 in. (10.2 cm). A 64 in. (162.6 cm) long catenoidal tube horn consisting of four welded steel flat-projection sheets forming a square cross section was connected to the shock tube using a PVC 4.5 in. (11.4 cm) coupler. An industrial air compressor (ILA#1883054; Industrial Air Corporation, Memphis, TN) supplied pressurized air (900 kilopascal) to the shock tube.

For each trial at 150 dBP, a 7 in. (17.8 cm) by 7 in. (17.8 cm) polyester sheet (SEVA Technical Services, Inc, Newport News, VA) was used as a membrane between the pressurized chamber and the catenoidal tube horn to enable pressurization of the air chamber. Each polyester sheet was 0.001 in. (1.0 mil, 25.4 micrometer [µm]) thick. For each trial at 160 and 170 dBP, a 7 in. (17.8 cm) by 7 in. (17.8 cm) acetate sheet (Grafix Plastic, Maple Heights, OH) was used as the membrane. Each acetate sheet was 0.002 in. (2.0 mil, 50.8 micrometer [µm]) thick.

All waveforms were recorded with an ANSI/ASA S12.42 (2010) compliant GRAS 45CB acoustic test fixture (ATF) with GRAS RA0045-S7 Ear Simulators (GRAS Sound and Vibration, Twinsburg, OH). The ATF was connected to a conditioning amplifier which served as the power supply (GRAS Type 12AA; GRAS Sound and Vibration, Twinsburg, OH). As required by ANSI/ASA S12.42/2010, the ATF was placed to front-face (i.e., nose facing) the catenoidal tube horn at 0° elevation and 0° azimuth.

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

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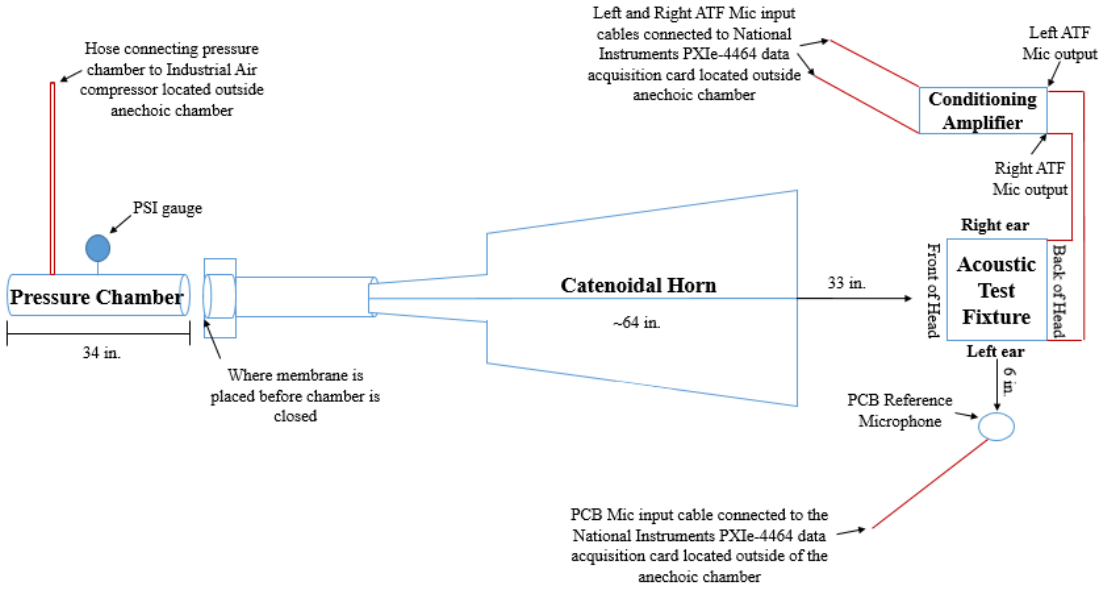
Figure 1.
Diagram of the NSMRL Acoustic Shock Tube and ATF.



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). In addition, it 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, right ATF, reference) 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 compliant in-line analog external Bessel filter 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. Then, a second digital Butterworth filter (6^{th} order, low-pass, corner frequency of 20 kHz [3 dB down]) was applied to all recordings by the MATLAB post-processing script. This digital filter was used to mimic the effect of the ANSI/ASA S12.42-2010 standard required anti-aliasing Bessel filter.

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 three microphone channels into a file (*.mat) that saved variables for input to analysis script (MATLAB) similar to the script provided in Annex H of the ANSI/ASA S12.42-2010 standard. Minor alterations were made to the analysis script in order to accept 150, 160, and 170 dBP data (see Data Analysis below).

Product Samples. Five samples (See Figure 2 for example) of the ComTac™ V Hearing Defender Headset (Manufacturer Product Number: MT20H682FB-09 CY) with foam ear cushions and headband, and five samples of the Oakley Standard Issue Ballistic M Frame® 2.0 Strike – ANSI Z87.1 Stamped eyewear (Manufacturer Product Number: 11-139) were tested in accordance with ANSI/ASA S12.42-2010. Each sample, consisting of one headset and one set of eyewear, was randomly assigned a number 1 through 5.

Figure 2.
Sample of the ComTac™ V Hearing Defender Headset (Headband Model) and Oakley SI M Frame® 2.0 Eyewear

Procedure

Because the ComTac™ V employs active technology, it was tested in both the passive (OFF) and active (i.e., the headset turned on and the sound output level set at its maximum limit [MAX]) modes. Each product sample combination was fitted to the ATF twice, resulting in two trials (trials A and B) per sample combination, and 10 total trials per nominal level test condition (160 and 170 dBP) for each HPD mode. ComTac™ V functionality and settings were confirmed via a listening check prior to each trial. No samples of either product 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. Each sample of the Oakley SI M Frame® 2.0 was fit onto the ATF prior to a ComTac™ V being fitted. The ComTac™ V 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 dBP nominal level was omitted, and the nominal level of 160 dBP was incorporated as impulses generated with the NSMRL 4 in. (10.2 cm) shock

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

Impulse noises were presented to the ATF in the occluded (i.e., products donned) and unoccluded (i.e., without the products donned) test configurations. For all occluded measures, the products were fitted to the ATF in accordance with the specifications outlined in ANSI/ASA S12.42-2010. Each product sample was exposed to two impulses at each tested nominal level in each test mode. Adequate pressure for each impulse was determined by increasing pressure (measured in pounds per square inch [psi]) to a point within a pre-specified range necessary for producing either 150 dBP (8.9 to 9.3 psi, 61 to 64 kilopascals [kPa]), 160 dBP (19.5 to 22.1 psi, 134 to 152 kPa), or 170 dBP impulses (28.5 to 29.5 psi, 197 to 203 kPa). The membrane was then punctured using a manual trigger, releasing pressurized air into the catenoidal horn, which created an impulse wave through the catenoidal horn to the ATF. The peak decibel level emitted was dependent upon the amount of air pressure released.

In place of the ANSI/ASA S12.42-2010 standardized calibration impulses at 130 dBP, six total calibration impulses (three pre-, three post-testing) were generated per nominal level (150,160 dBP) in the unoccluded test configuration. Calibrations were not completed at the 170 dBP nominal level due to exposure limitations of the ATF microphones.

The clamping force of each ComTac™ V earmuff sample was measured using Michael & Associates, Inc.'s Muff-type HPD Force Measurement System (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). Clamping force was measured once post- data collection for all five device samples (See Table 3.).

Data Analysis

MATLAB (Natick, MA) was used to calculate the IPIL values at the 150, 160, and 170 dBP nominal levels and to generate all waveform graphs (See Appendices A to R). 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. Then, the difference between the maximum absolute values of the calculated and measured values was determined, 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 mean for each nominal level. 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 (SD) IPIL values for the ComTac™ V combined with the Oakley SI M Frame® 2.0 were 15.6 (2.2) dB in the passive (i.e., OFF) test mode and 15.6 (2.4) dB in the active (i.e., MAX) test mode in response to the 150 dBP nominal level impulse. At 160 dBP, the calculated overall mean (SD) IPIL values were 18.1 (2.4) dB in the passive (i.e., OFF) mode and 18.3 (2.3) dB in the active (i.e., MAX) mode. At 170 dBP, the calculated overall mean (SD) IPIL values were 20.5 (2.5) dB in the passive (i.e., OFF) mode and 20.4 (2.5) dB in the active (i.e., MAX) mode. Calculated IPIL values for all sample trials in the OFF mode ranged between 12.2 to 20.1 dB at 150 dBP, between 14.0 to 22.2 dB at 160 dBP, and 16.2 to 25.4 dB at 170 dBP, while all tested sample trials in the MAX mode ranged between 10.9 to 20.2 dB at 150 dBP, between 13.4 to 21.8 dB at 160 dBP, and between 15.6 to 25.4 dB at 170 dBP.

Table 2.
Mean (SD) IPIL values (in dB) for Tested ComTac™ V and Oakley SI M Frame® 2.0 Samples.

	150 dBP				**160 dBP**				**170 dBP**			
	OFF		***MAX***		***OFF***		***MAX***		***OFF***		***MAX***	
	Right	*Left*	*Right*	*Left*	*Right*	*Left*	*Right*	*Left*	*Right*	*Left*	*Right*	*Left*
HPD 1, Trial A	12.2	14.2	18.3	15.9	14.1	16.3	21.3	19.2	17.2	19.5	17.0	19.1
HPD 1, Trial B	17.9	13.1	16.1	11.0	19.0	14.0	18.3	13.4	21.3	16.4	20.8	15.6
HPD 2, Trial A	16.2	14.3	16.4	14.7	19.9	17.8	19.5	17.6	22.4	20.1	22.2	19.9
HPD 2, Trial B	20.1	17.0	20.2	17.4	22.2	19.6	21.8	19.1	25.4	22.0	25.4	22.1
HPD 3, Trial A	17.1	12.4	17.7	12.1	20.5	14.7	19.6	14.1	22.5	16.6	22.4	16.6
HPD 3, Trial B	16.7	12.7	15.0	10.9	18.5	14.5	18.4	14.3	20.7	16.2	21.1	16.3
HPD 4, Trial A	18.2	14.5	19.0	15.5	21.1	17.9	20.6	17.5	23.5	20.6	23.1	20.4
HPD 4, Trial B	15.2	14.9	15.5	15.4	18.1	18.1	18.3	18.3	21.2	20.9	21.1	21.0
HPD 5, Trial A	16.8	15.5	16.2	15.3	19.5	18.8	18.7	18.2	21.5	21.5	20.9	20.9
HPD 5, Trial B	18.4	14.1	17.1	13.2	20.2	16.3	20.5	16.8	22.4	19.0	23.1	19.7
Ear Specific Mean (SD)	16.9 (2.1)	14.3 (1.4)	17.2 (1.6)	14.1 (2.2)	19.3 (2.2)	16.8 (1.9)	19.7 (1.3)	16.9 (2.1)	21.8 (2.1)	19.3 (2.2)	21.7 (2.2)	19.2 (2.2)
Level Overall Mean (SD)	**15.6 (2.2)**		**15.6 (2.4)**		**18.1 (2.4)**		**18.3 (2.3)**		**20.5 (2.5)**		**20.4 (2.5)**	

As shown in Table 3, the measured clamping force of the ComTac™ V samples 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
MEAN (SD)	2.7 (0.1)

The waveforms for the passive (i.e., OFF) test mode for all trials of the ComTac™ V plus the Oakley SI M Frame® 2.0 are provided in Appendices A to I and are color-coded green. The waveforms for the active (i.e., MAX) test mode of the ComTac™ V plus the Oakley SI M Frame® 2.0 are provided in Appendices J to R and are color-coded orange.

Discussion

As required by ANSI/ASA S12.42-2010, the ComTac™ V Hearing Defender was tested in both its passive and active modes. The ComTac™ V uses an external microphone, an amplifier, a signal limiting circuit, and an internal loudspeaker to pass low-level sounds through the HPD. According to the manufacturer, when a signal exceeds 82 dB A-weighted (dBA), the limiting circuit automatically turns 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. One possible mode of failure could occur if the limiting circuit fails to turn off quickly enough. This would allow some portion 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.

Results revealed overall mean IPILs across test modes (i.e., OFF, MAX) within 0.0 dB of each other for the 150 dBP nominal test level, within 0.2 dB of each other for the 160 dBP nominal test level, and within 0.1 dB of each other for the 170 dBP nominal test level. Across ears, the individual trial mean IPIL values were found to vary as much as 7.9 dB at 150 dBP, 8.2 dB at 160 dBP, and 9.2 dB at 170 dBP in the OFF test mode, while all individual trial mean IPIL values varied as much as 9.3 dB at 150 dBP, 8.4 dB at 160 dBP, and 9.8 dB at 170 dBP in the MAX test mode. These results may be explained by a combination of inherent variance within the impulse system, variability in passive (i.e., OFF) and active (i.e., MAX) attenuation, and/or variability in fit as a result of each product sample combination being fitted twice.

In addition, results consistency across the passive (i.e., OFF) and active (i.e., MAX) test modes could be explained by proper function of the active limiting circuit, or, alternatively, a ComTac™ V device complete failure (i.e., device complete failure

would be equivalent to passive mode). Variance in the data could also be explained by intermittent function or digital signal processing algorithms contained in the active electronics. However, device complete failures were accounted for via a listening check before each test trial to confirm that the active electronics were functioning and set at the appropriate maximum sound output level. Further, based on the results obtained, there is little reason to conclude that the active limiting circuit was intermittent in any tested samples of the ComTac™ V. However, additional testing of the ComTac™ V's signal processing and subsequent effects on input and output signals was outside of the scope of this report.

The calculated overall mean IPIL values (i.e., OFF, MAX) for the ComTac™ V worn in combination with the Oakley SI M Frame® 2.0 at the nominal levels of 160 and 170 dBP were found to be lower than the NSMRL reported IPIL values for the ComTac™ V donned alone (i.e., 160 dBP: 25.2 dB [OFF], 26.1 [MAX], 170 dBP: 27.5 [OFF], 28.5 [MAX]; Silvia et al., 2021). Specifically, differences of 7.1 dB (OFF) and 7.8 dB (MAX) were noted at the 160 dBP nominal level, and differences of 7.0 dB (OFF) and 8.1 dB (MAX) were noted at the 170 dBP nominal level. No comparison data at the nominal level of 150 dBP were available. These differences are most likely explained by the Oakley SI M Frame® 2.0 eyewear causing a slit leak in the seal of the ComTac™ V earmuffs when donned.

It is important to note that the results contained in this report do not guarantee similar performance of the tested products 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, HPD configuration (e.g., single, double- or triple- configuration), and/or use with other head worn protective devices (e.g., helmet, knit headwear).

Conclusions

This report described the process for determining the mean impulse peak insertion loss (IPIL) values provided by the Oakley Standard Issue Ballistic M Frame® 2.0 Strike eyewear worn with the ComTac™ V Hearing Defender Headset at the nominal levels of 150, 160, and 170 dBP. The calculated overall mean (SD) IPIL values for the Oakley SI M Frame® 2.0 with the ComTac™ V Hearing Defender Headset in the passive (OFF) mode were found to be 15.6 (2.2) dB at 150 dBP, 18.1 (2.4) dB at 160 dBP, and 20.5 (2.5) dB at 170 dBP. When the Oakley SI M Frame® 2.0 was worn with the ComTac™ V in the active mode (turned on, and output level set to MAX), the overall mean (SD) IPIL values were 15.6 (2.4) dB at 150 dBP, 18.3 (2.3) dB at 160 dBP, and 20.4 (2.5) dB at 170 dBP.

The results of testing suggest that, when properly fit and functional, the ComTac™ V worn in combination with the Oakley SI M Frame® 2.0 can adequately protect (i.e., reduce the exposure level below 140 dBP) the user from impulses below 155.6 dBP in both the passive (i.e., OFF) and the active (i.e., MAX) modes. However, performance of the ComTac™ V may be negatively affected by sound leakage when the Oakley SI M Frame® 2.0 is donned compared to when doffed.

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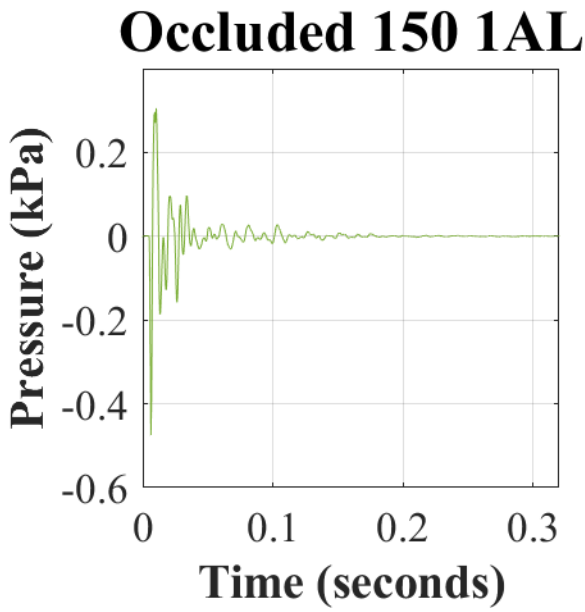
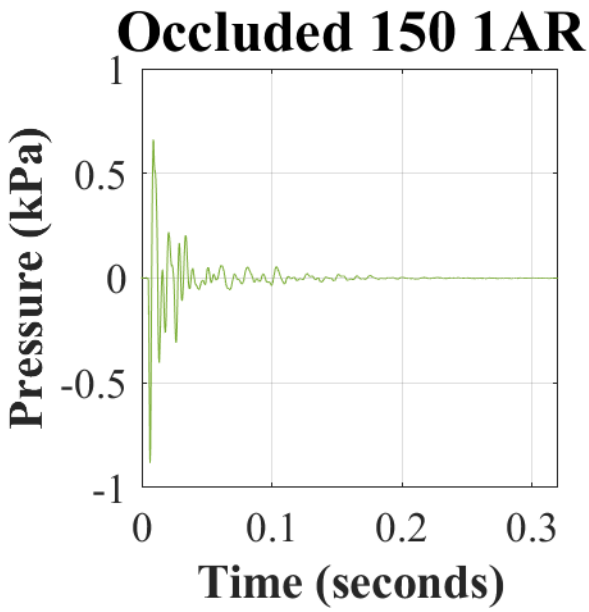
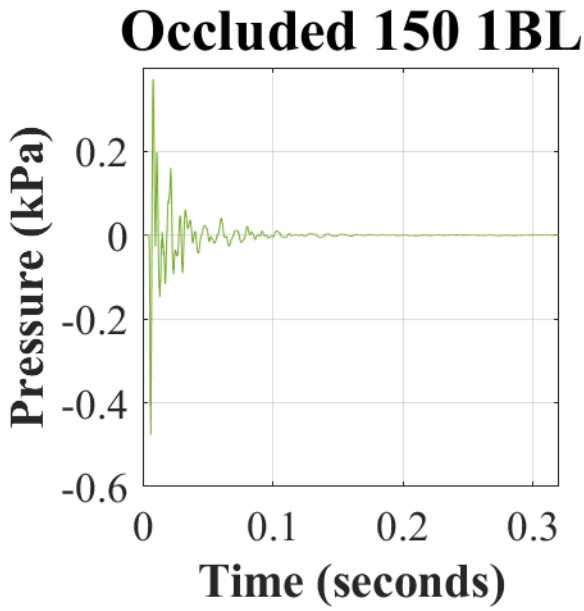
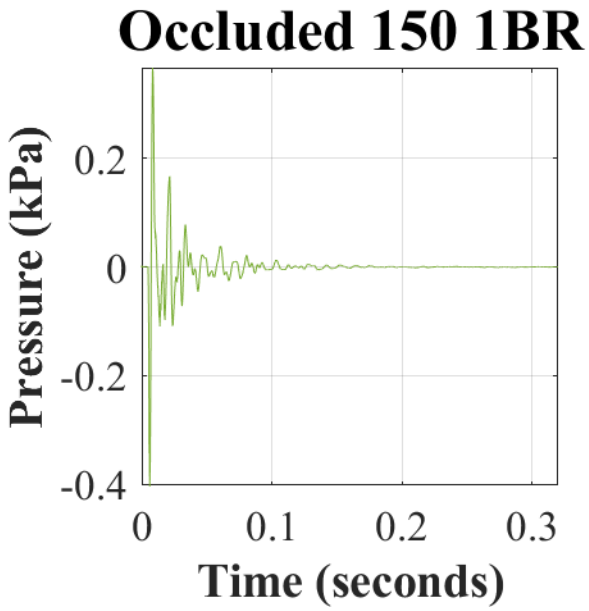
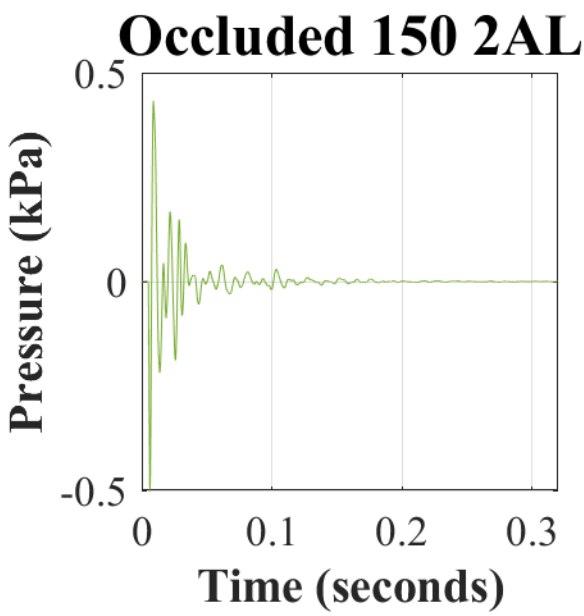
Appendix A. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 150 dBP with the ComTac™ V (OFF).

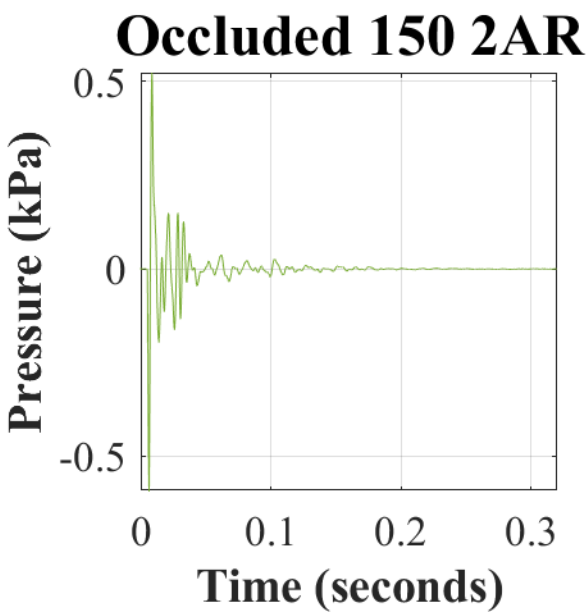


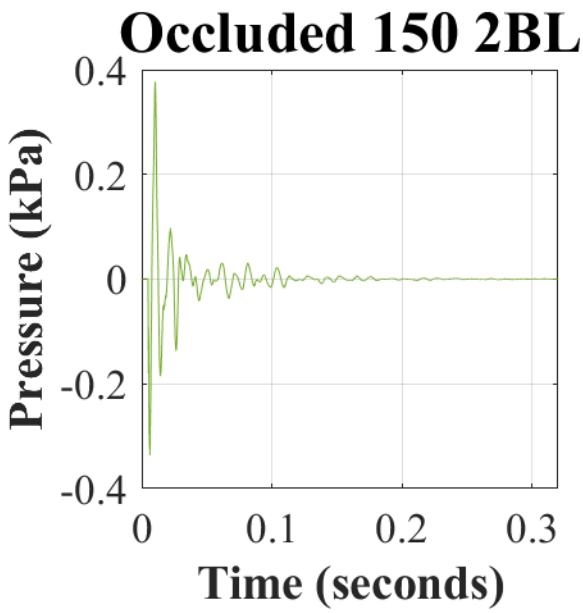


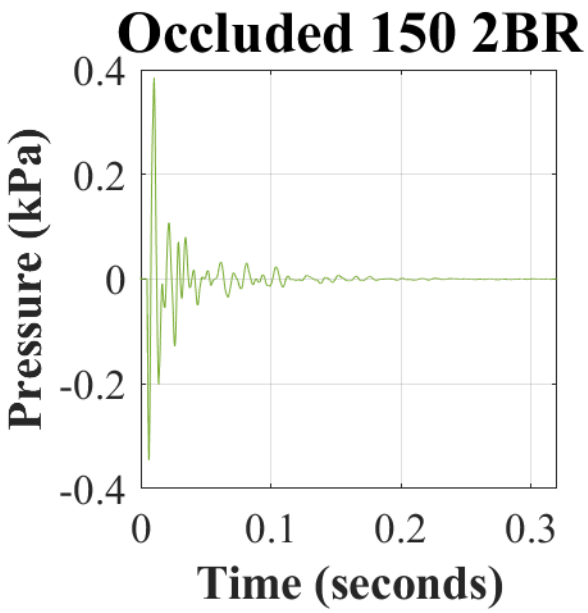


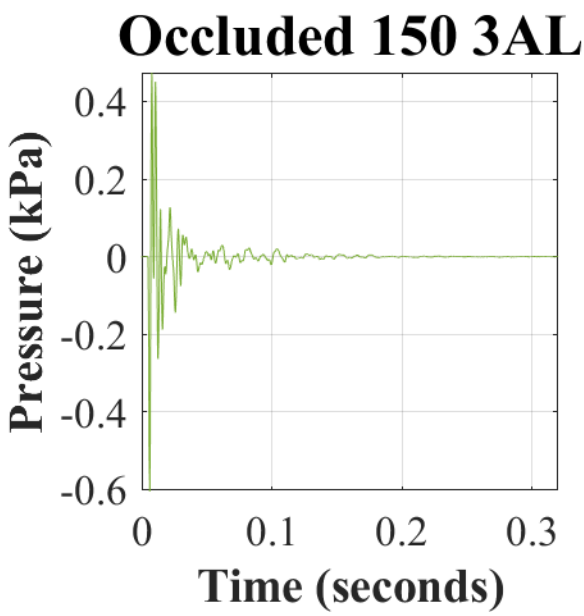


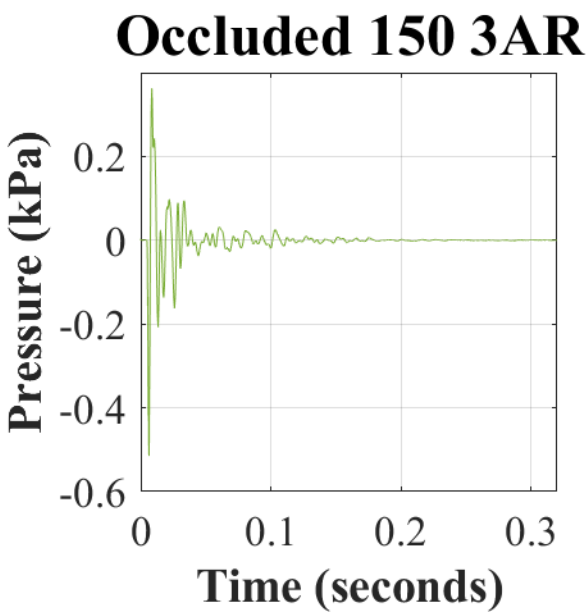

Occluded 150 2AL
Pressure (kPa)
0.5
0
-0.5
0
0.1
0.2
0.3
Time (seconds)

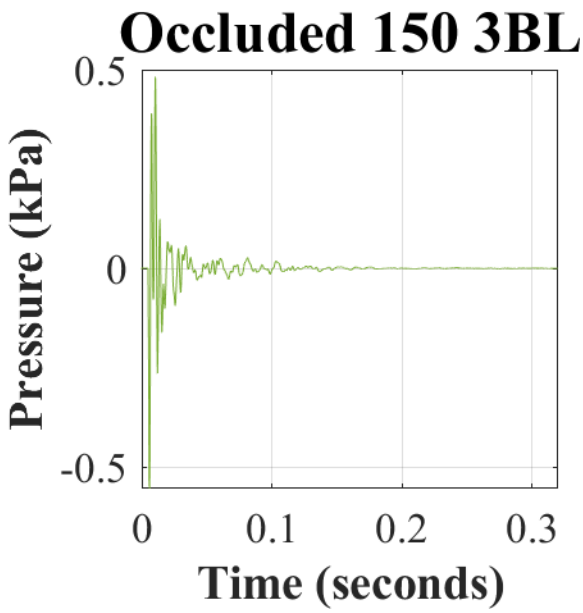

Occluded 150 2AR
Pressure (kPa)
0.5
0
-0.5
0
0.1
0.2
0.3
Time (seconds)

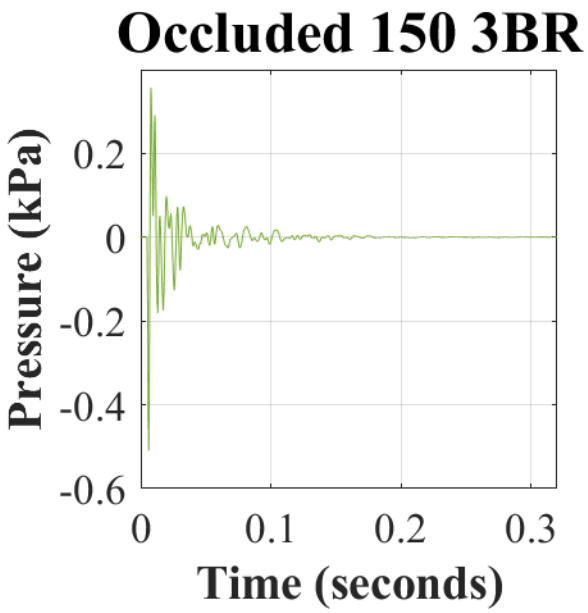

Occluded 150 2BL
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

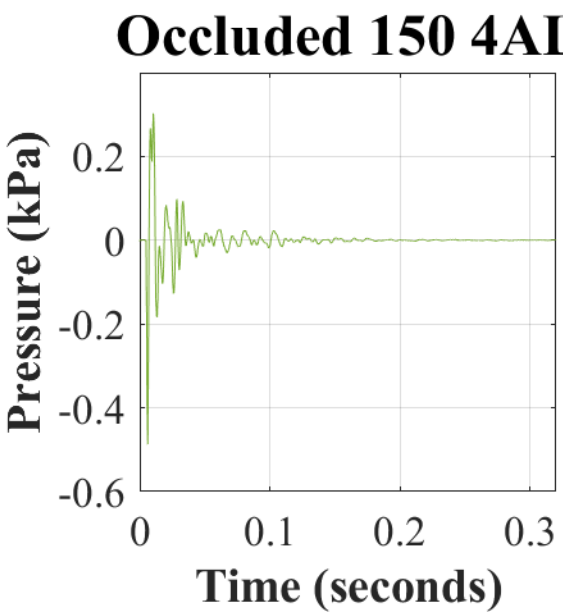

Occluded 150 2BR
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

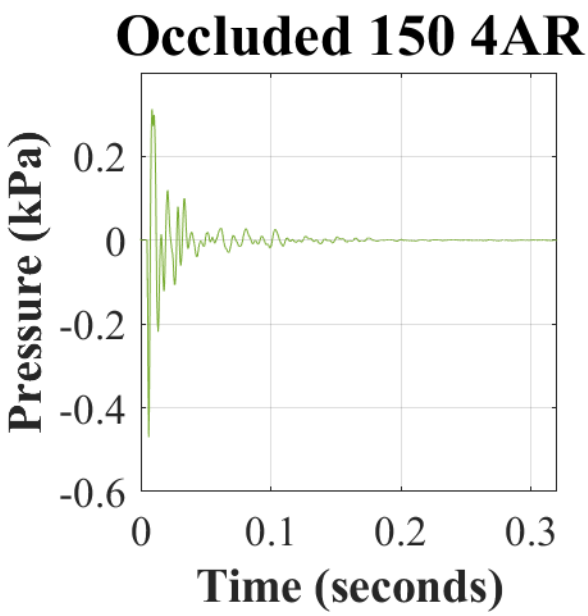

Occluded 150 3AL
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)

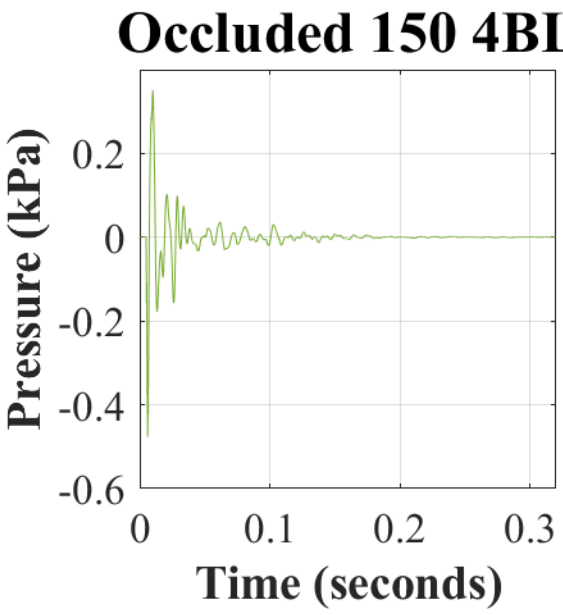

Occluded 150 3AR
Pressure (kPa)
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)

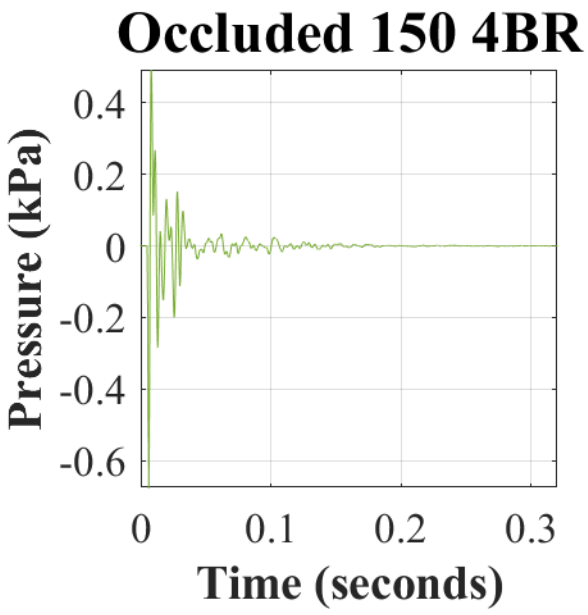

Occluded 150 3BL
Pressure (kPa)
0.5
0
-0.5
0
0.1
0.2
0.3
Time (seconds)

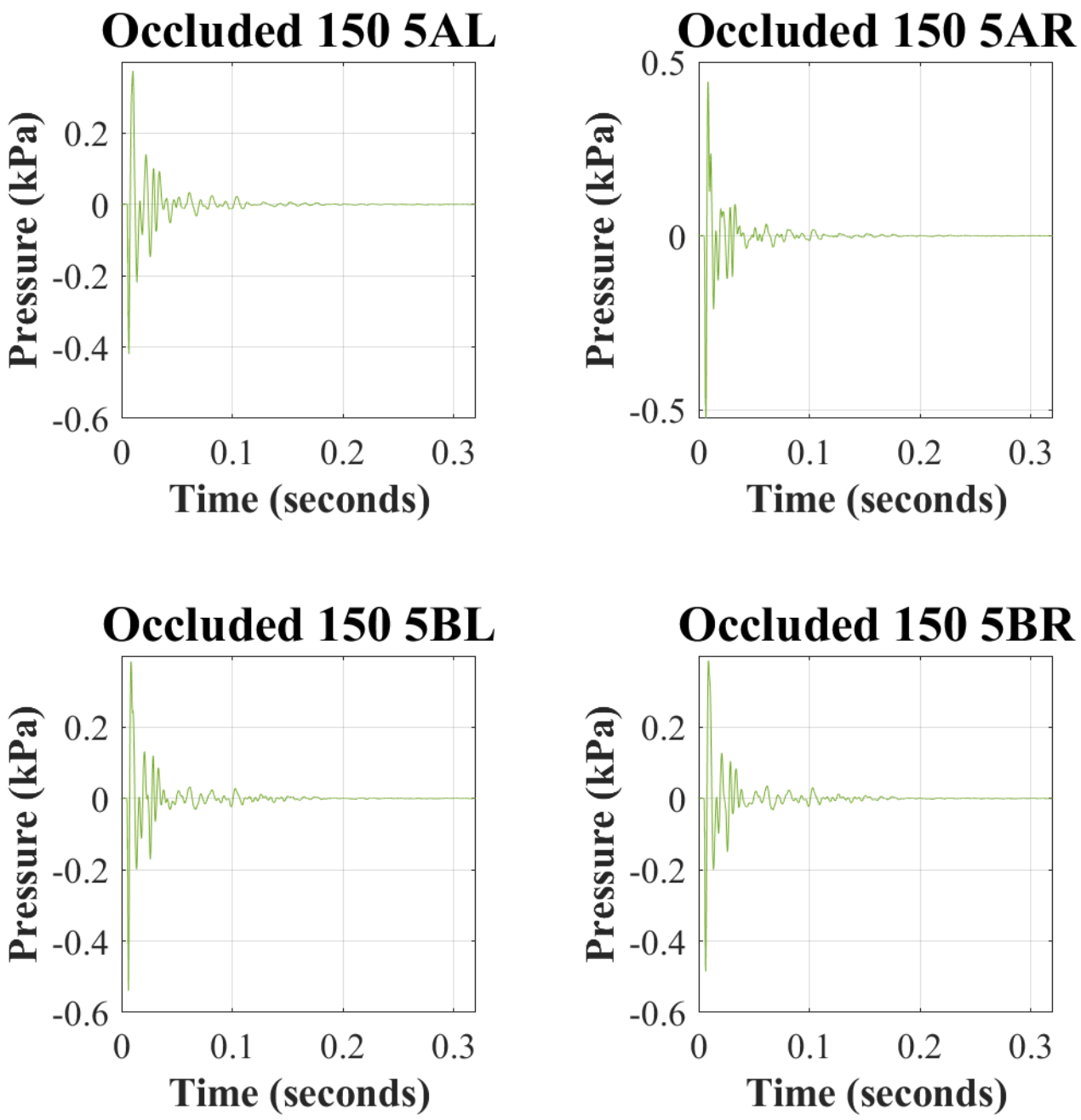

Occluded 150 3BR
Pressure (kPa)
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)


Occluded 150 4AL
Pressure (kPa)
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)


Occluded 150 4AR
Pressure (kPa)
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)

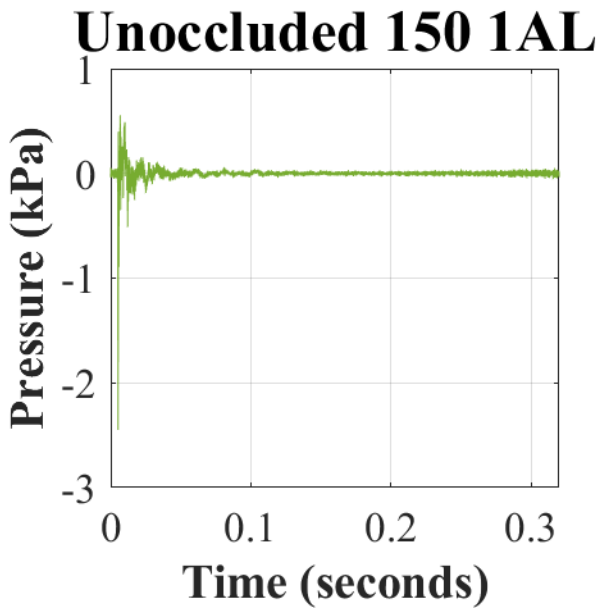

Occluded 150 4BL
Pressure (kPa)
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)

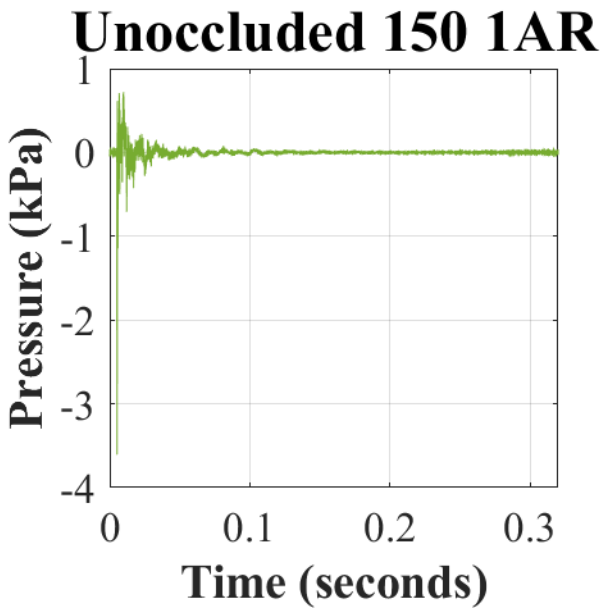

Occluded 150 4BR
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)

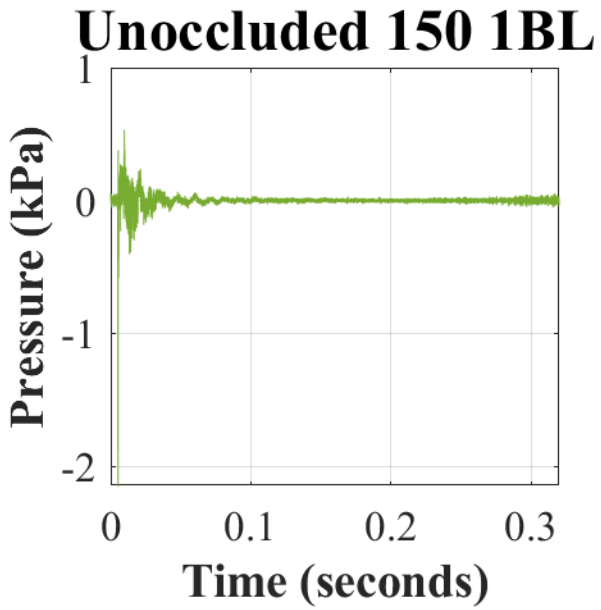


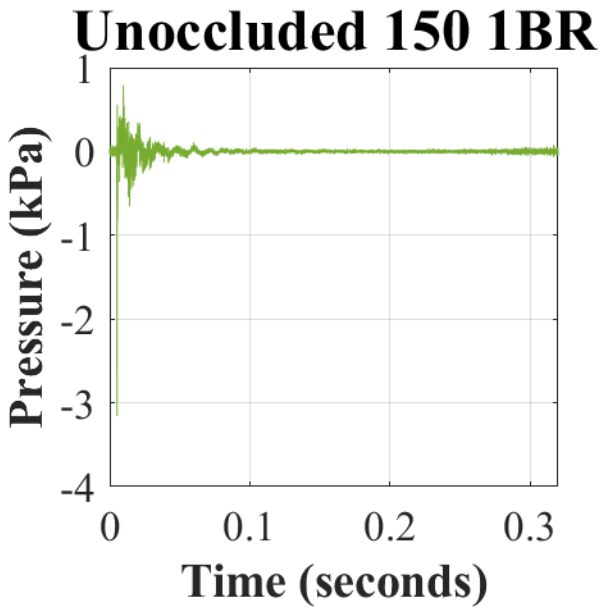
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating HPD fit (i.e., first or second, respectively), and ‘X’ indicates from what ATF microphone the recording is from (i.e., right [R] or left [L] pinnae).

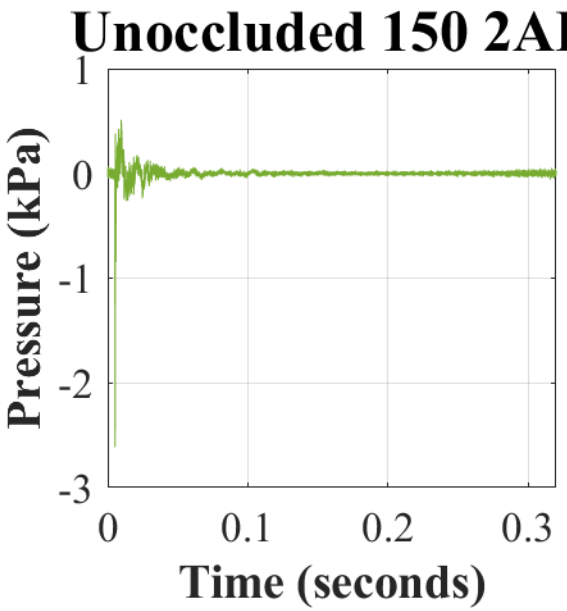
Appendix B. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 150 dBP with the ComTac™ V (OFF).

