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Impulse Assessment of the Enhanced Combat Helmet – Marine Corps and Five Samples of the ComTac™ V Hearing Defender Headset

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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 Gentex[®] Corporation Enhanced Combat Helmet – Marine Corps (ECH-M; Model: A14493-3A1A6, Model: A14493-3A0A6) 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 ECH-M and the ComTac[™] V 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 μ Pa). A total of five samples (one helmet plus one headset) 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 23.9 (1.2) dB SPL for the passive (i.e., OFF) mode, and 23.7 (1.5) dB SPL for the active (i.e., MAX) mode. Results obtained at the 160 dBp presentation level showed mean (SD) IPIL values of 26.2 (1.2) dB SPL for the passive mode, and 25.6 (1.3) dB SPL for the active mode. Results obtained at the 170 dBp presentation level showed mean (SD) IPIL values of 28.7 (0.7) dB SPL for the passive mode, and 28.5 (0.7) 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 ECH-M can adequately protect (i.e., reduce exposure to less than 140 dBp) against impulses below 166.2 dBp in the passive (OFF) test mode, and 165.6 dBp in the active (on and set to MAX) test mode.

Table 1.

ECH-M with ComTac[™] V mean (SD) IPIL value (in dB) for all test conditions.

	150 dBp	160 dBp	170 dBp
OFF	23.9 (1.2)	26.2 (1.2)	28.7 (0.7)
MAX	23.7 (1.5)	25.6 (1.3)	28.5 (0.7)

Introduction

One of the helmets currently fielded by the U.S. Marine Corps (USMC) for use is the Gentex[®] Corporation Enhanced Combat Helmet – Marine Corps (ECH-M; Gentex Corporation, Carbondale, PA). The ECH-M is commercially available in size small, medium, large, extra-large, and extra-extra-large. The operator manual (Headquarters, Department of the Army, 2015) states that the ECH provides ballistic (via the shell configuration) and impact (via the shell geometry pad suspension system) protection. The reduced shell edge cut in front of the eyes and at the ears is intended to provide “an unobstructed field of view and increased ambient hearing capabilities” to the Service Member, thereby allowing for maximum sensory and situational awareness while donned. While the ECH-M was not designed to serve as a hearing protection device (HPD), it can be worn in tandem with a HPD, such as an earmuff.

The earmuff selected for the testing described herein was the 3M[™] PELTOR[™] ComTac[™] V Hearing Defender Headset (ComTac[™] V; 3M, St. Paul, MN), which is an active earmuff-style communications headset. 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.

Separate calculated impulse peak insertion loss (IPIL) values for both the ComTac[™] V and the ECH-M have been previously reported by the Naval Submarine Medical Research Laboratory (NSMRL; Silvia et al., 2021; Koliass et al., 2021). IPIL Values for five samples of the ECH-M worn in combination with one singular ComTac[™] V sample have also been reported by the NSMRL (Koliass et al., 2022).

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 the user’s noise hazard below the 140 dBp limit is the use of HPDs.

To calculate whether an issued HPD or HPD combination will reduce the impulse noise exposure 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 ECH-M 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 ECH-M 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

output level) 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 m³ 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.

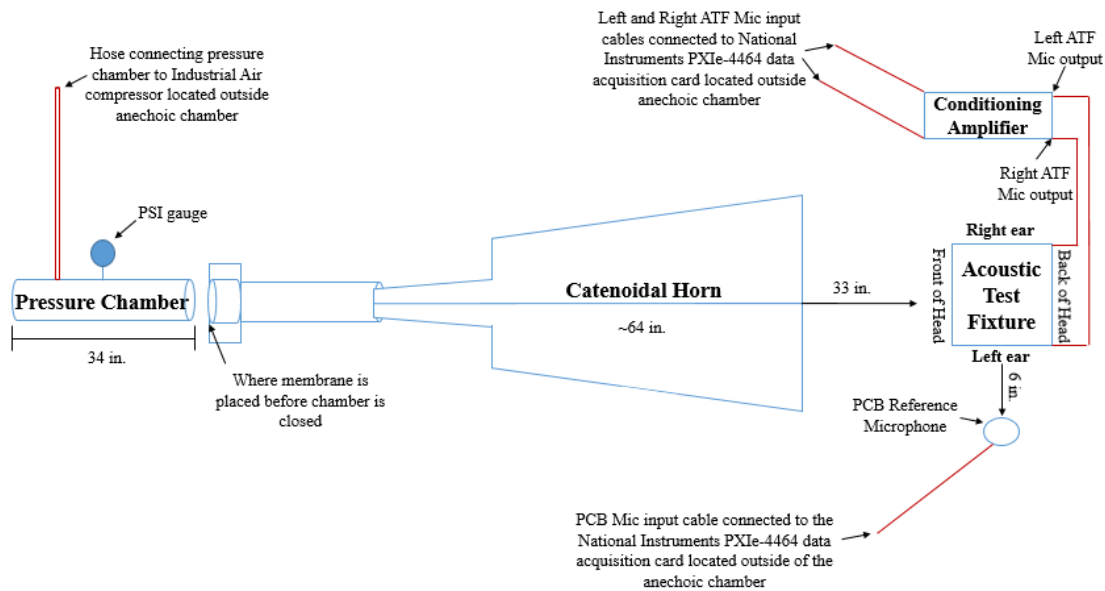
For each trial at 150 dBp, a 7 in. (17.8 cm) by 7 in. (17.8 cm) polyester sheet (SEVA Technical Services, Inc, Newport News, VA) was used as a membrane between the pressurized chamber and the catenoidal tube horn to enable pressurization of the air chamber. Each polyester sheet was 0.001 in. (1.0 mil, 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 microphone, the left ATF microphone, and the right ATF microphone were calibrated each morning prior to data collection at 124 dB sound pressure level (SPL) using a 250 hertz (Hz) tone generator (Bruel & Kjaer, Marlborough, MA). A diagram depicting the aerial view of the NSMRL 4 in. (10.2 cm) shock tube and test system can be seen in Figure 1.

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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 (6th 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 reference PCB microphone, left ATF microphone, and right ATF microphone channels into a file (*.mat) that saved variables for input to analysis script (MATLAB) similar to the script provided in Annex H of the ANSI/ASA S12.42-2010 standard. Minor alterations were made to the analysis script in order to accept 150, 160, and 170 dB data (see Data Analysis below).

Product Samples. Five samples (See Figure 2 for example) of the helmet/HPD configuration were tested. Five large (NSN: NSN 8470-01-592-6208) ECH-M helmet systems (Part Numbers: A14493-3A1A6, A14493-3A0A6) with H-Nape chinstrap retention system (NSN: 8470-01-599-3210) and five neckband versions of the ComTac™ V Hearing Defender Headset (Manufacturer Product Number: MT20H682FB-09 CY) with foam ear cushions were used. Each sample, consisting of one ECH-M helmet system and one ComTac™ V Hearing Defender, was randomly assigned a number 1 through 5.

Figure 2.

Gentex® Corporation ECH-M Helmet and ComTac™ V Hearing Defender Headset.



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 sample combination (ECH-M helmet plus headset) 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 (150, 160, and 170 dB) 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. Regarding helmet samples, a sample would be rejected if deemed unusable for testing due to damage.

To achieve an appropriate fit that would provide maximum attenuation, each sample was expertly fitted to the ATF following the instructions provided on the device packaging. The 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 neckband adjusted to just rest on the neck of the ATF. The helmet manufacturer fitting guidelines stated that all samples be inspected for any damage, blistering, loose material, or fraying prior to use. Each helmet was then placed on the ATF with the front brim approximately two

fingers width above the eyes and the lower side edges sitting along the top of the ear canals. Once properly placed, the chinstrap was buckled and side straps were tightened to achieve a snug fit. If necessary, the nape strap was also adjusted until the ECH-M was stable on 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., products doffed) test configurations. For all occluded measures, the helmet and headset were fitted to the ATF in accordance with the specifications outlined in ANSI/ASA S12.42-2010. Specifically, 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 (i.e., without products) test configuration. Calibrations were not completed at the 170 dBP nominal level in order to avoid exceeding the input limitations of the ATF microphones.