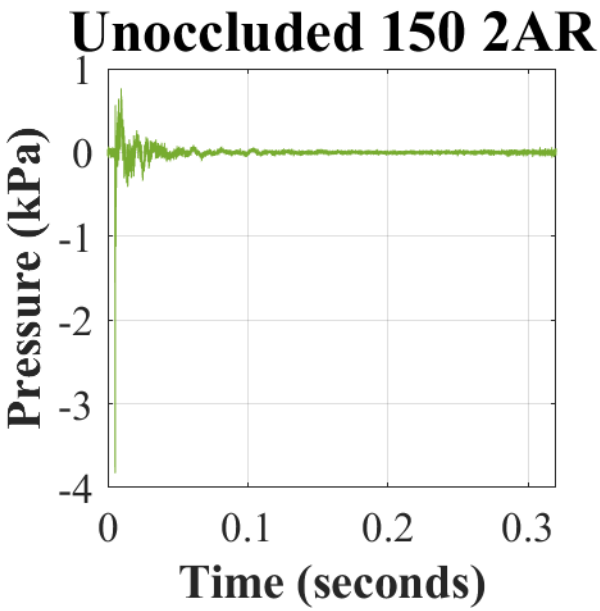


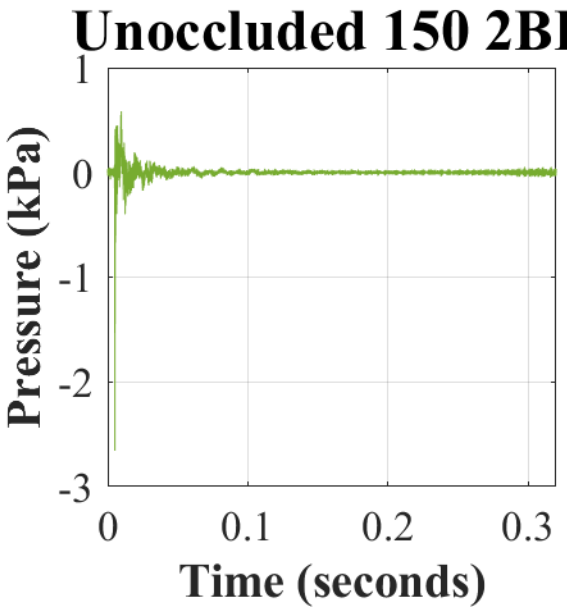


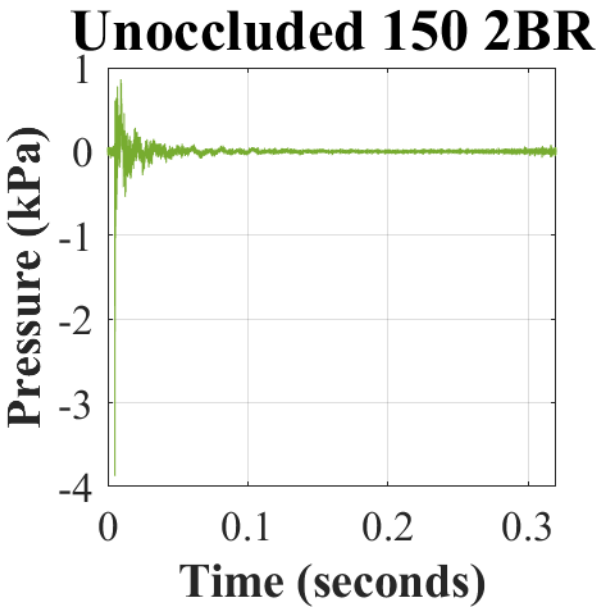


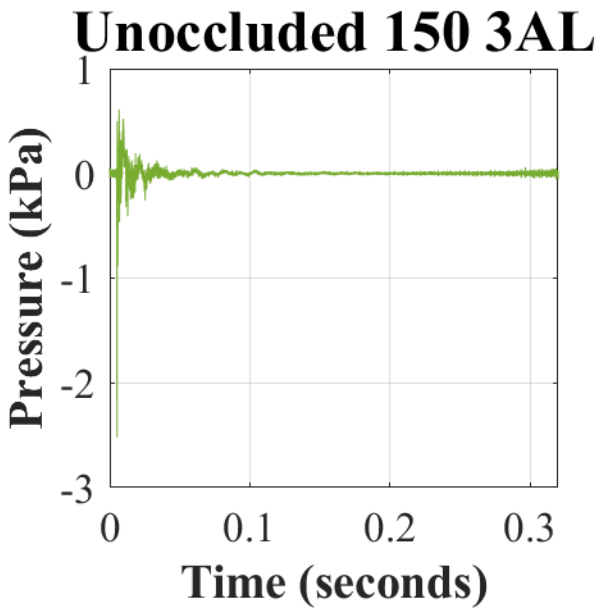


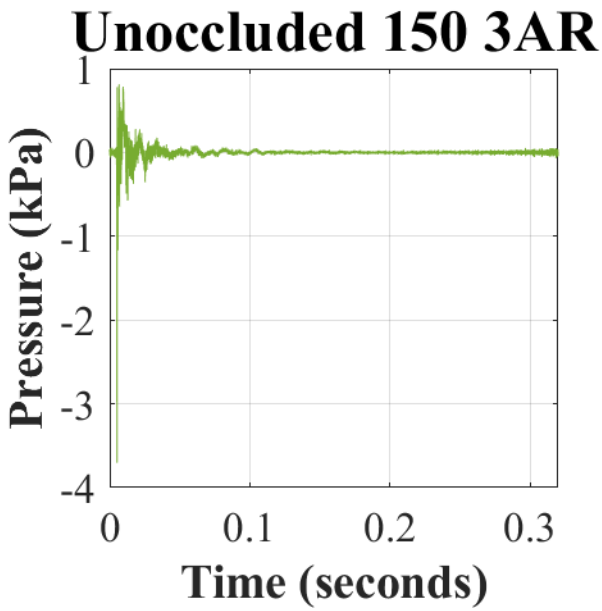

Unoccluded 150 2AL
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

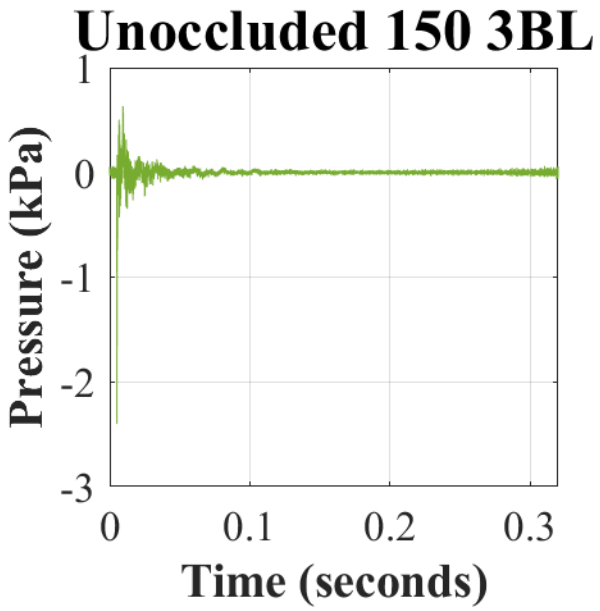

Unoccluded 150 2AR
Pressure (kPa)
1
0
-1
-2
-3
-4
0
0.1
0.2
0.3
Time (seconds)

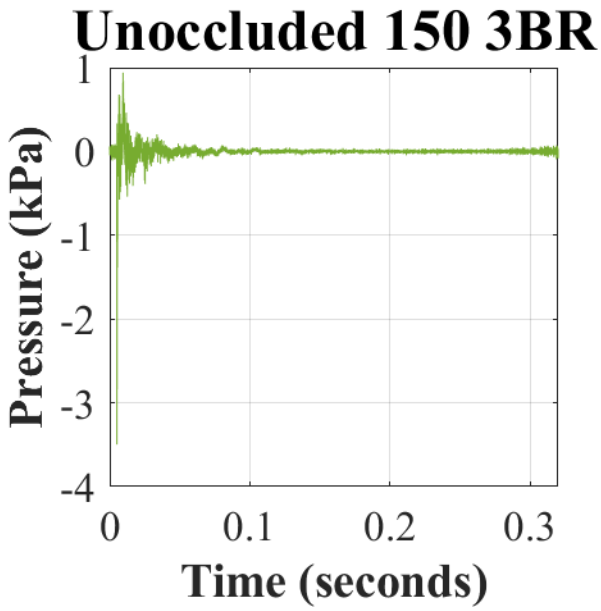

Unoccluded 150 2BL
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

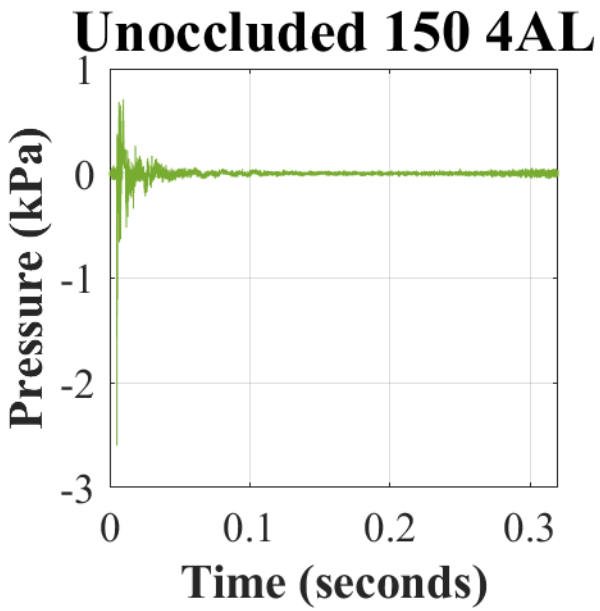

Unoccluded 150 2BR
Pressure (kPa)
1
0
-1
-2
-3
-4
0
0.1
0.2
0.3
Time (seconds)

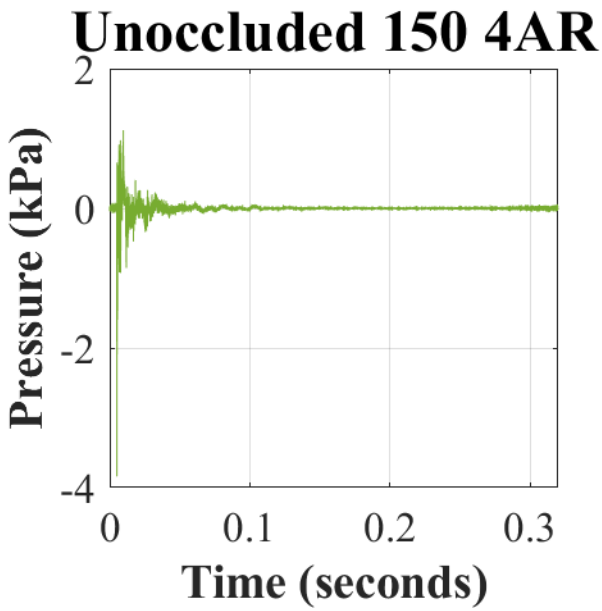

Unoccluded 150 3AL
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

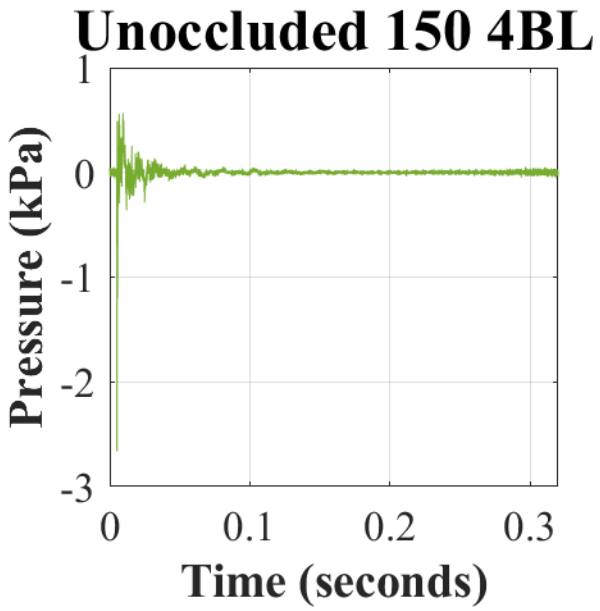

Unoccluded 150 3AR
Pressure (kPa)
1
0
-1
-2
-3
-4
0
0.1
0.2
0.3
Time (seconds)

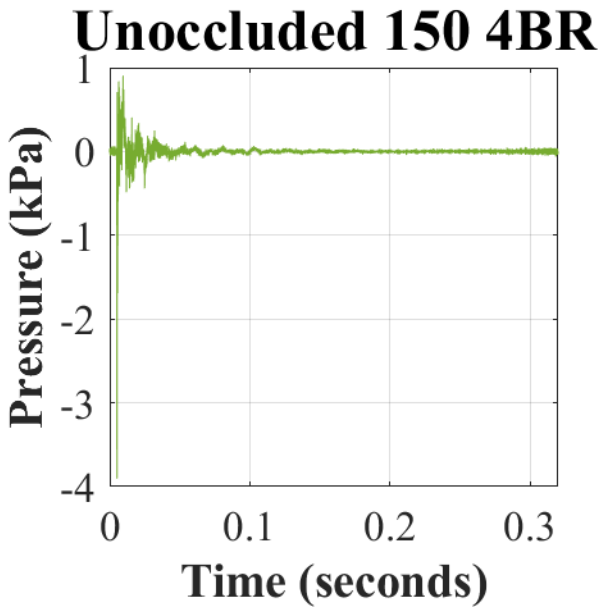

Unoccluded 150 3BL
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

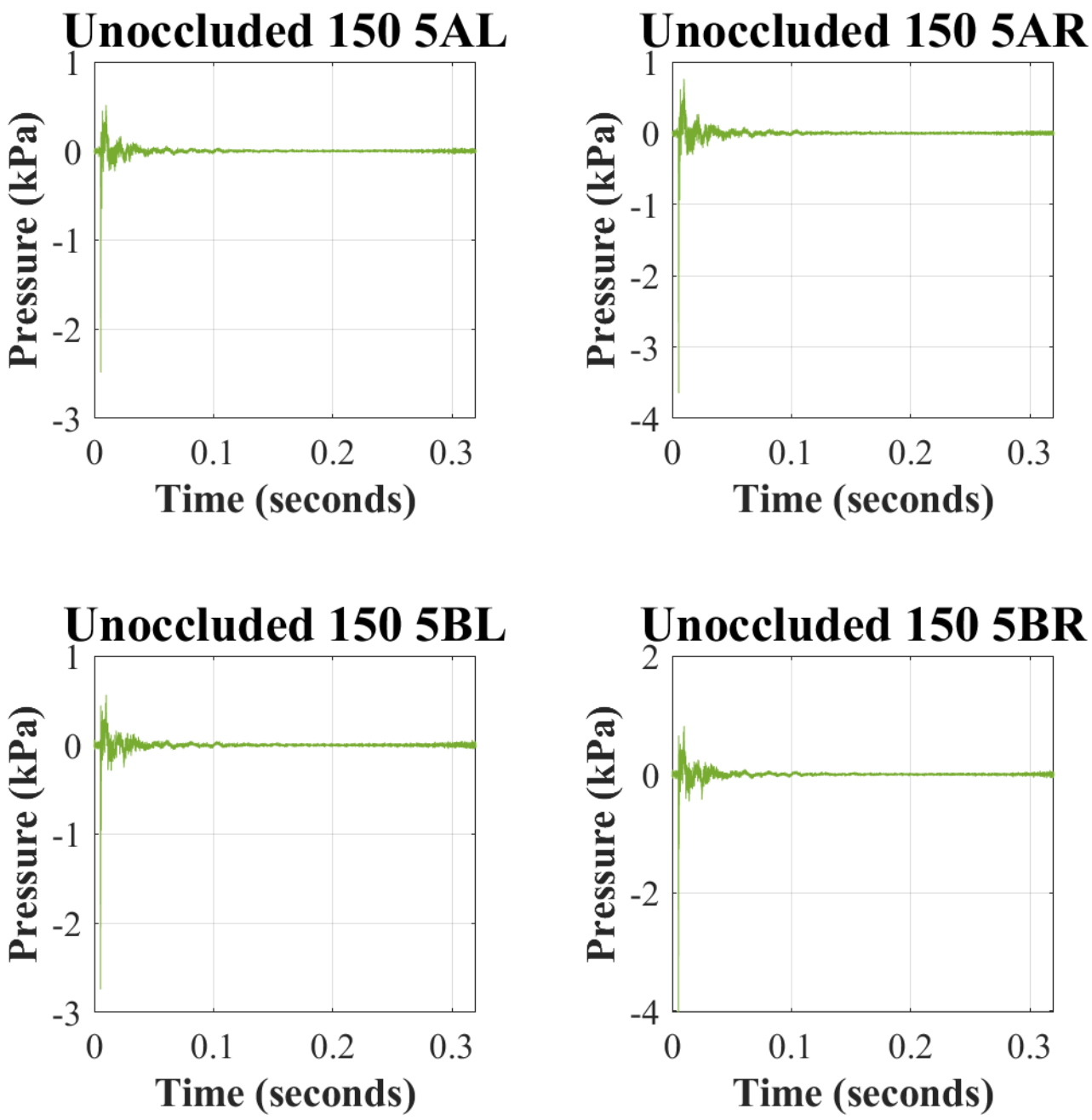

Unoccluded 150 3BR
Pressure (kPa)
1
0
-1
-2
-3
-4
0
0.1
0.2
0.3
Time (seconds)


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


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

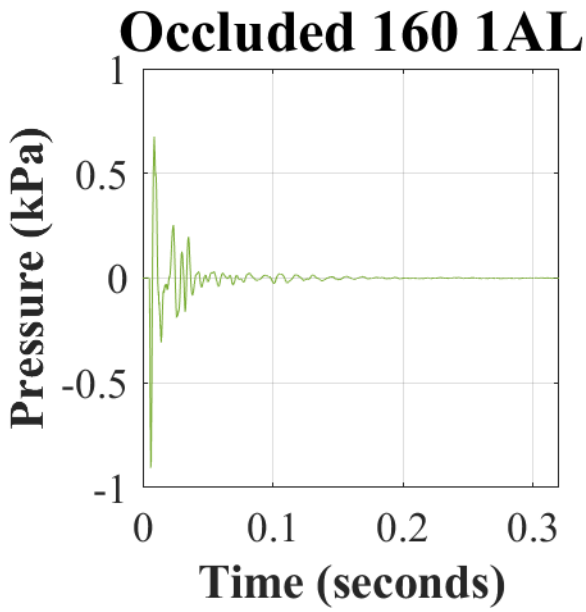

Unoccluded 150 4BL
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

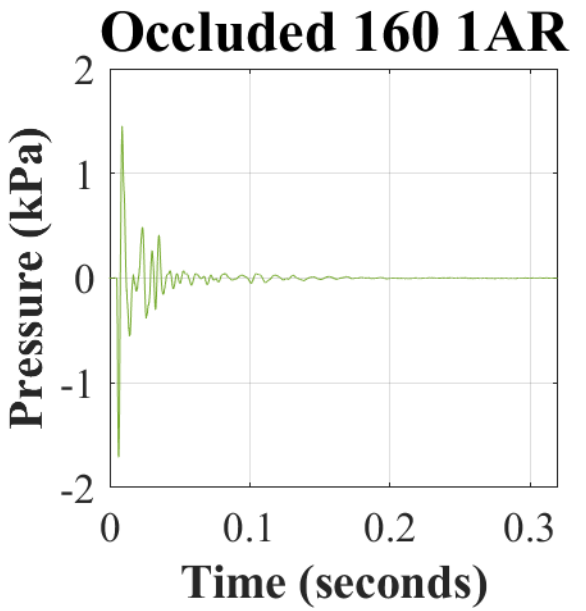

Unoccluded 150 4BR
Pressure (kPa)
1
0
-1
-2
-3
-4
0
0.1
0.2
0.3
Time (seconds)

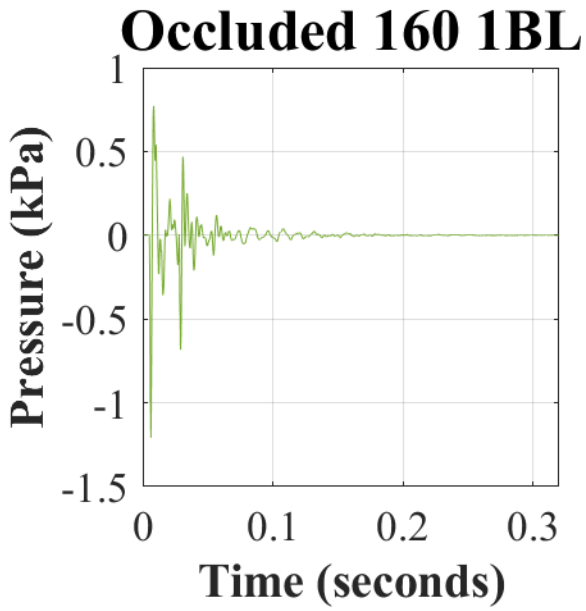


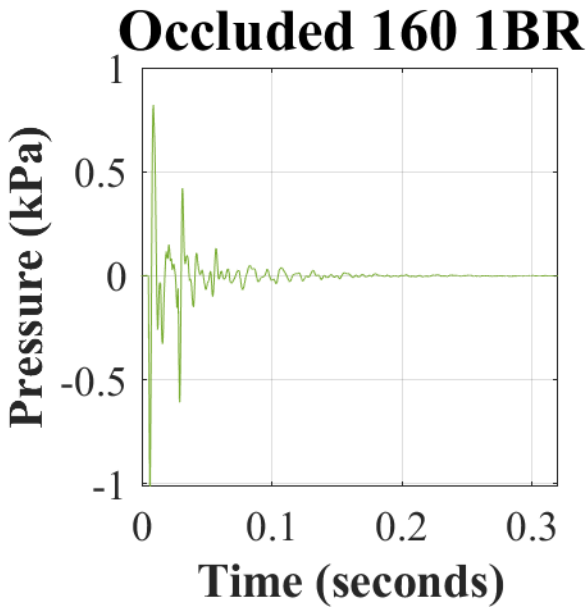
Note. The naming convention for all unoccluded waveforms is "Unoccluded LvL NnX", where 'Unoccluded' is the test condition (i.e., ATF has the HPD doffed), 'LvL' is the nominal test level (i.e., 150, 160 or 170 dBP), 'N' is the sample number (i.e., 1 to 5) of the device tested, 'n' is the trial (i.e., A or B) indicating HPD fit (i.e., first or second, respectively), and 'X' indicates from what ATF microphone the recording is from (i.e., right [R] or left [L] pinnae).

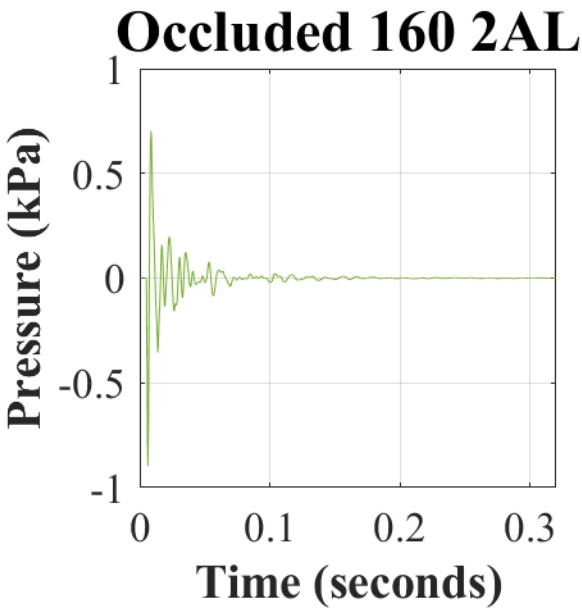
Appendix C. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 160 dBP with the ComTac™ V (OFF).

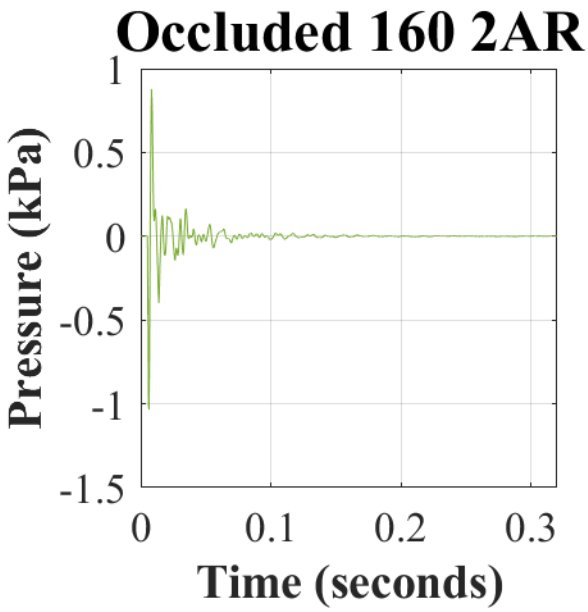


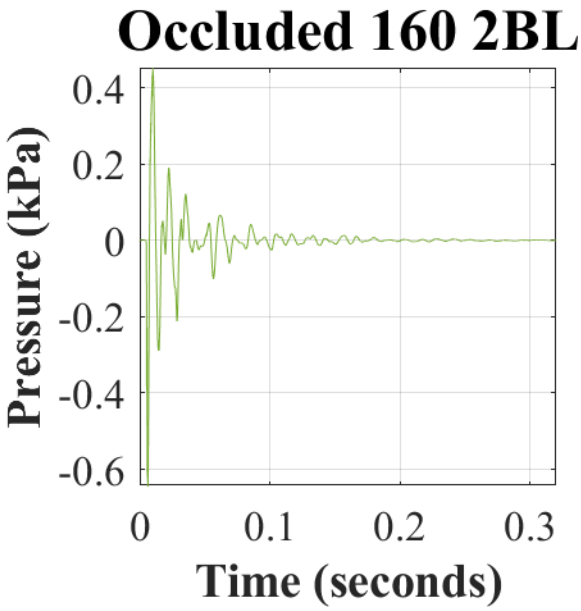


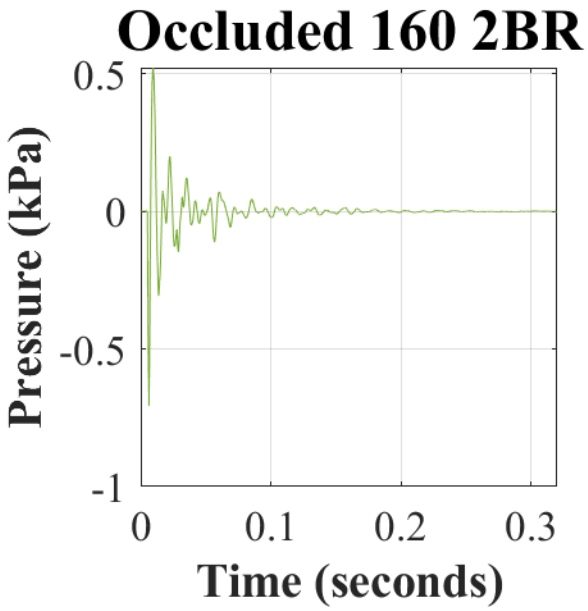


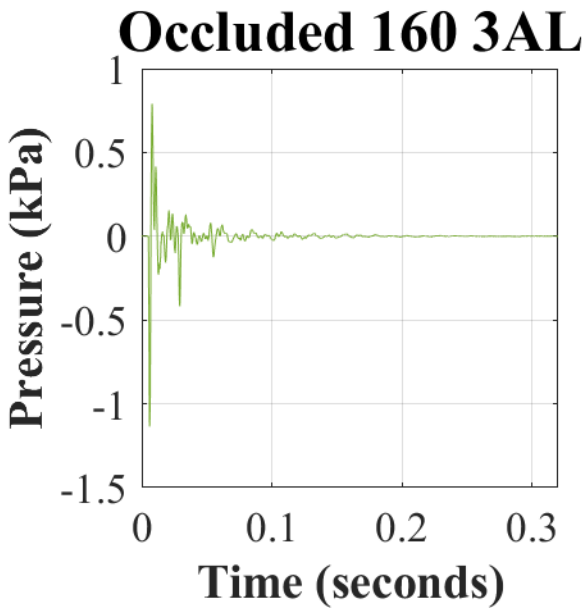


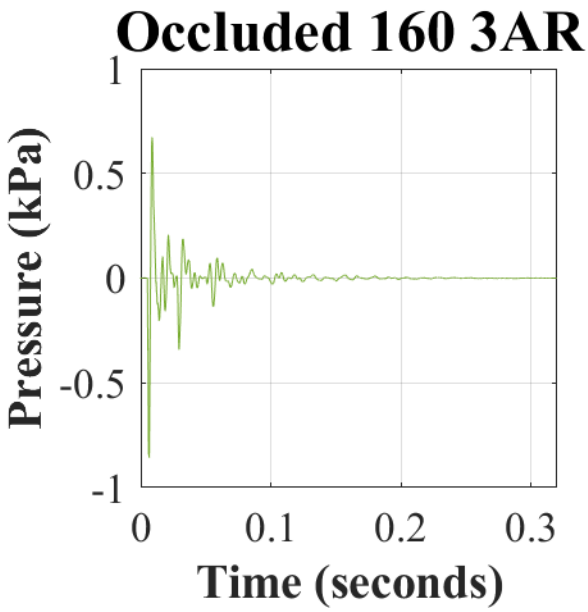

Occluded 160 2AL
Pressure (kPa)
1
0.5
0
-0.5
-1
0
0.1
0.2
0.3
Time (seconds)

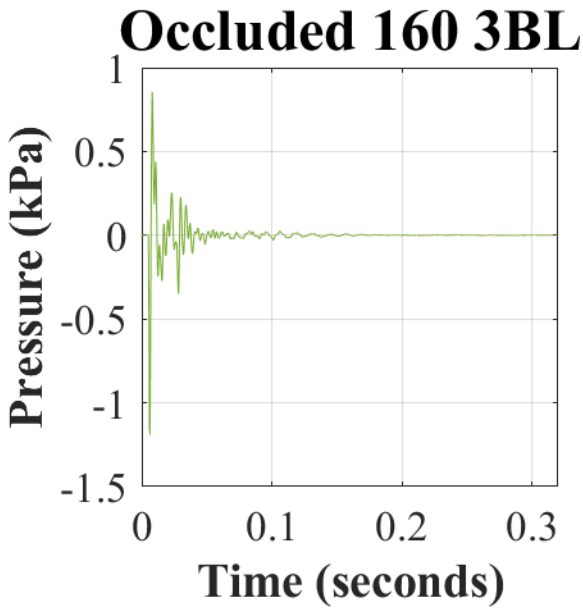

Occluded 160 2AR
Pressure (kPa)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3
Time (seconds)

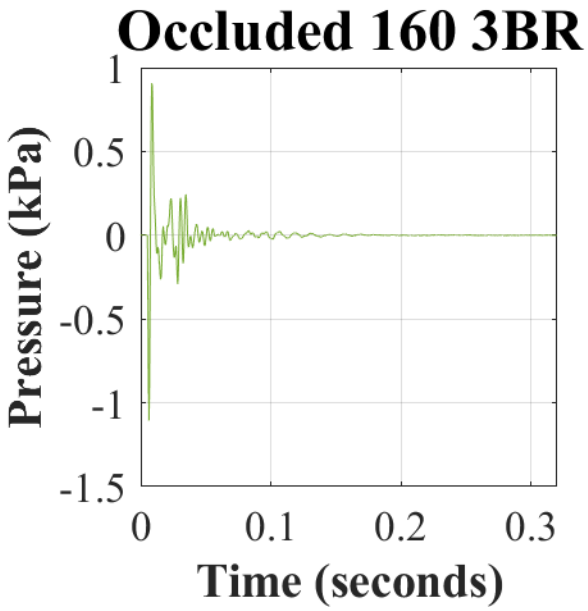

Occluded 160 2BL
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)

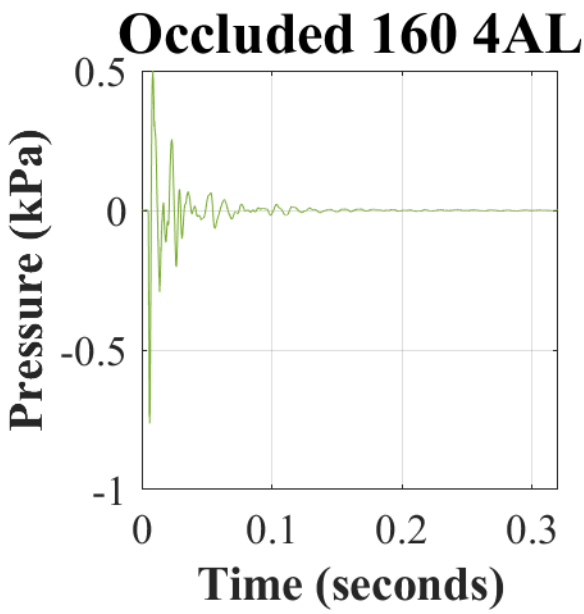

Occluded 160 2BR
Pressure (kPa)
0.5
0
-0.5
-1
0
0.1
0.2
0.3
Time (seconds)

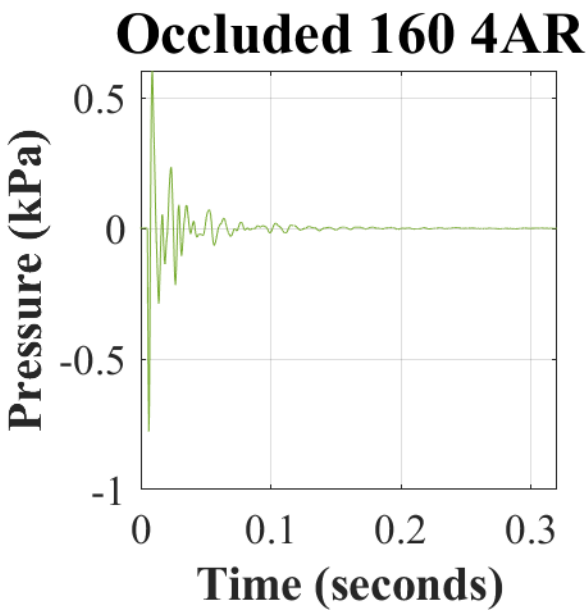

Occluded 160 3AL
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3

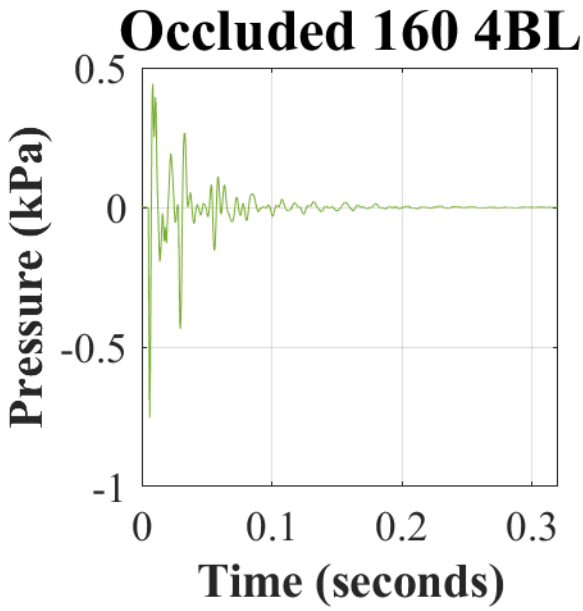

Occluded 160 3AR
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
0
0.1
0.2
0.3

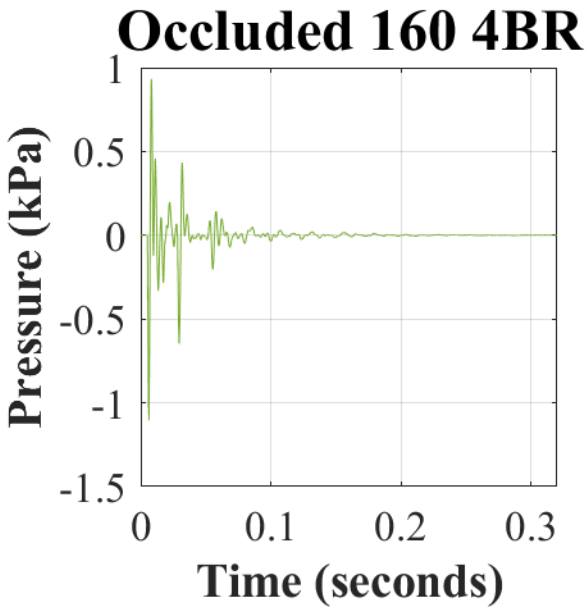

Occluded 160 3BL
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3

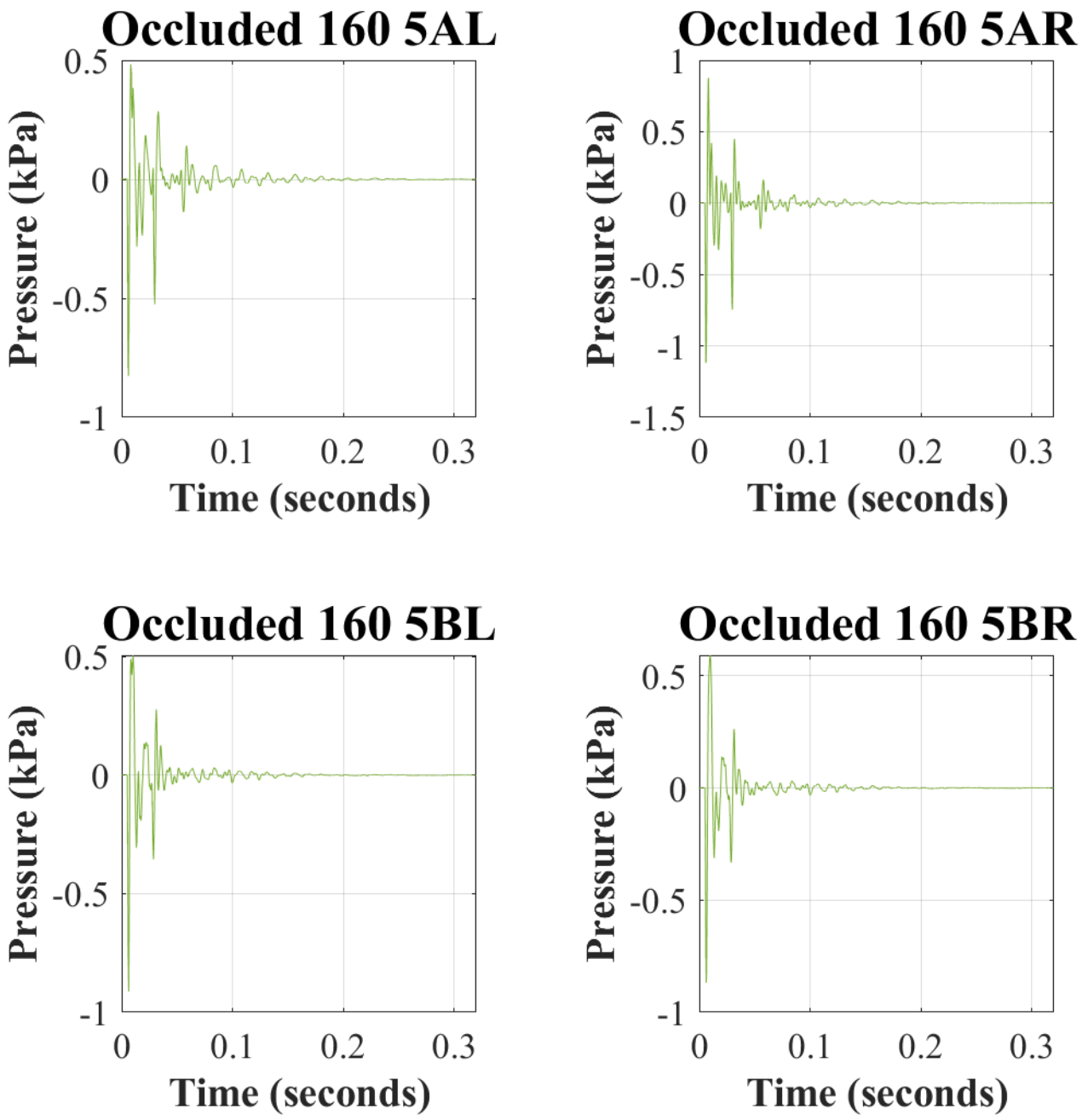

Occluded 160 3BR
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3


Occluded 160 4AL
Pressure (kPa)
0.5
0
-0.5
-1
0
0.1
0.2
0.3
Time (seconds)


Occluded 160 4AR
Pressure (kPa)
0.5
0
-0.5
-1
0
0.1
0.2
0.3
Time (seconds)

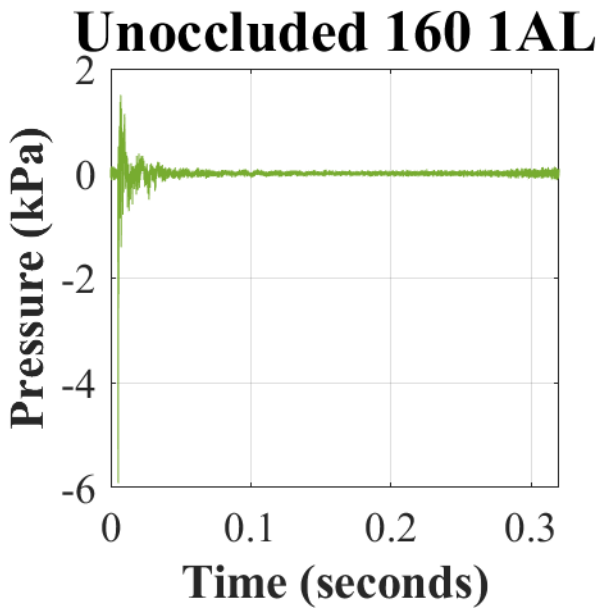

Occluded 160 4BL
Pressure (kPa)
0.5
0
-0.5
-1
0
0.1
0.2
0.3
Time (seconds)

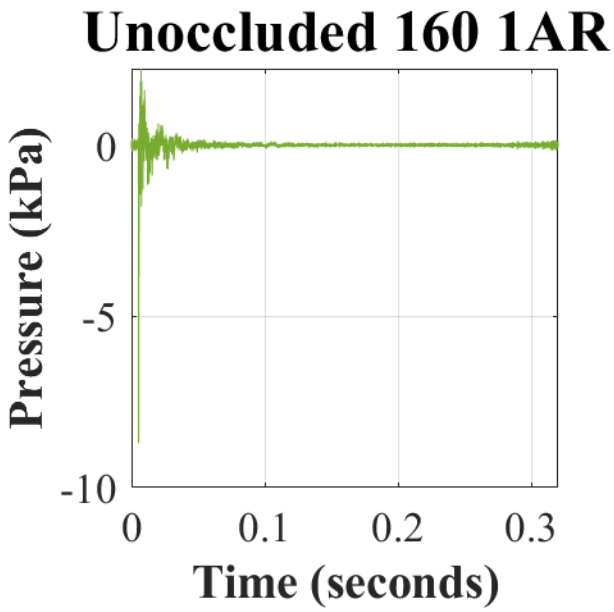

Occluded 160 4BR
Pressure (kPa)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3
Time (seconds)

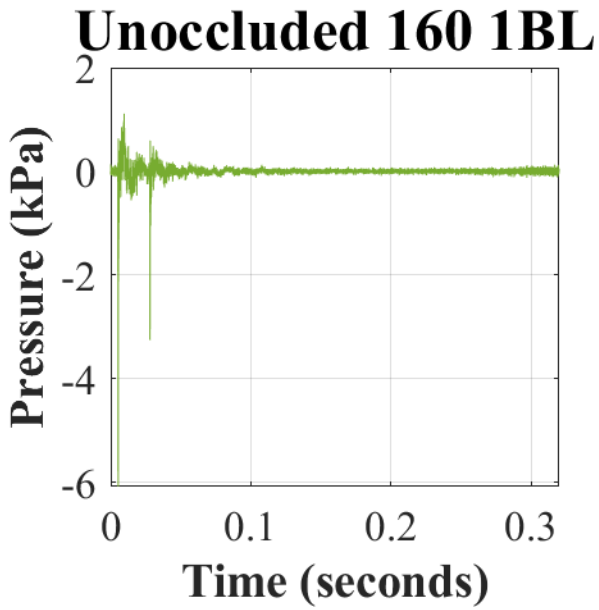


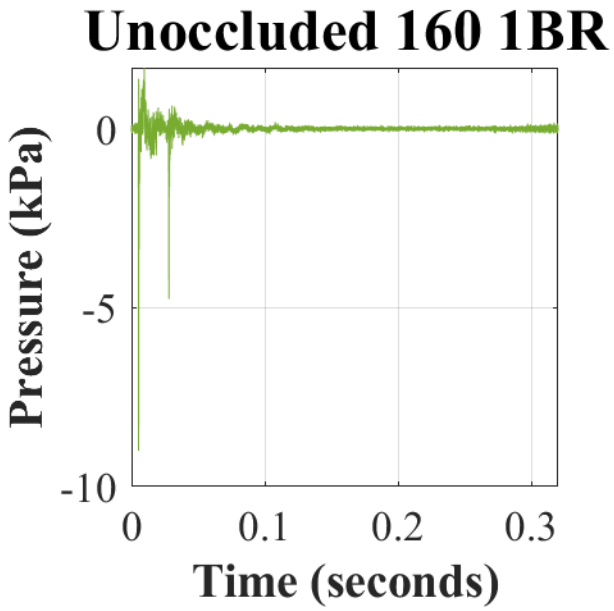
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating HPD fit (i.e., first or second, respectively), and ‘X’ indicates from what ATF microphone the recording is from (i.e., right [R] or left [L] pinnae).

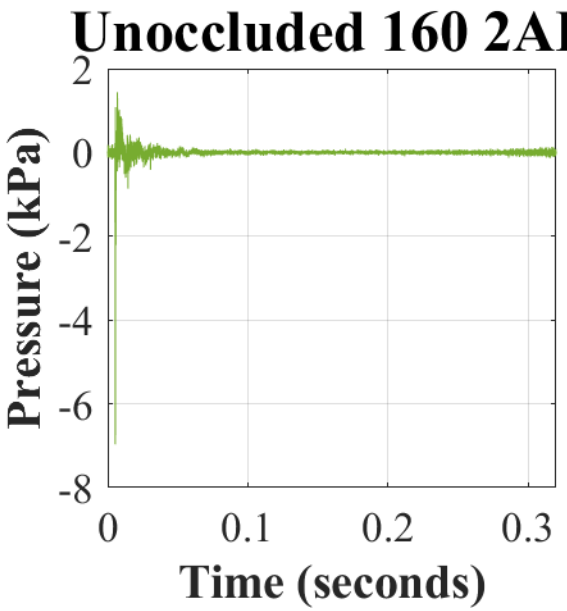
Appendix D. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 160 dBP with the ComTac™ V (OFF).

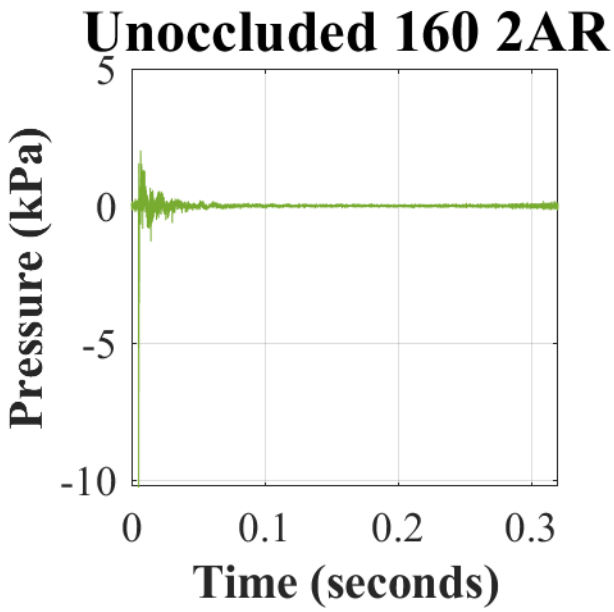


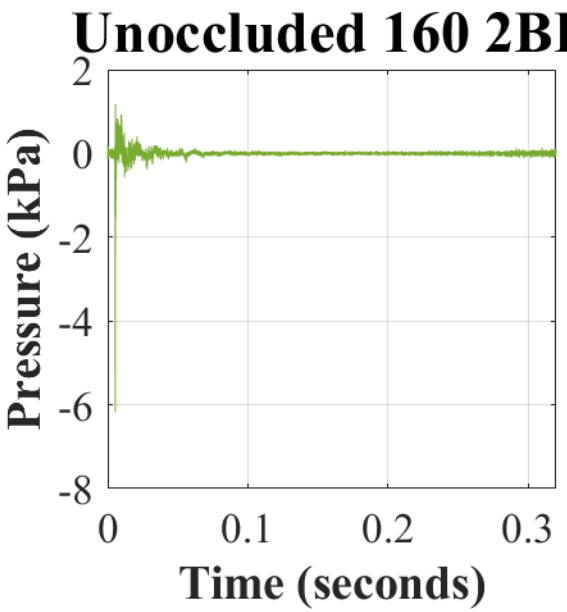


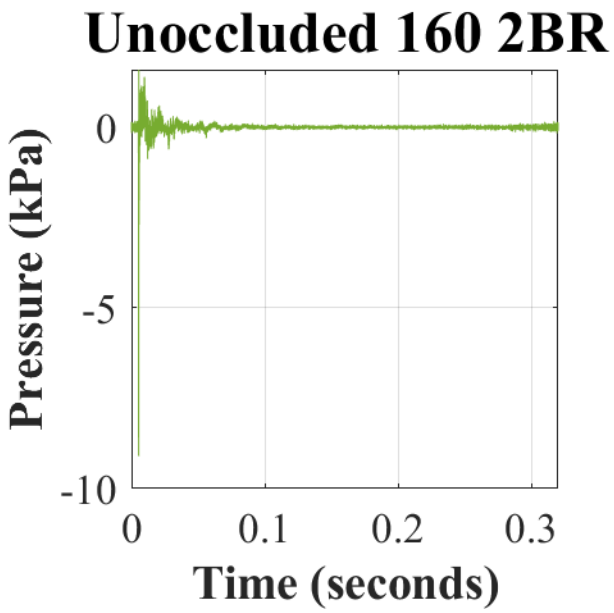


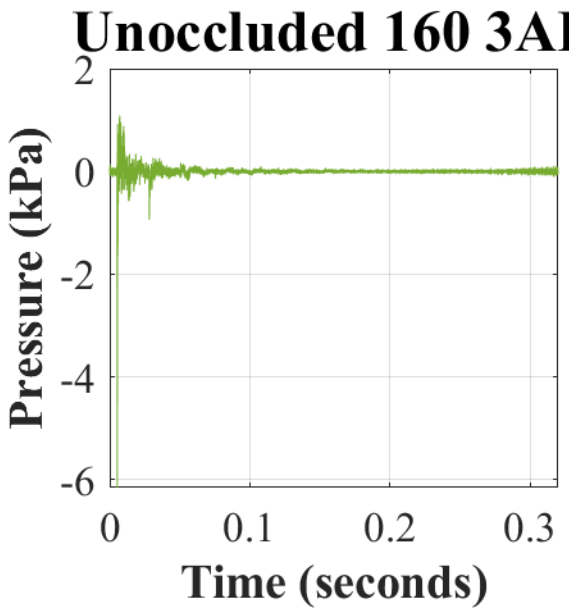


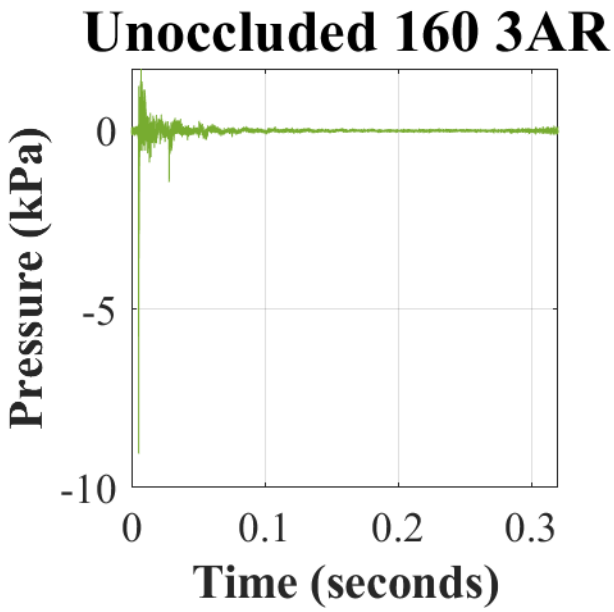

Unoccluded 160 2AL
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

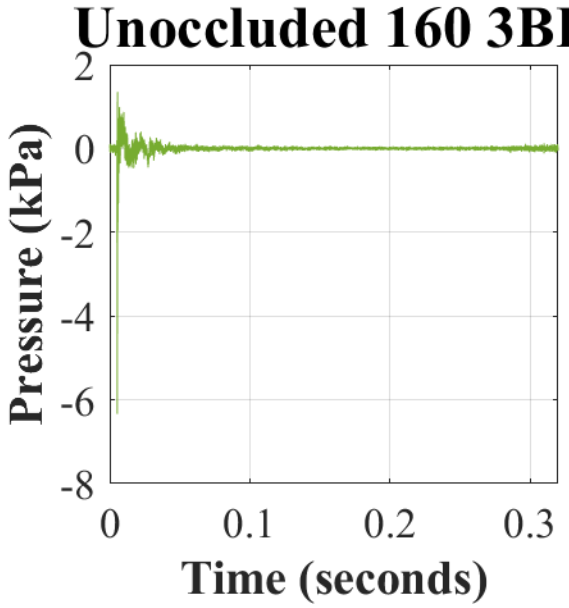

Unoccluded 160 2AR
Pressure (kPa)
5
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

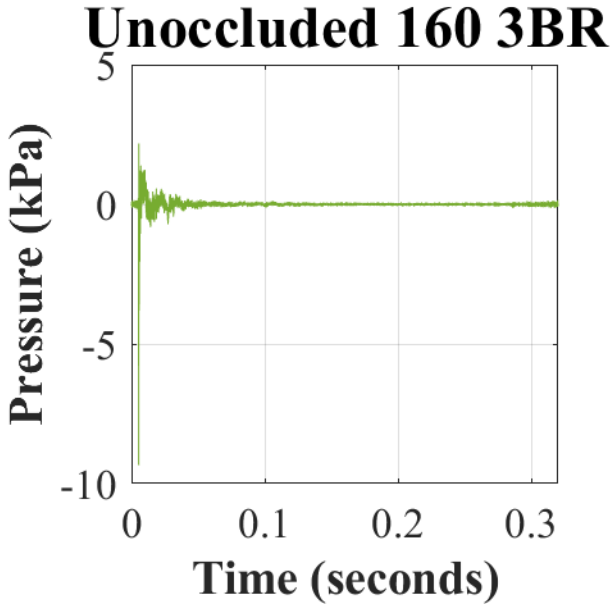

Unoccluded 160 2BL
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

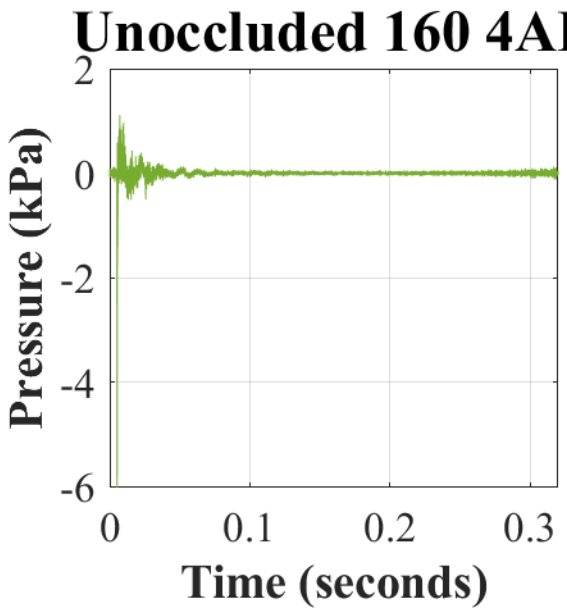

Unoccluded 160 2BR
Pressure (kPa)
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

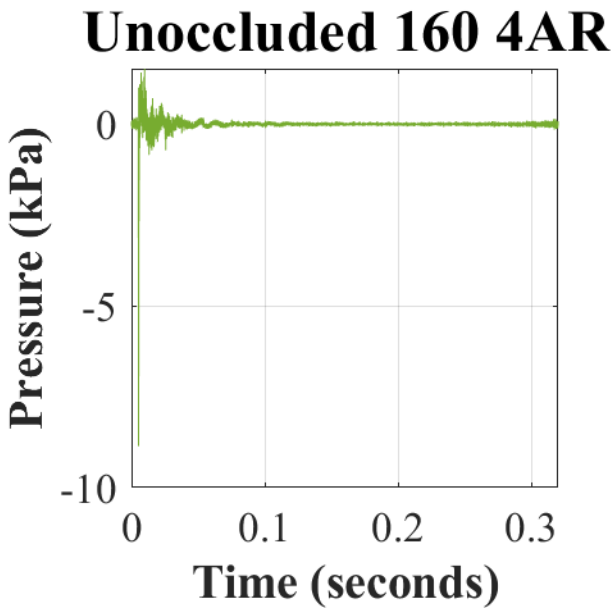

Unoccluded 160 3AL
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

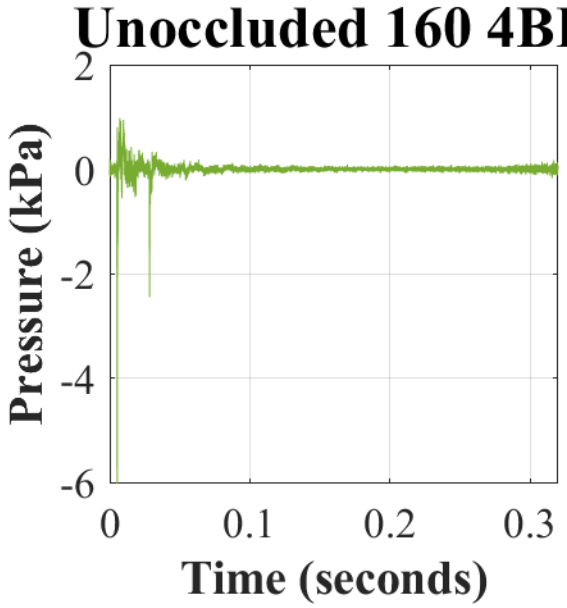

Unoccluded 160 3AR
Pressure (kPa)
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

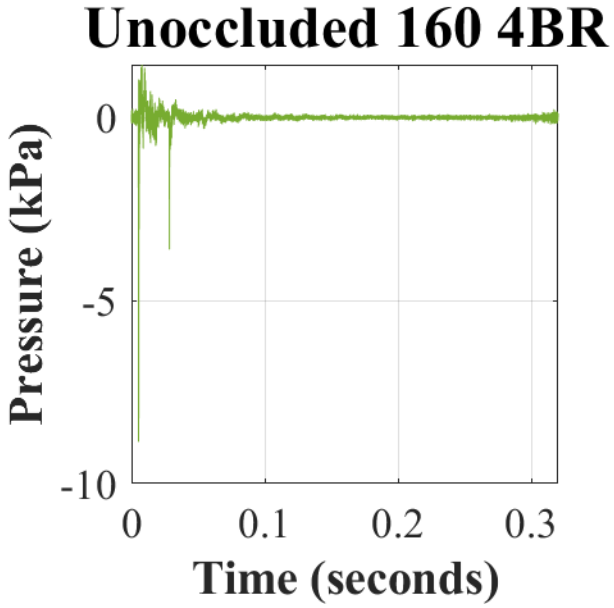

Unoccluded 160 3BL
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

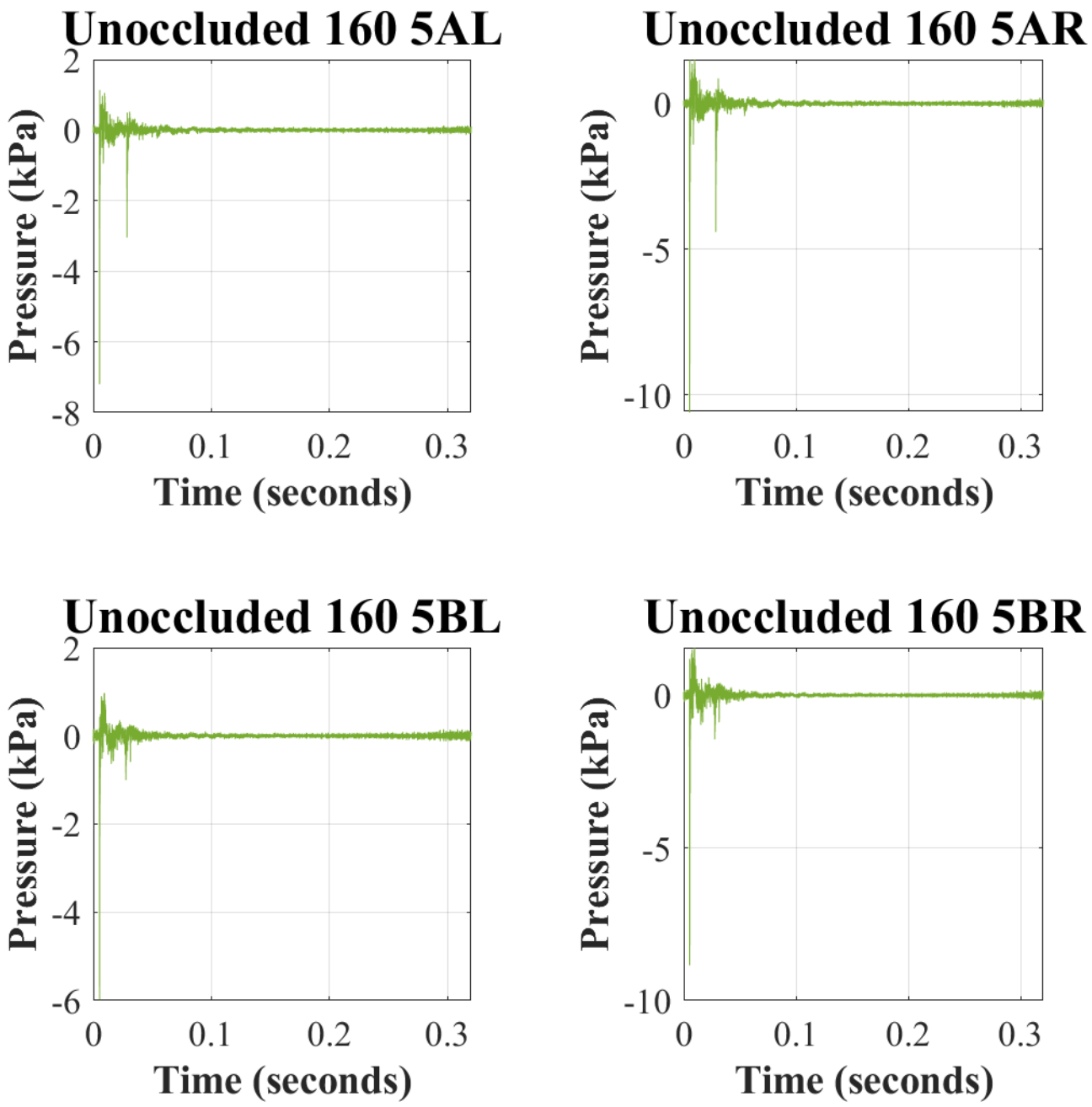

Unoccluded 160 3BR
Pressure (kPa)
5
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)


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


Unoccluded 160 4AR
Pressure (kPa)
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

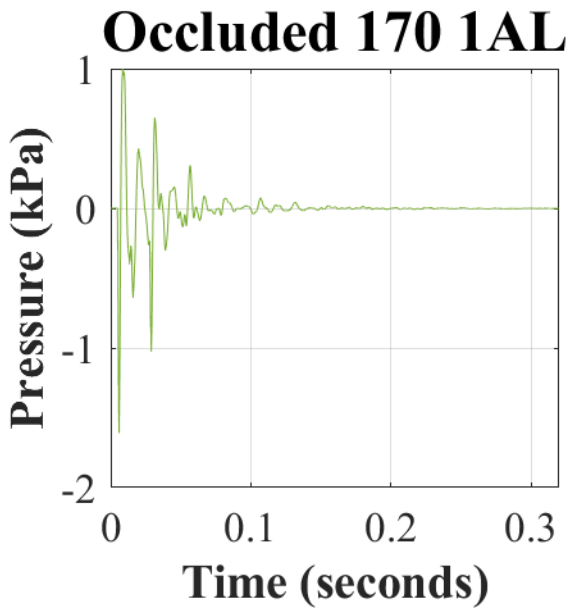

Unoccluded 160 4BL
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

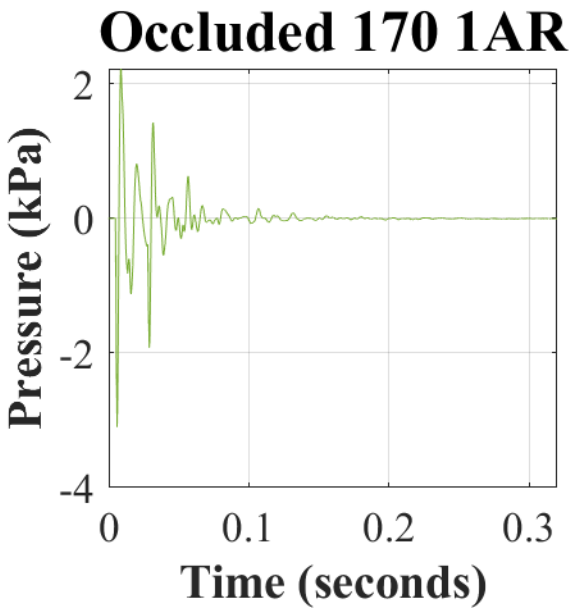

Unoccluded 160 4BR
Pressure (kPa)
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

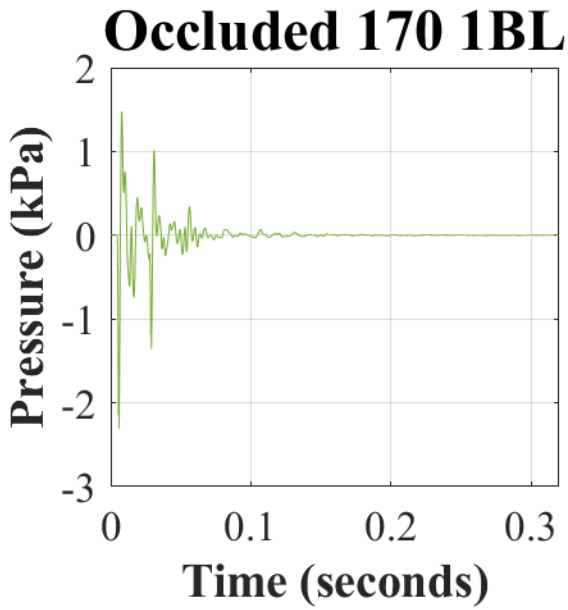


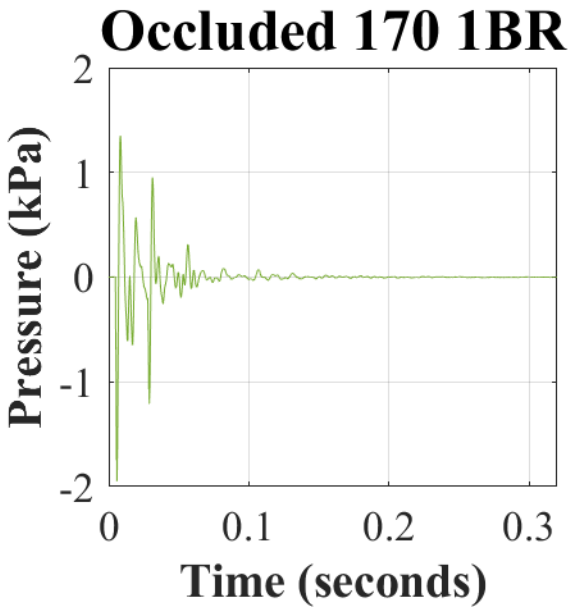
Note. The naming convention for all unoccluded waveforms is "Unoccluded LvL NnX", where 'Unoccluded' is the test condition (i.e., ATF has the HPD doffed), 'LvL' is the nominal test level (i.e., 150, 160 or 170 dBP), 'N' is the sample number (i.e., 1 to 5) of the device tested, 'n' is the trial (i.e., A or B) indicating HPD fit (i.e., first or second, respectively), and 'X' indicates from what ATF microphone the recording is from (i.e., right [R] or left [L] pinnae).

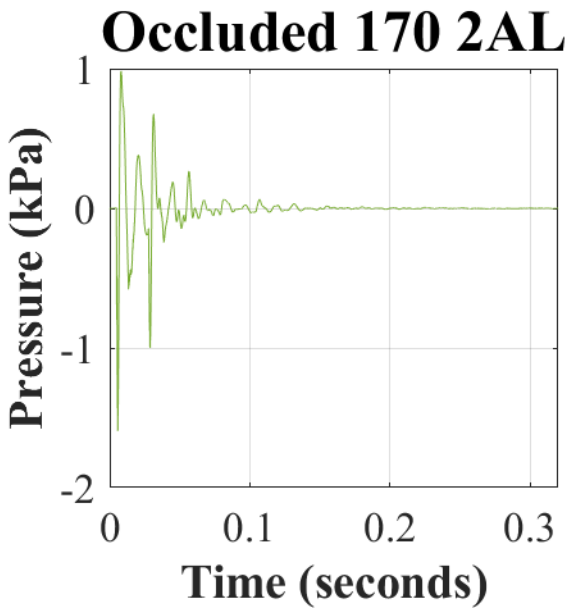
Appendix E. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 170 dBP with the ComTac™ V (OFF).

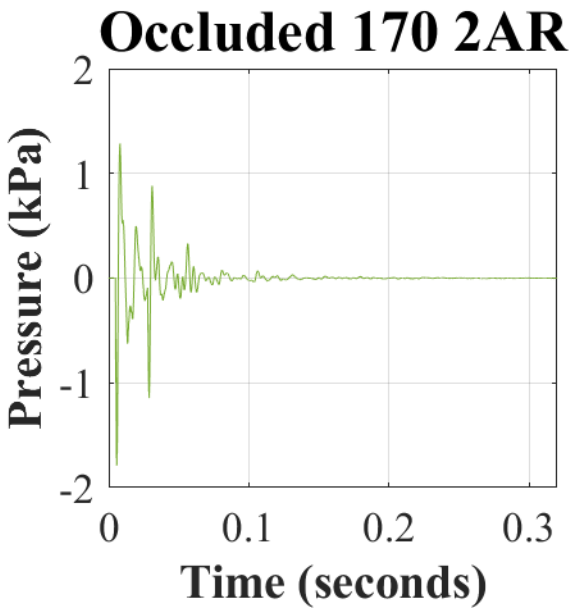


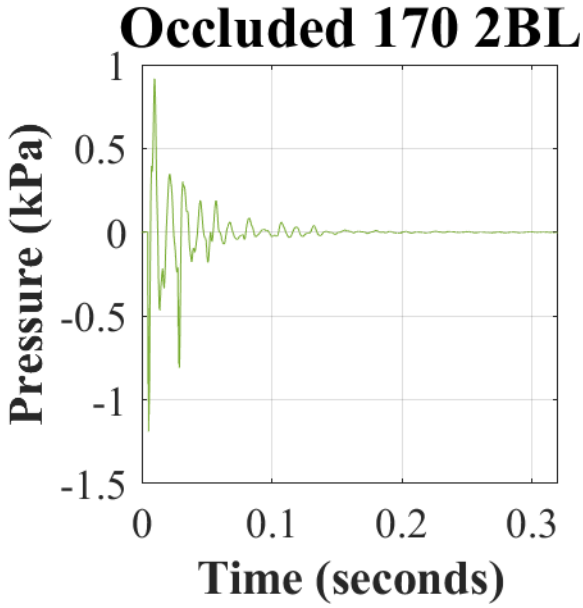


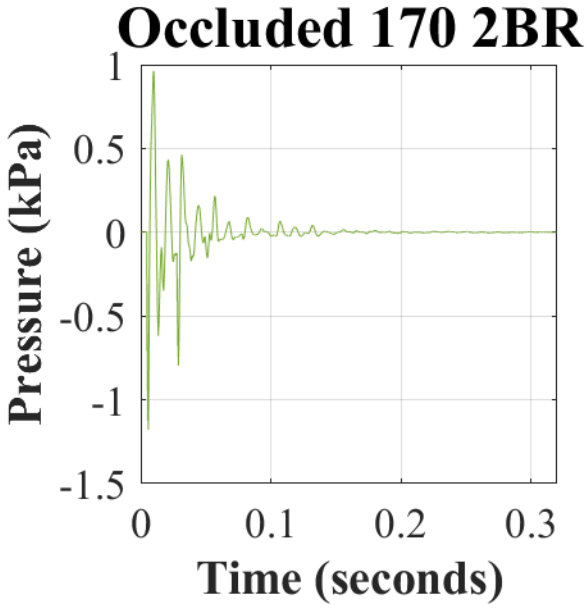


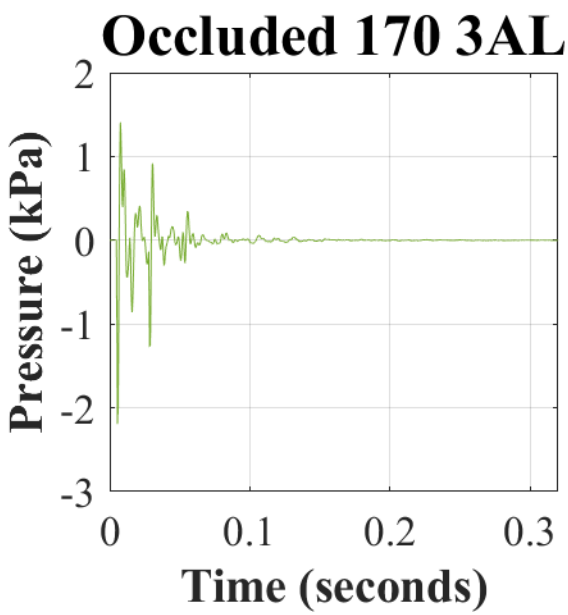


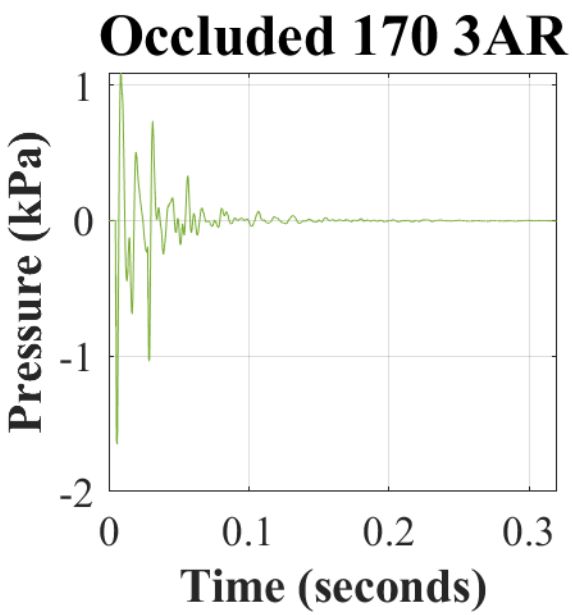

Occluded 170 2AL
Pressure (kPa)
Time (seconds)
1
0
-1
-2
0
0.1
0.2
0.3

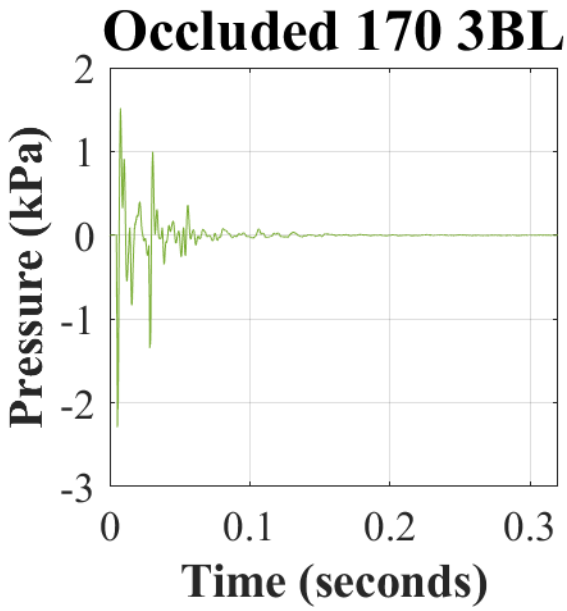

Occluded 170 2AR
Pressure (kPa)
Time (seconds)
2
1
0
-1
-2
0
0.1
0.2
0.3

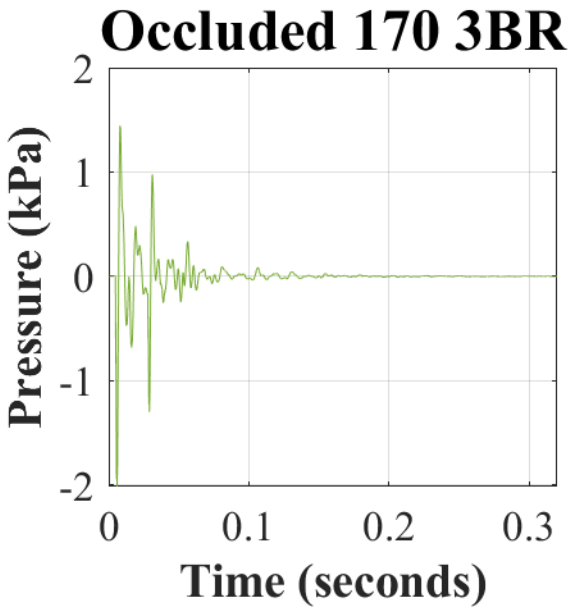

Occluded 170 2BL
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3

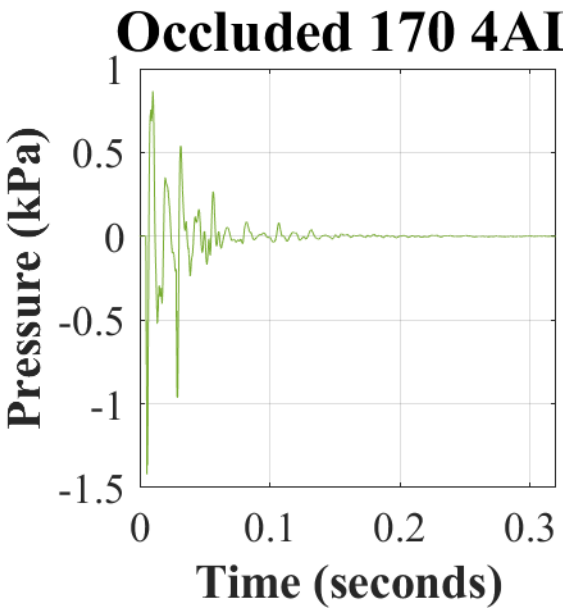

Occluded 170 2BR
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3

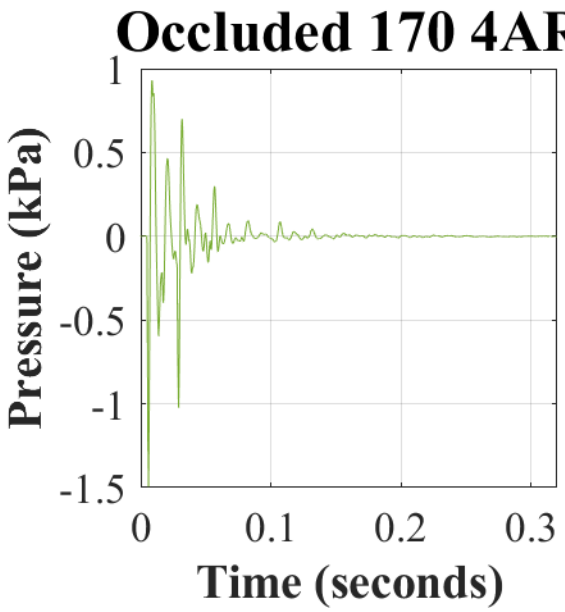

Occluded 170 3AL
Pressure (kPa)
Time (seconds)
2
1
0
-1
-2
-3
0
0.1
0.2
0.3

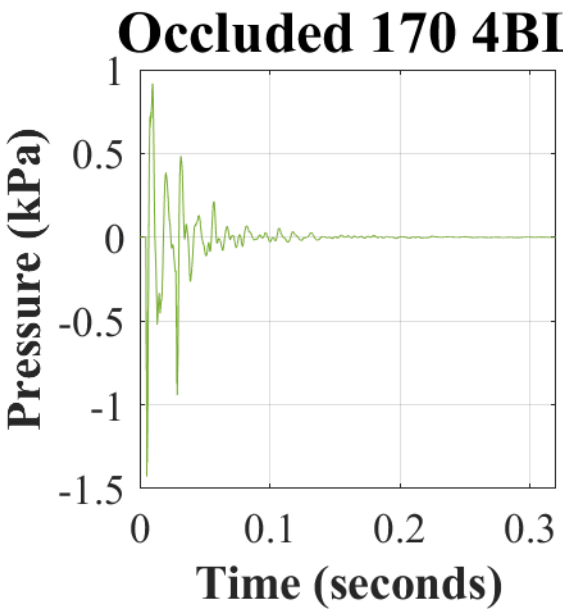

Occluded 170 3AR
Pressure (kPa)
Time (seconds)
1
0
-1
-2
0
0.1
0.2
0.3

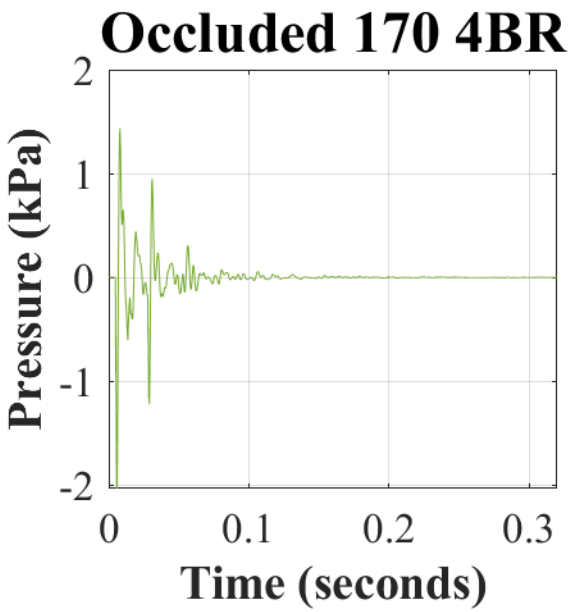

Occluded 170 3BL
Pressure (kPa)
Time (seconds)
2
1
0
-1
-2
-3
0
0.1
0.2
0.3

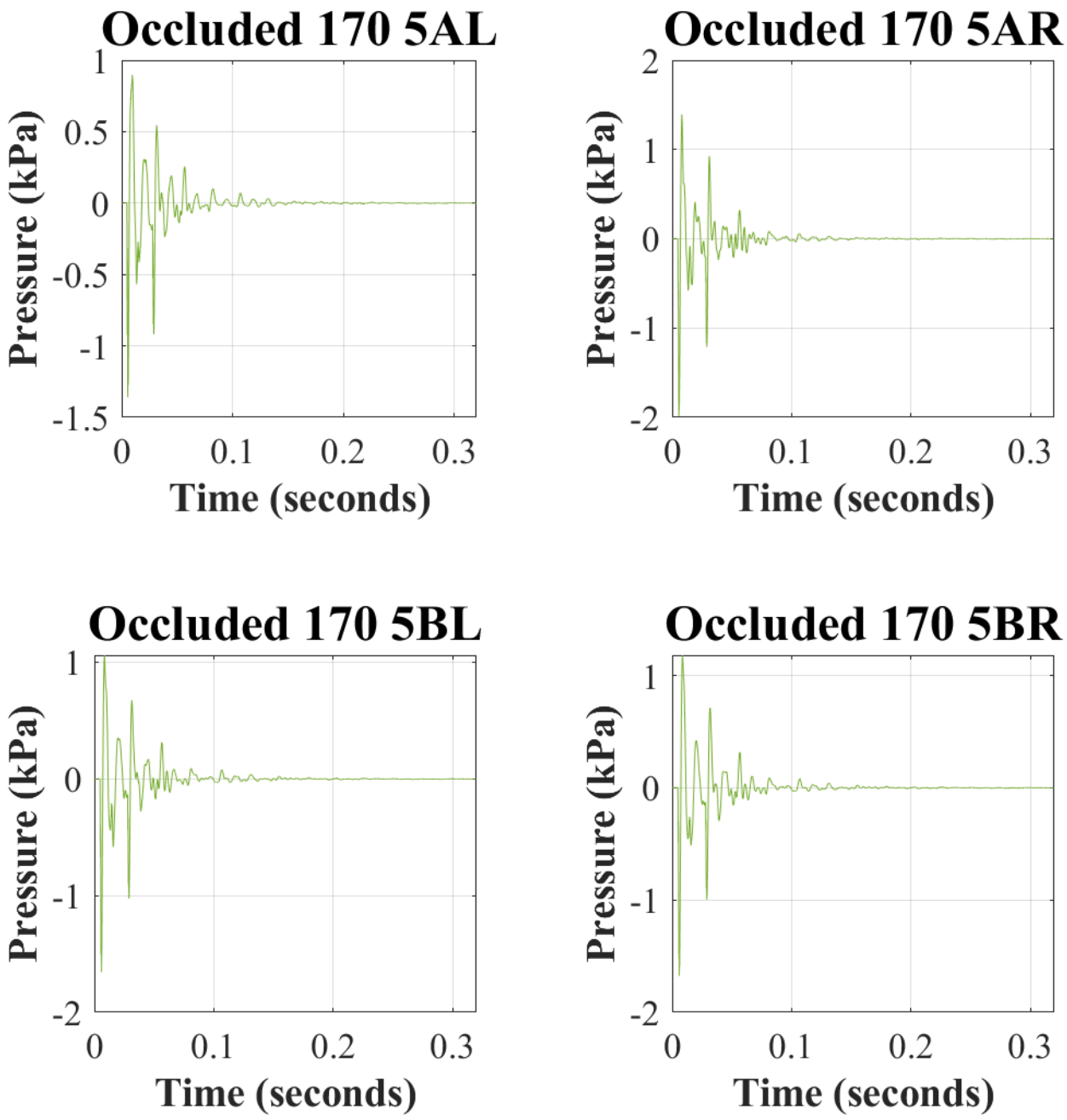

Occluded 170 3BR
Pressure (kPa)
Time (seconds)
2
1
0
-1
-2
0
0.1
0.2
0.3


Occluded 170 4AL
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3


Occluded 170 4AR
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3

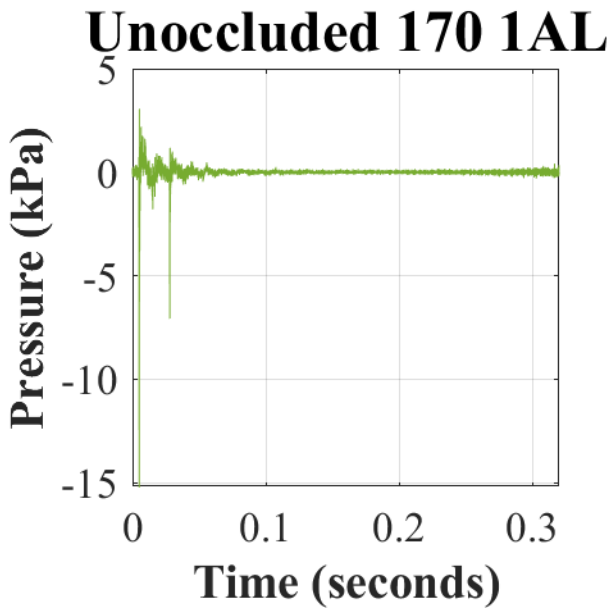

Occluded 170 4BL
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3

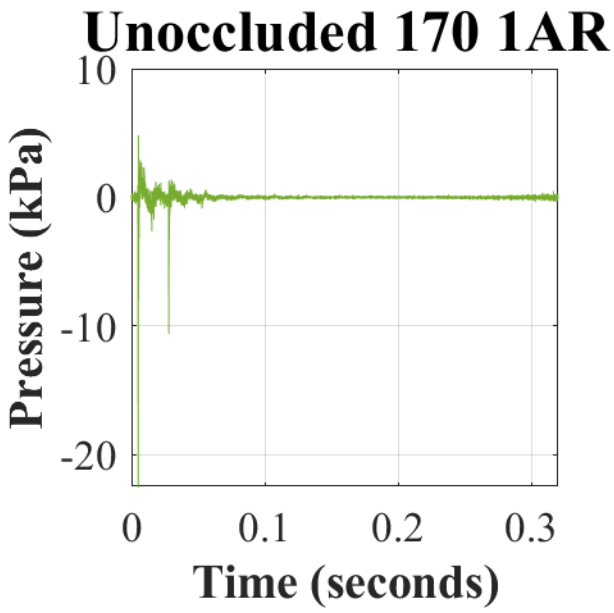

Occluded 170 4BR
Pressure (kPa)
Time (seconds)
2
1
0
-1
-2
0
0.1
0.2
0.3

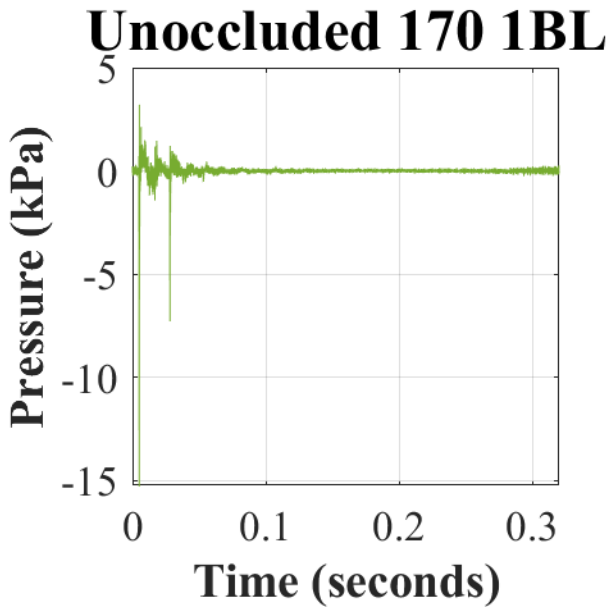


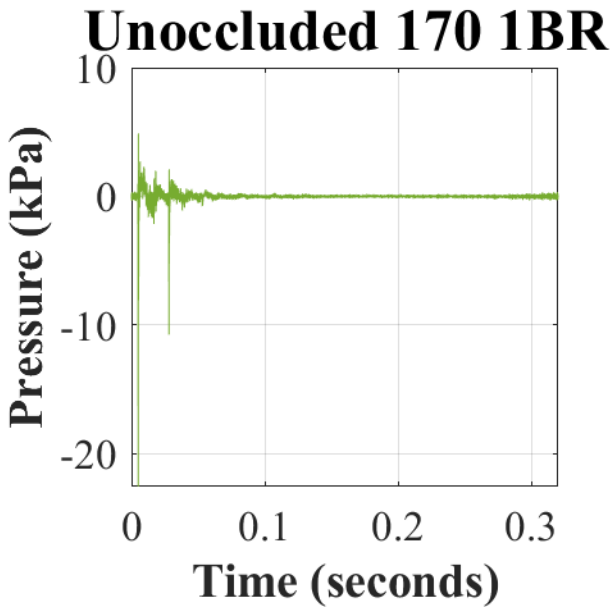
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating HPD fit (i.e., first or second, respectively), and ‘X’ indicates from what ATF microphone the recording is from (i.e., right [R] or left [L] pinnae).

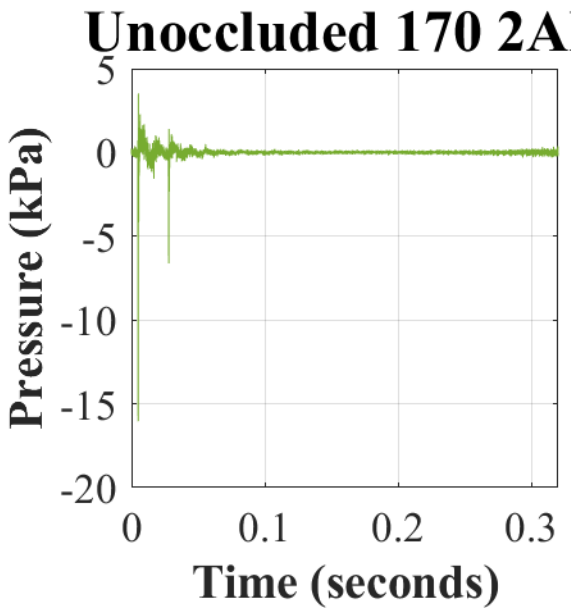
Appendix F. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 170 dBP with the ComTac™ V (OFF).