The clamping force of each ECH-M donned with 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 sample 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 ECH-M combined with the ComTac™ V were 23.9 (1.2) dB in the passive (i.e., OFF) test mode and 23.7 (1.5) 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 26.2 (1.2) dB in the passive (i.e., OFF) mode and 25.6 (1.3) dB in the active (i.e., MAX) mode. At 170 dBP, the calculated overall mean (SD) IPIL values were 28.7 (0.7) dB in the passive (i.e., OFF) mode and 28.5 (0.7) dB in the active (i.e., MAX) mode. Calculated IPIL values for all sample trials in the OFF mode ranged between 21.3 to 26.0 dB at 150 dBP, between 24.4 to 28.1 dB at 160 dBP, and 27.1 to 30.1 dB at 170 dBP, while all tested sample trials in the MAX mode ranged between 21.5 to 26.5 dB at 150 dBP, between 23.6 to 29.0 dB at 160 dBP, and between 26.8 to 29.8 dB at 170 dBP.

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Table 2.*Mean (SD) IPIL values (in dB) for Tested ECH-M and ComTac™ V 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	23.2	23.1	22.4	22.7	24.4	24.5	25.8	26.2	28.3	28.6	28.2	28.6
HPD 1, Trial B	26.0	25.7	22.1	21.9	25.0	24.9	25.2	25.0	28.2	28.0	28.2	27.9
HPD 2, Trial A	24.5	23.6	26.5	25.7	28.1	27.8	25.5	25.2	29.3	29.0	29.2	29.0
HPD 2, Trial B	23.1	25.7	23.1	23.7	25.2	26.1	24.4	24.7	27.4	28.3	27.5	27.9
HPD 3, Trial A	24.8	23.3	25.2	24.0	26.4	25.3	29.0	28.1	30.1	28.8	29.8	28.8
HPD 3, Trial B	24.7	22.9	23.2	21.5	27.6	26.4	25.7	24.6	29.3	28.4	28.8	27.9
HPD 4, Trial A	21.3	23.5	21.5	23.7	25.6	27.1	23.6	25.6	27.1	28.5	26.8	28.9
HPD 4, Trial B	21.9	23.8	23.9	24.6	26.2	27.0	26.2	26.4	28.9	29.6	28.7	29.2
HPD 5, Trial A	25.4	24.1	24.1	23.2	26.0	25.0	26.1	25.4	29.3	28.5	28.6	27.8
HPD 5, Trial B	24.0	23.7	25.9	25.2	27.9	27.6	24.5	23.9	29.1	28.8	29.2	28.5
Ear Specific Mean (SD)	23.9 (1.5)	23.9 (1.0)	23.8 (1.7)	23.6 (1.4)	26.2 (1.3)	26.2 (1.2)	25.6 (1.5)	25.5 (1.2)	28.7 (0.9)	28.7 (0.4)	28.5 (0.9)	28.5 (0.5)
Level Overall Mean (SD)	23.9 (1.2) 23.7 (1.5)				26.2 (1.2) 25.6 (1.3)				28.7 (0.7) 28.5 (0.7)			

As shown in Table 3, the measured clamping force of the ComTac™ V samples ranged from 2.2 to 2.4 lbf, with a mean (SD) of 2.3 (0.1) lbf.

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

	Band Force
HPD 1	2.3
HPD 2	2.2
HPD 3	2.2
HPD 4	2.3
HPD 5	2.4
MEAN (SD)	2.3 (0.1)

The waveforms for the passive (i.e., OFF) test mode for all trials of the ComTac™ V plus the ECH-M 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 ECH-M 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 sound above 82 dBA. As a result, when the active technology is functional and the ear cups are fitted properly, it is expected 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 0.2 dB of each other for the 150 dBP nominal test level, within 0.6 dB of each other for the 160 dBP nominal test level, and within 0.2 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 4.7 dB at 150 dBP, 3.7 dB at 160 dBP, and 3.0 dB at 170 dBP in the OFF test mode, while all individual trial mean IPIL values varied as much as 5.0 dB at 150 dBP, 5.4 dB at 160 dBP, and 3.0 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 helmet and headset sample 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.

It is important to note that these results 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 like that of eye protection.

Conclusions

This report described the process for determining the mean impulse peak insertion loss (IPIL) values provided by the ECH-M 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 ECH-M with the ComTac™ V Hearing Defender Headset in the passive (OFF) mode were found to be 23.9 (1.2) dB at 150 dBP, 26.2 (1.2) dB at 160 dBP, and 28.7 (0.7) dB at 170 dBP. When the ECH-M was worn with the ComTac™ V in the active mode (turned on, and output level set to

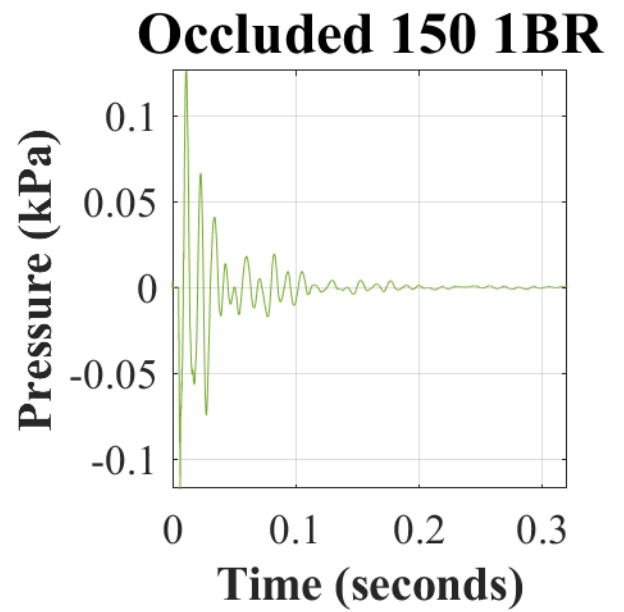
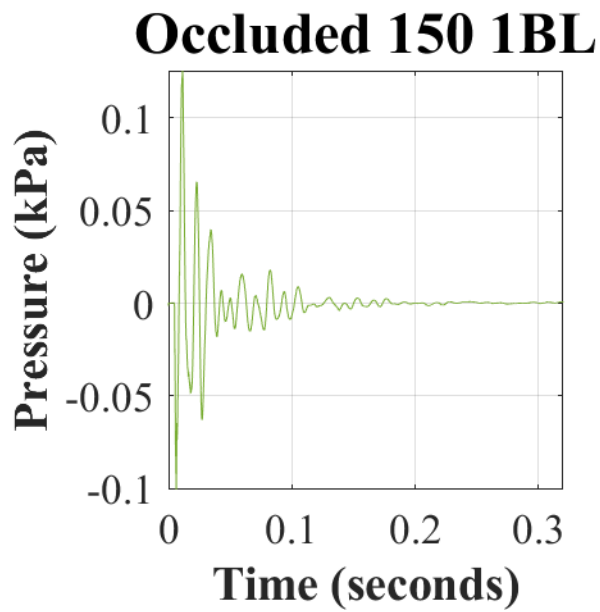
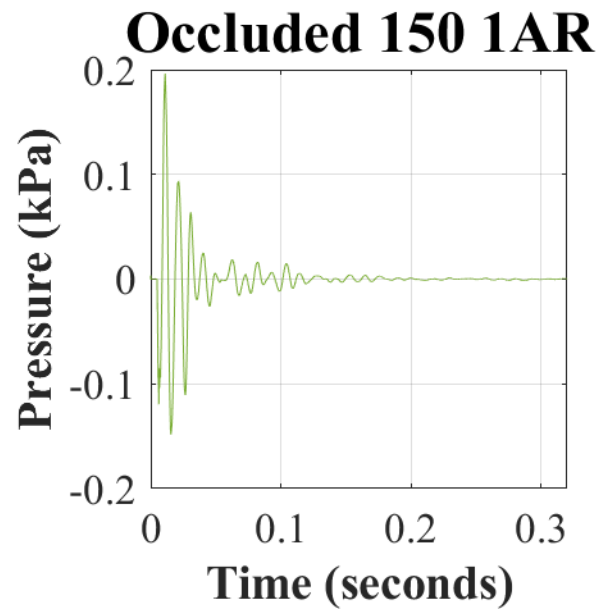
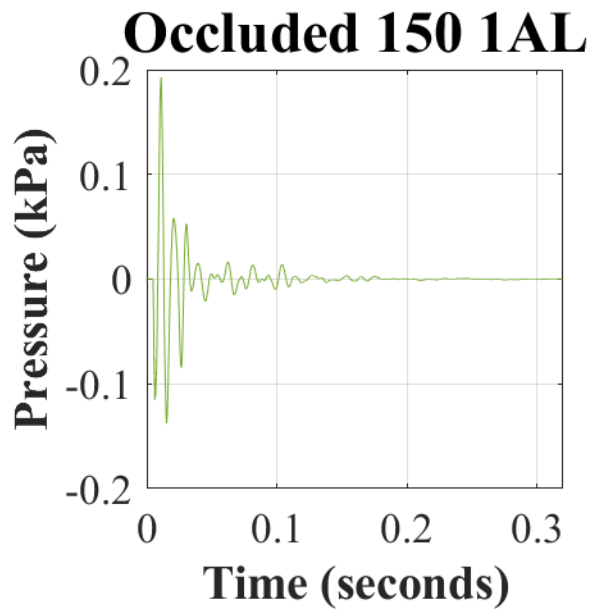
MAX), the overall mean (SD) IPIL values were 23.7 (1.5) dB at 150 dBP, 25.6 (1.3) dB at 160 dBP, and 28.5 (0.7) dB at 170 dBP.