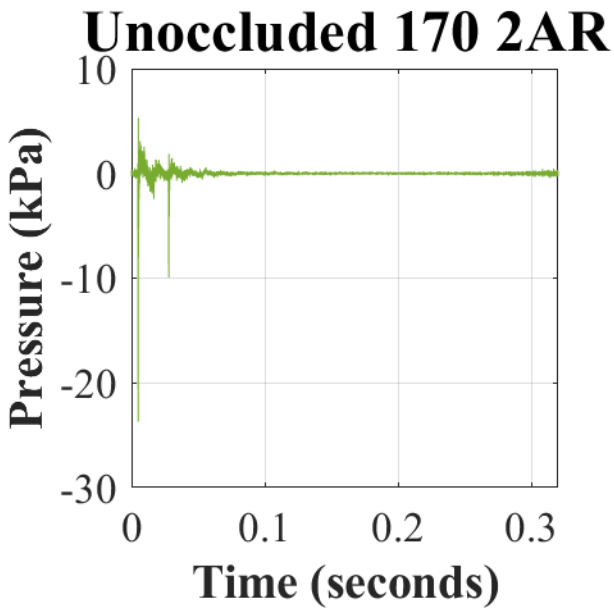


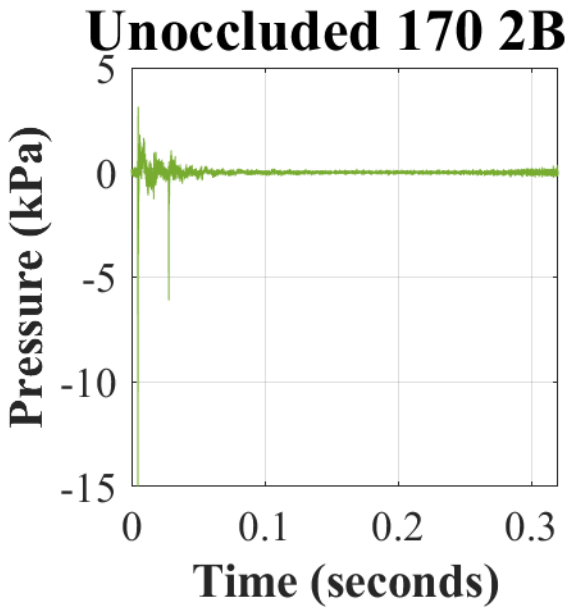


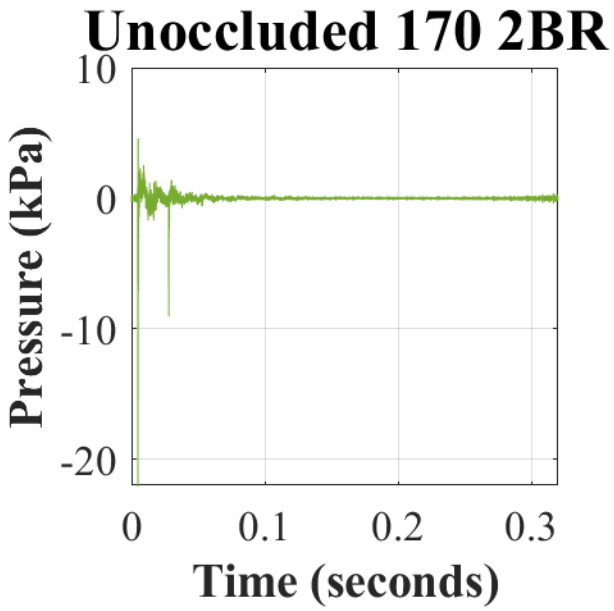


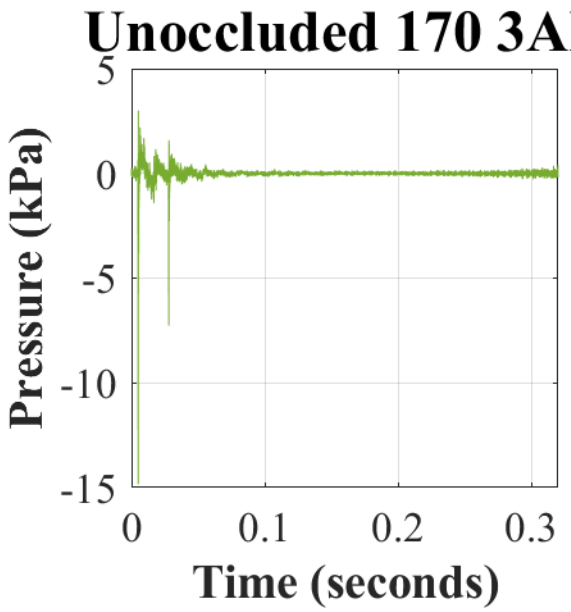


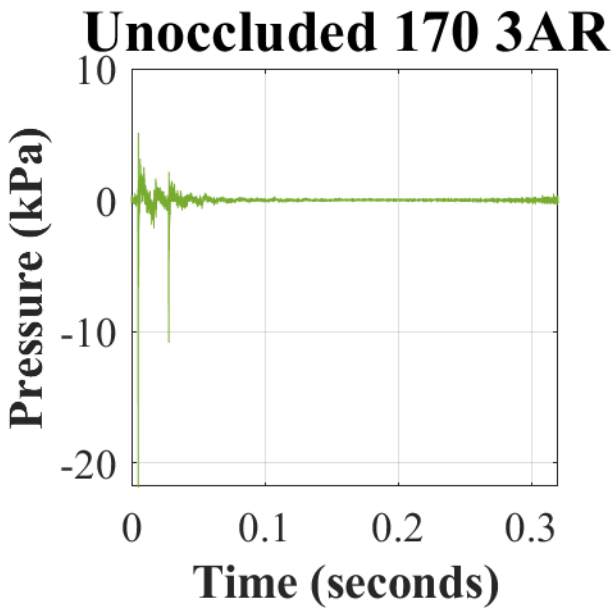

Unoccluded 170 2AL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

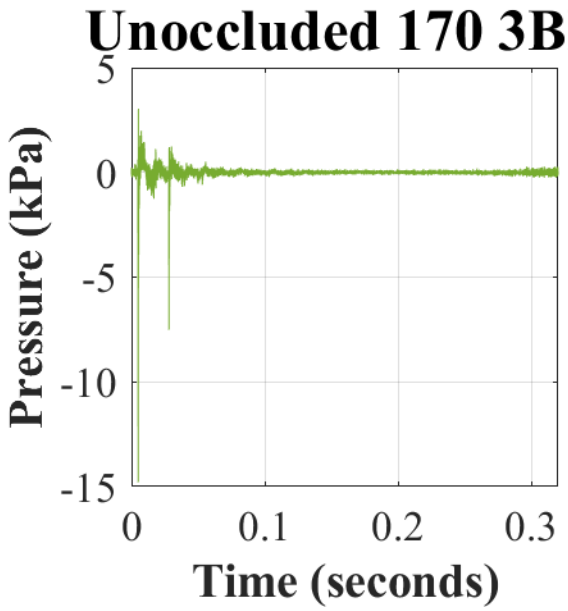

Unoccluded 170 2AR
Pressure (kPa)
10
0
-10
-20
-30
0
0.1
0.2
0.3
Time (seconds)

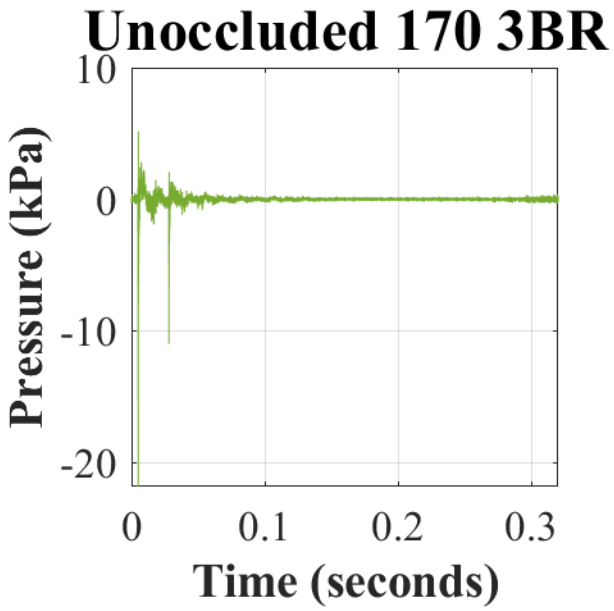

Unoccluded 170 2BL
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

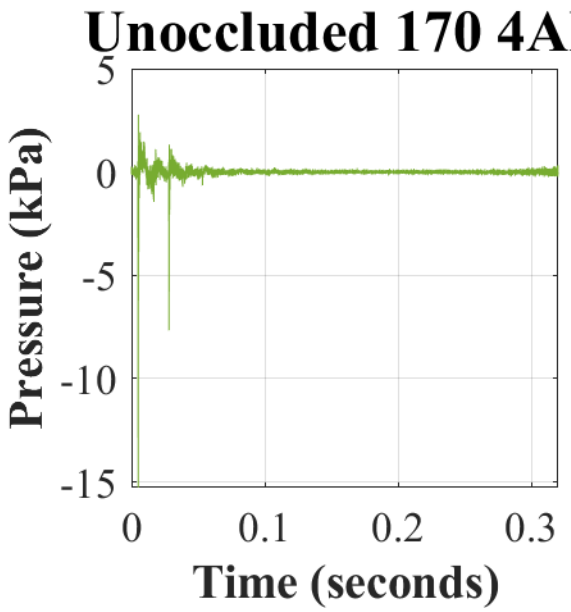

Unoccluded 170 2BR
Pressure (kPa)
10
0
-10
-20
0
0.1
0.2
0.3
Time (seconds)

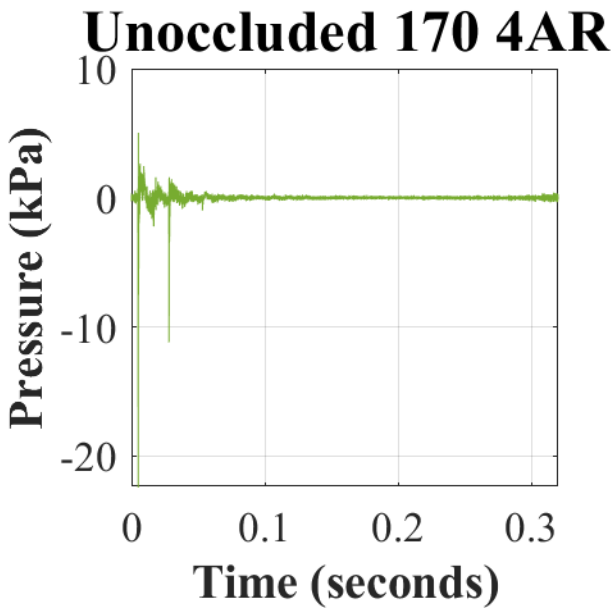

Unoccluded 170 3AL
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

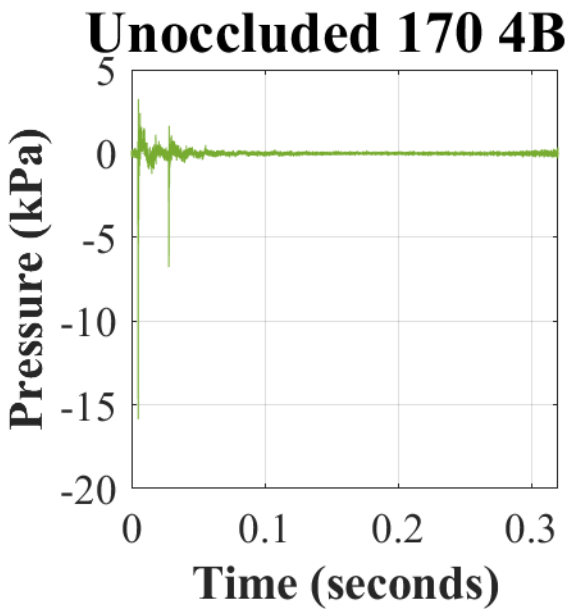

Unoccluded 170 3AR
Pressure (kPa)
10
0
-10
-20
0
0.1
0.2
0.3
Time (seconds)

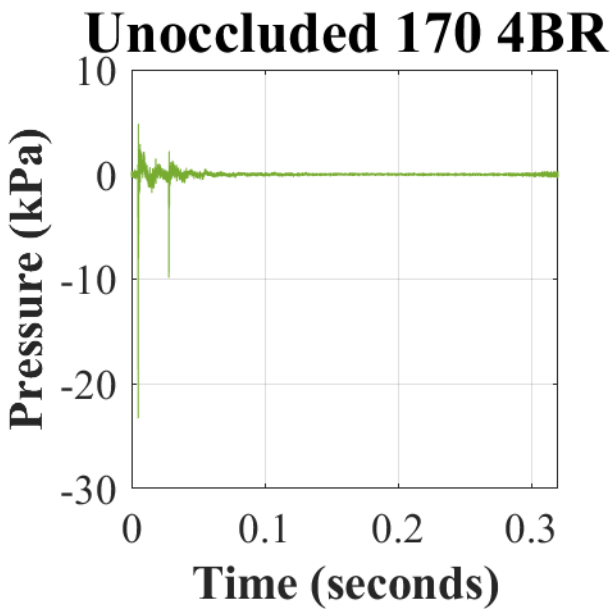

Unoccluded 170 3BL
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

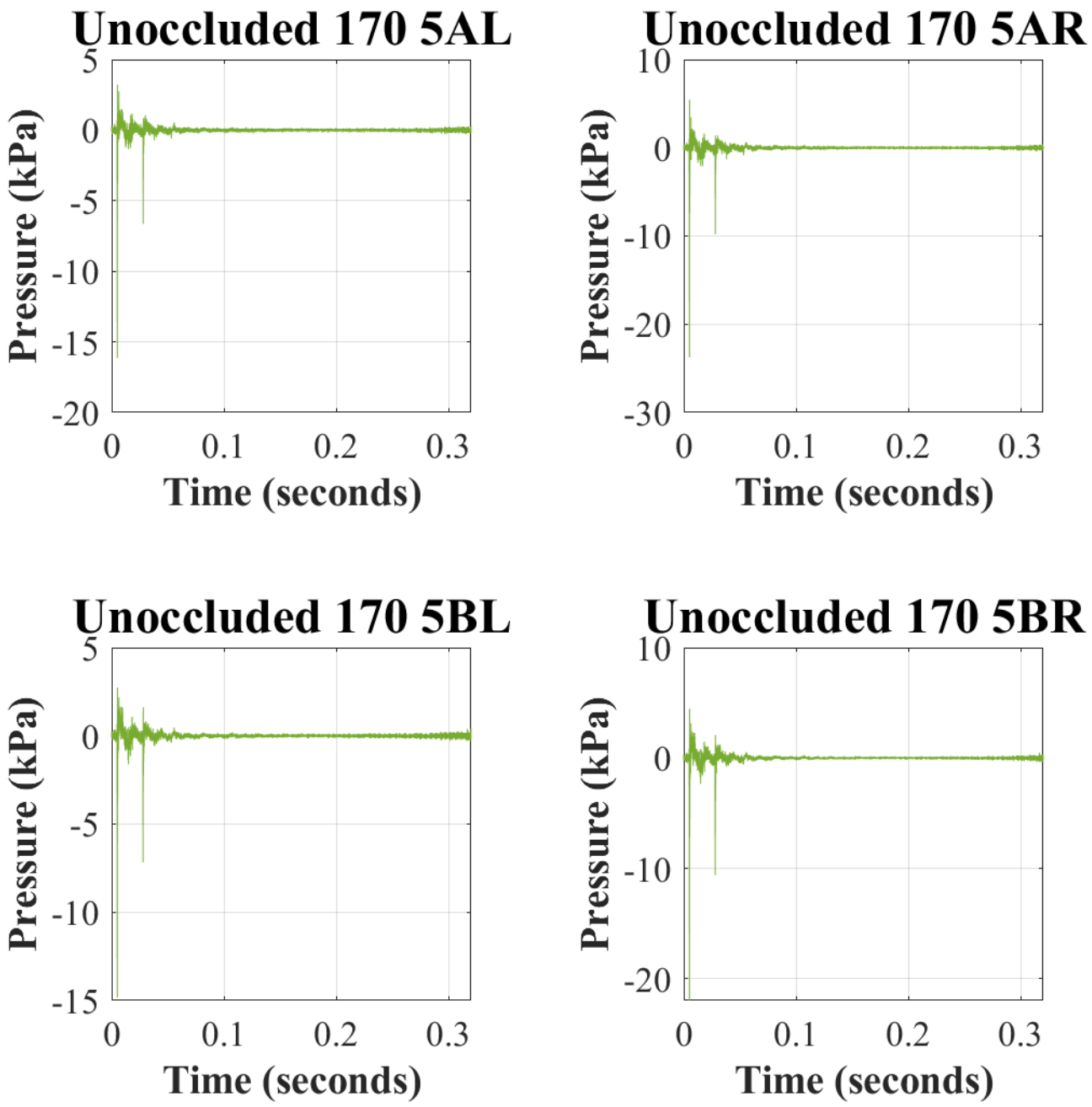

Unoccluded 170 3BR
Pressure (kPa)
10
0
-10
-20
0
0.1
0.2
0.3
Time (seconds)


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


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

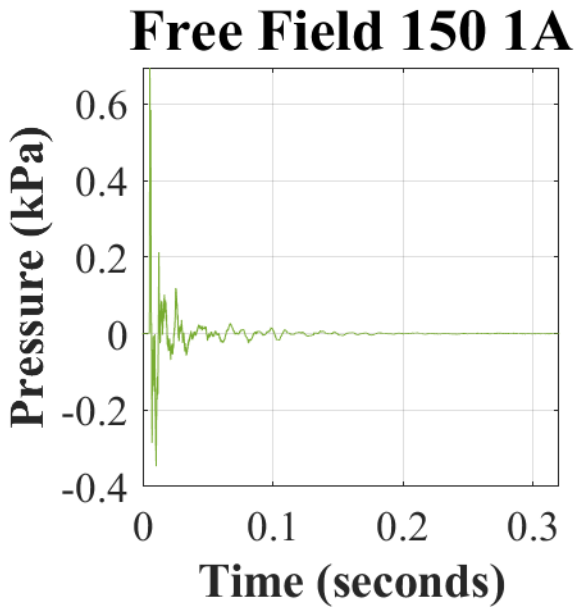

Unoccluded 170 4BL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

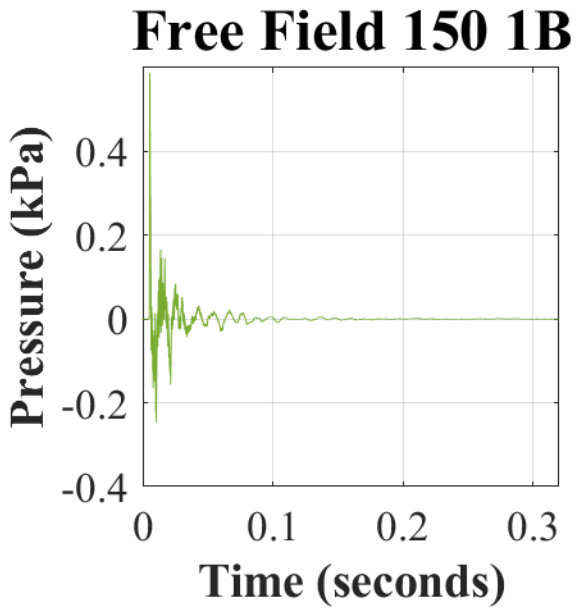

Unoccluded 170 4BR
Pressure (kPa)
10
0
-10
-20
-30
0
0.1
0.2
0.3
Time (seconds)

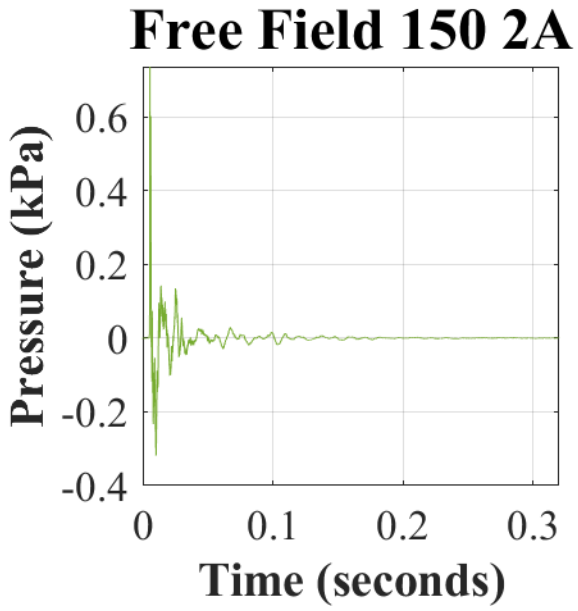


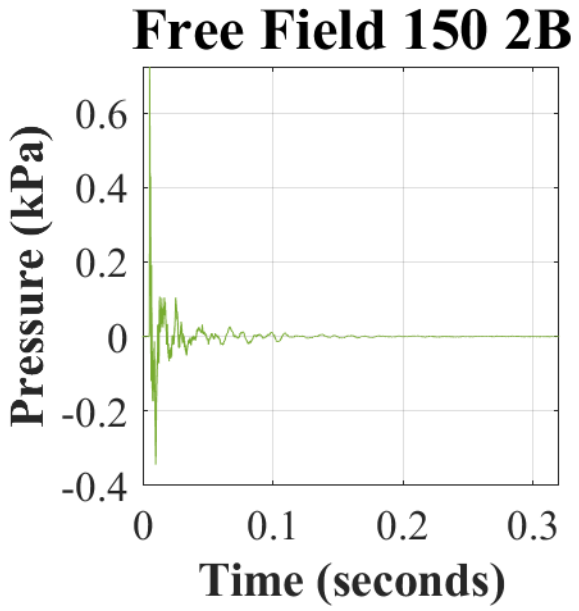
Note. The naming convention for all unoccluded waveforms is "Unoccluded LvL NnX", where 'Unoccluded' is the test condition (i.e., ATF has the HPD doffed), 'LvL' is the nominal test level (i.e., 150, 160 or 170 dBP), 'N' is the sample number (i.e., 1 to 5) of the device tested, 'n' is the trial (i.e., A or B) indicating HPD fit (i.e., first or second, respectively), and 'X' indicates from what ATF microphone the recording is from (i.e., right [R] or left [L] pinnae).

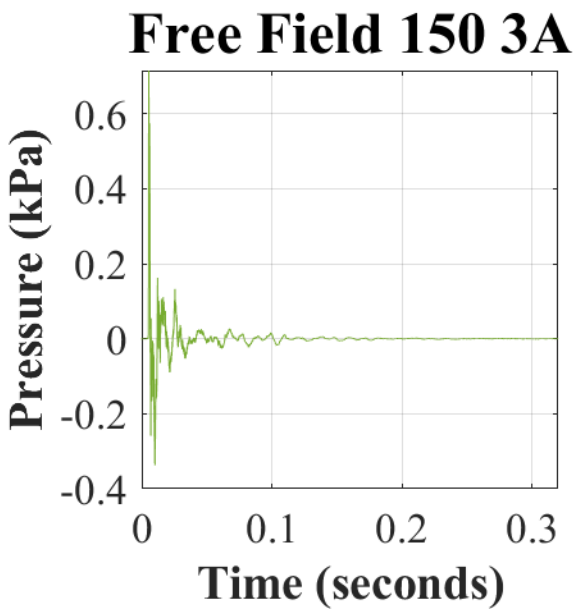
Appendix G. Recorded waveform (in kilopascals [kPa]) over time (in seconds [s]) of the impulse measured with the free-field probe at 150 dBP and the ComTac™ V (OFF) donned.

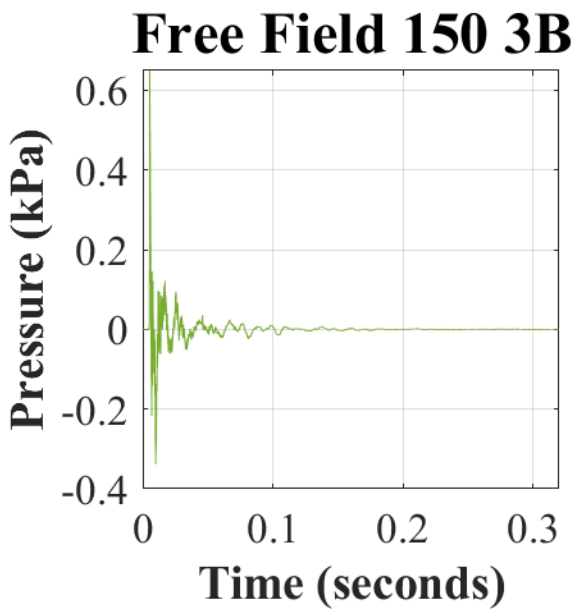


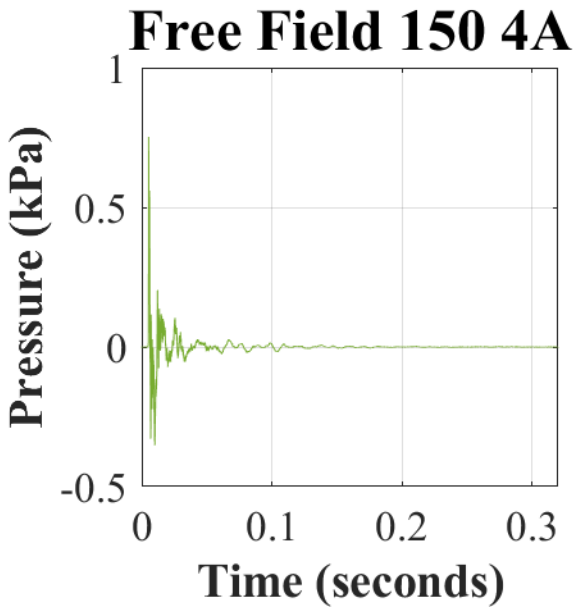


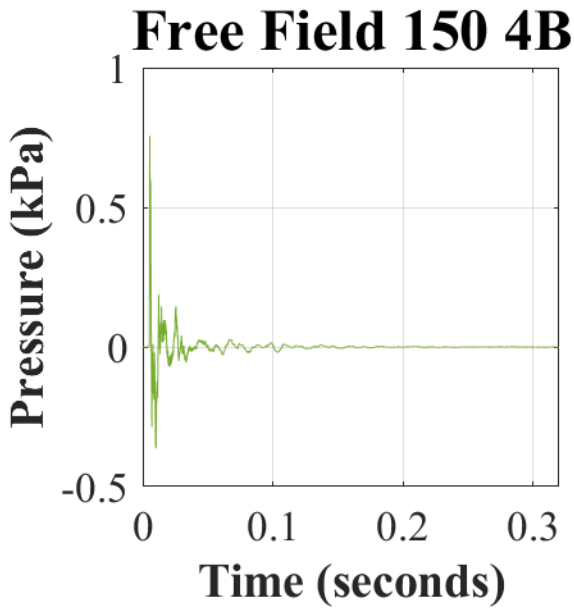


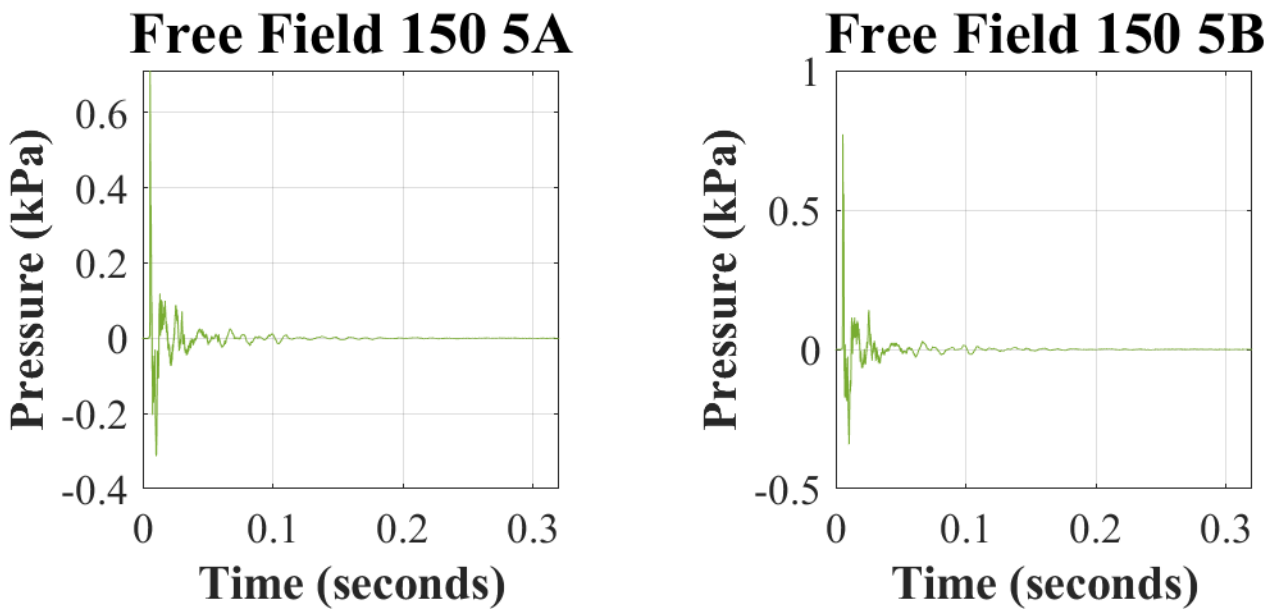



Free Field 150 3A
Pressure (kPa)
0.6
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)


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

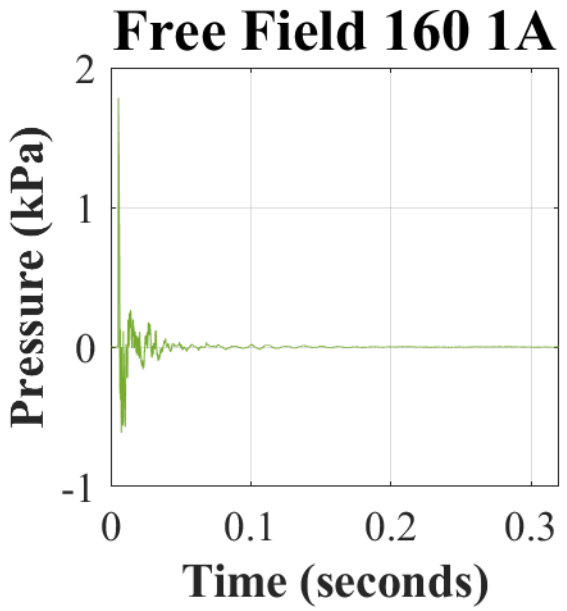

Free Field 150 4A
Pressure (kPa)
1
0.5
0
-0.5
0
0.1
0.2
0.3
Time (seconds)

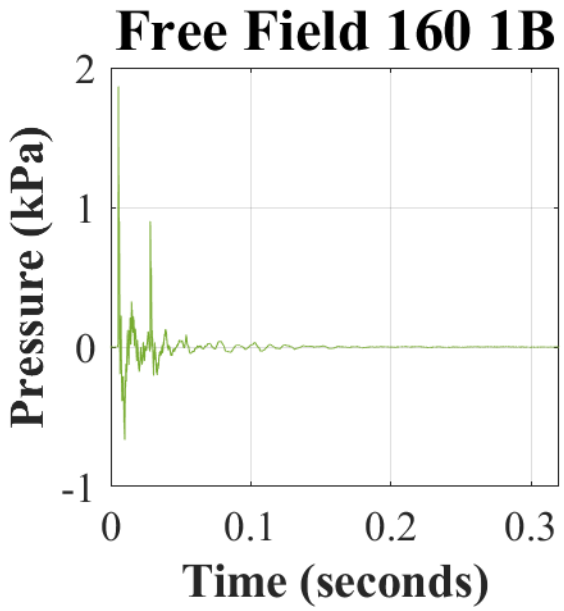

Free Field 150 4B
Pressure (kPa)
1
0.5
0
-0.5
0
0.1
0.2
0.3
Time (seconds)

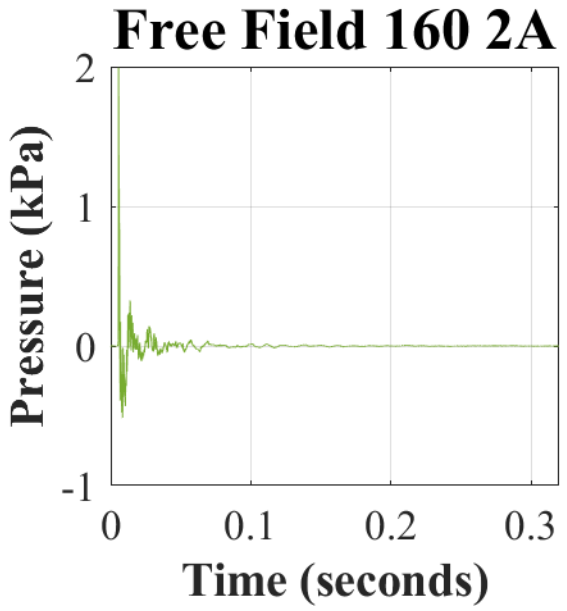


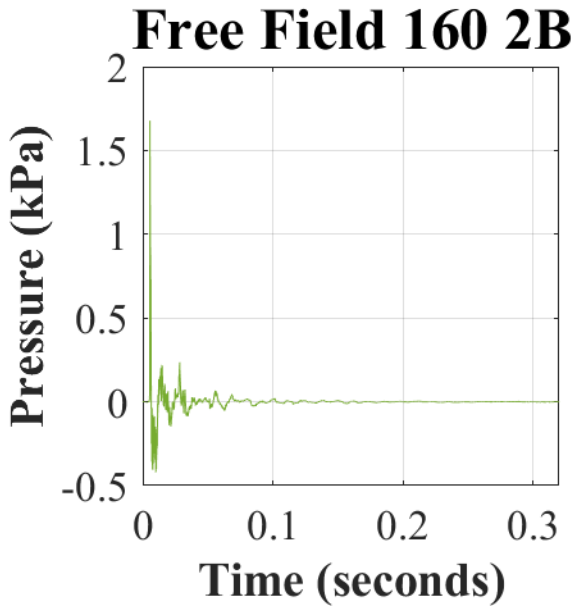
Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (150 dBP), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

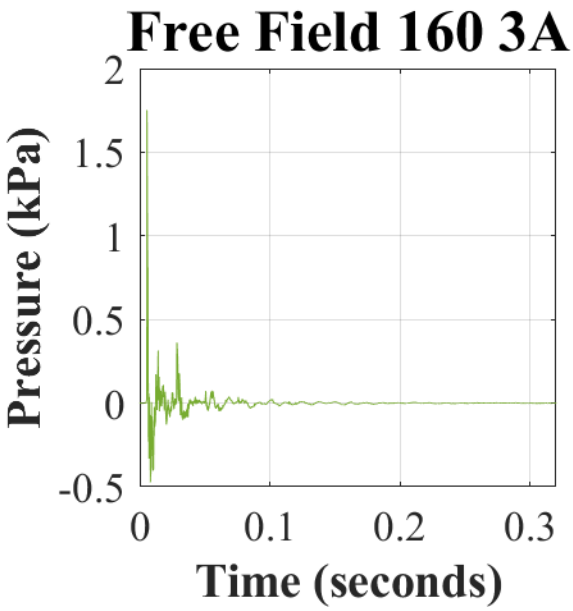
Appendix H. Recorded waveform (in kilopascals [kPa]) over time (in seconds [s]) of the impulse measured with the free-field probe at 160 dBP and the ComTac™ V (OFF) donned.

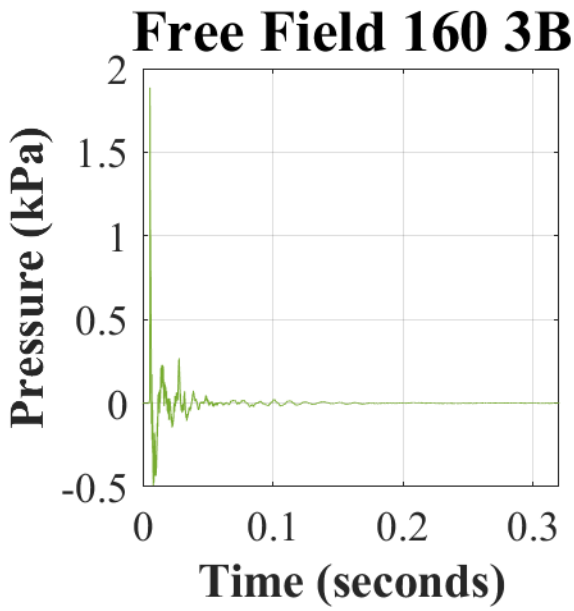


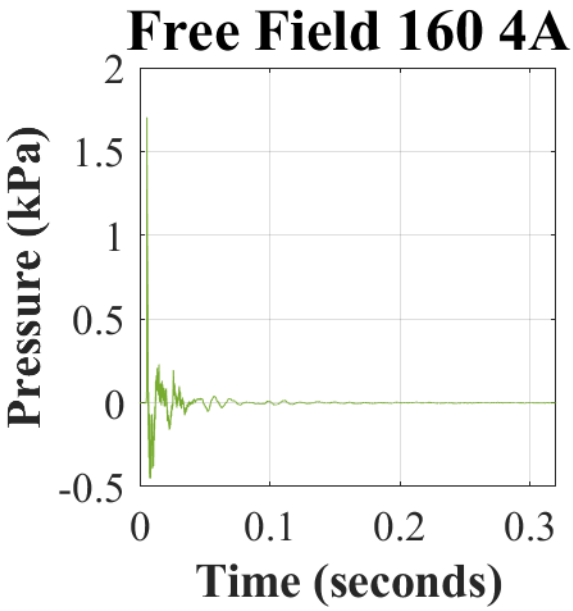


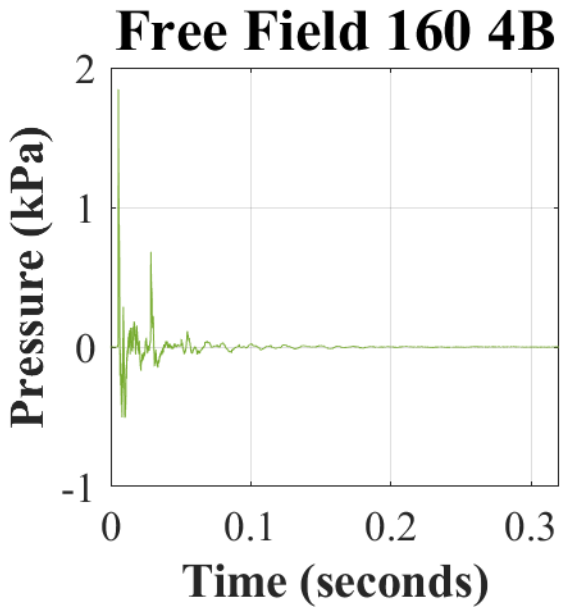


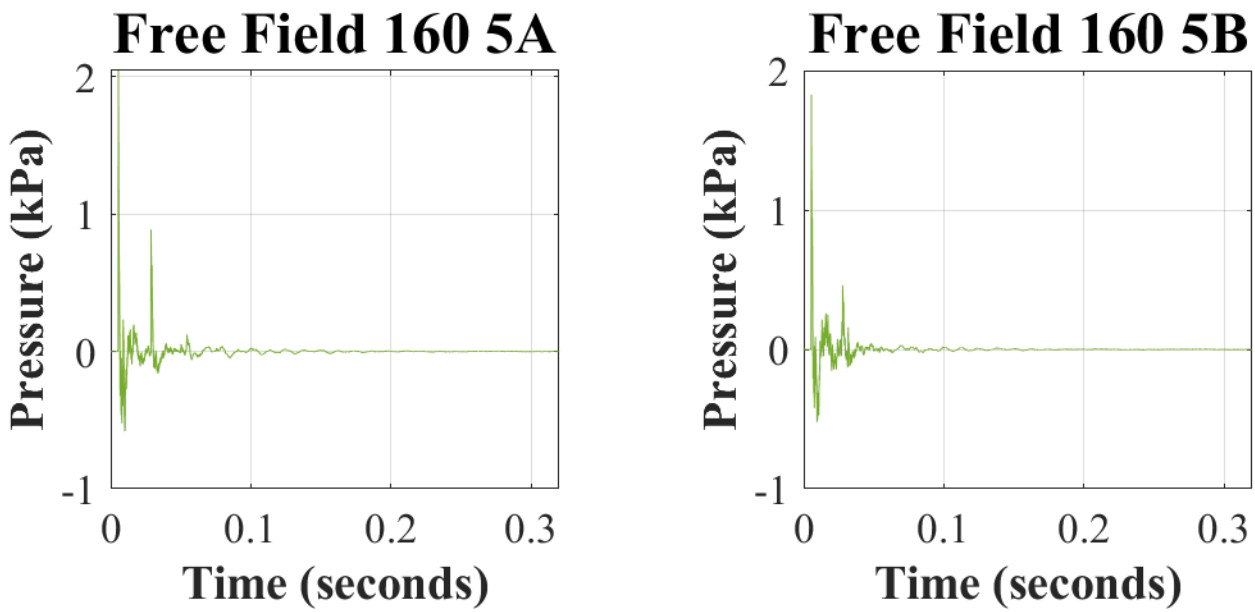



Free Field 160 3A
Pressure (kPa)
Time (seconds)
2
1.5
1
0.5
0
-0.5
0
0.1
0.2
0.3


Free Field 160 3B
Pressure (kPa)
Time (seconds)
2
1.5
1
0.5
0
-0.5
0
0.1
0.2
0.3

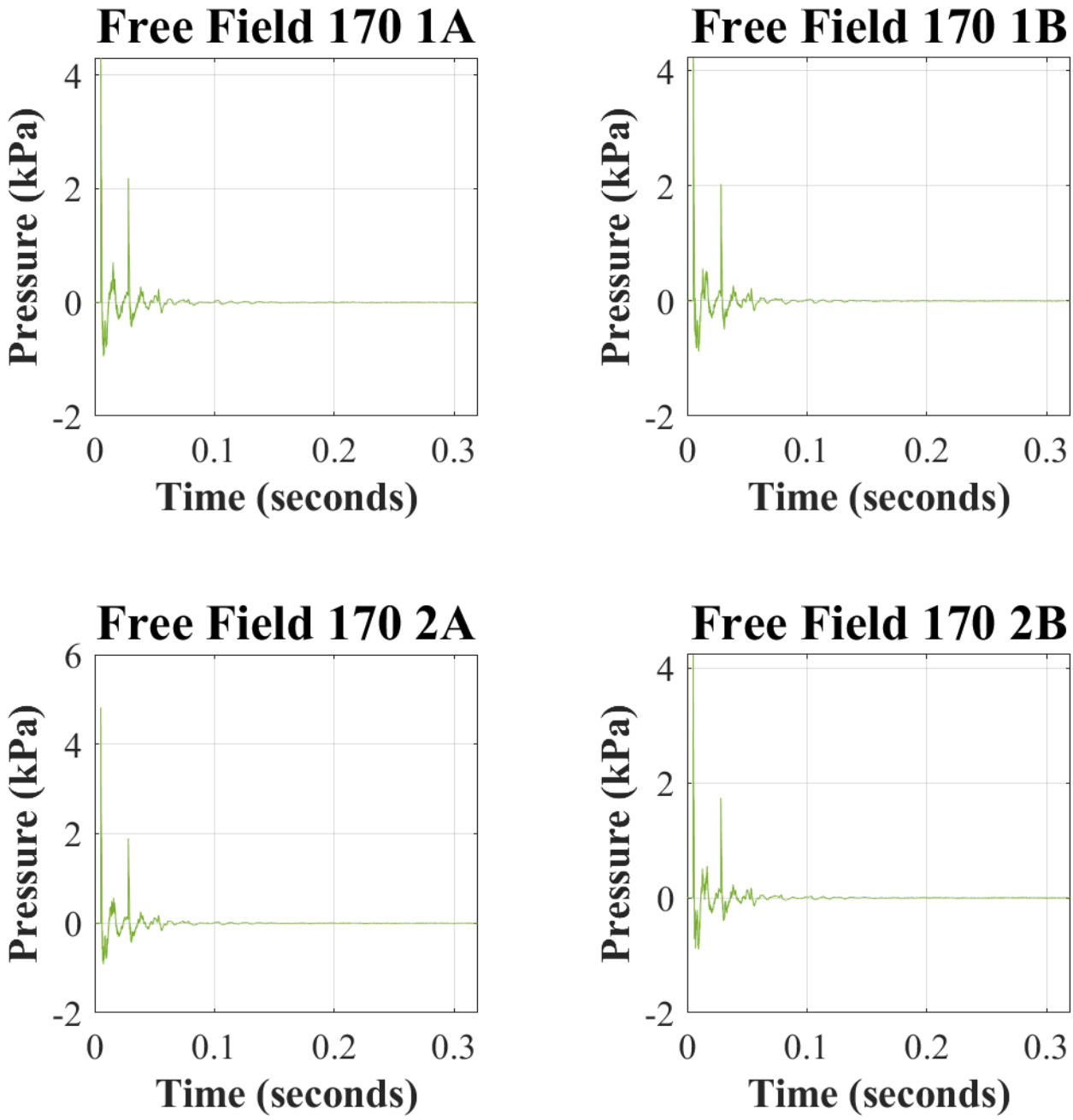

Free Field 160 4A
Pressure (kPa)
Time (seconds)
2
1.5
1
0.5
0
-0.5
0
0.1
0.2
0.3

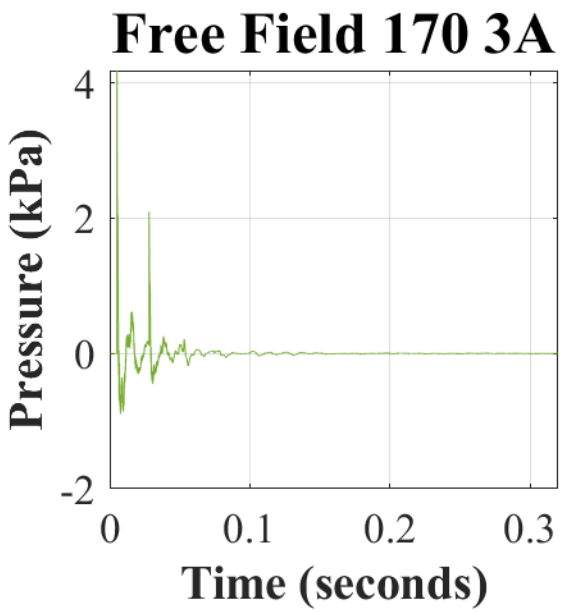

Free Field 160 4B
Pressure (kPa)
Time (seconds)
2
1
0
-1
0
0.1
0.2
0.3

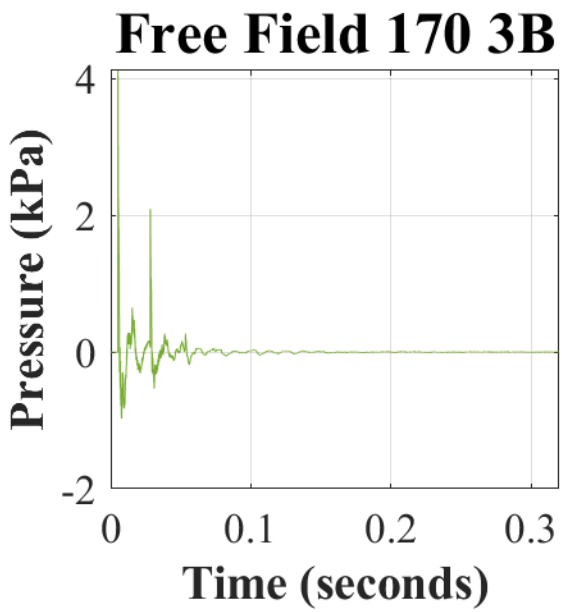


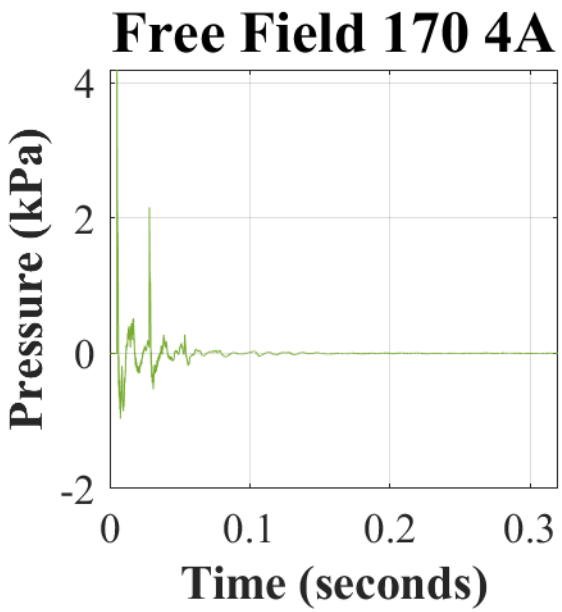
Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (160 dBP), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

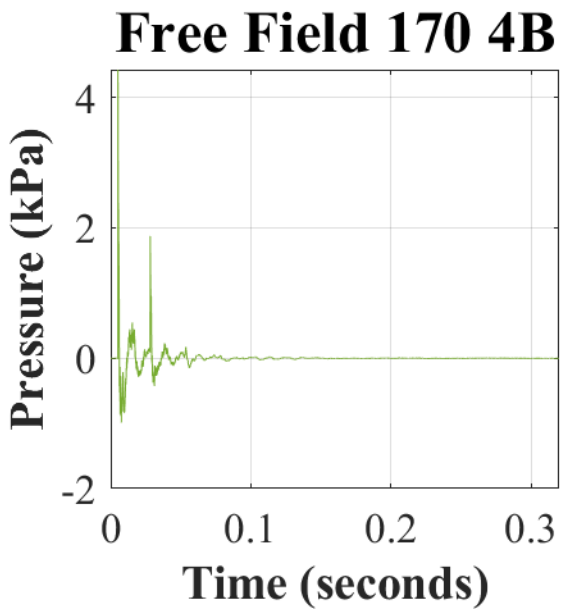
Appendix I. Recorded waveform (in kilopascals [kPa]) over time (in seconds [s]) of the impulse measured with the free-field probe at 170 dBP and the ComTac™ V (OFF) donned.

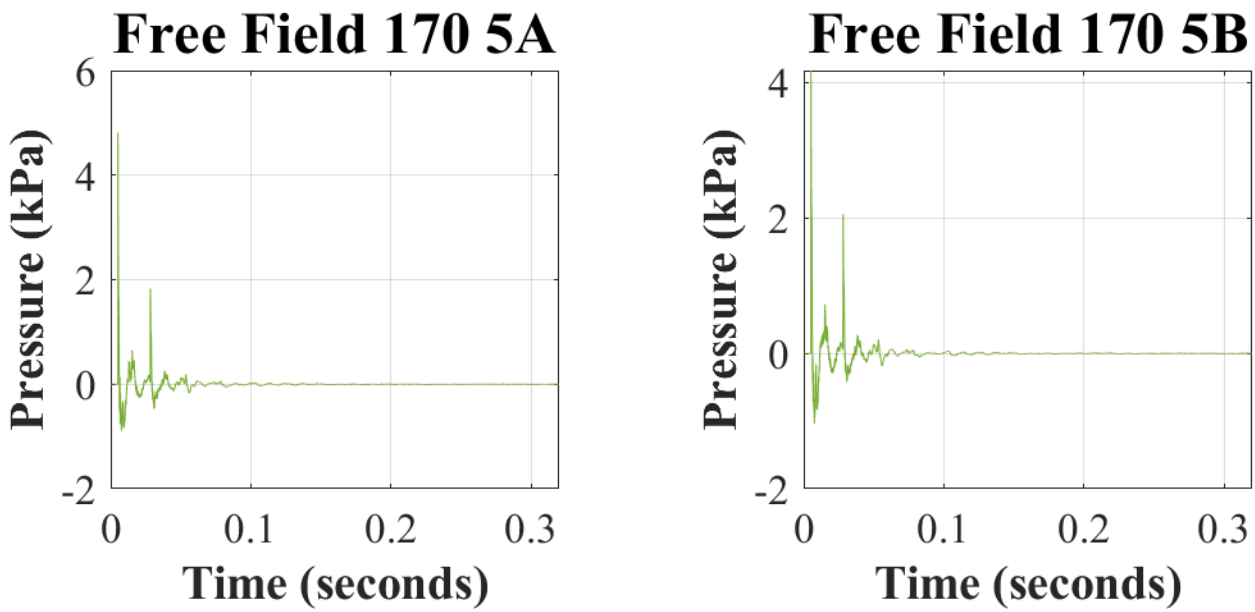



Free Field 170 3A
Pressure (kPa)
4
2
0
-2
0
0.1
0.2
0.3
Time (seconds)


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

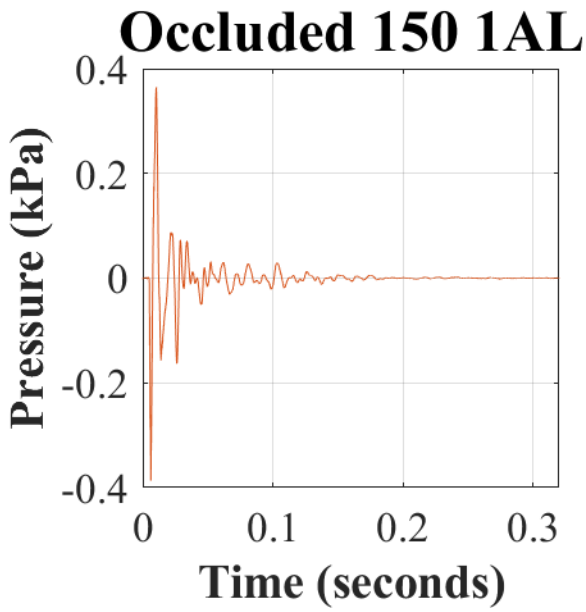

Free Field 170 4A
Pressure (kPa)
4
2
0
-2
0
0.1
0.2
0.3
Time (seconds)

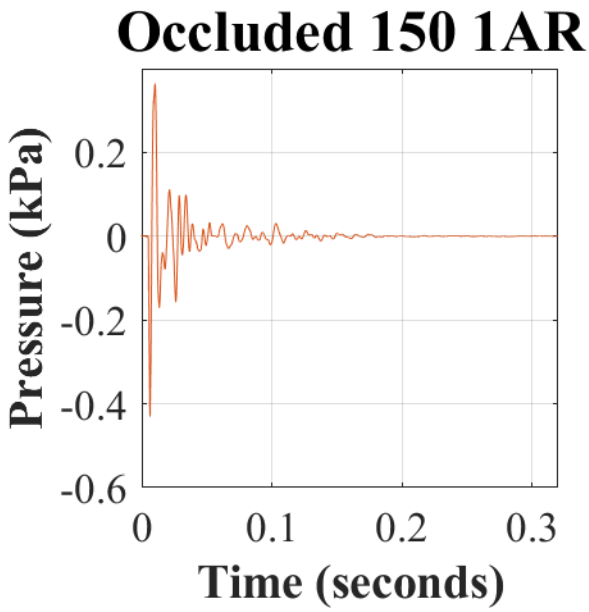

Free Field 170 4B
Pressure (kPa)
4
2
0
-2
0
0.1
0.2
0.3
Time (seconds)

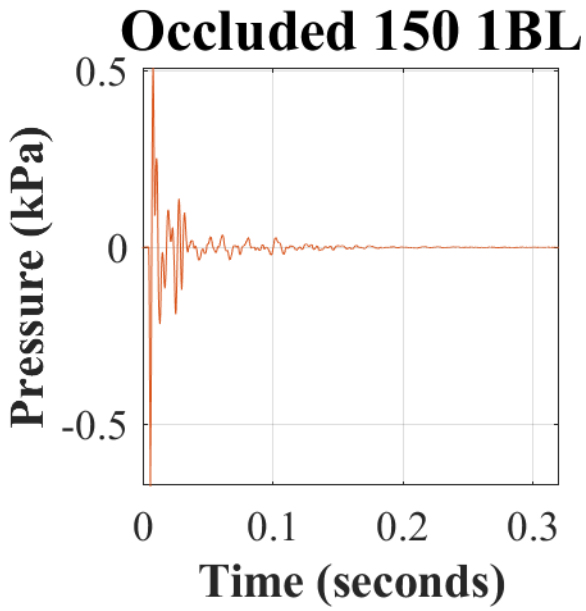


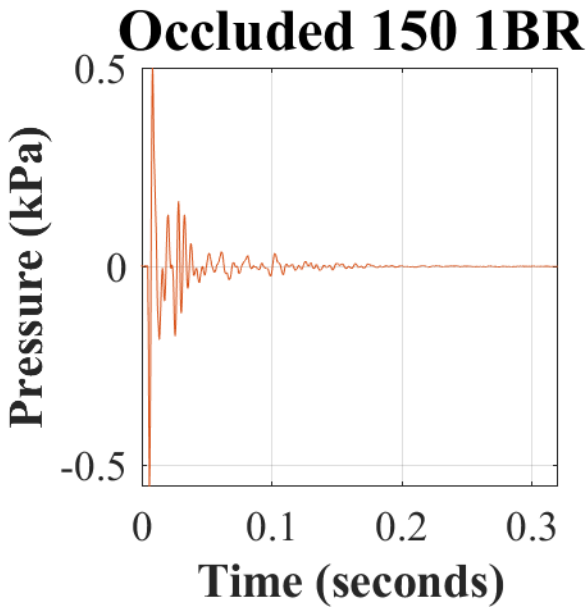
Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (170 dBP), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

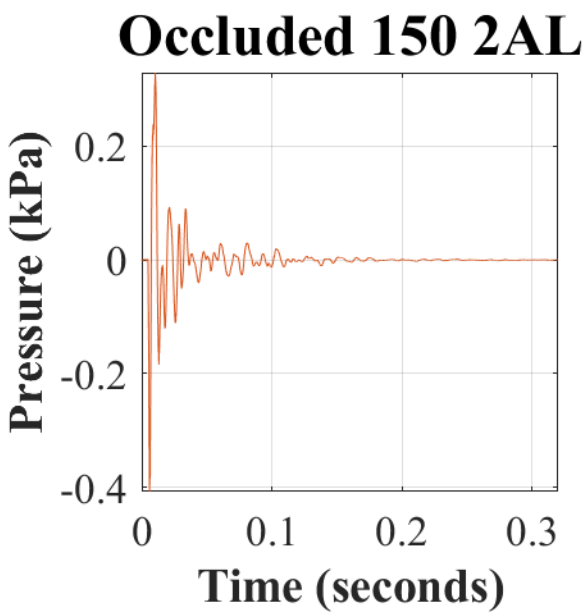
Appendix J. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 150 dBP with the ComTac™ V (MAX).

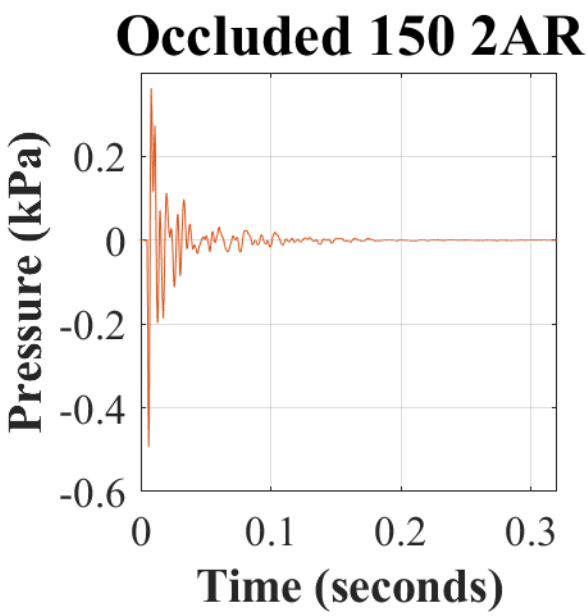


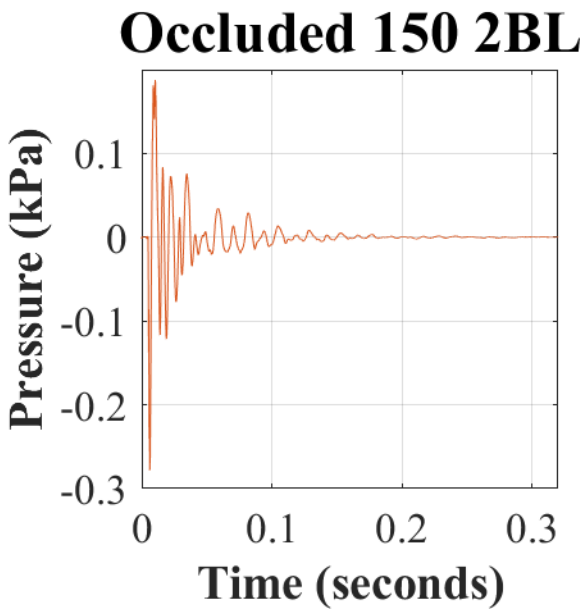


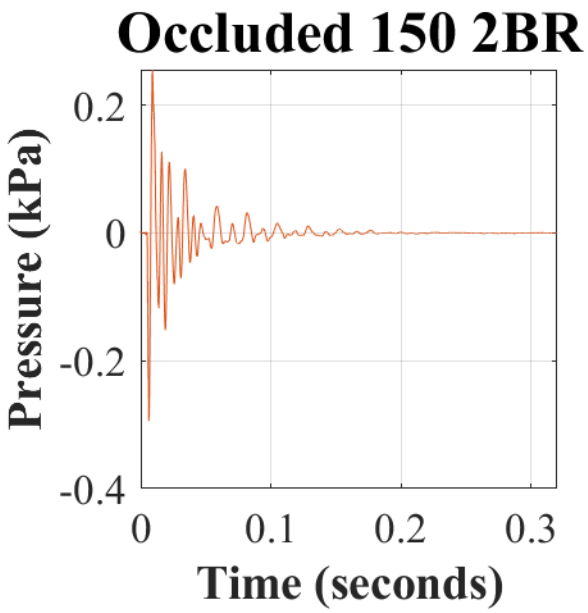


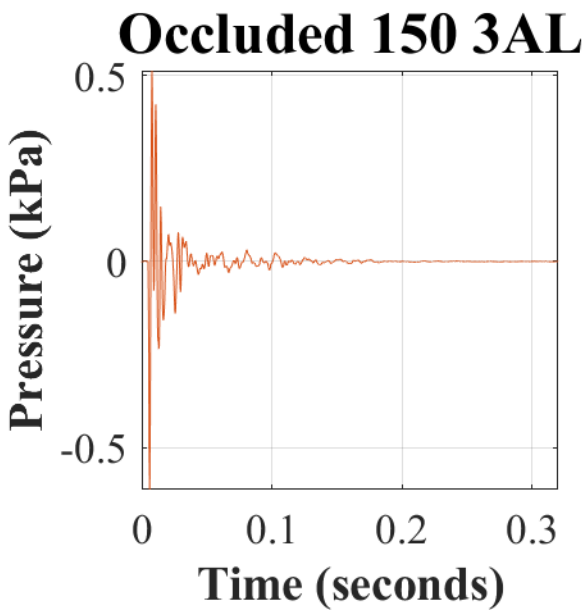


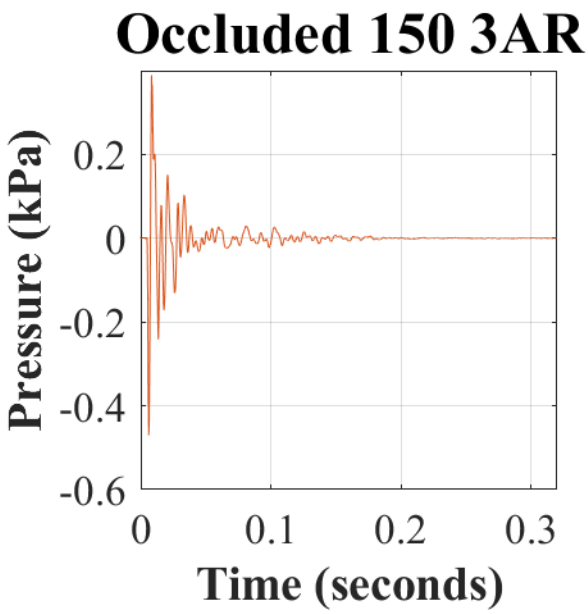

Occluded 150 2AL
Pressure (kPa)
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

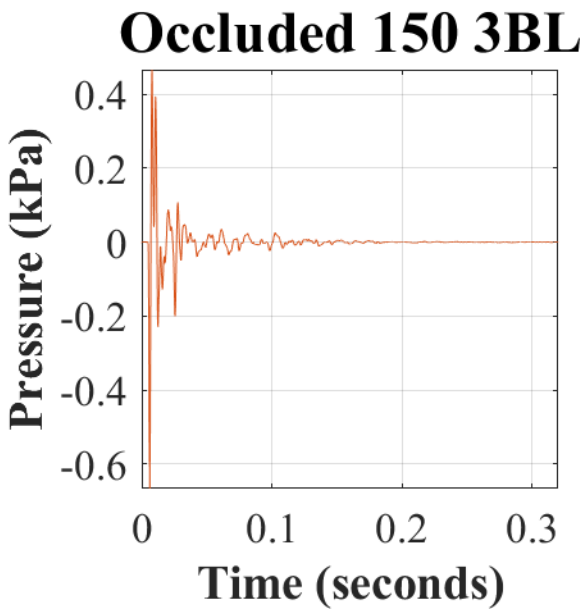

Occluded 150 2AR
Pressure (kPa)
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)

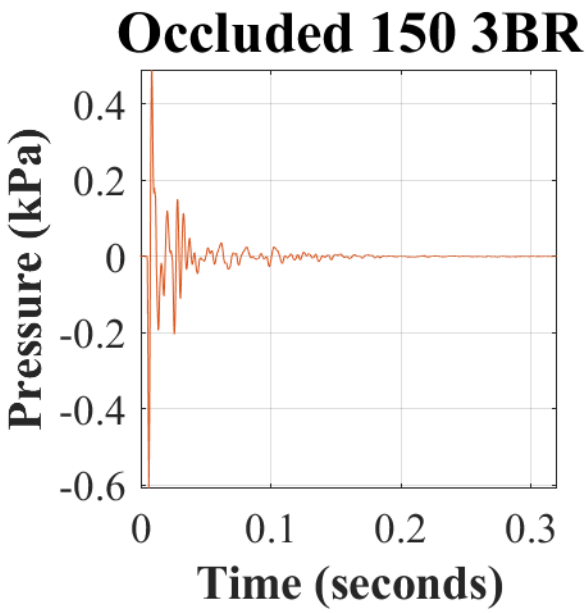

Occluded 150 2BL
Pressure (kPa)
0.1
0
-0.1
-0.2
-0.3
0
0.1
0.2
0.3
Time (seconds)

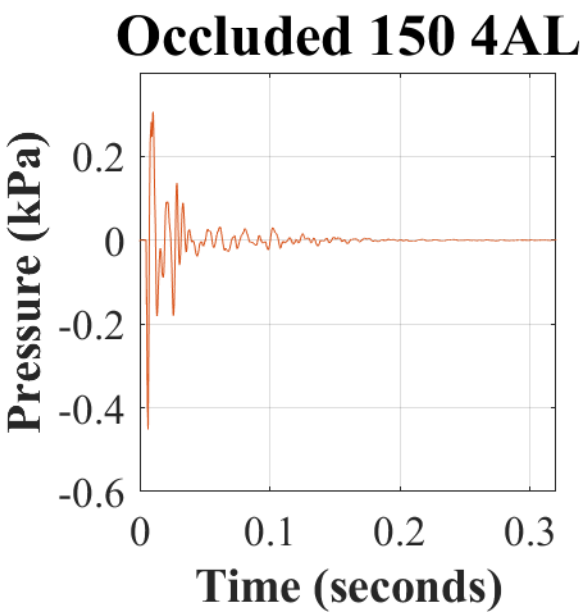

Occluded 150 2BR
Pressure (kPa)
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

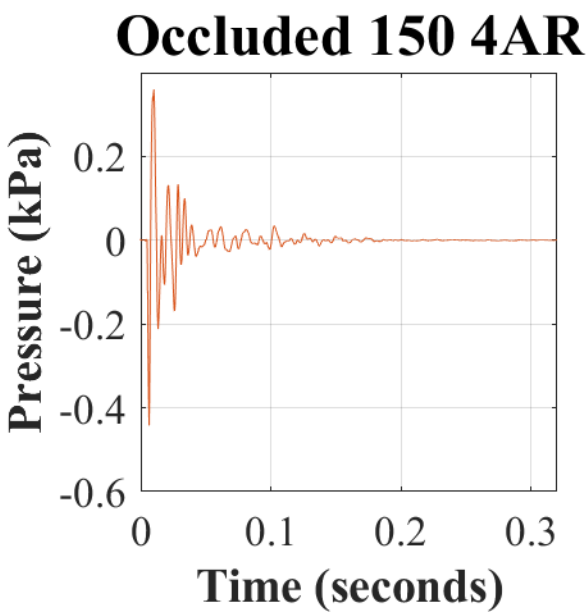

Occluded 150 3AL
Pressure (kPa)
0.5
0
-0.5
0
0.1
0.2
0.3
Time (seconds)

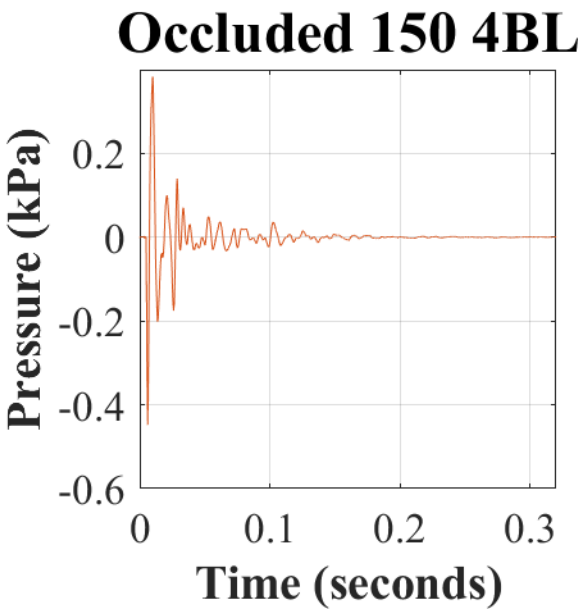

Occluded 150 3AR
Pressure (kPa)
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)

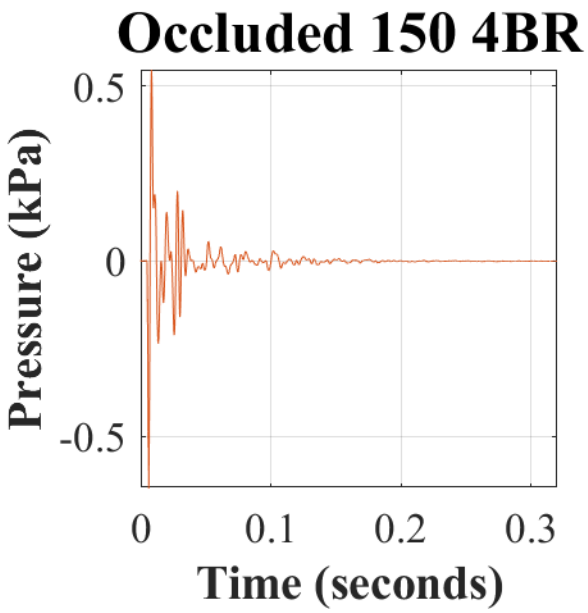

Occluded 150 3BL
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)

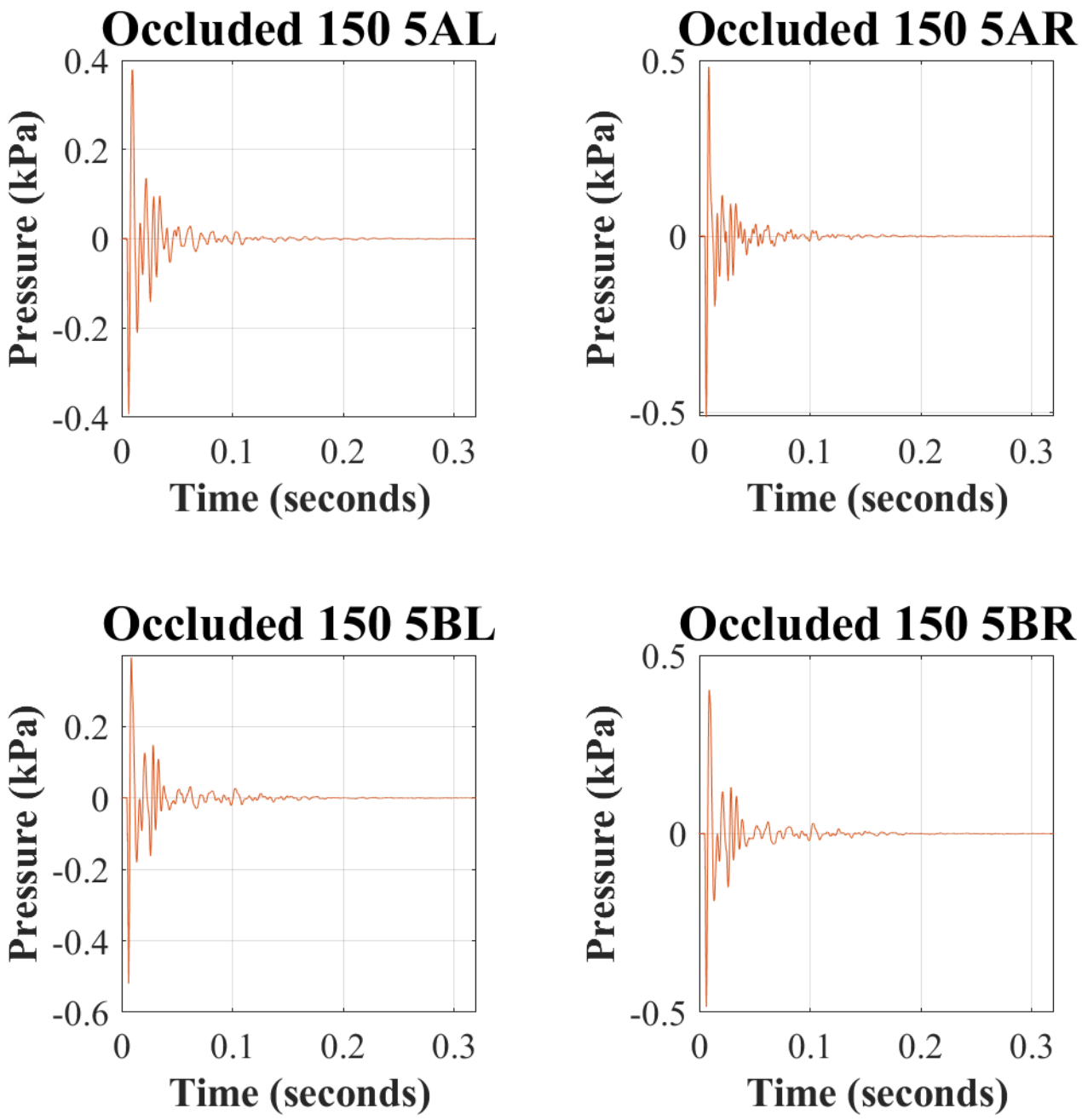

Occluded 150 3BR
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)


Occluded 150 4AL
Pressure (kPa)
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)


Occluded 150 4AR
Pressure (kPa)
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)

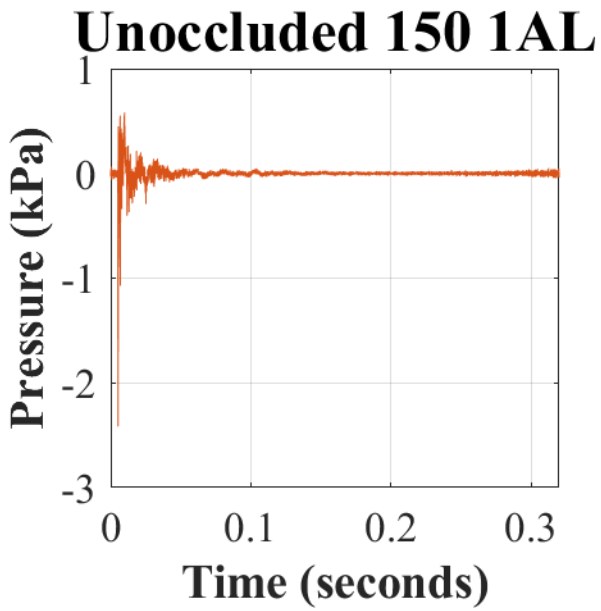

Occluded 150 4BL
Pressure (kPa)
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)

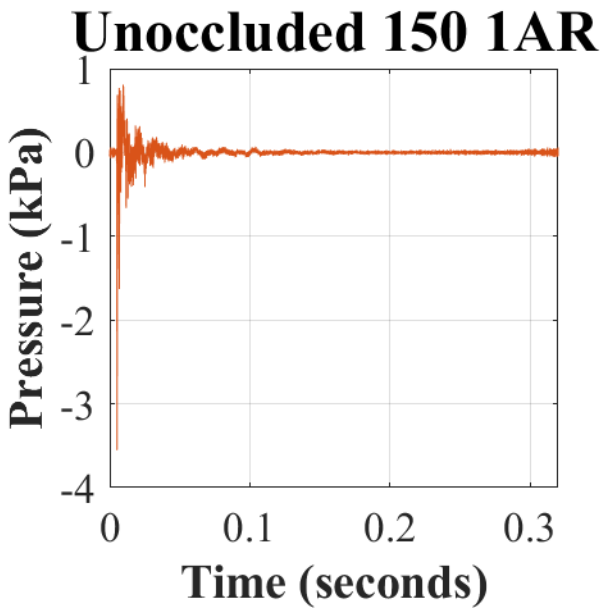

Occluded 150 4BR
Pressure (kPa)
0.5
0
-0.5
0
0.1
0.2
0.3
Time (seconds)

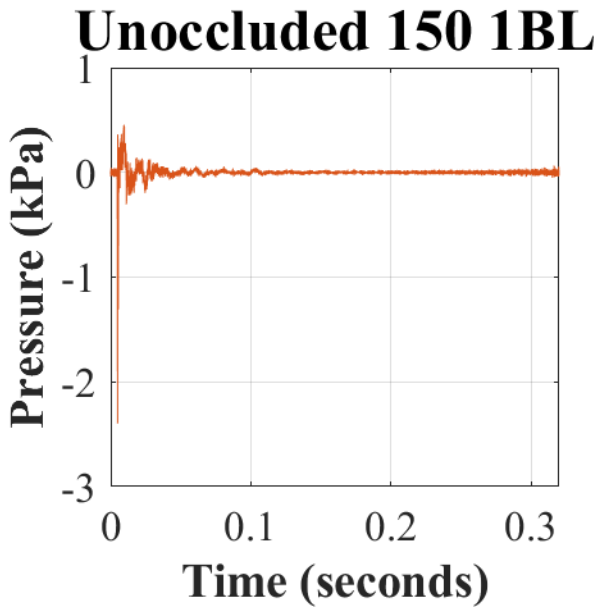


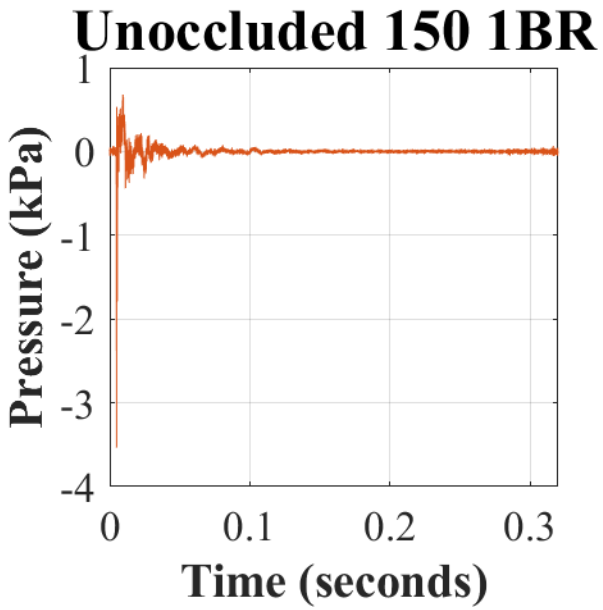
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating HPD fit (i.e., first or second, respectively), and ‘X’ indicates from what ATF microphone the recording is from (i.e., right [R] or left [L] pinnae).

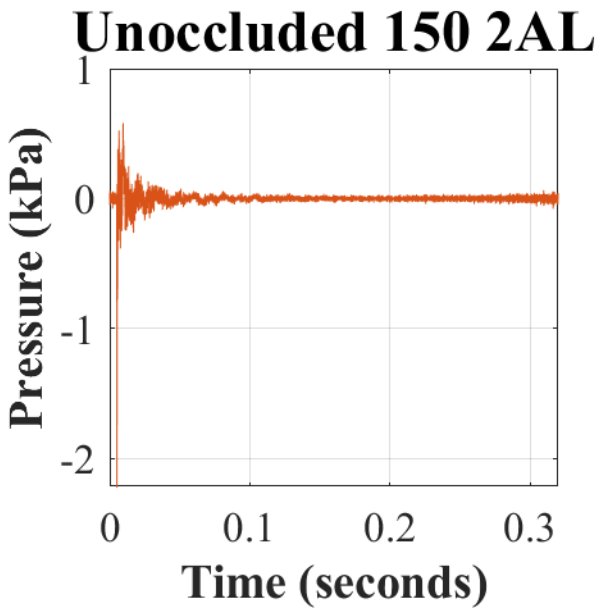
Appendix K. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 150 dBP with the ComTac™ V (MAX).

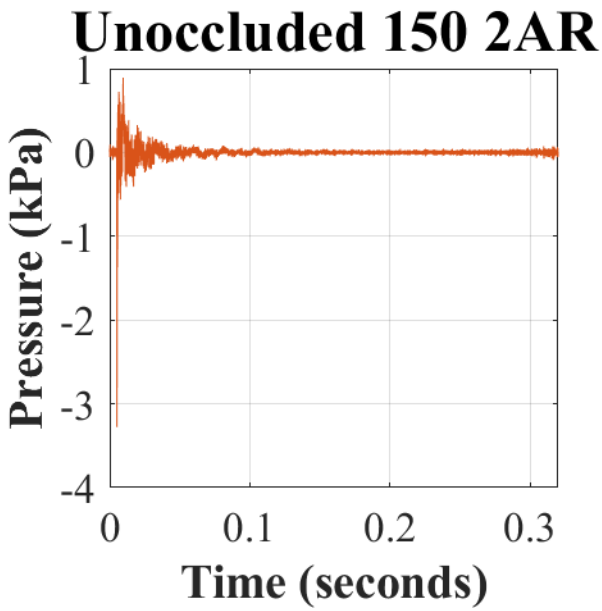


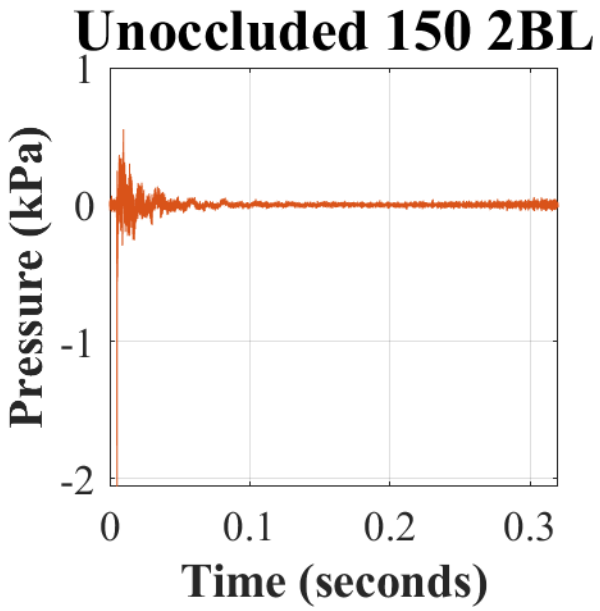


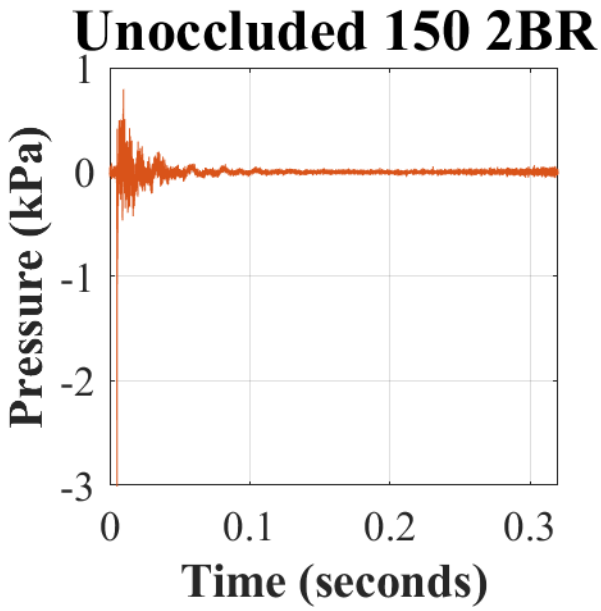


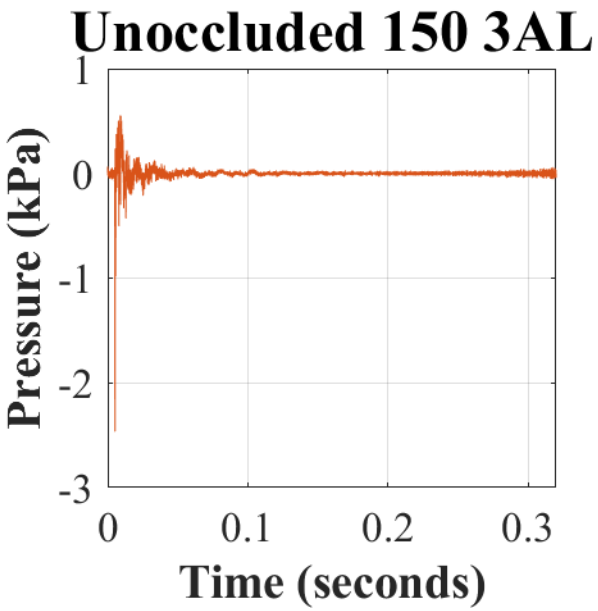


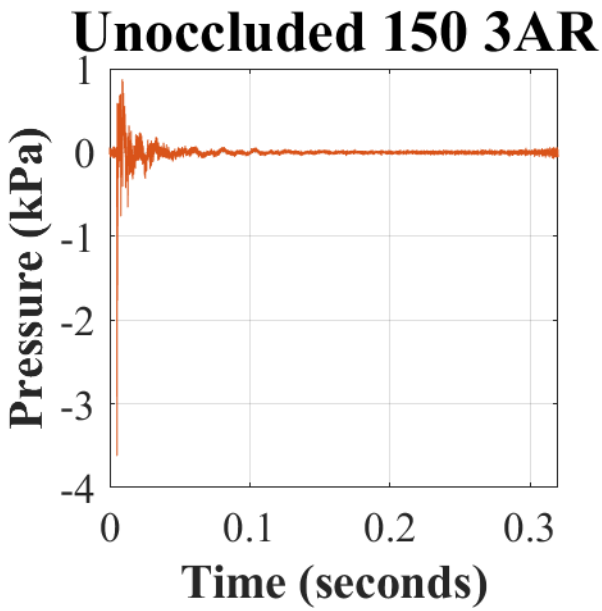

Unoccluded 150 2AL
Pressure (kPa)
1
0
-1
-2
0
0.1
0.2
0.3
Time (seconds)

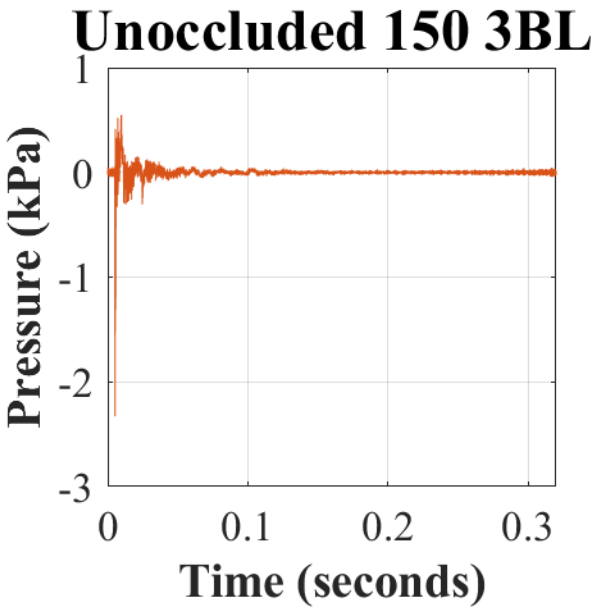

Unoccluded 150 2AR
Pressure (kPa)
1
0
-1
-2
-3
-4
0
0.1
0.2
0.3
Time (seconds)

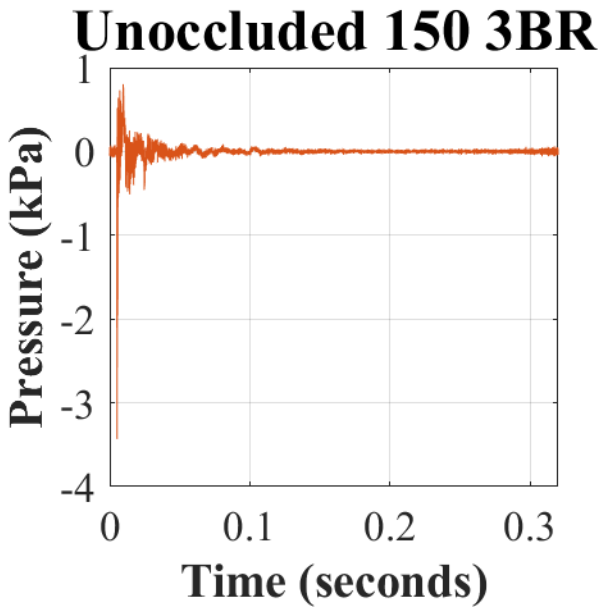

Unoccluded 150 2BL
Pressure (kPa)
1
0
-1
-2
0
0.1
0.2
0.3
Time (seconds)