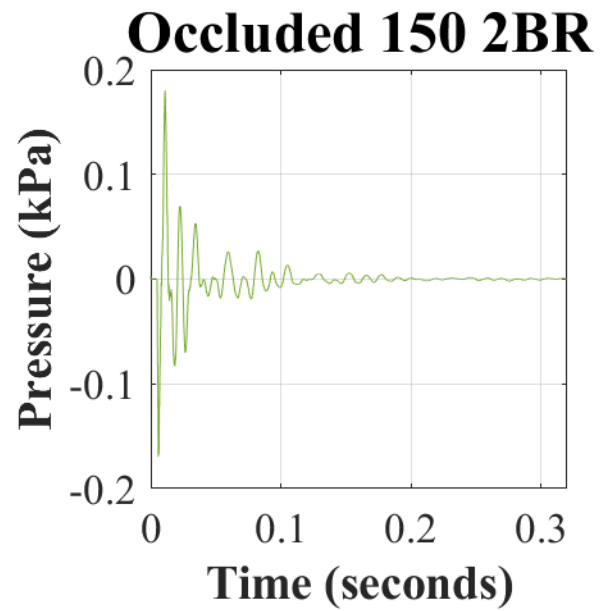
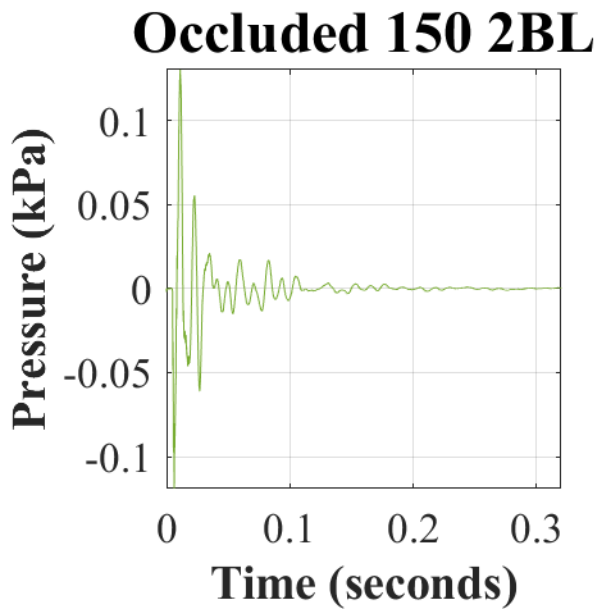
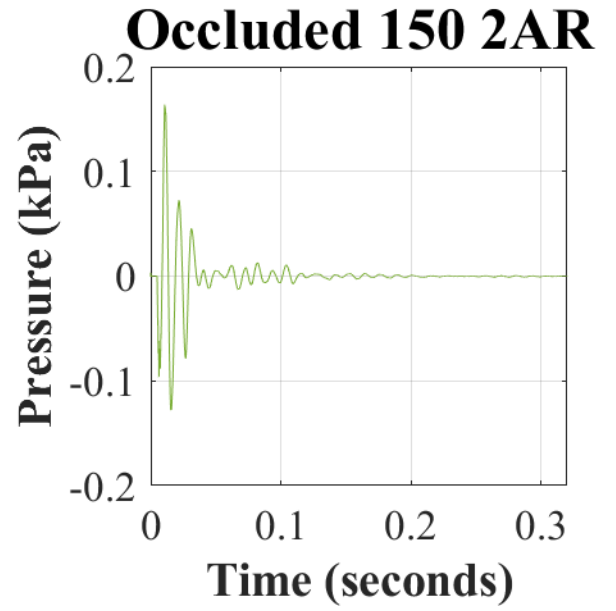
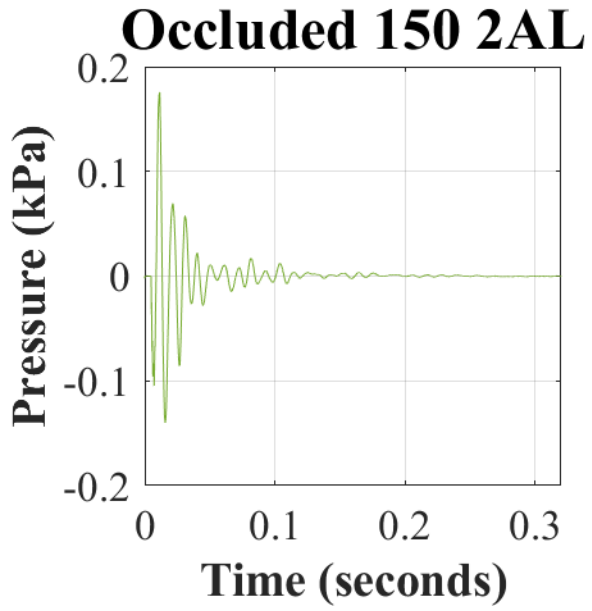
The results of testing suggest that, when properly fit and functional, the ComTac™ V worn in combination with the ECH-M can adequately protect (i.e., reduce the exposure level below 140 dBP) the user from impulses below 166.2 dBP in the passive (i.e., OFF) mode, and 165.6 dBP in the active (i.e., MAX) mode.