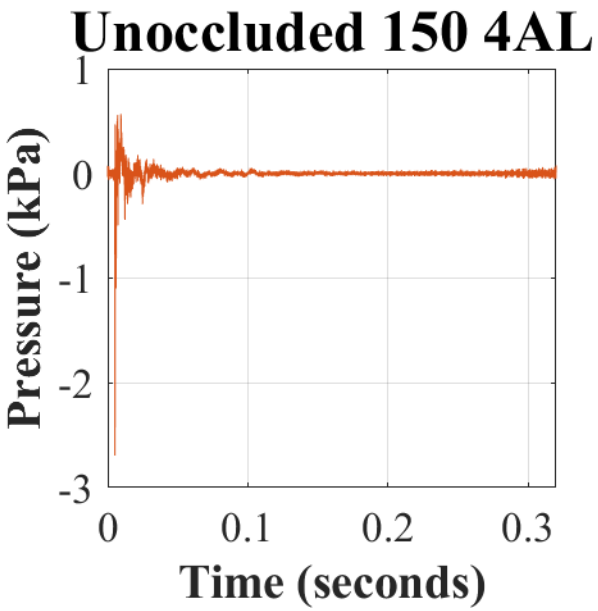

Unoccluded 150 2BR
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

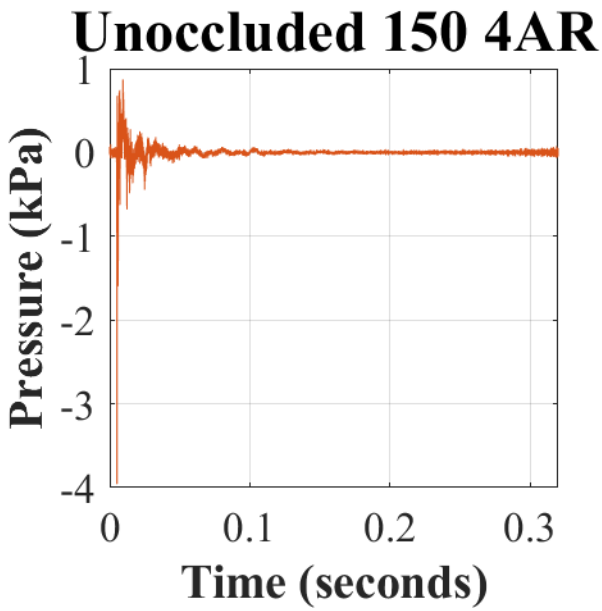

Unoccluded 150 3AL
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

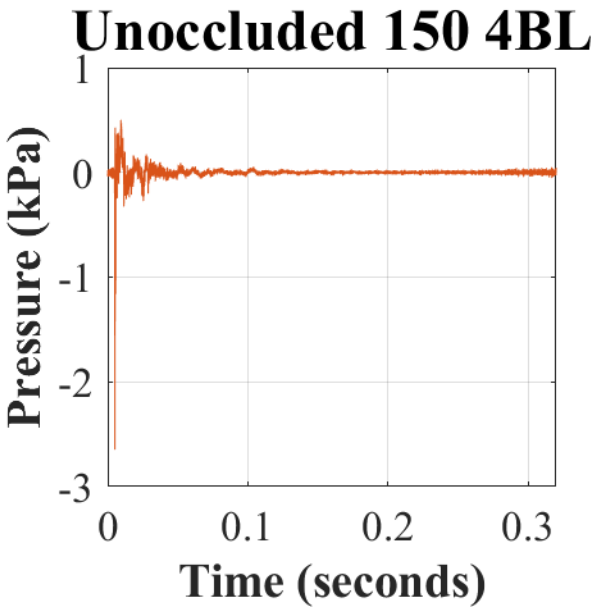

Unoccluded 150 3AR
Pressure (kPa)
1
0
-1
-2
-3
-4
0
0.1
0.2
0.3
Time (seconds)

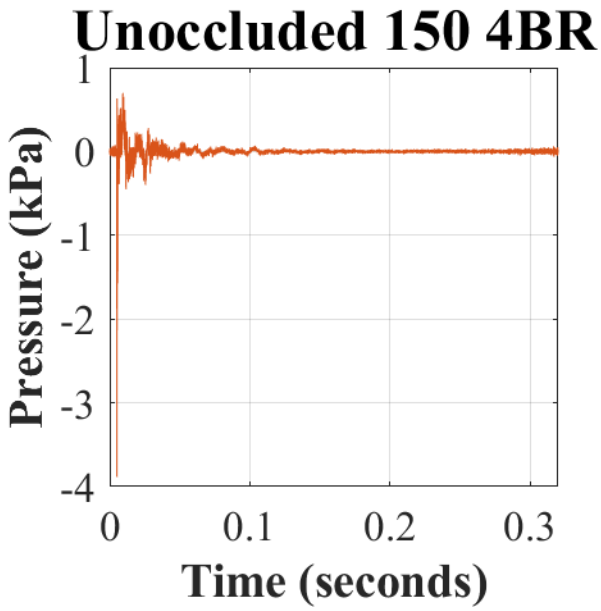

Unoccluded 150 3BL
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

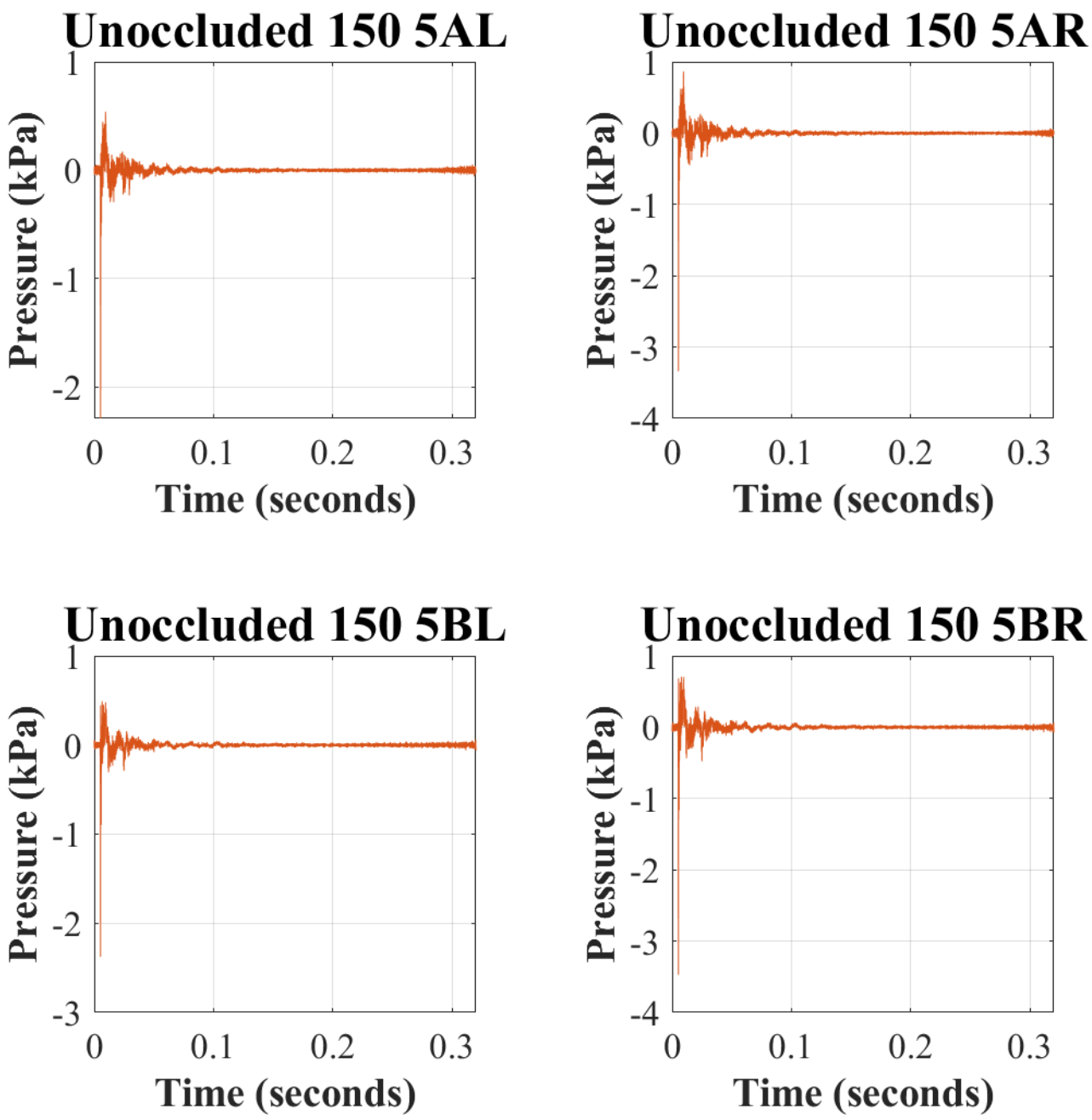

Unoccluded 150 3BR
Pressure (kPa)
1
0
-1
-2
-3
-4
0
0.1
0.2
0.3
Time (seconds)


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


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

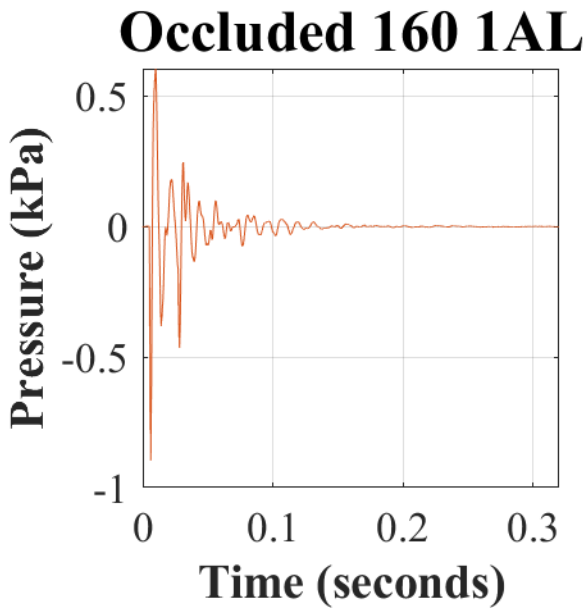

Unoccluded 150 4BL
Pressure (kPa)
1
0
-1
-2
-3
0
0.1
0.2
0.3
Time (seconds)

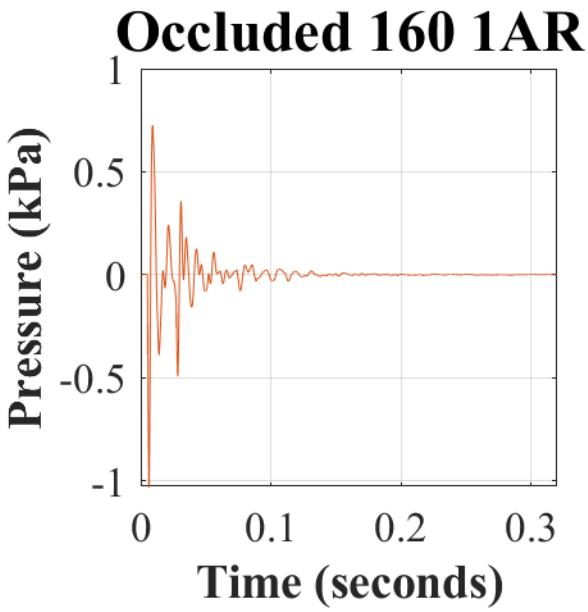

Unoccluded 150 4BR
Pressure (kPa)
1
0
-1
-2
-3
-4
0
0.1
0.2
0.3
Time (seconds)

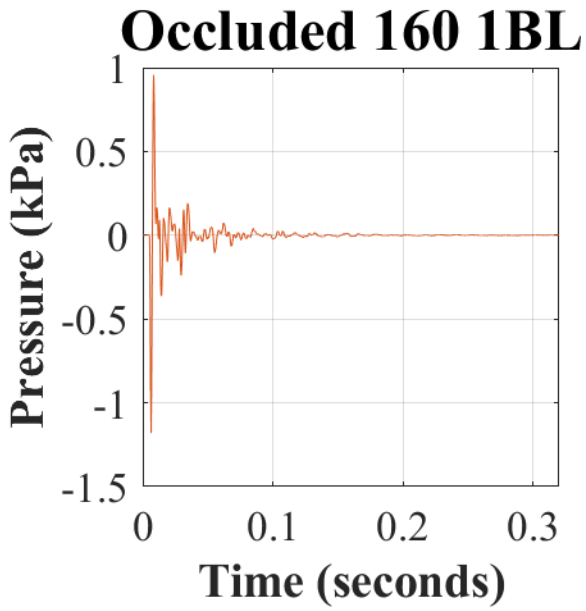


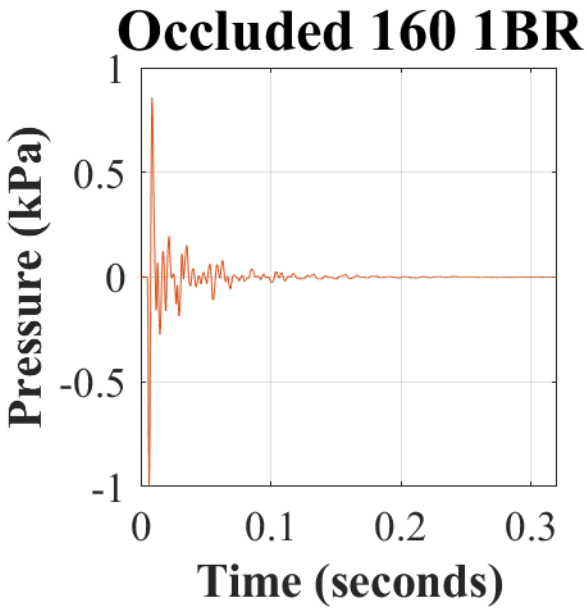
Note. The naming convention for all unoccluded waveforms is "Unoccluded LvL NnX", where 'Unoccluded' is the test condition (i.e., ATF has the HPD doffed), 'LvL' is the nominal test level (i.e., 150, 160 or 170 dBP), 'N' is the sample number (i.e., 1 to 5) of the device tested, 'n' is the trial (i.e., A or B) indicating HPD fit (i.e., first or second, respectively), and 'X' indicates from what ATF microphone the recording is from (i.e., right [R] or left [L] pinnae).

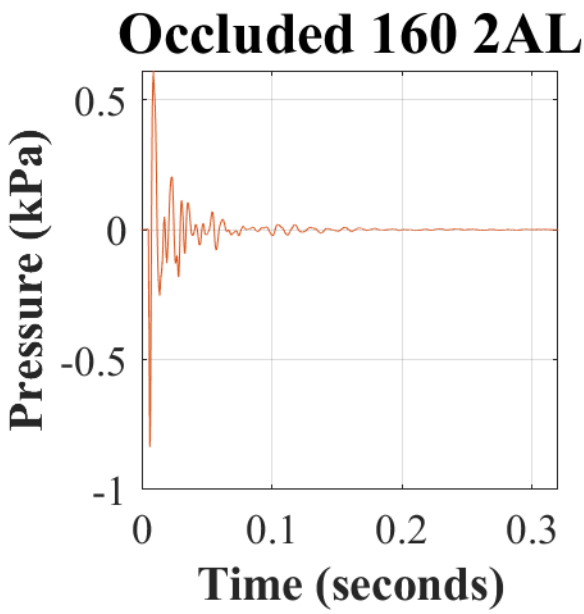
Appendix L. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 160 dBP with the ComTac™ V (MAX).

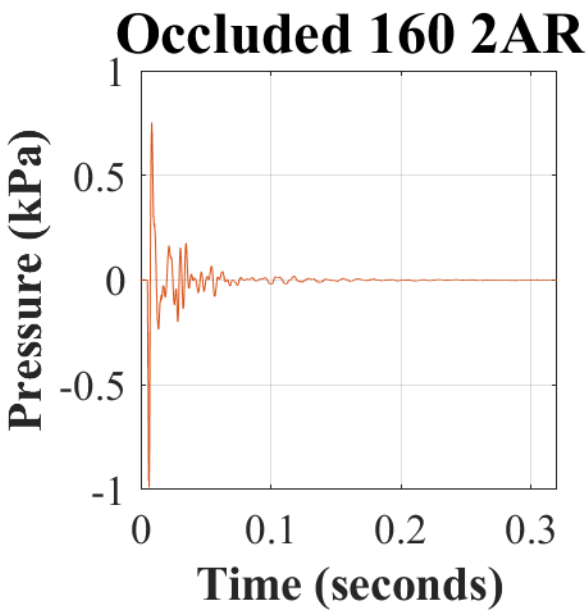


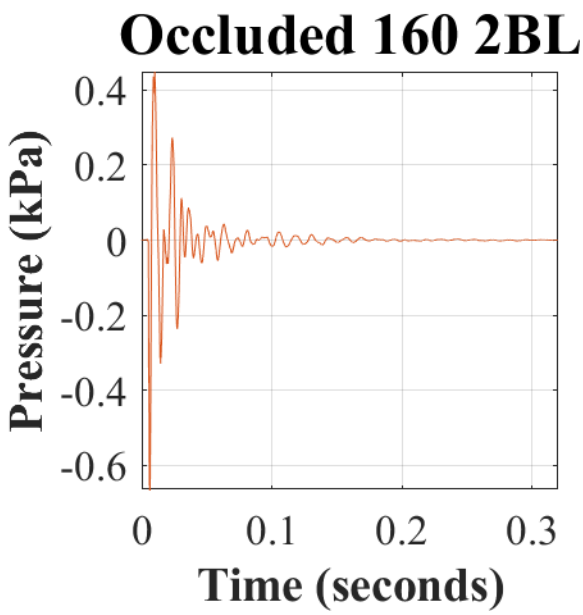


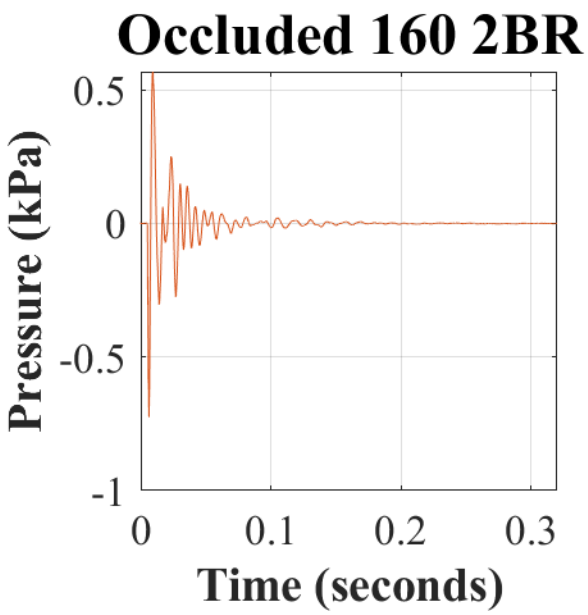


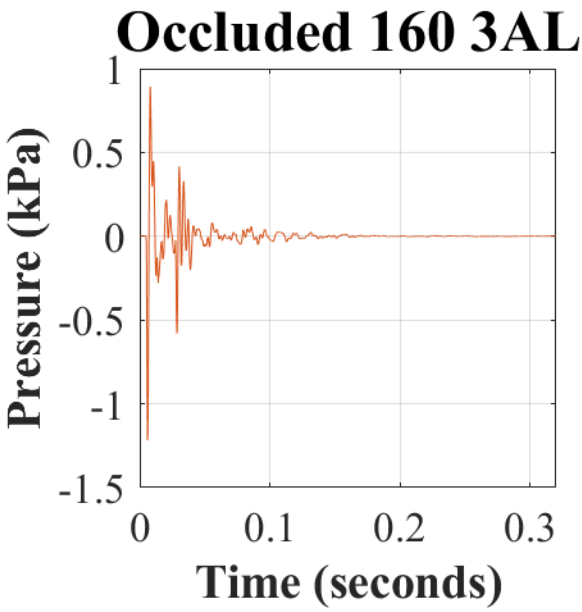


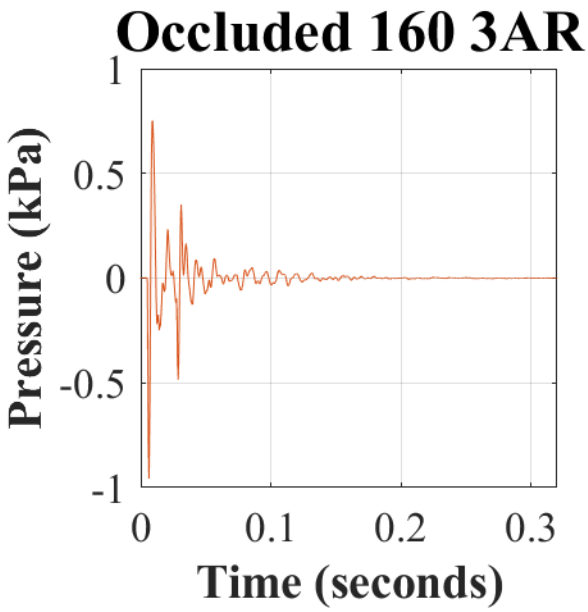

Occluded 160 2AL
Pressure (kPa)
0.5
0
-0.5
-1
0
0.1
0.2
0.3
Time (seconds)

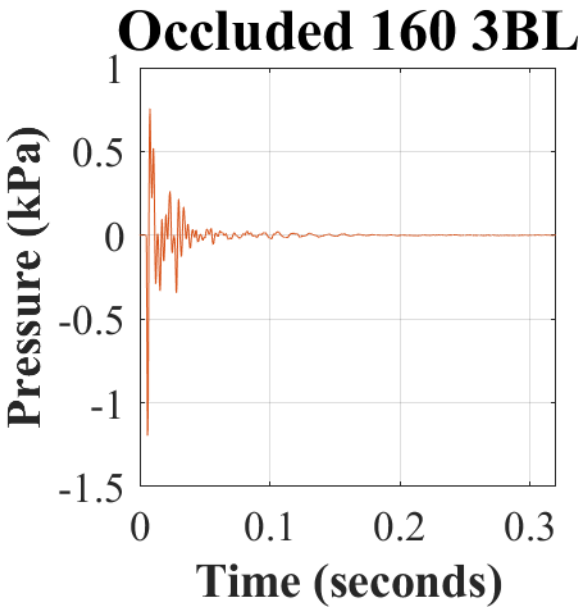

Occluded 160 2AR
Pressure (kPa)
1
0.5
0
-0.5
-1
0
0.1
0.2
0.3
Time (seconds)

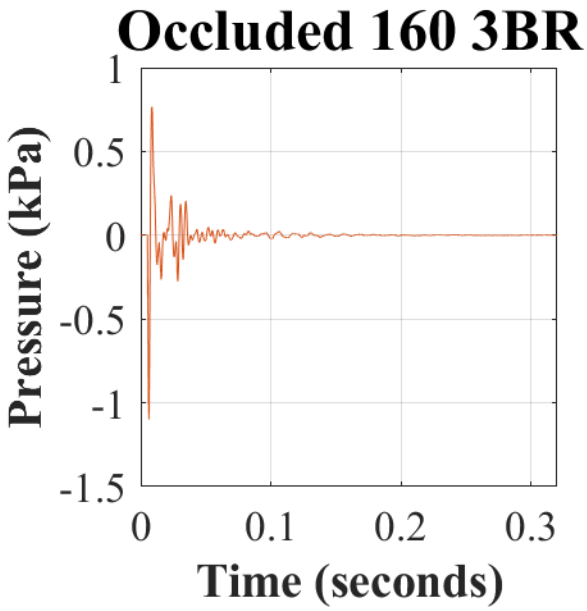

Occluded 160 2BL
Pressure (kPa)
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.1
0.2
0.3
Time (seconds)

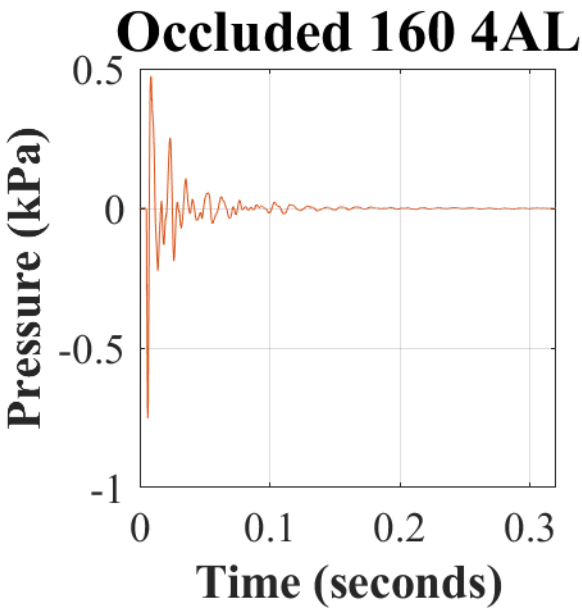

Occluded 160 2BR
Pressure (kPa)
0.5
0
-0.5
-1
0
0.1
0.2
0.3
Time (seconds)

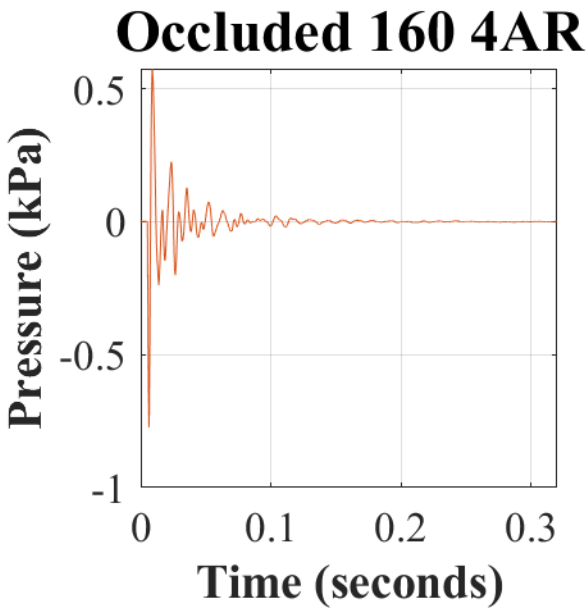

Occluded 160 3AL
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3

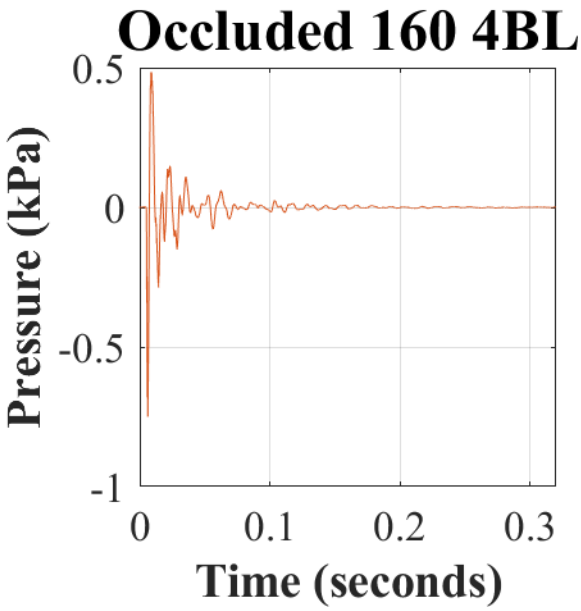

Occluded 160 3AR
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
0
0.1
0.2
0.3

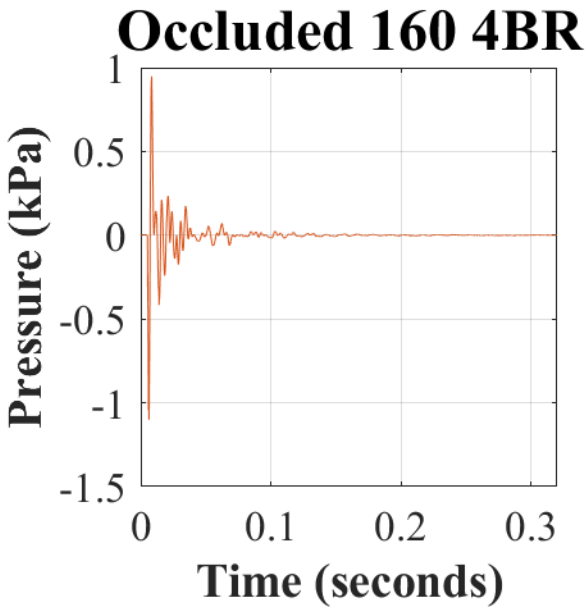

Occluded 160 3BL
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3

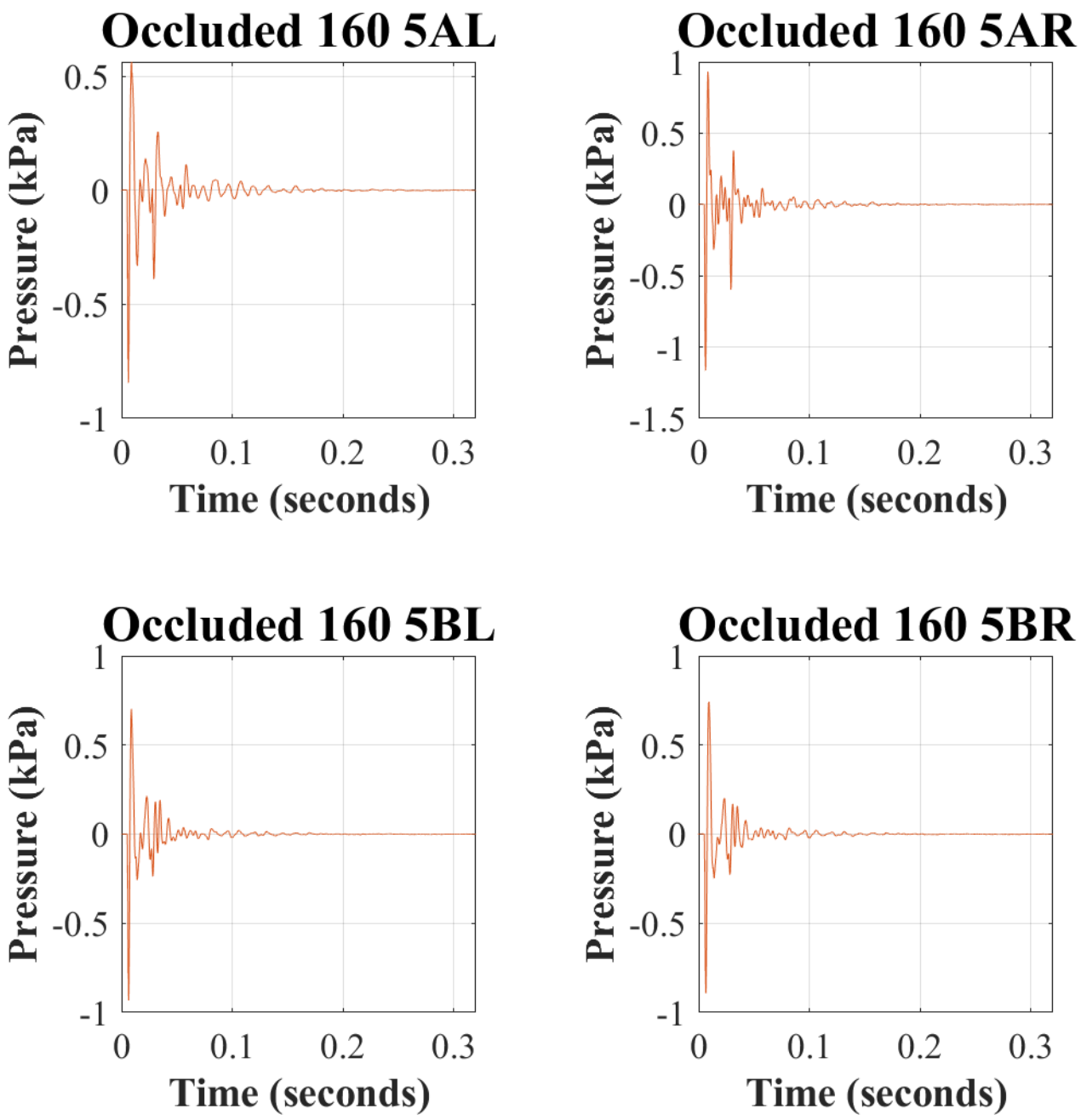

Occluded 160 3BR
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3


Occluded 160 4AL
Pressure (kPa)
0.5
0
-0.5
-1
0
0.1
0.2
0.3
Time (seconds)


Occluded 160 4AR
Pressure (kPa)
0.5
0
-0.5
-1
0
0.1
0.2
0.3
Time (seconds)

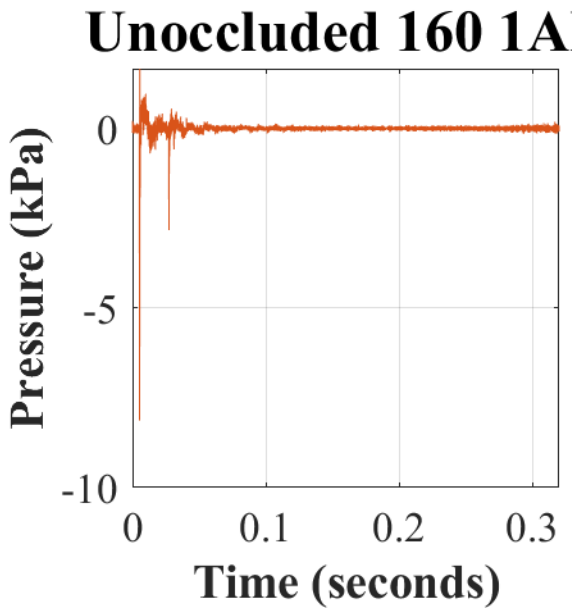

Occluded 160 4BL
Pressure (kPa)
0.5
0
-0.5
-1
0
0.1
0.2
0.3
Time (seconds)

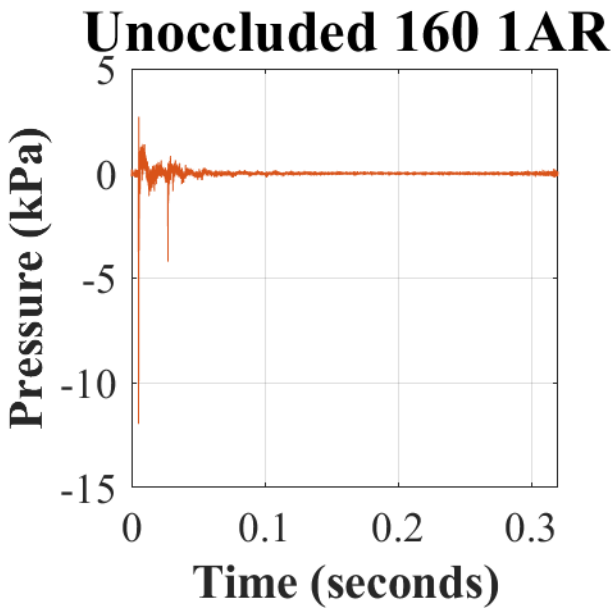

Occluded 160 4BR
Pressure (kPa)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3
Time (seconds)

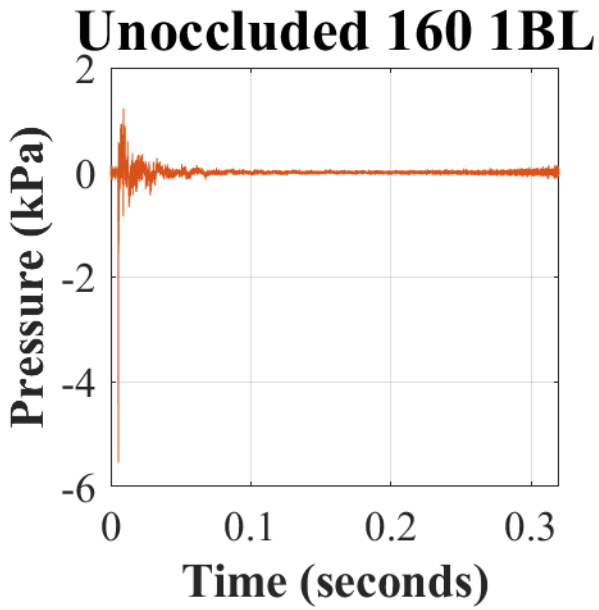


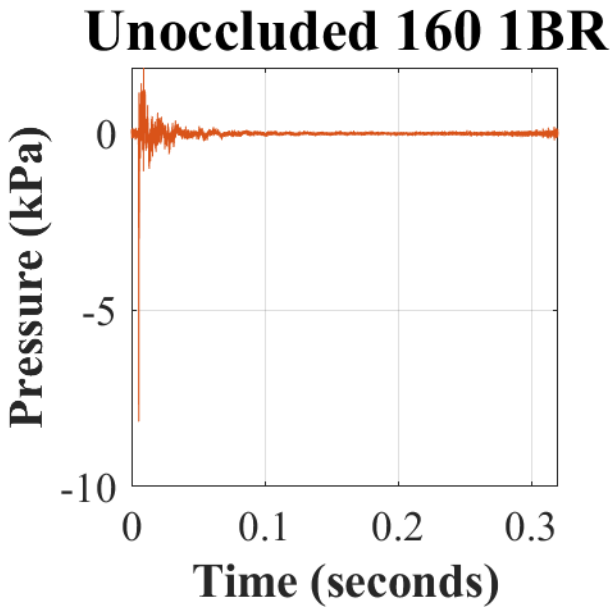
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating HPD fit (i.e., first or second, respectively), and ‘X’ indicates from what ATF microphone the recording is from (i.e., right [R] or left [L] pinnae).

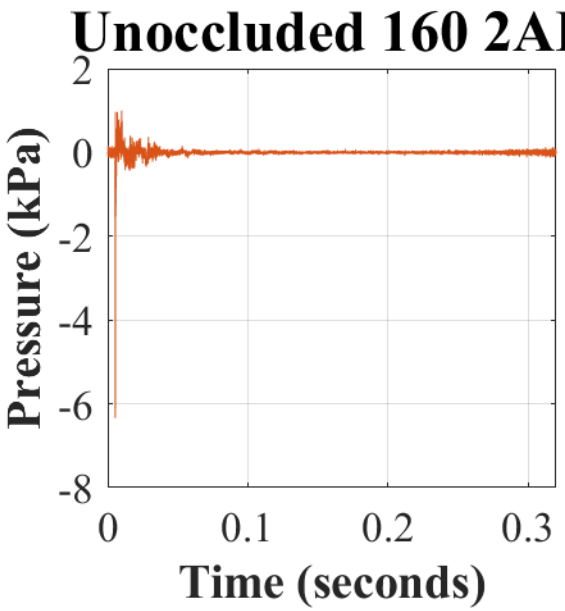
Appendix M. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 160 dBP with the ComTac™ V (MAX).

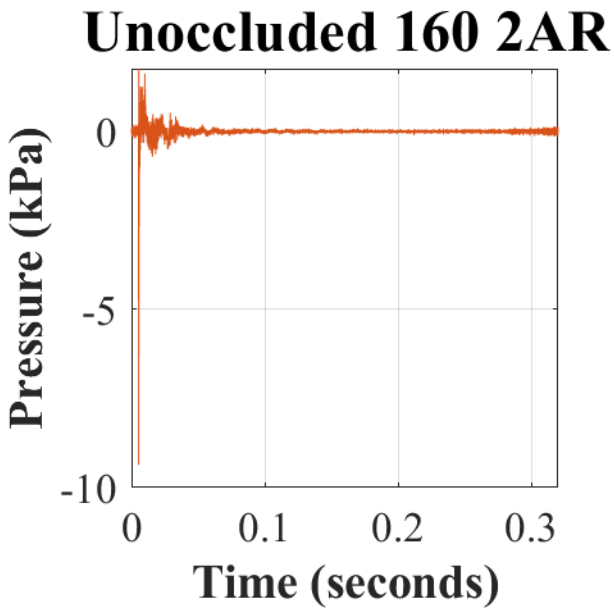


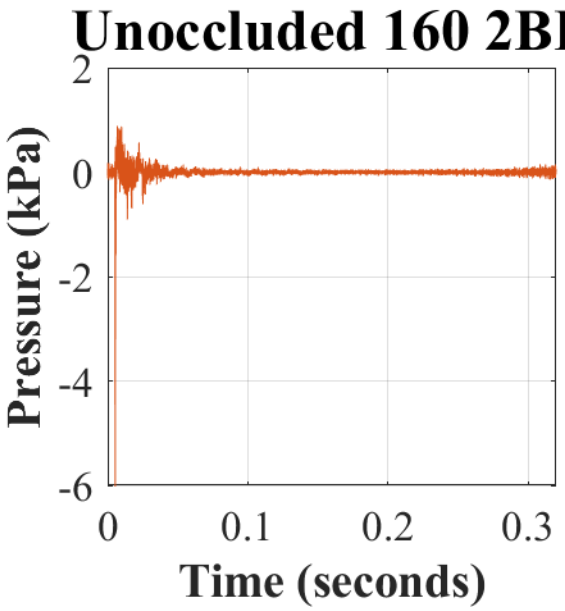


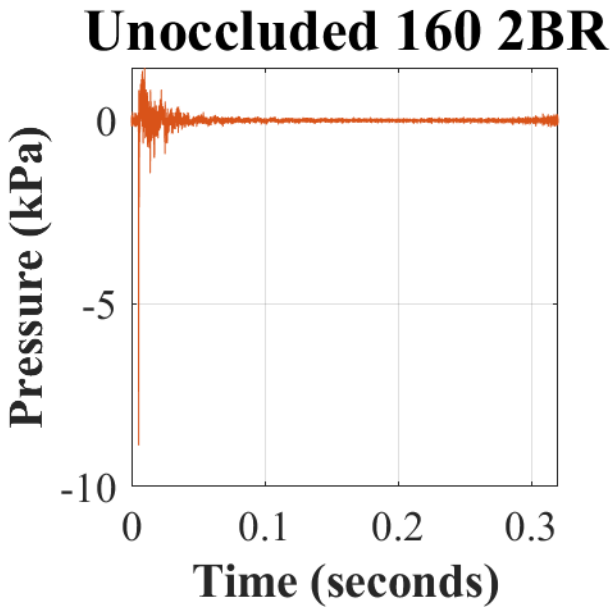


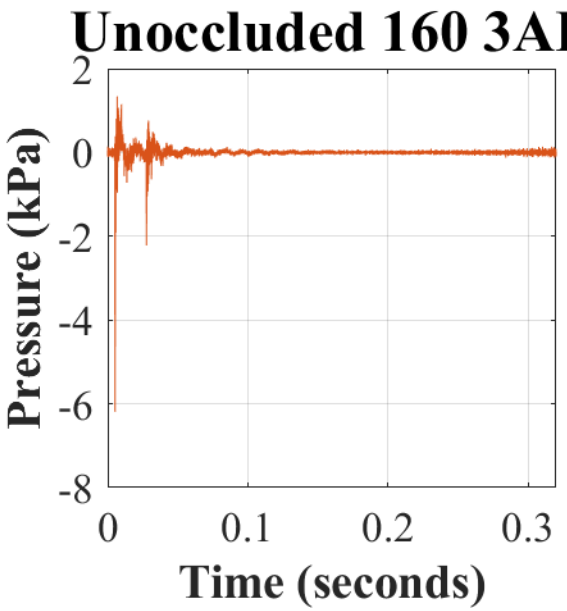


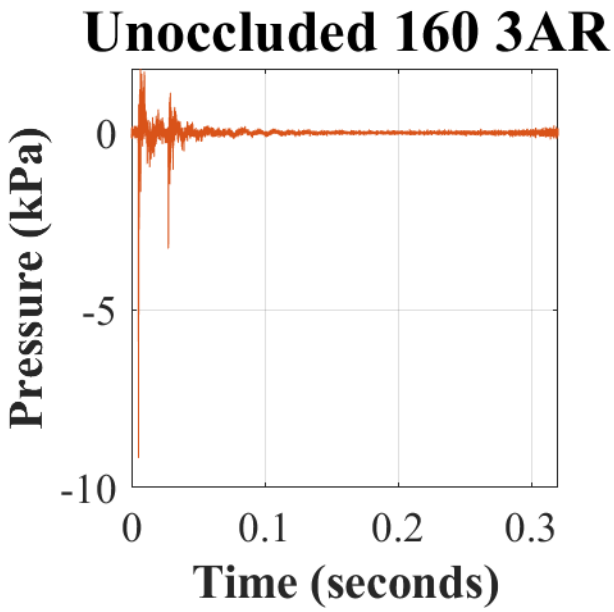

Unoccluded 160 2AL
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

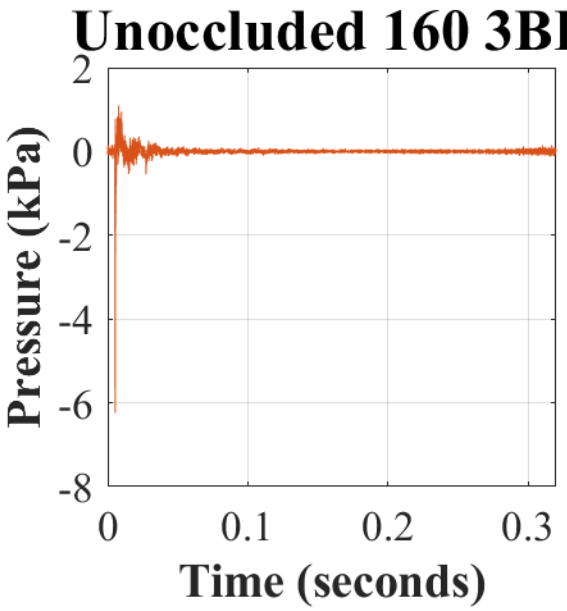

Unoccluded 160 2AR
Pressure (kPa)
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