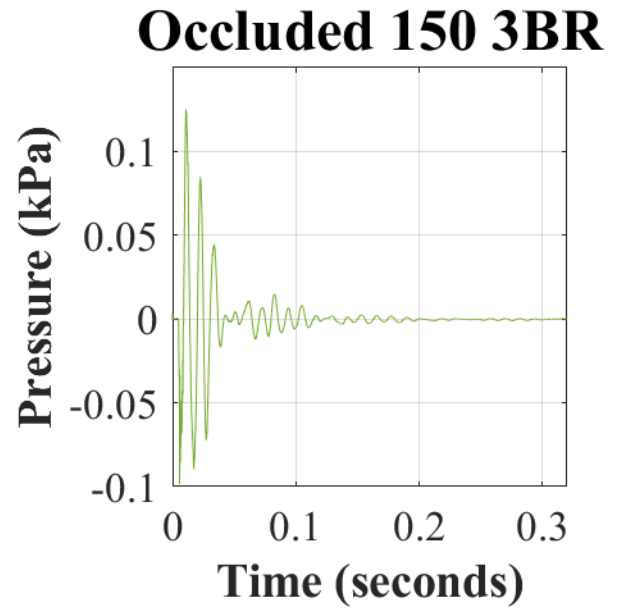
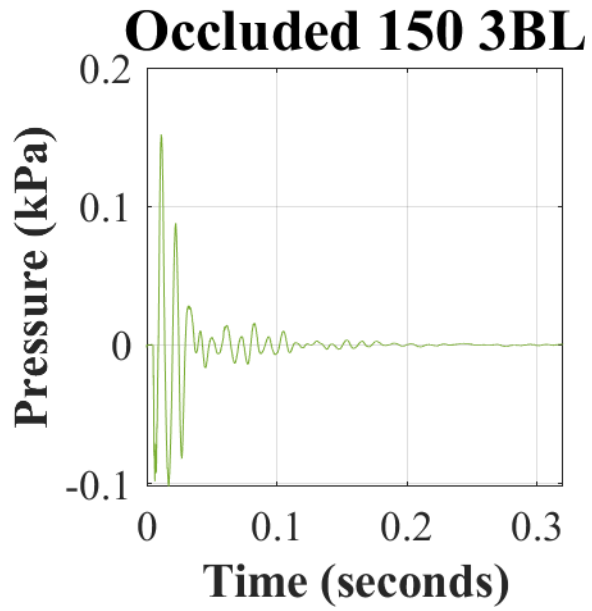
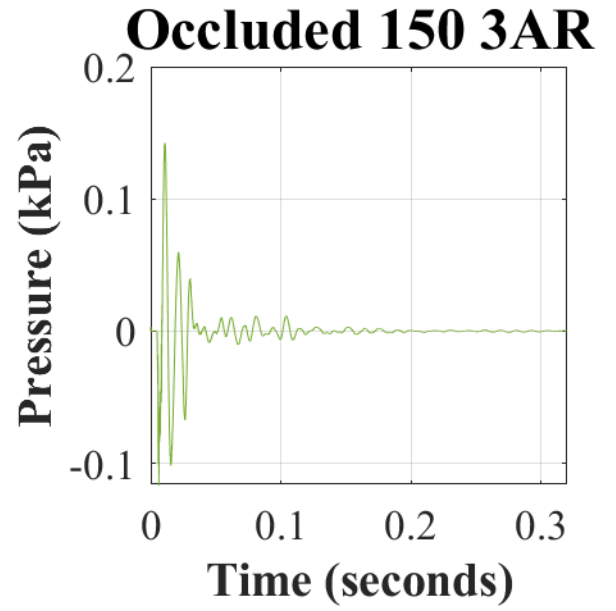
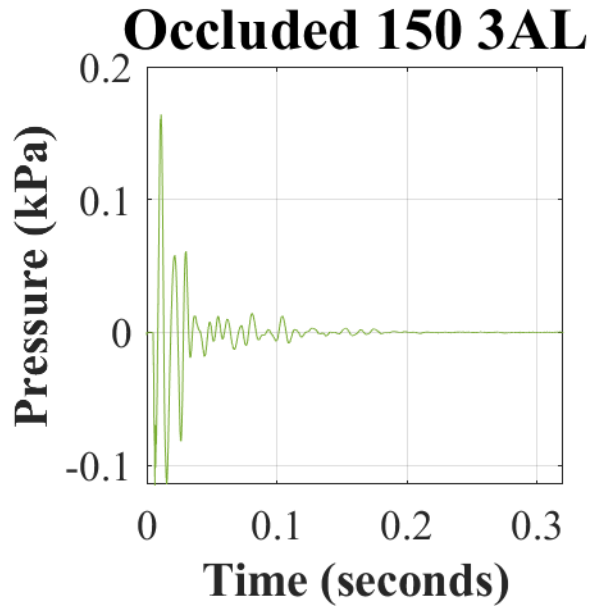
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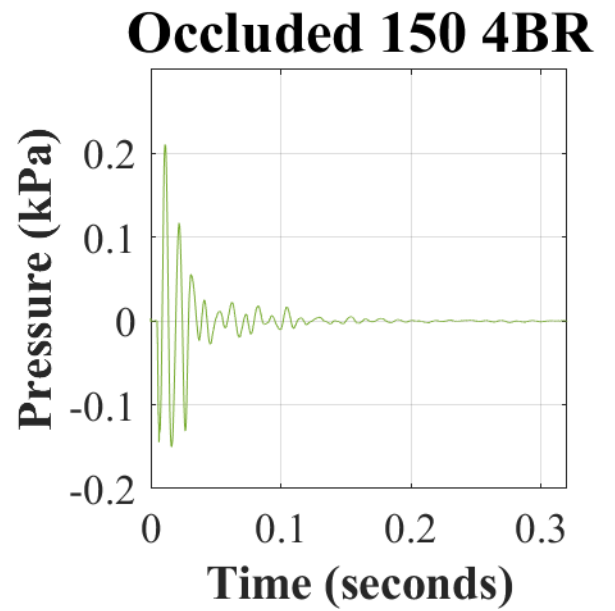
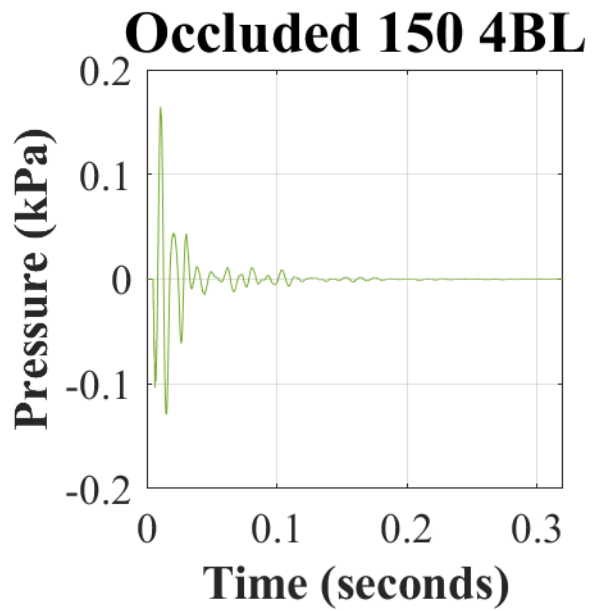
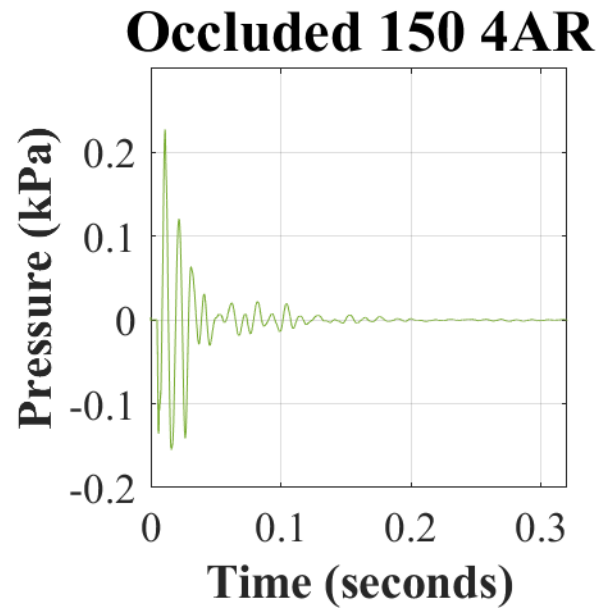
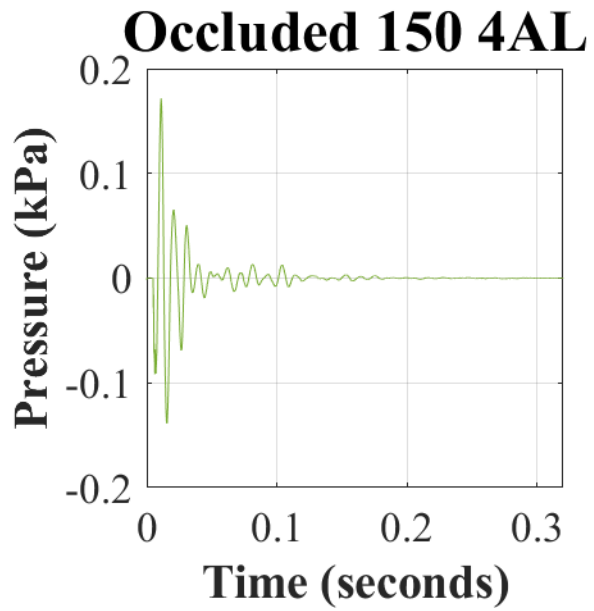
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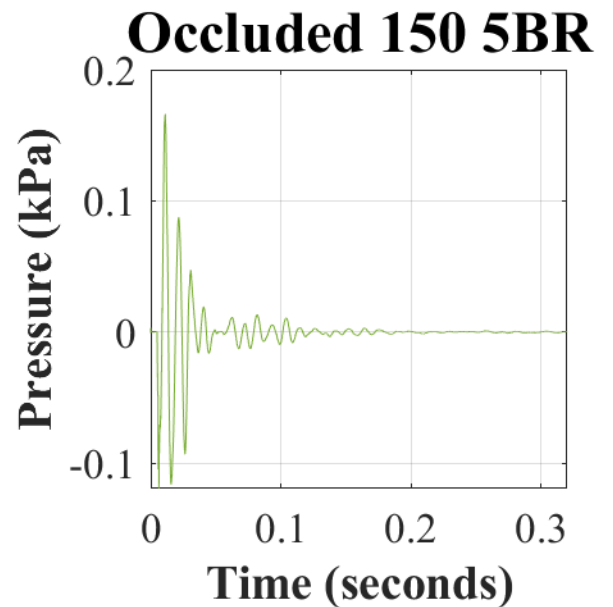
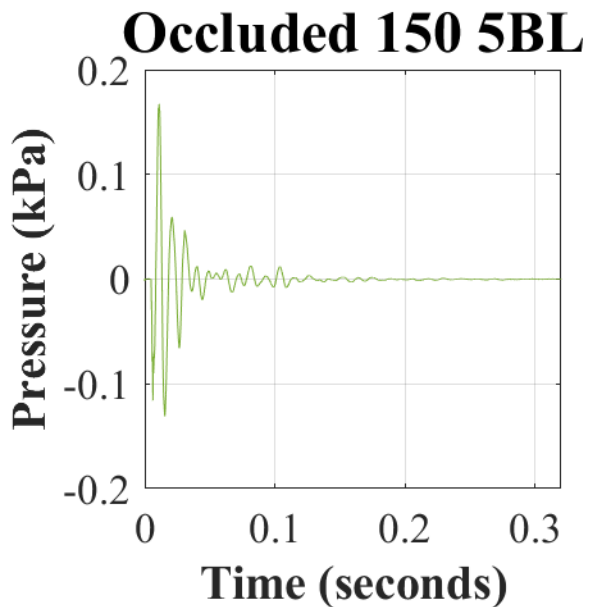
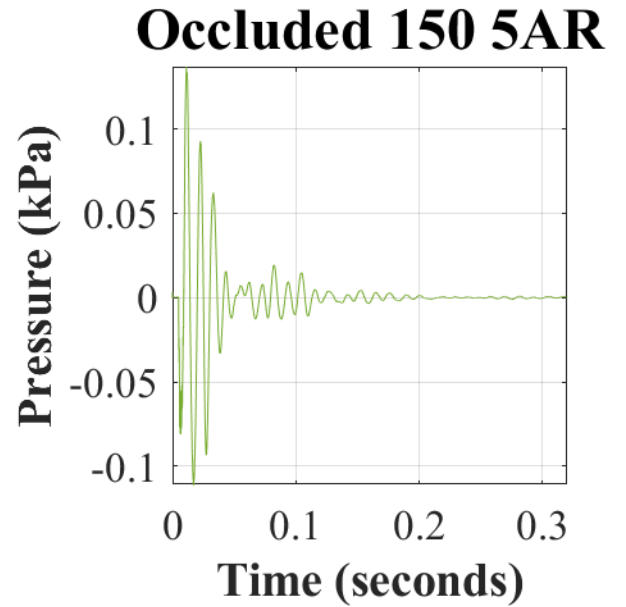
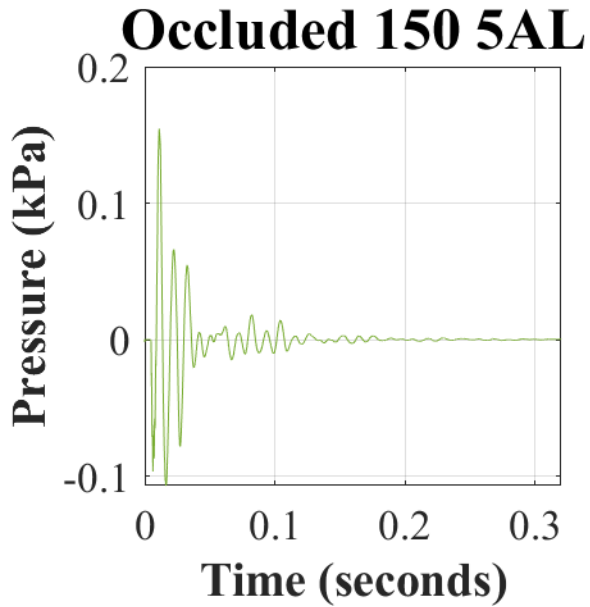
Appendix A. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 150 dBp with the ComTac™ V (OFF).