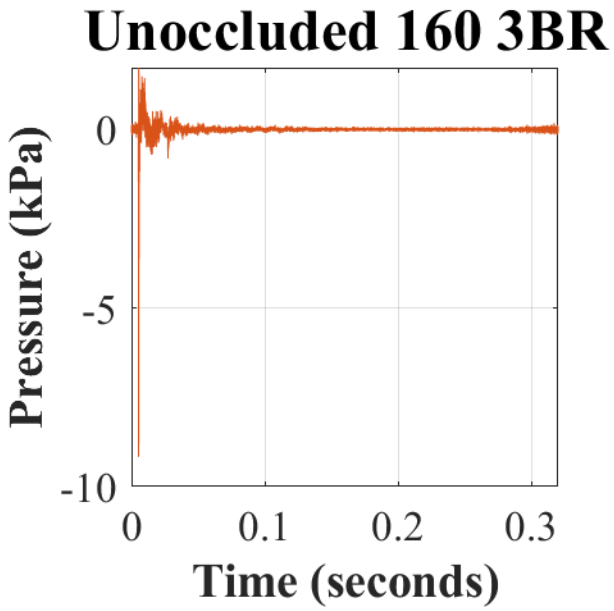

Unoccluded 160 2BL
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

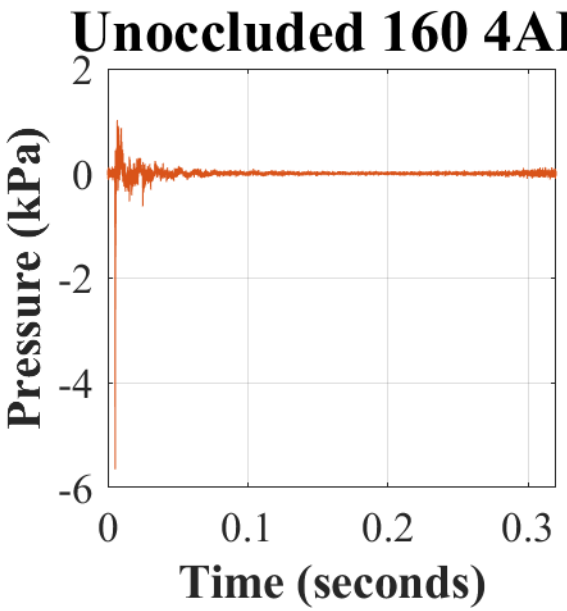

Unoccluded 160 2BR
Pressure (kPa)
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

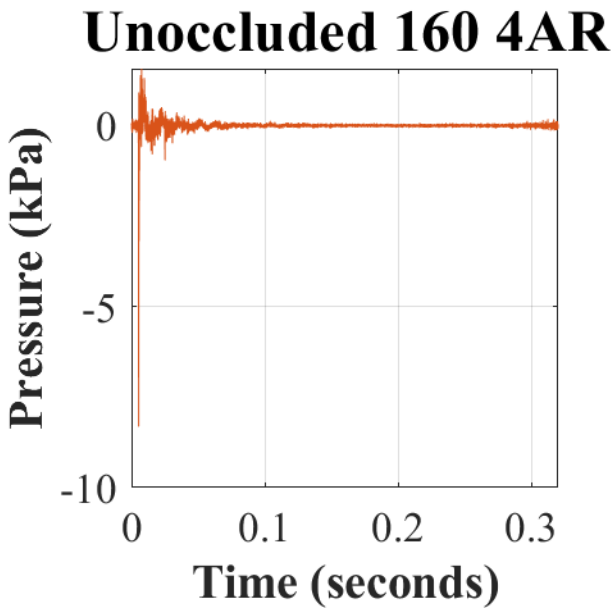

Unoccluded 160 3AL
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

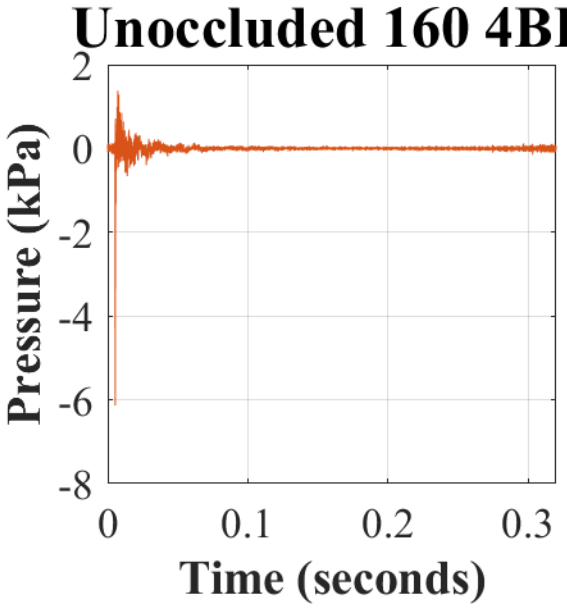

Unoccluded 160 3AR
Pressure (kPa)
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

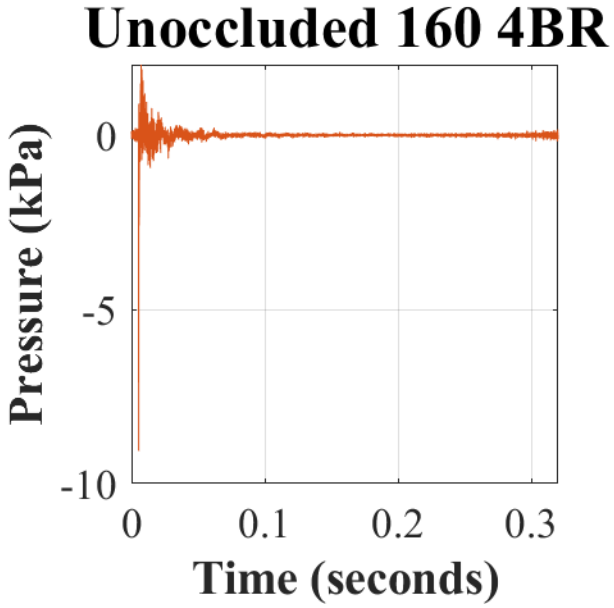

Unoccluded 160 3BL
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

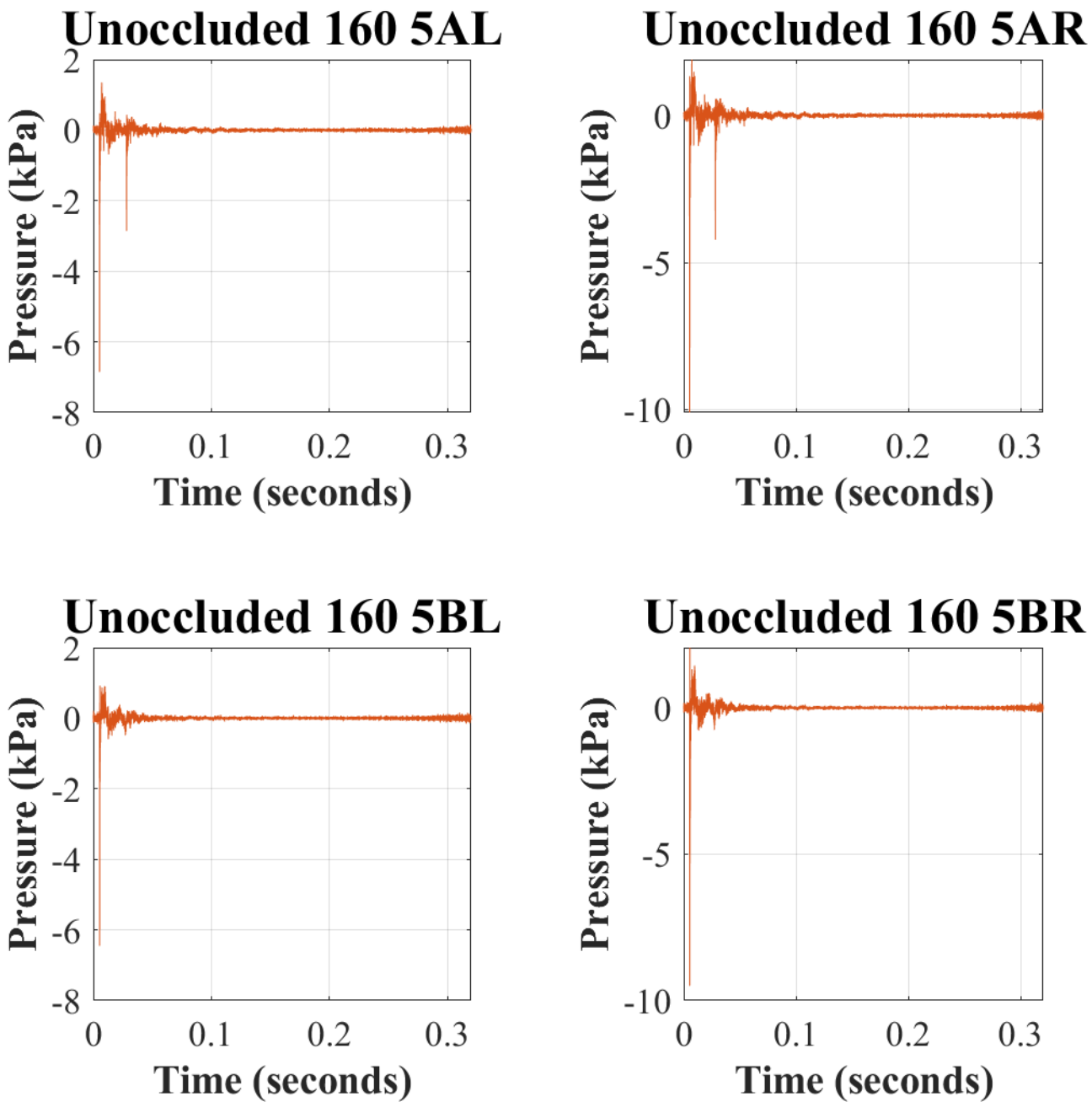

Unoccluded 160 3BR
Pressure (kPa)
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)


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


Unoccluded 160 4AR
Pressure (kPa)
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

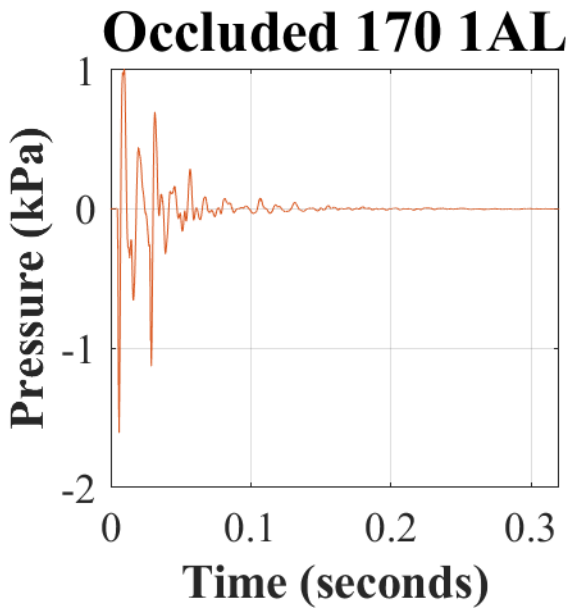

Unoccluded 160 4BL
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

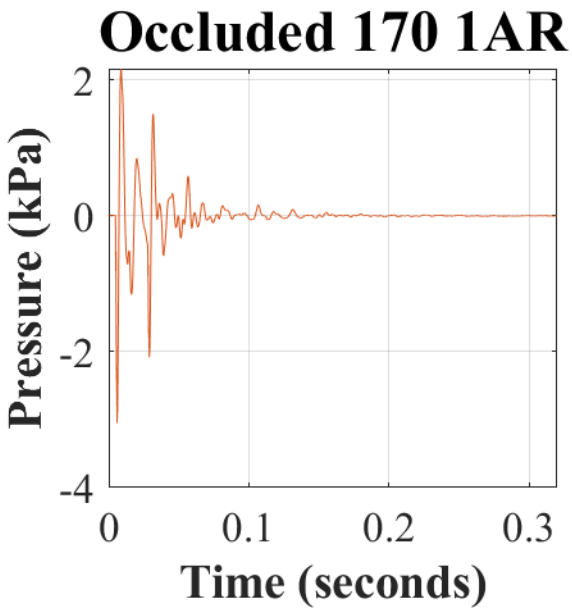

Unoccluded 160 4BR
Pressure (kPa)
0
-5
-10
0
0.1
0.2
0.3
Time (seconds)

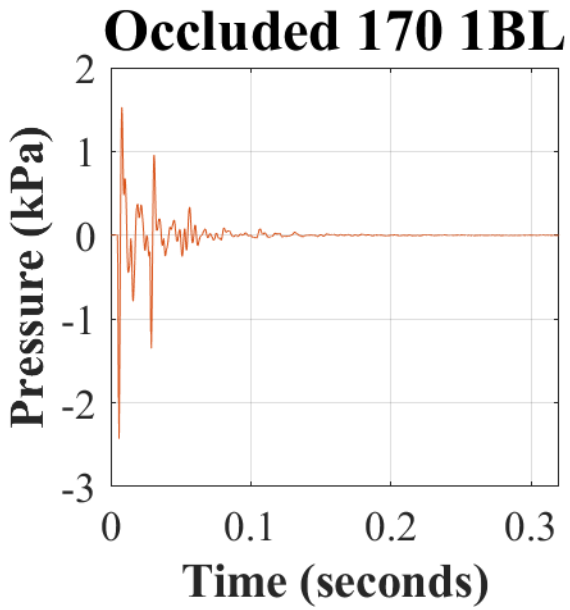


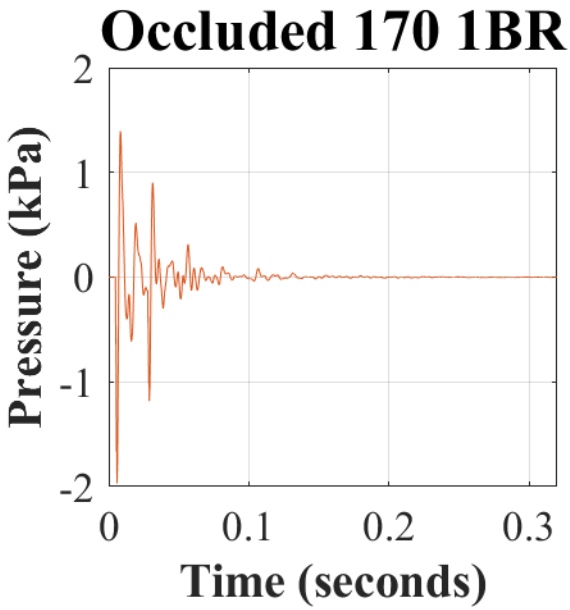
Note. The naming convention for all unoccluded waveforms is "Unoccluded LvL NnX", where 'Unoccluded' is the test condition (i.e., ATF has the HPD doffed), 'LvL' is the nominal test level (i.e., 150, 160 or 170 dBP), 'N' is the sample number (i.e., 1 to 5) of the device tested, 'n' is the trial (i.e., A or B) indicating HPD fit (i.e., first or second, respectively), and 'X' indicates from what ATF microphone the recording is from (i.e., right [R] or left [L] pinnae).

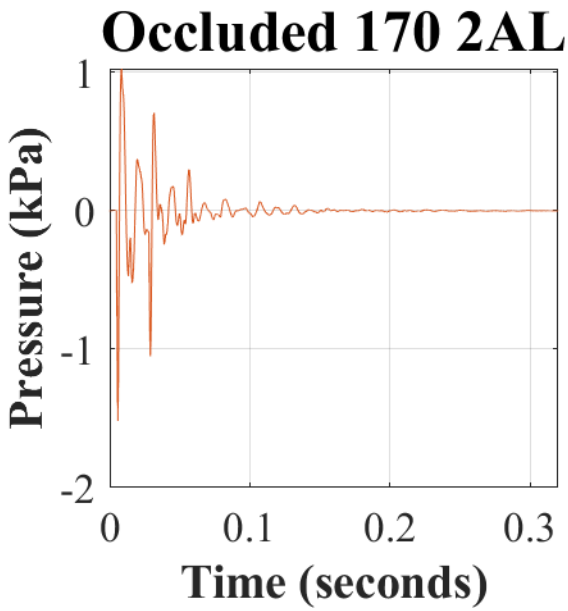
Appendix N. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 170 dBP with the ComTac™ V (MAX).

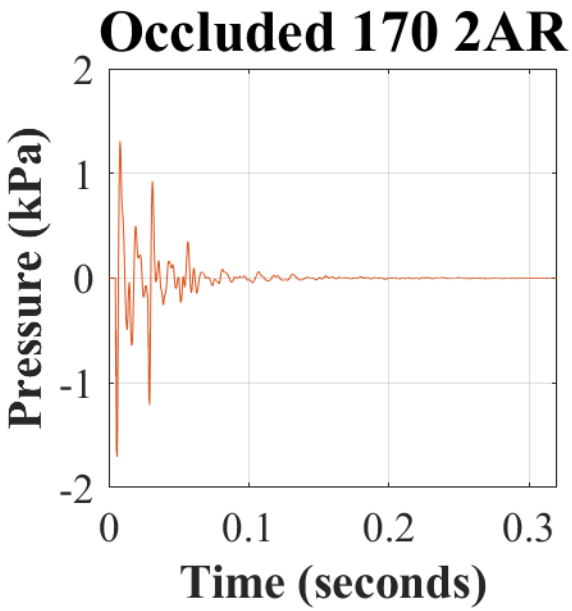


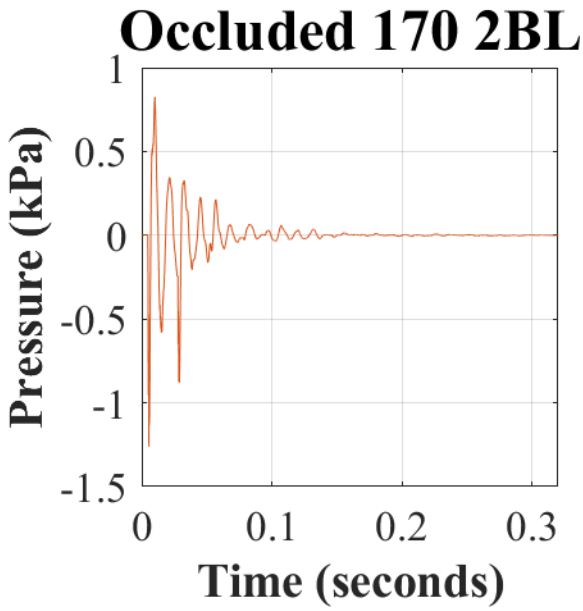


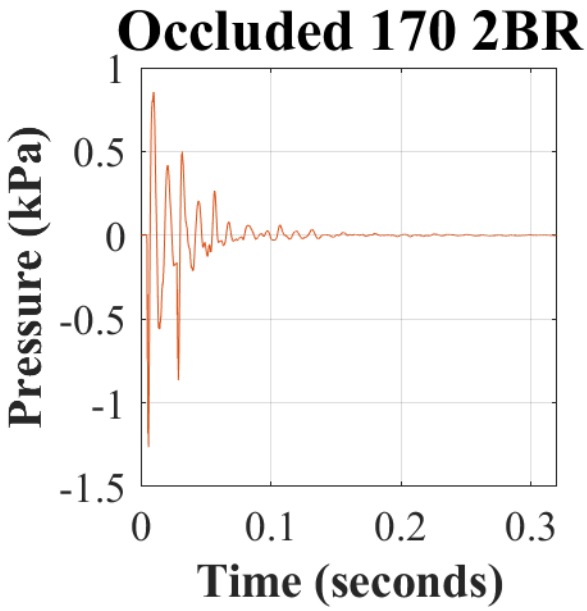


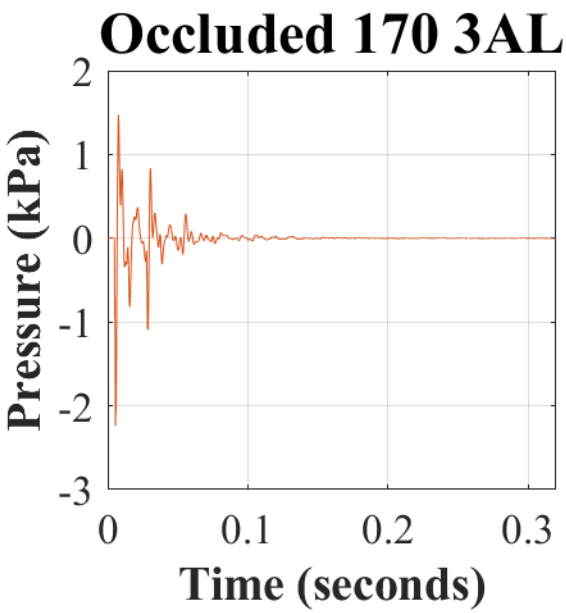


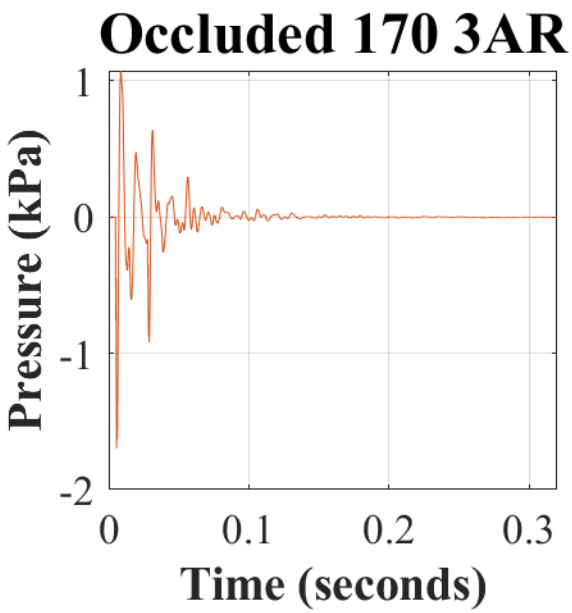

Occluded 170 2AL
Pressure (kPa)
Time (seconds)
1
0
-1
-2
0
0.1
0.2
0.3

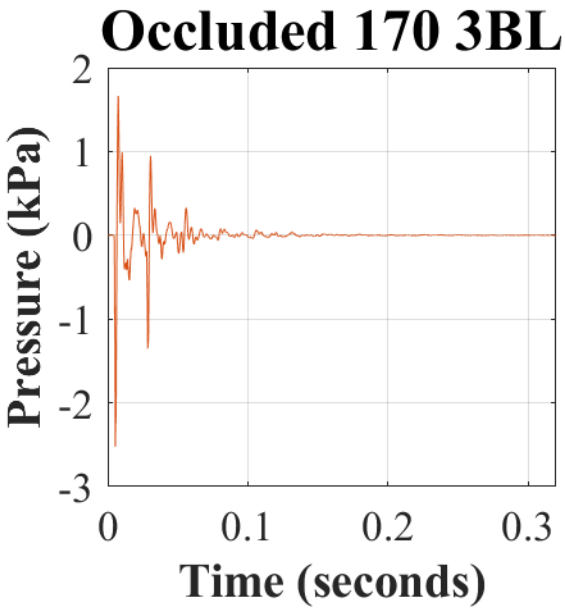

Occluded 170 2AR
Pressure (kPa)
Time (seconds)
2
1
0
-1
-2
0
0.1
0.2
0.3

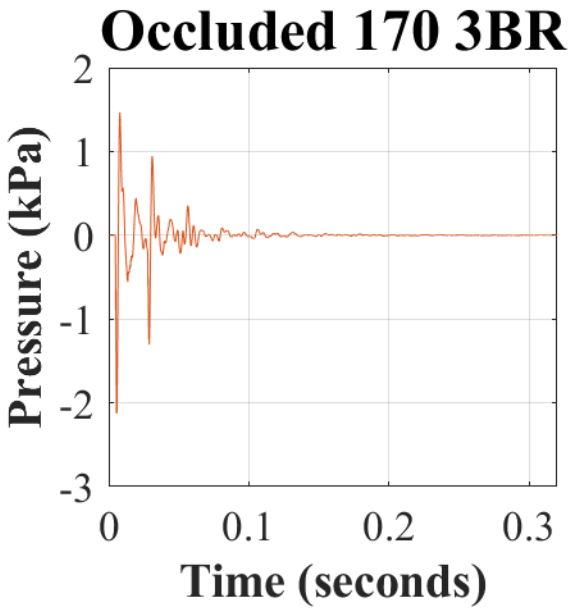

Occluded 170 2BL
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3

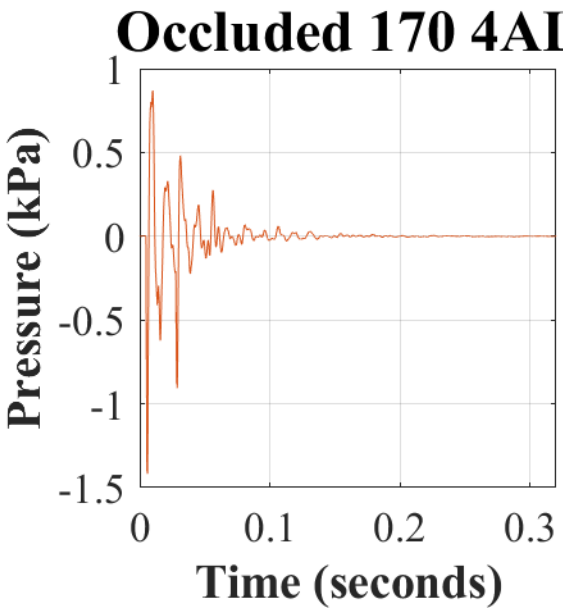

Occluded 170 2BR
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3

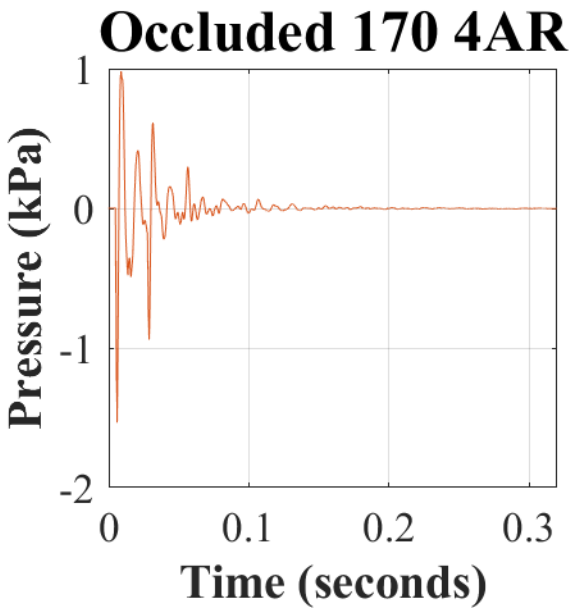

Occluded 170 3AL
Pressure (kPa)
Time (seconds)
2
1
0
-1
-2
-3
0
0.1
0.2
0.3

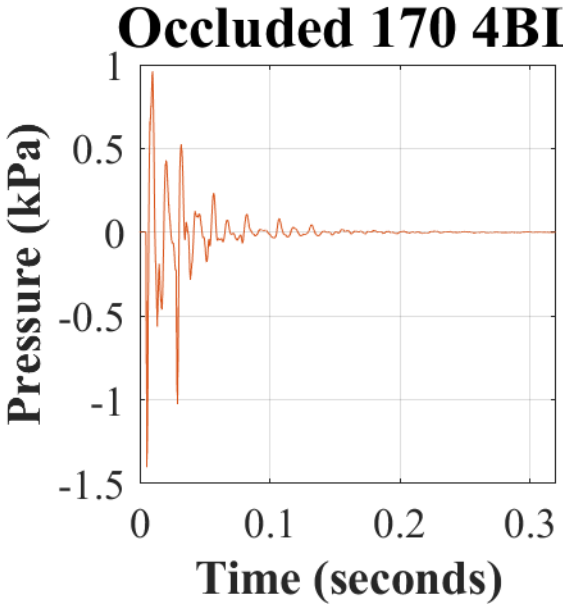

Occluded 170 3AR
Pressure (kPa)
Time (seconds)
1
0
-1
-2
0
0.1
0.2
0.3

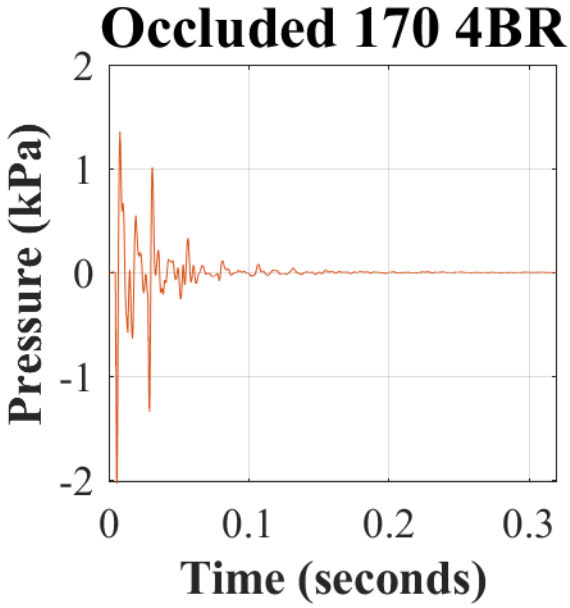

Occluded 170 3BL
Pressure (kPa)
Time (seconds)
2
1
0
-1
-2
-3
0
0.1
0.2
0.3

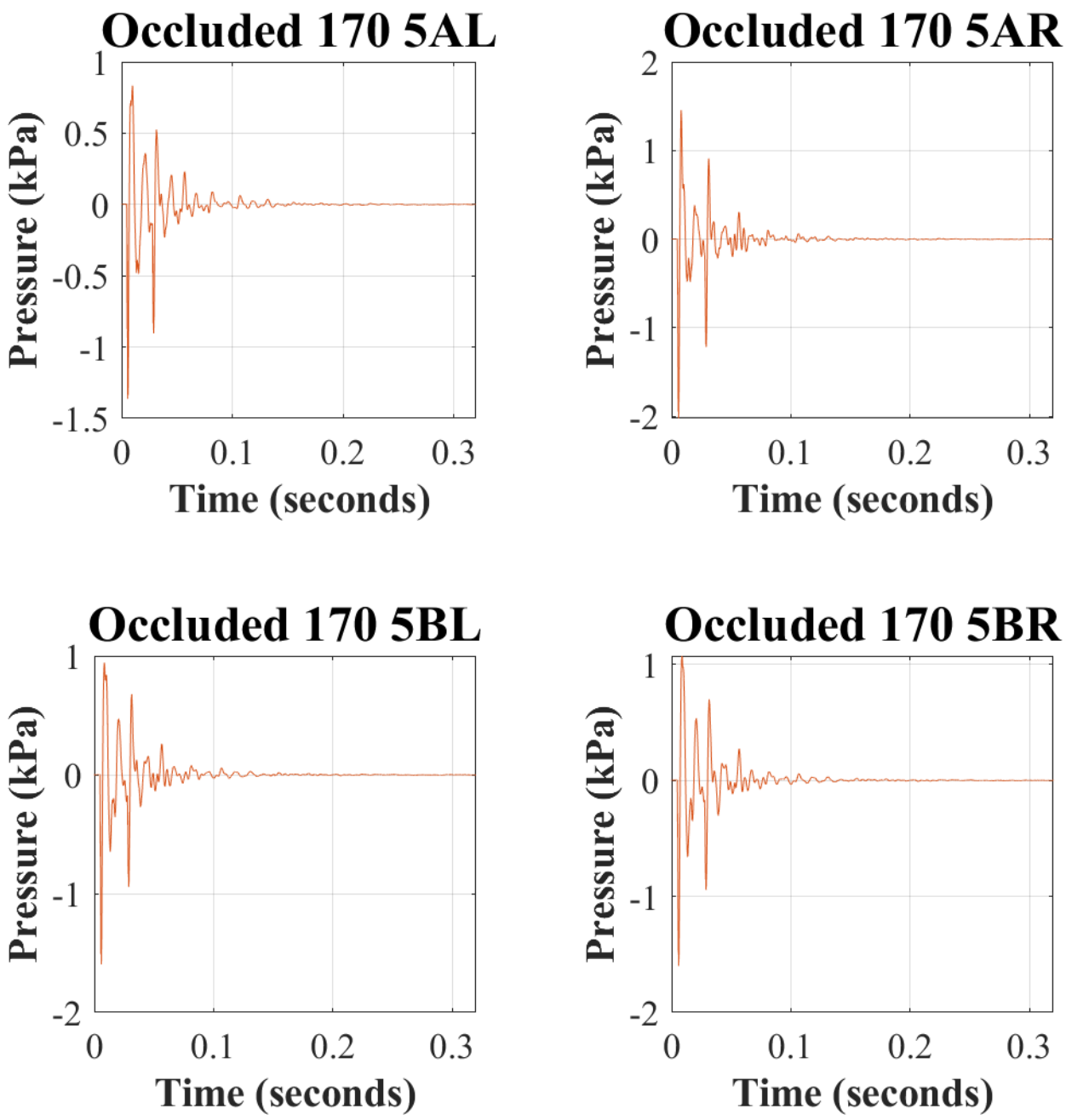

Occluded 170 3BR
Pressure (kPa)
Time (seconds)
2
1
0
-1
-2
-3
0
0.1
0.2
0.3


Occluded 170 4AL
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3


Occluded 170 4AR
Pressure (kPa)
Time (seconds)
1
0
-1
-2
0
0.1
0.2
0.3

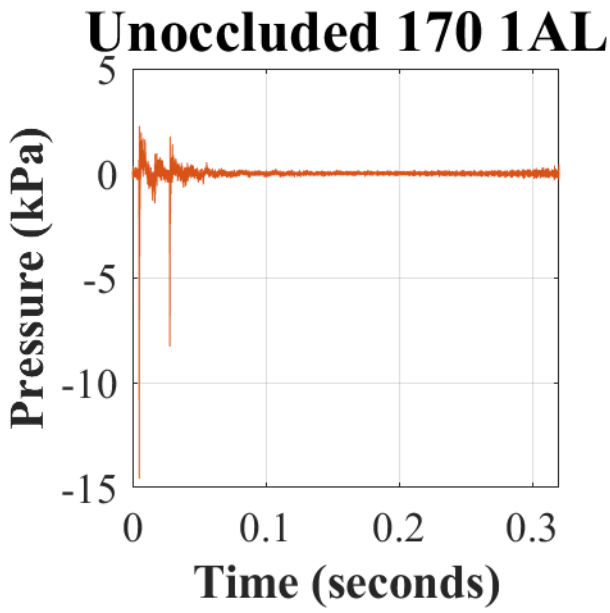

Occluded 170 4BL
Pressure (kPa)
Time (seconds)
1
0.5
0
-0.5
-1
-1.5
0
0.1
0.2
0.3

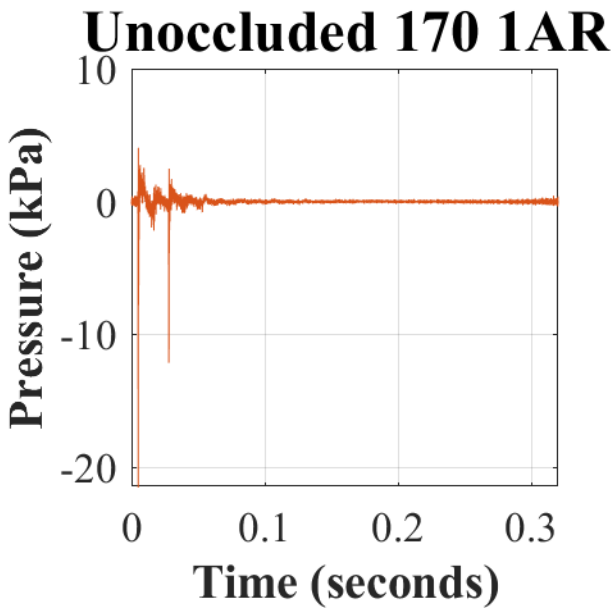

Occluded 170 4BR
Pressure (kPa)
Time (seconds)
2
1
0
-1
-2
0
0.1
0.2
0.3

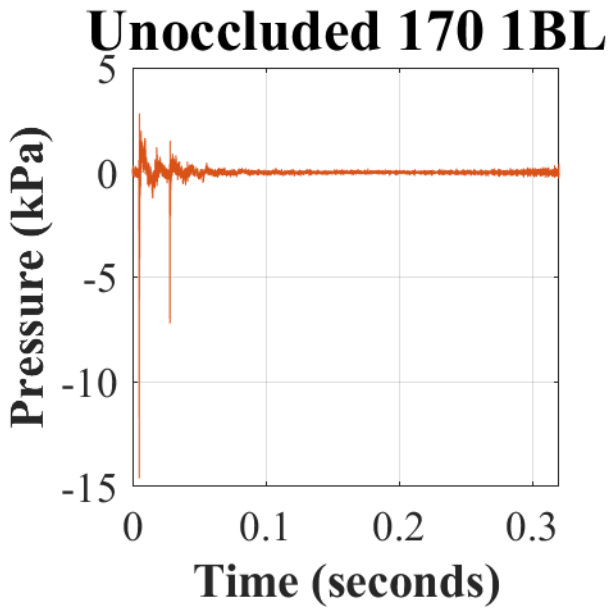


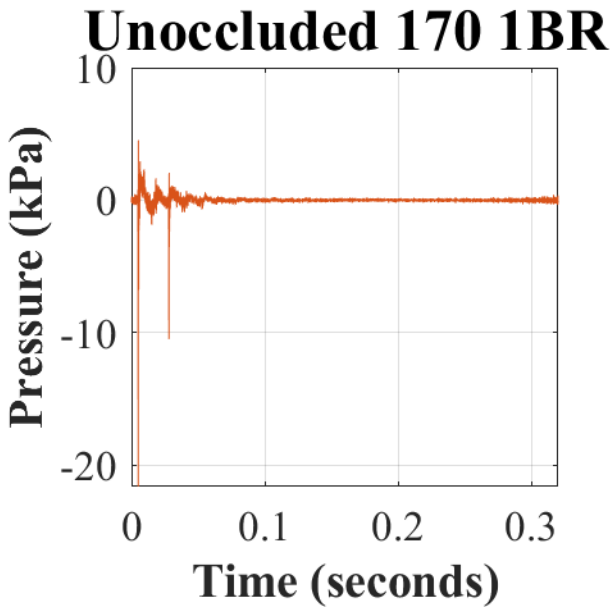
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B) indicating HPD fit (i.e., first or second, respectively), and ‘X’ indicates from what ATF microphone the recording is from (i.e., right [R] or left [L] pinnae).

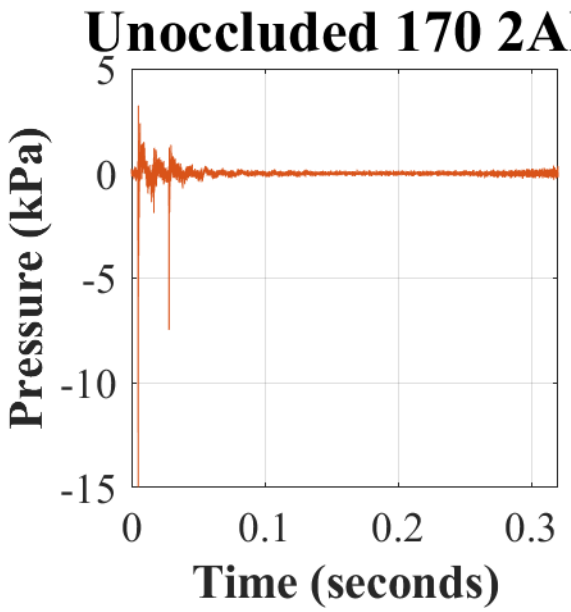
Appendix O. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 170 dBP with the ComTac™ V (MAX).

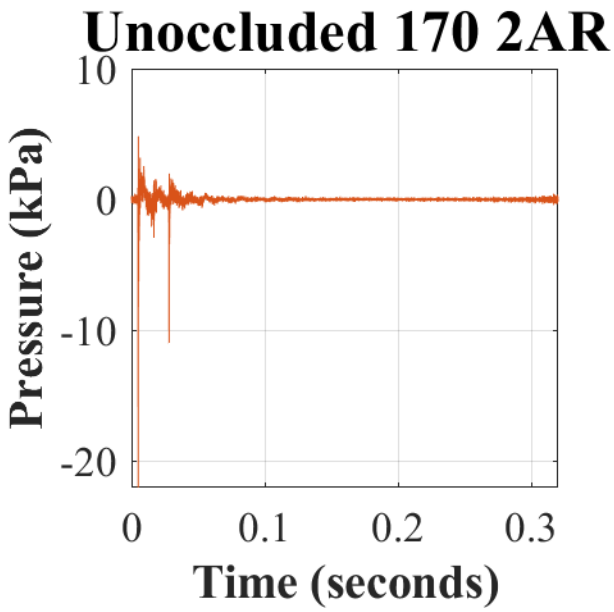


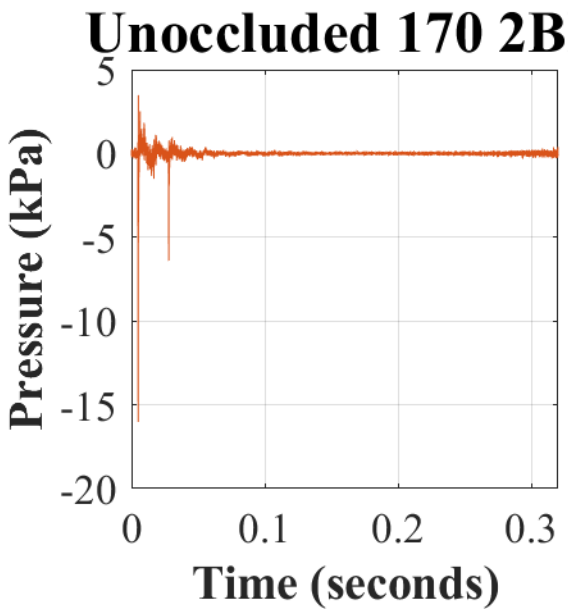


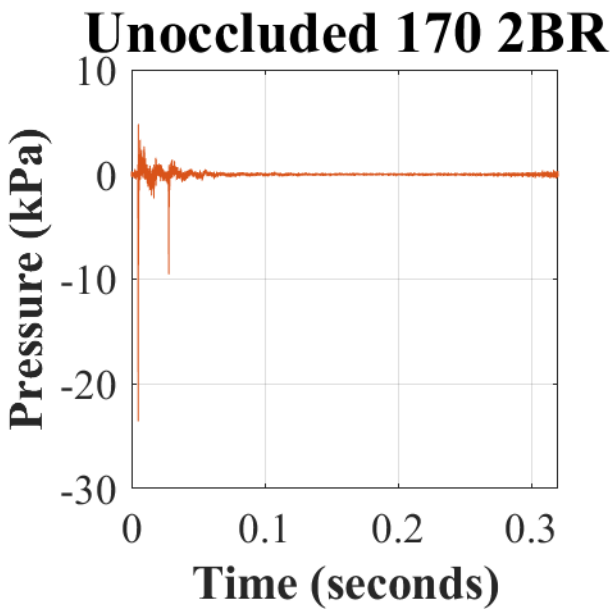


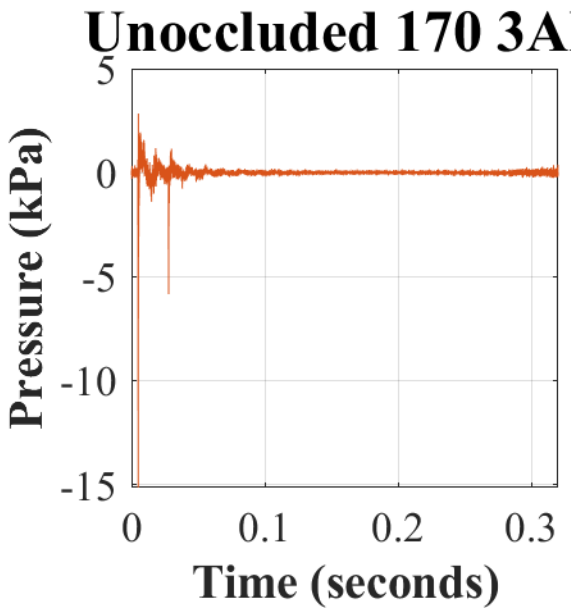


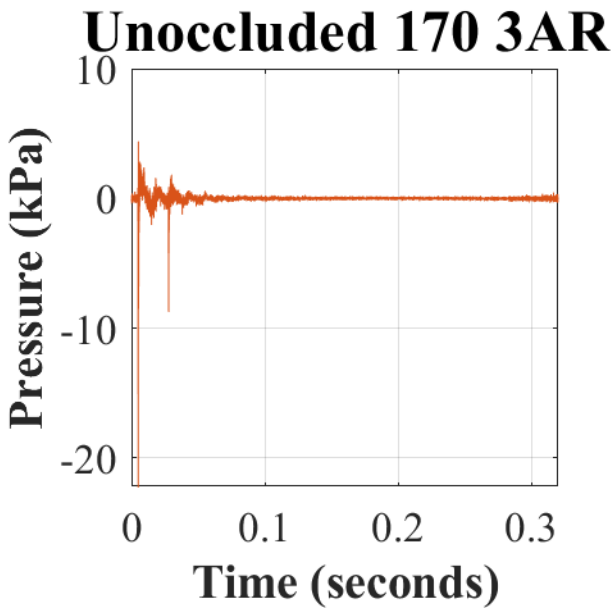

Unoccluded 170 2AL
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

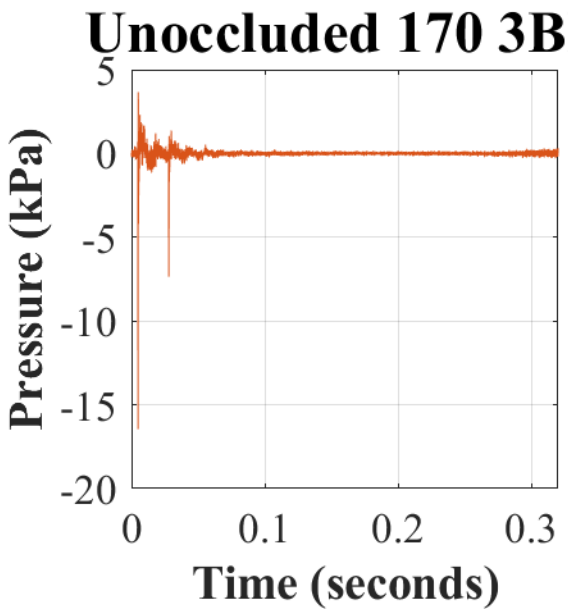

Unoccluded 170 2AR
Pressure (kPa)
10
0
-10
-20
0
0.1
0.2
0.3
Time (seconds)