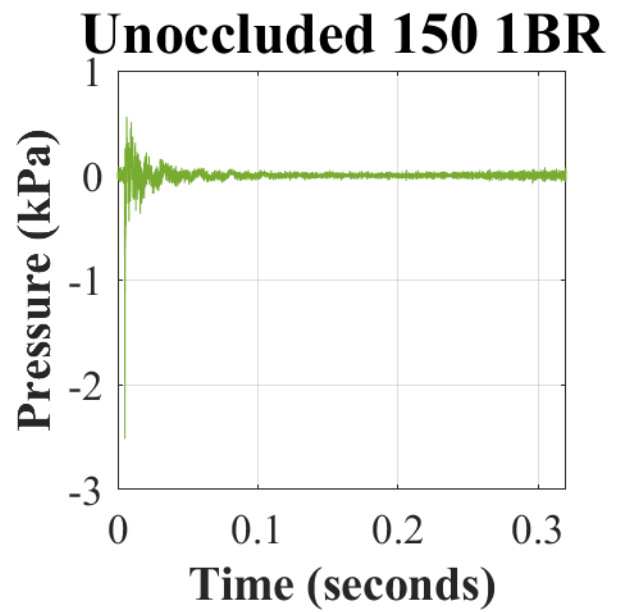
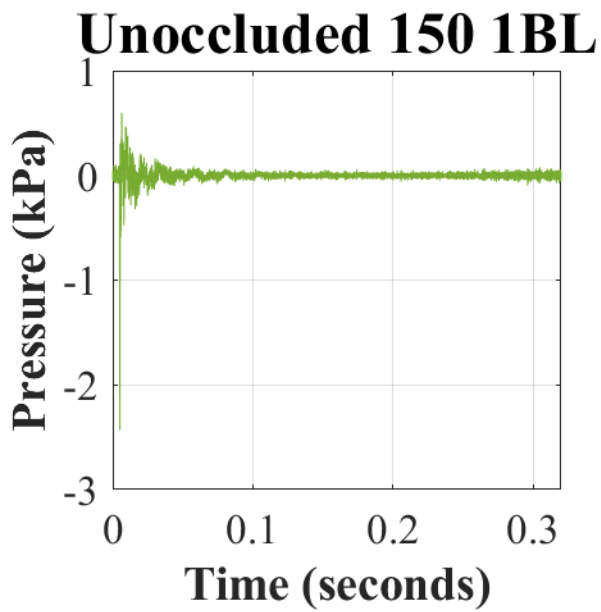
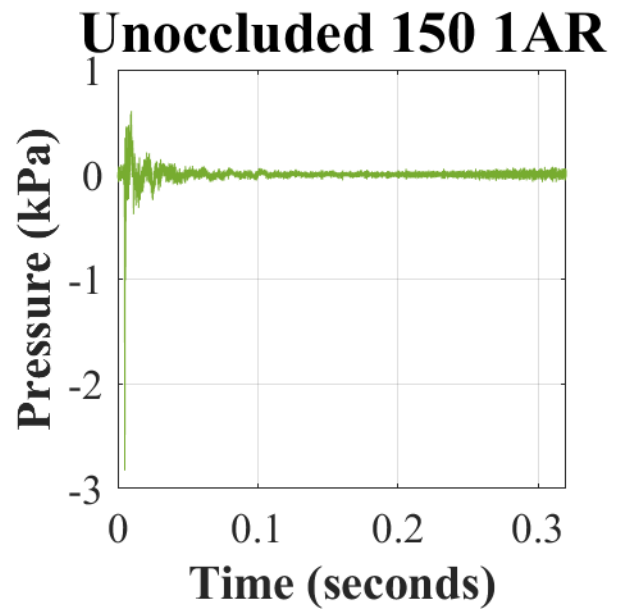
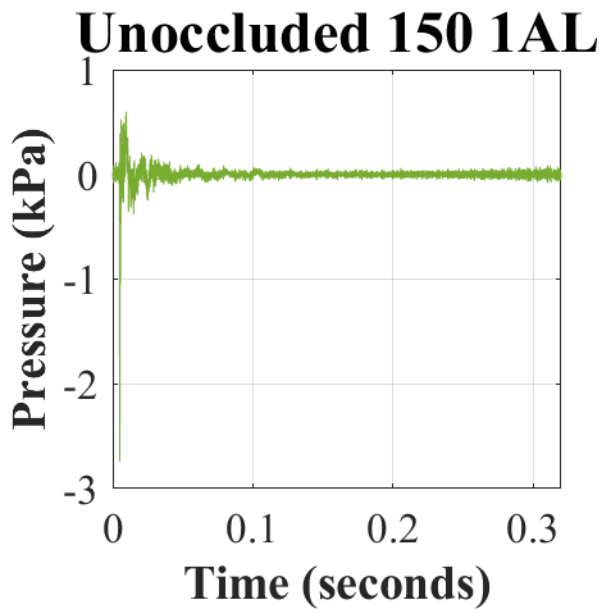


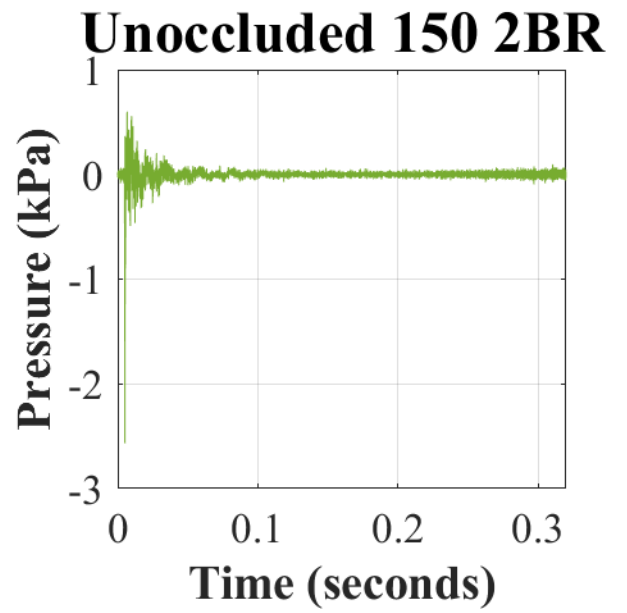
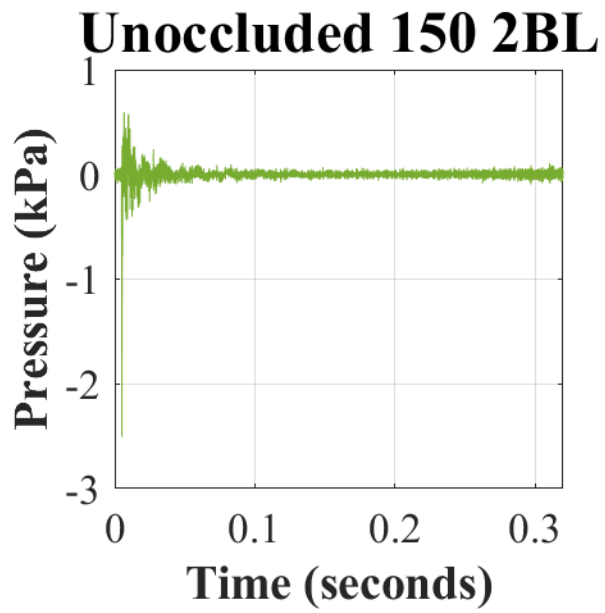
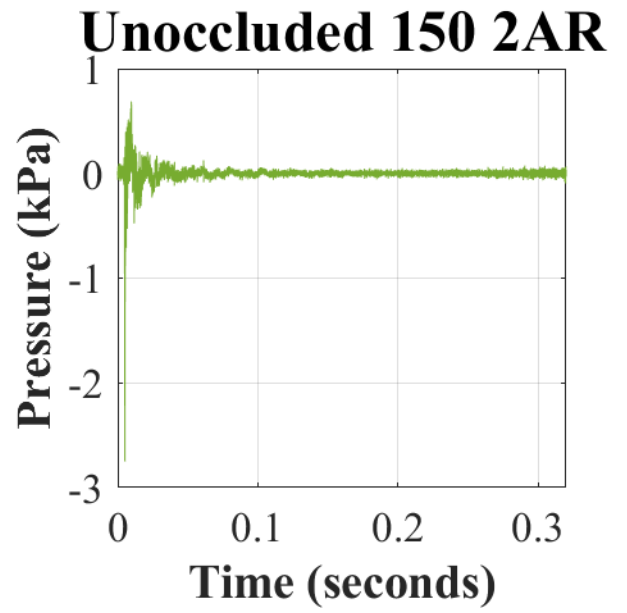
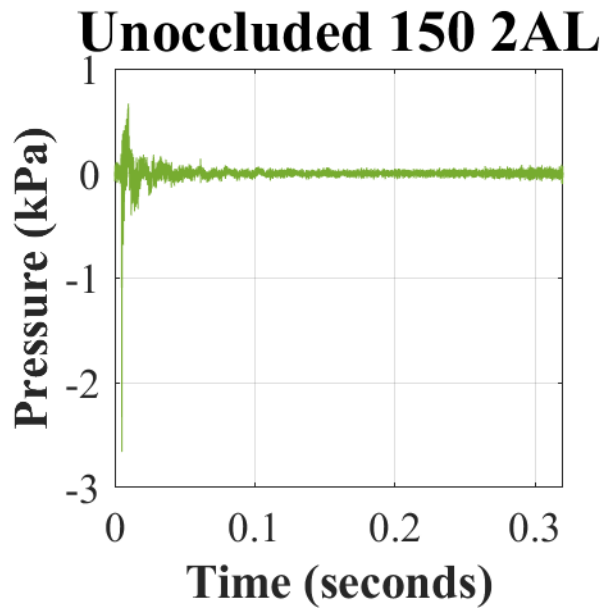