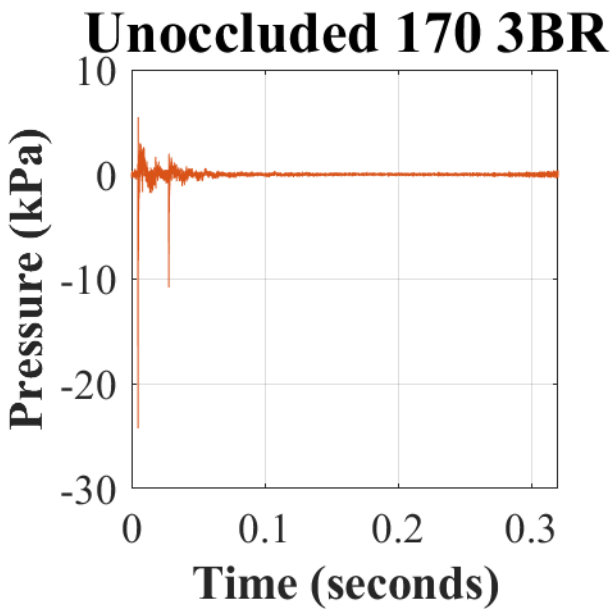

Unoccluded 170 2BL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

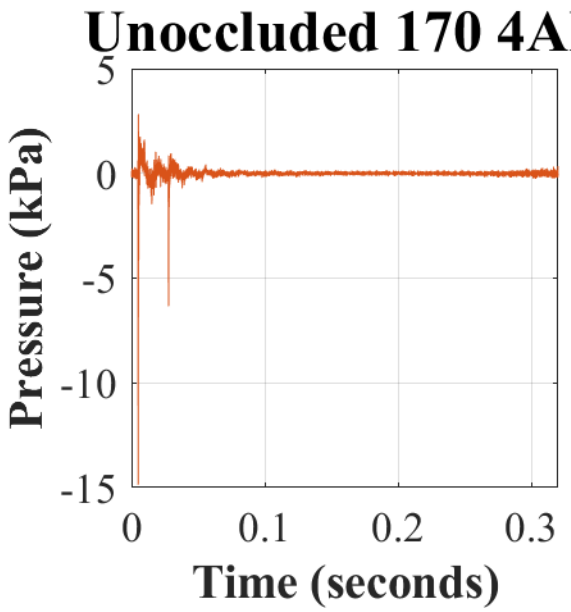

Unoccluded 170 2BR
Pressure (kPa)
10
0
-10
-20
-30
0
0.1
0.2
0.3
Time (seconds)

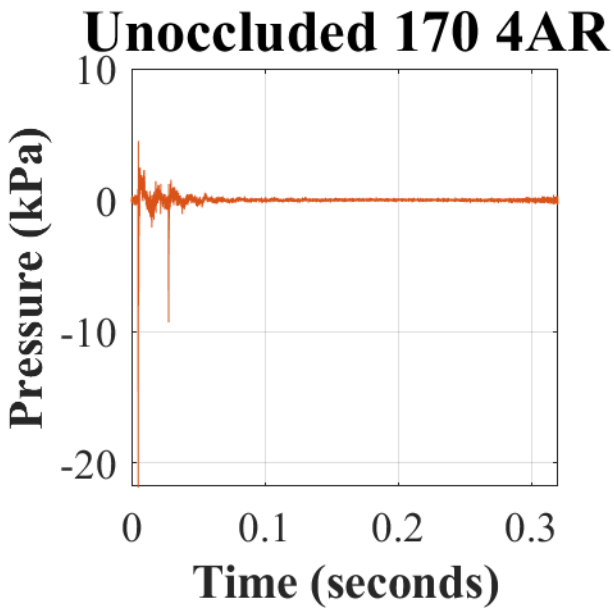

Unoccluded 170 3AL
Pressure (kPa)
5
0
-5
-10
-15
0
0.1
0.2
0.3
Time (seconds)

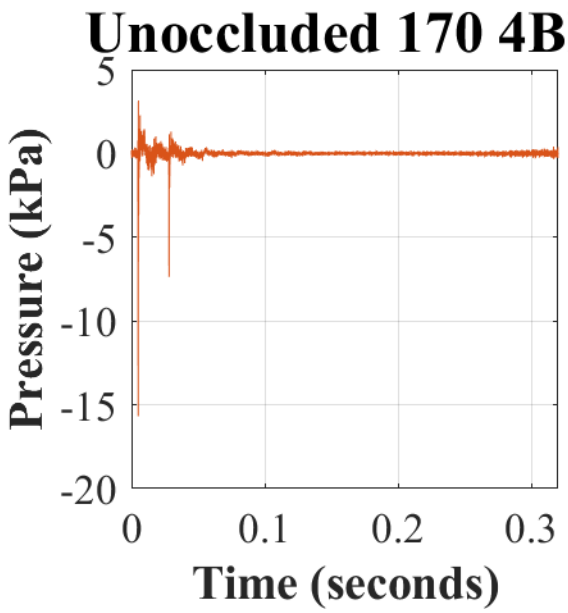

Unoccluded 170 3AR
Pressure (kPa)
10
0
-10
-20
0
0.1
0.2
0.3
Time (seconds)

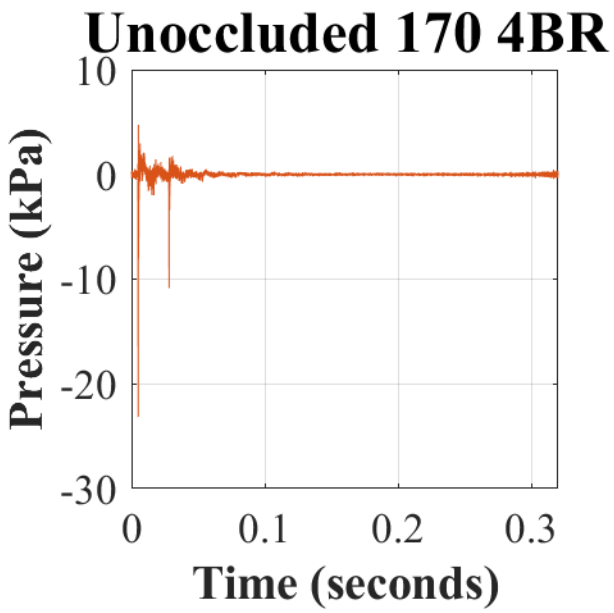

Unoccluded 170 3BL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

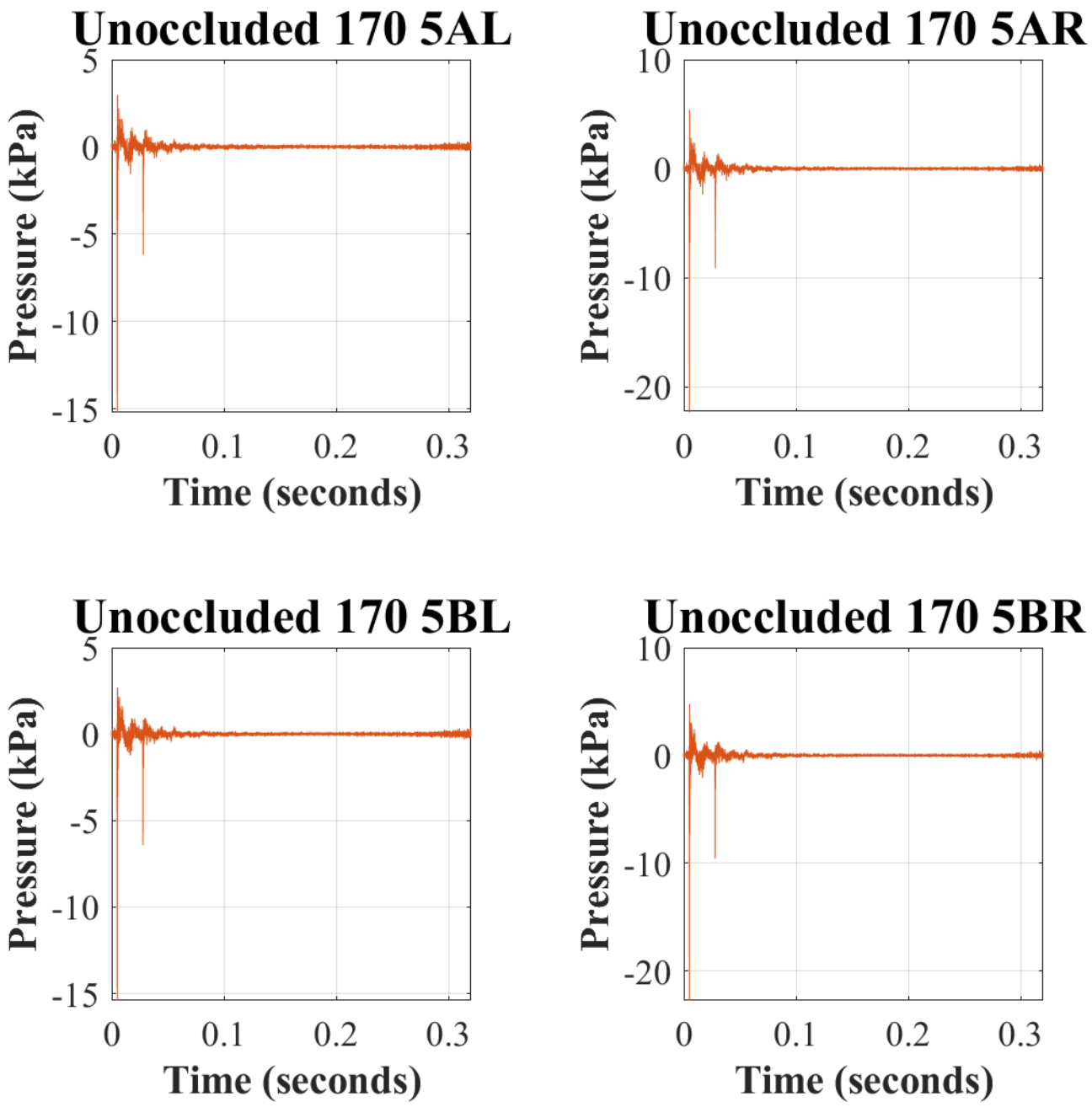

Unoccluded 170 3BR
Pressure (kPa)
10
0
-10
-20
-30
0
0.1
0.2
0.3
Time (seconds)


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


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

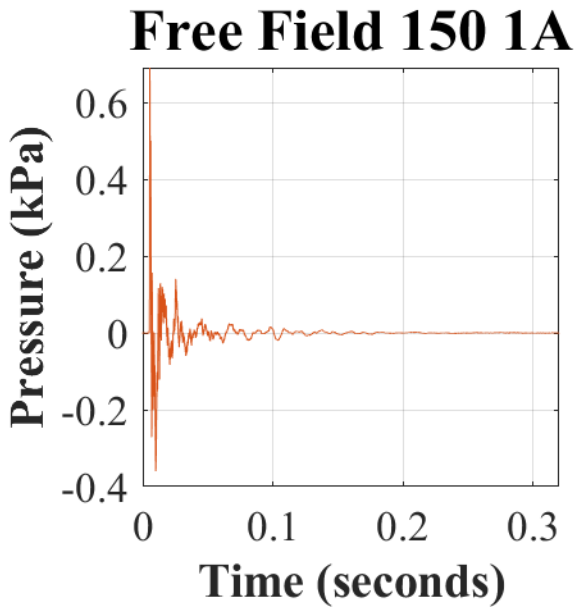

Unoccluded 170 4BL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

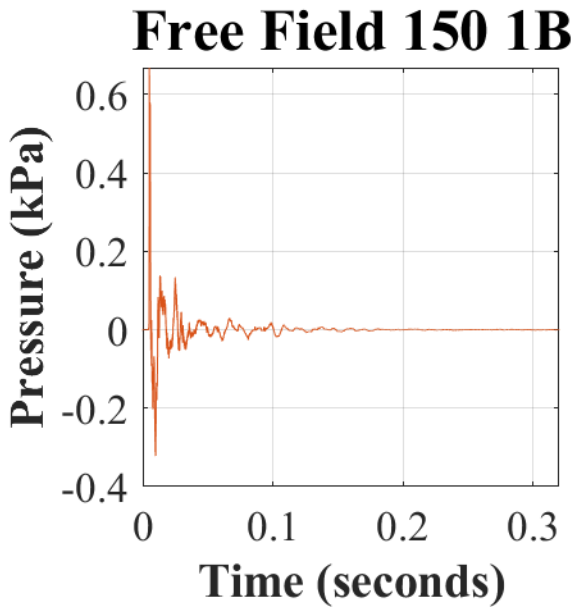

Unoccluded 170 4BR
Pressure (kPa)
10
0
-10
-20
-30
0
0.1
0.2
0.3
Time (seconds)

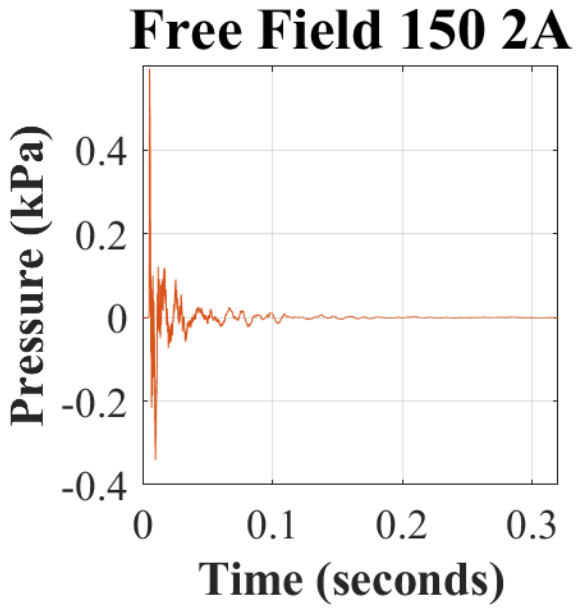


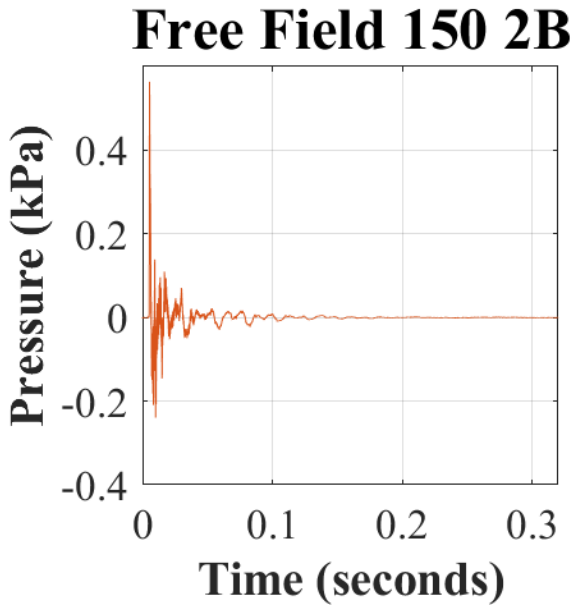
Note. The naming convention for all unoccluded waveforms is "Unoccluded LvL NnX", where 'Unoccluded' is the test condition (i.e., ATF has the HPD doffed), 'LvL' is the nominal test level (i.e., 150, 160 or 170 dBP), 'N' is the sample number (i.e., 1 to 5) of the device tested, 'n' is the trial (i.e., A or B) indicating HPD fit (i.e., first or second, respectively), and 'X' indicates from what ATF microphone the recording is from (i.e., right [R] or left [L] pinnae).

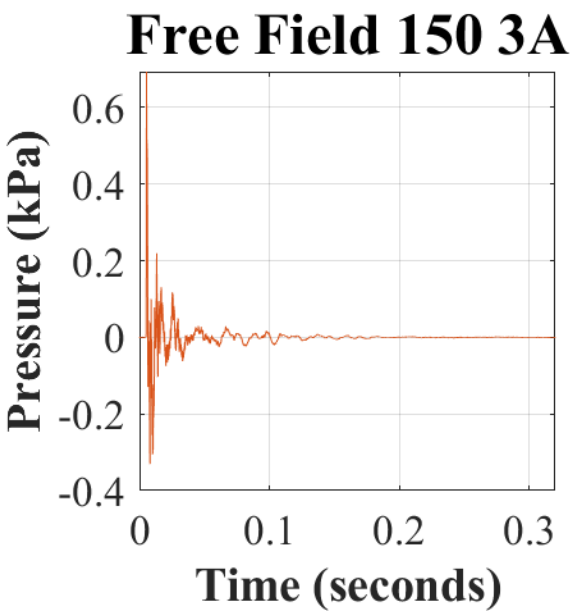
Appendix P. Recorded waveform (in kilopascals [kPa]) over time (in seconds [s]) of the impulse measured with the free-field probe at 150 dBP and the ComTac™ V (MAX) donned.

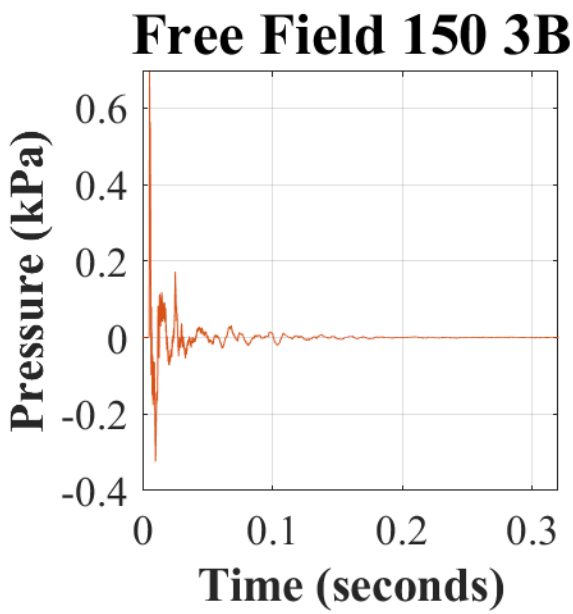


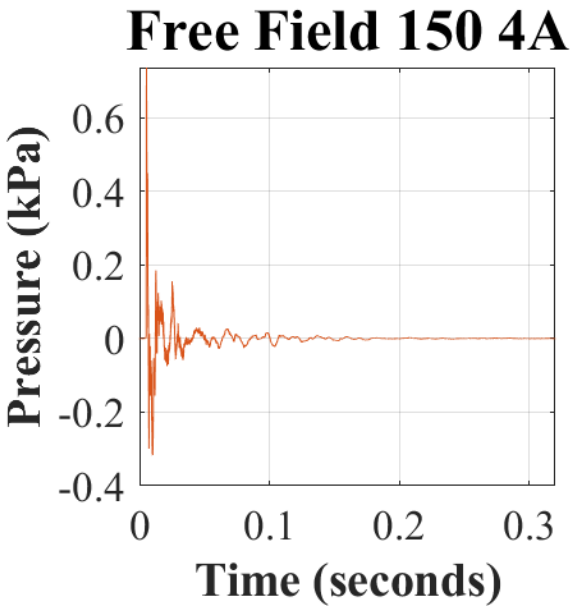


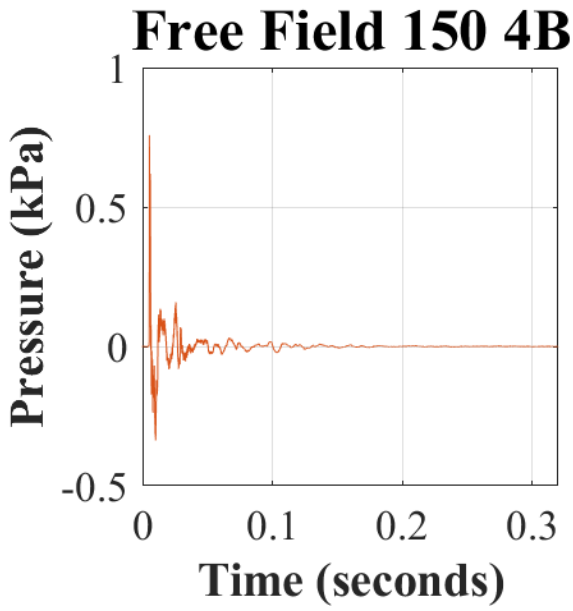


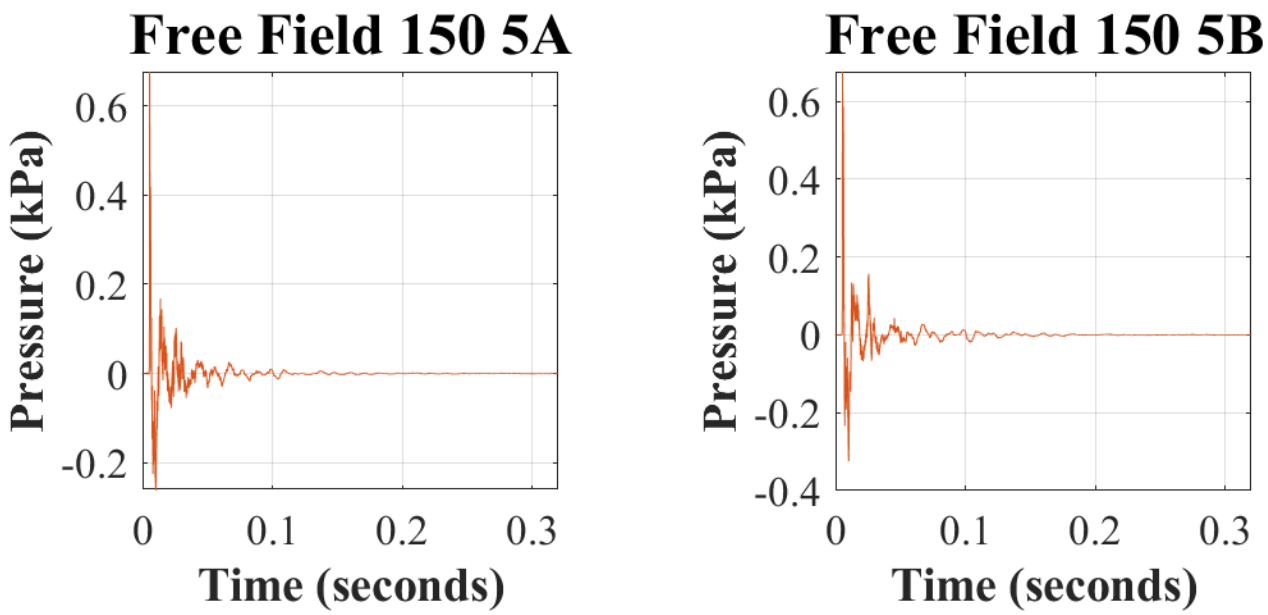



Free Field 150 3A
Pressure (kPa)
0.6
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)


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

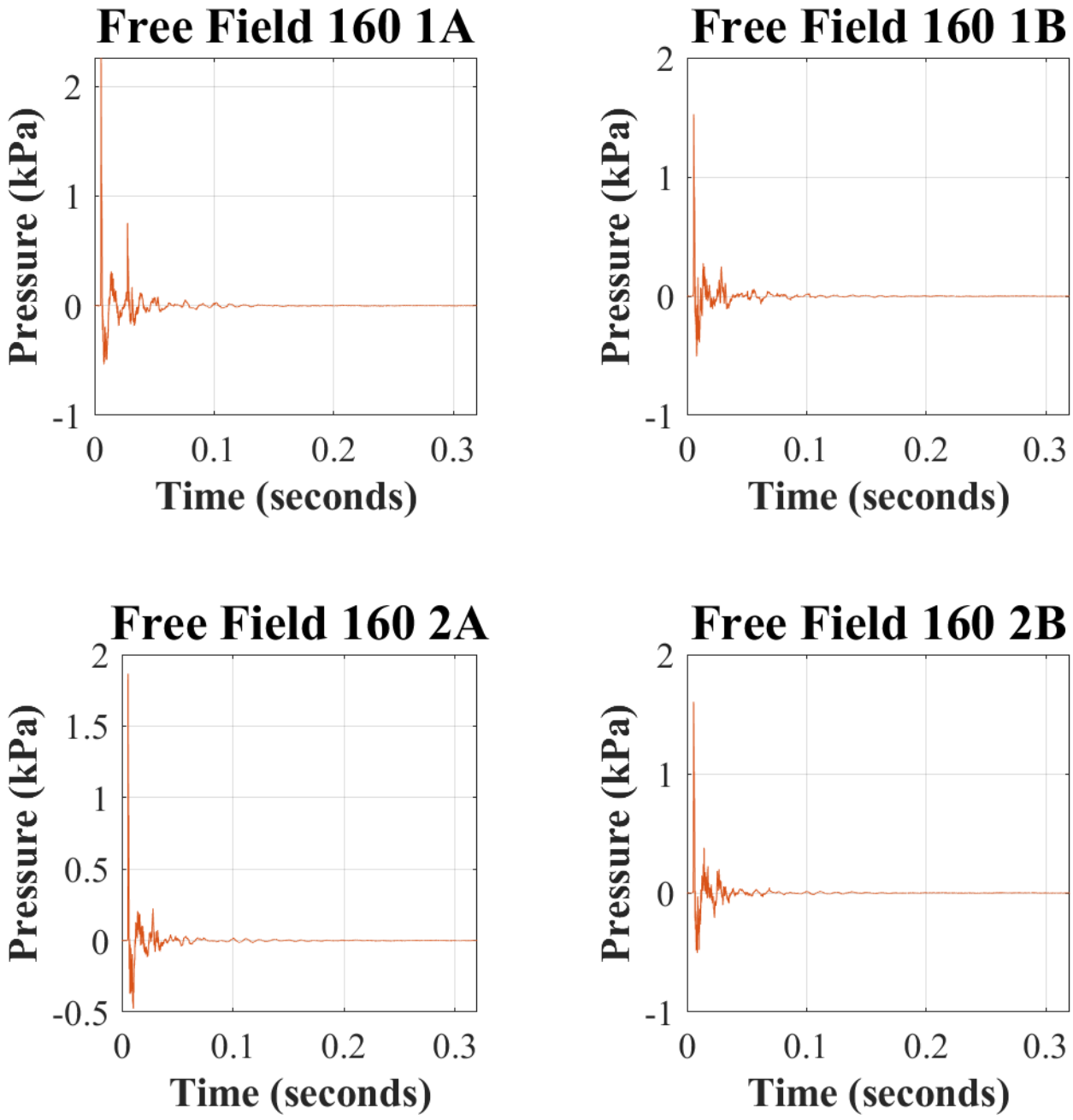

Free Field 150 4A
Pressure (kPa)
0.6
0.4
0.2
0
-0.2
-0.4
0
0.1
0.2
0.3
Time (seconds)

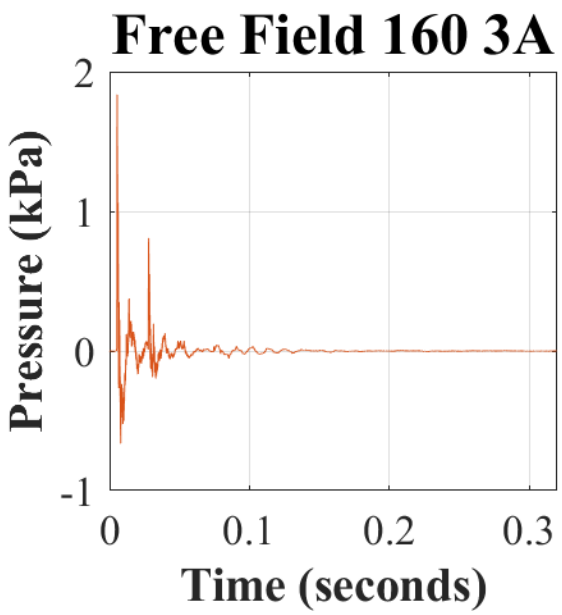

Free Field 150 4B
Pressure (kPa)
1
0.5
0
-0.5
0
0.1
0.2
0.3
Time (seconds)

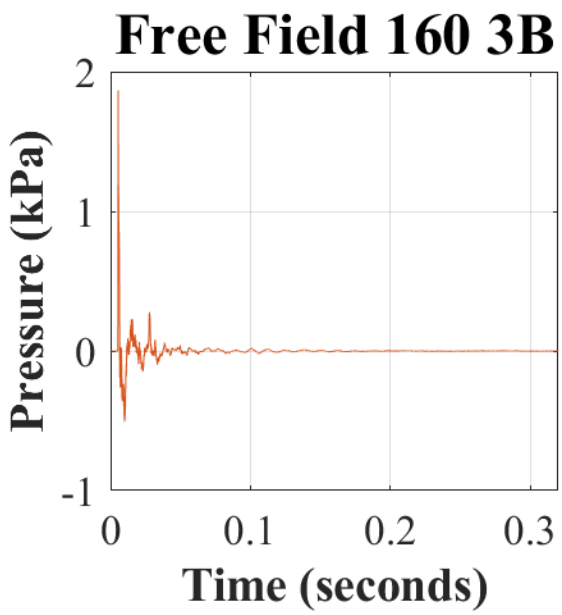


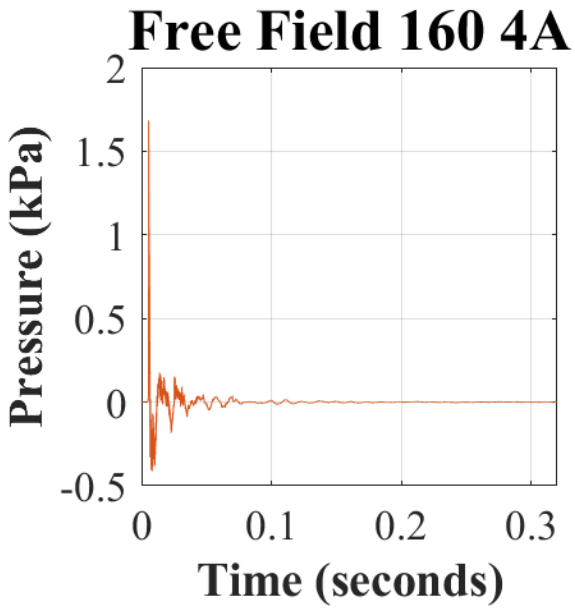
Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (150 dBP), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

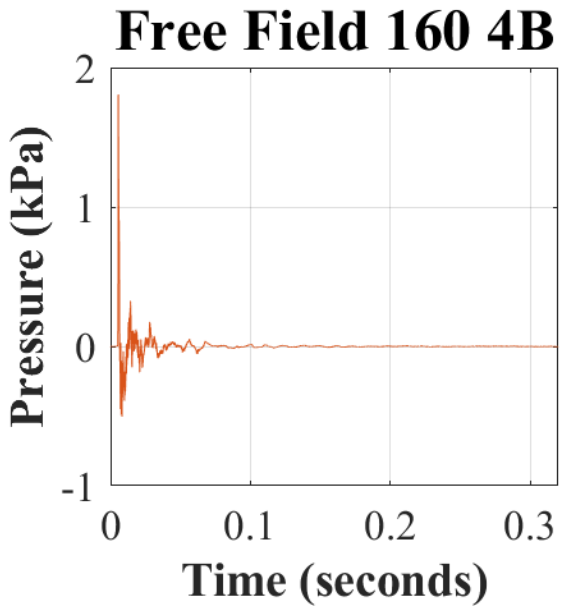
Appendix Q. Recorded waveform (in kilopascals [kPa]) over time (in seconds [s]) of the impulse measured with the free-field probe at 160 dBP and the ComTac™ V (MAX) donned.

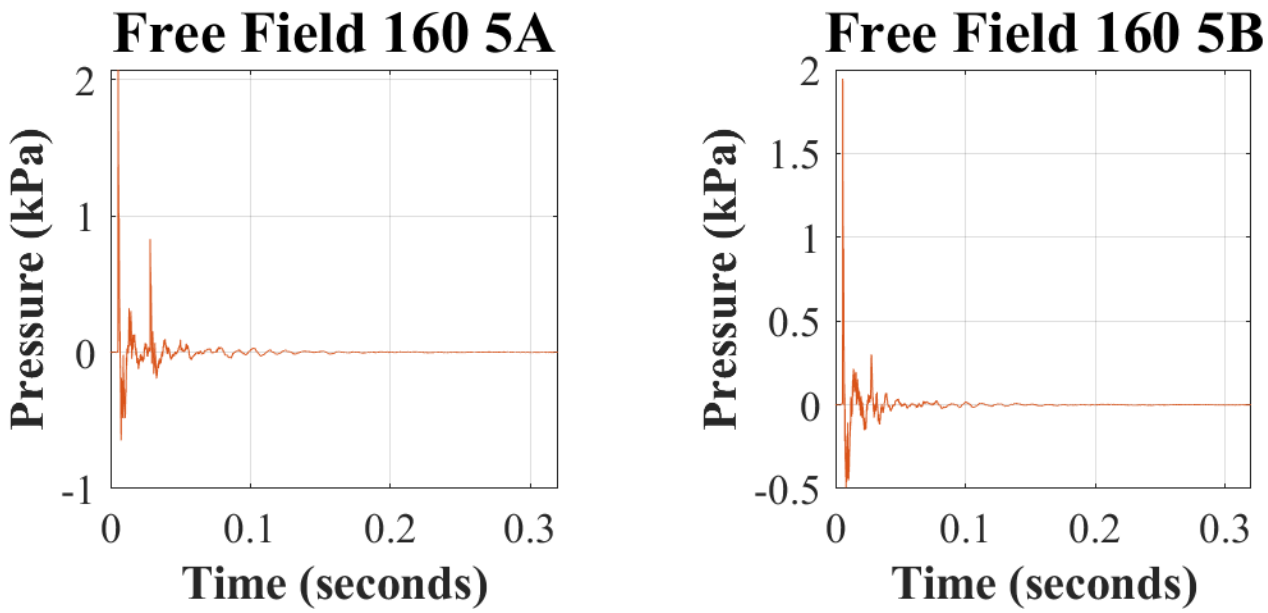



Free Field 160 3A
Pressure (kPa)
Time (seconds)
2
1
0
-1
0
0.1
0.2
0.3


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

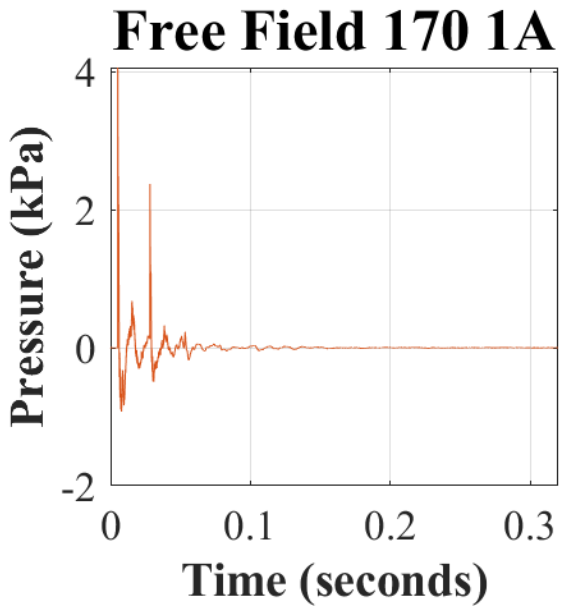

Free Field 160 4A
Pressure (kPa)
Time (seconds)
2
1.5
1
0.5
0
-0.5
0
0.1
0.2
0.3

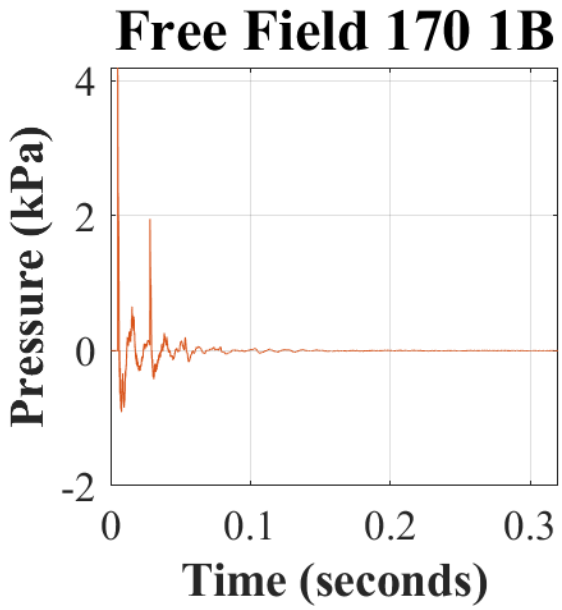

Free Field 160 4B
Pressure (kPa)
Time (seconds)
2
1
0
-1
0
0.1
0.2
0.3

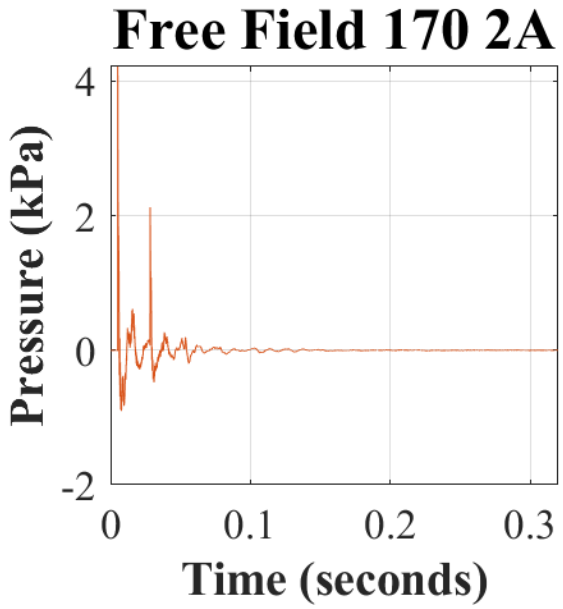


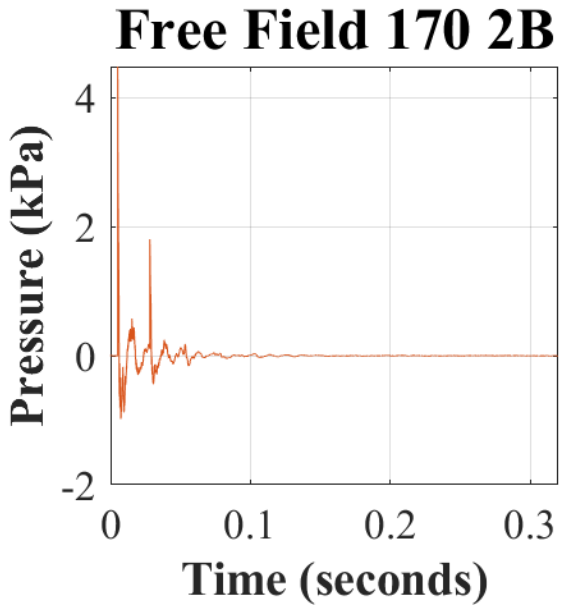
Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (160 dBP), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

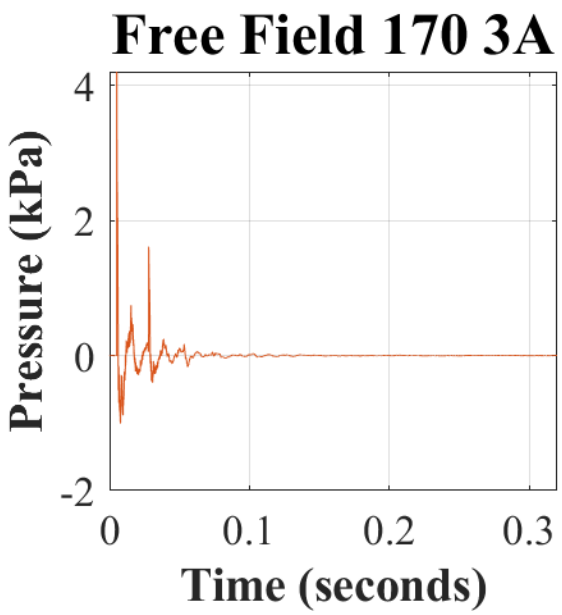
Appendix R. Recorded waveform (in kilopascals [kPa]) over time (in seconds [s]) of the impulse measured with the free-field probe at 170 dBP and the ComTac™ V (MAX) donned.

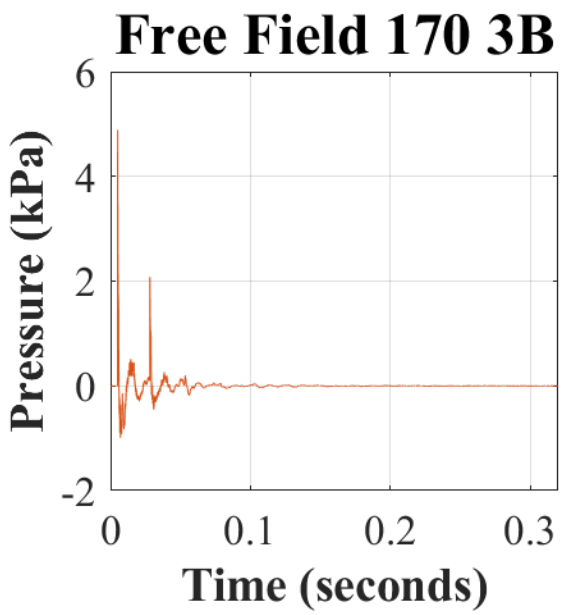


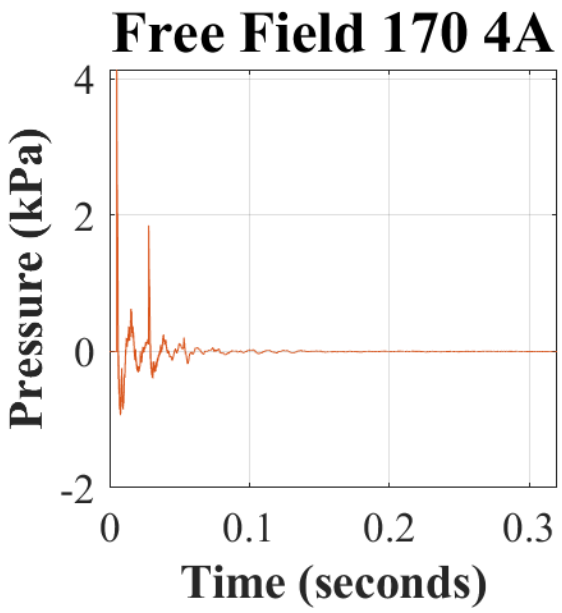


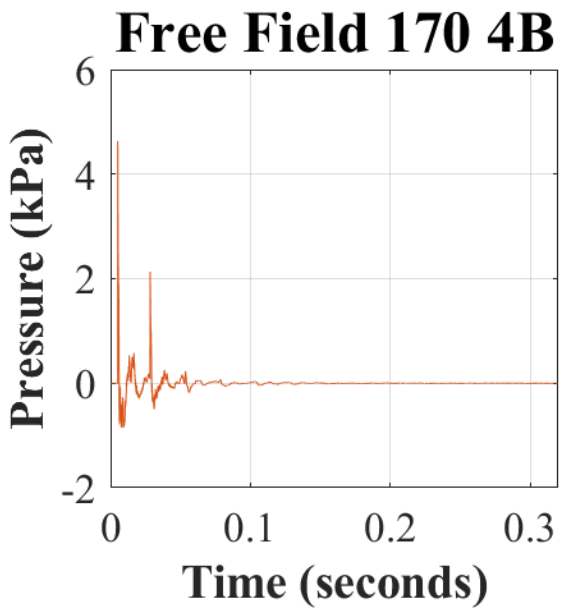


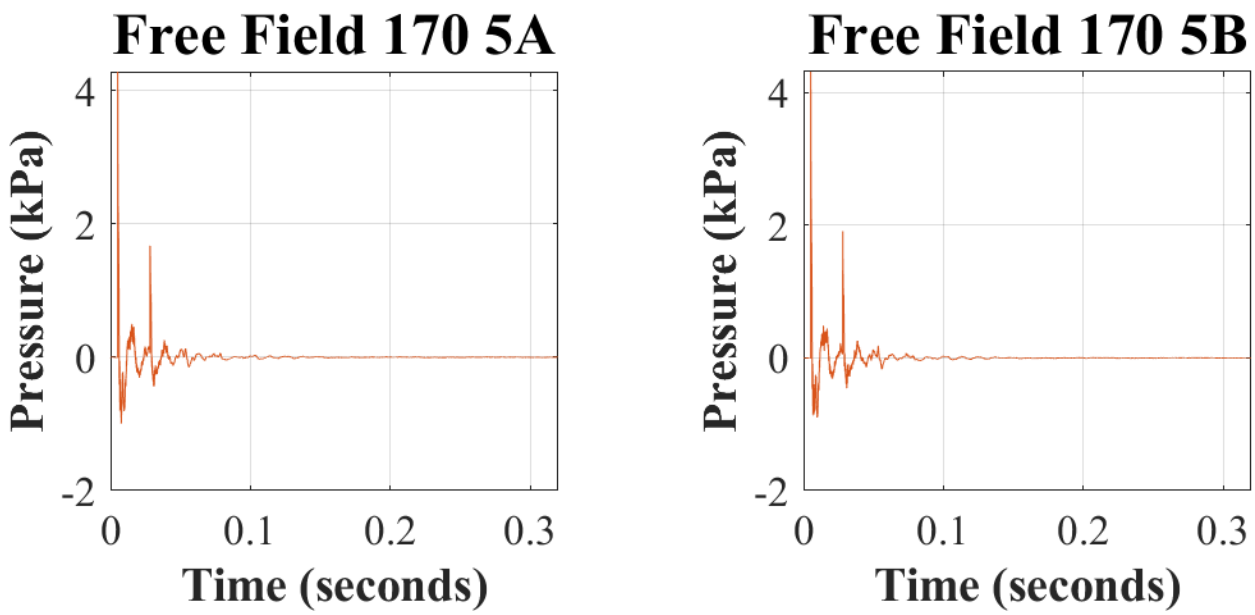



Free Field 170 3A
Pressure (kPa)
4
2
0
-2
0
0.1
0.2
0.3
Time (seconds)


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


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


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



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