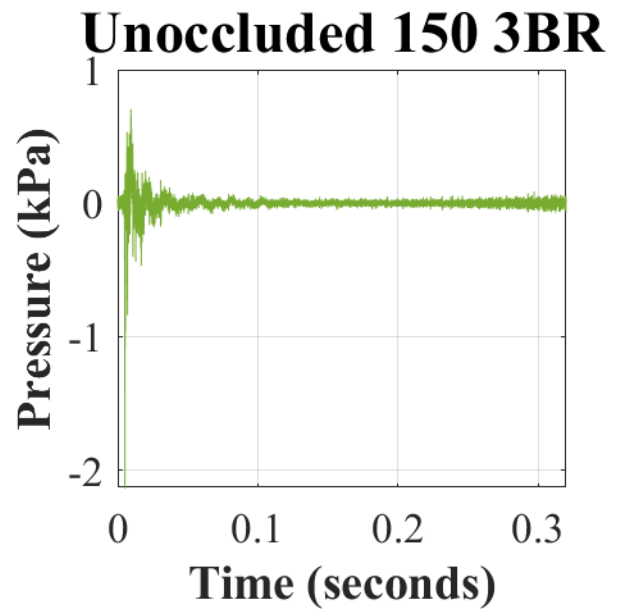
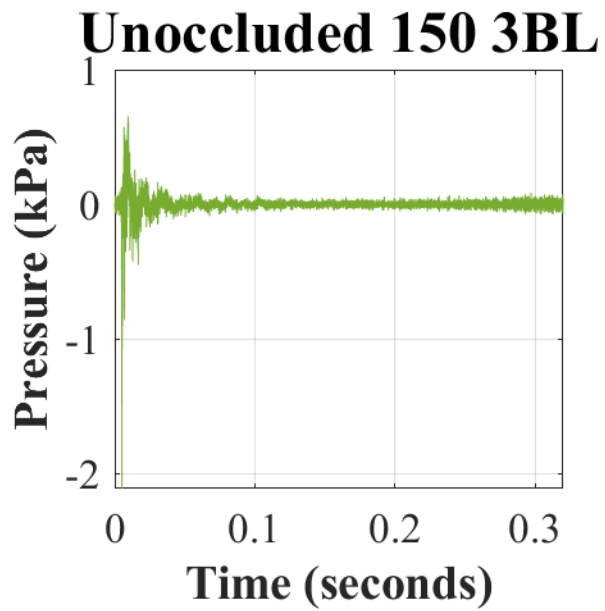
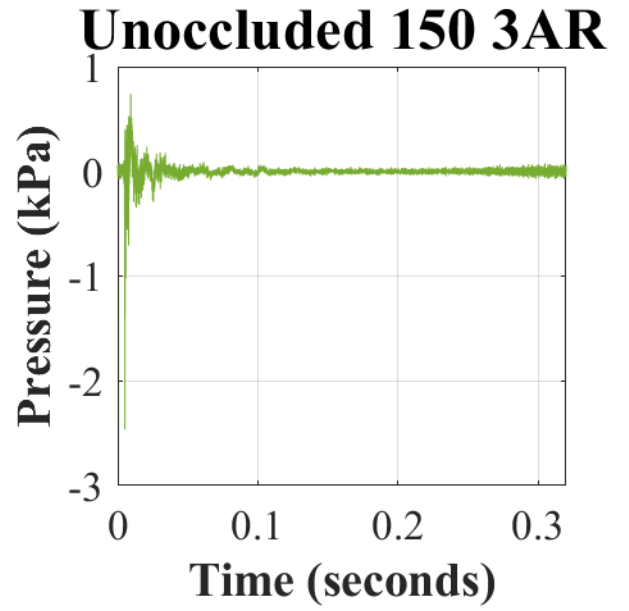
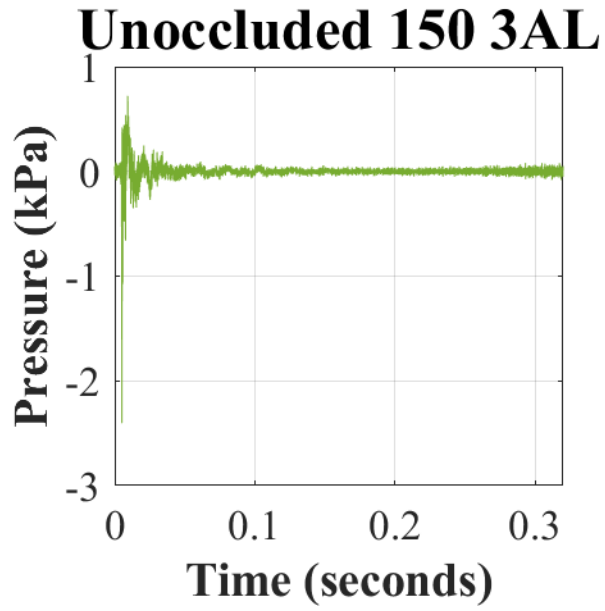


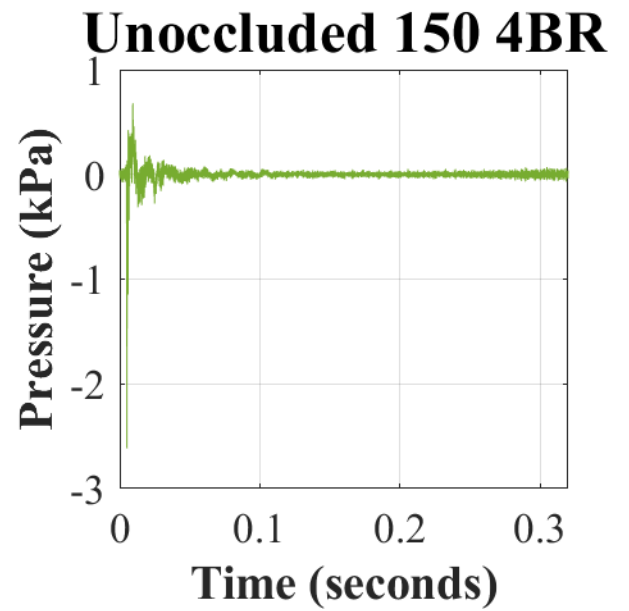
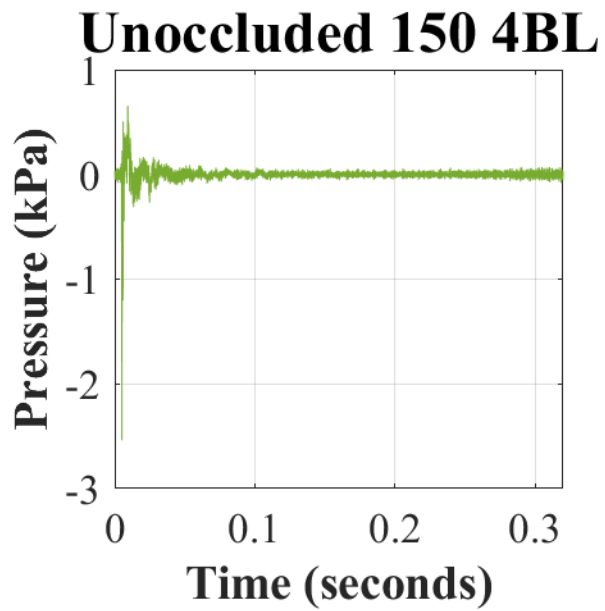
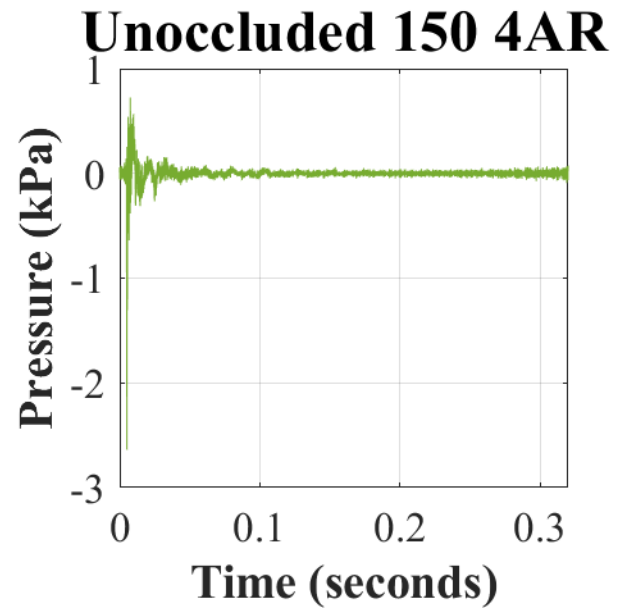
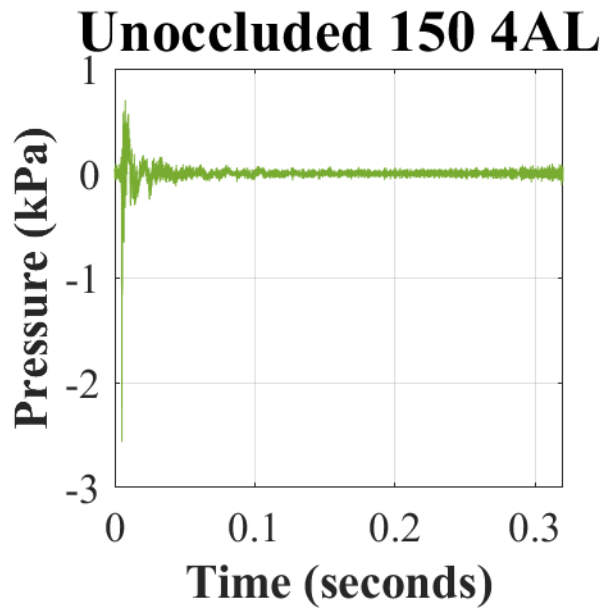
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or 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).

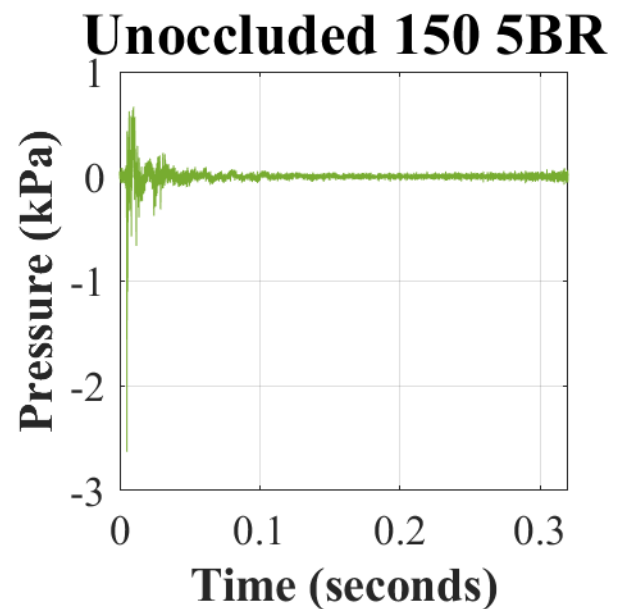
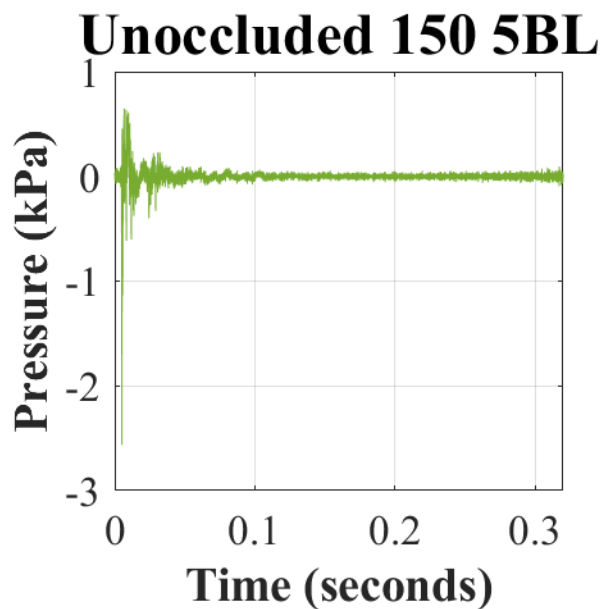
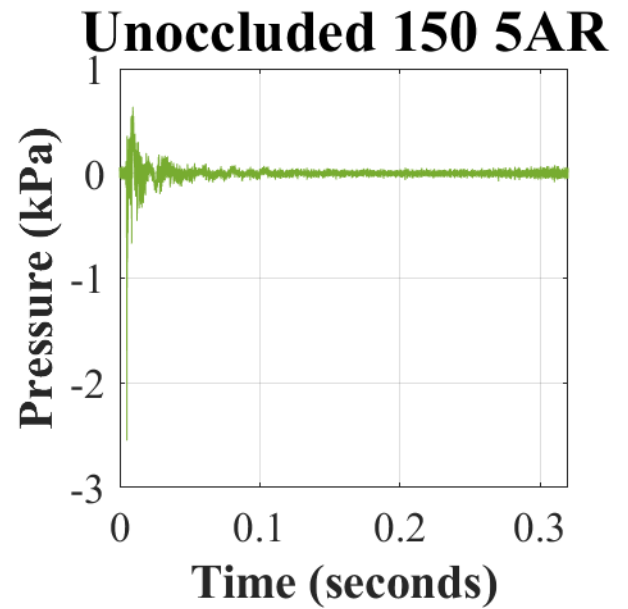
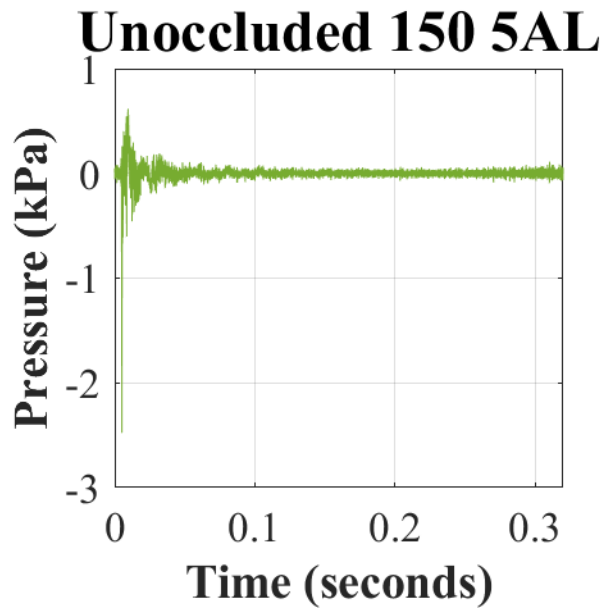
Appendix B. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 150 dBp with the ComTac™ V (OFF).





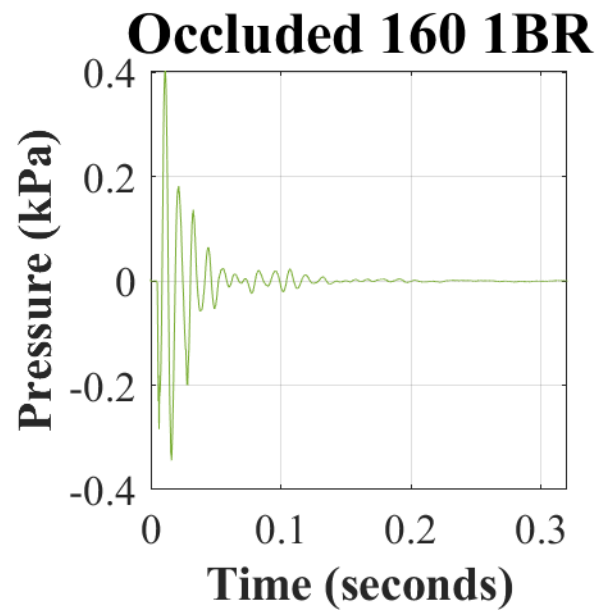
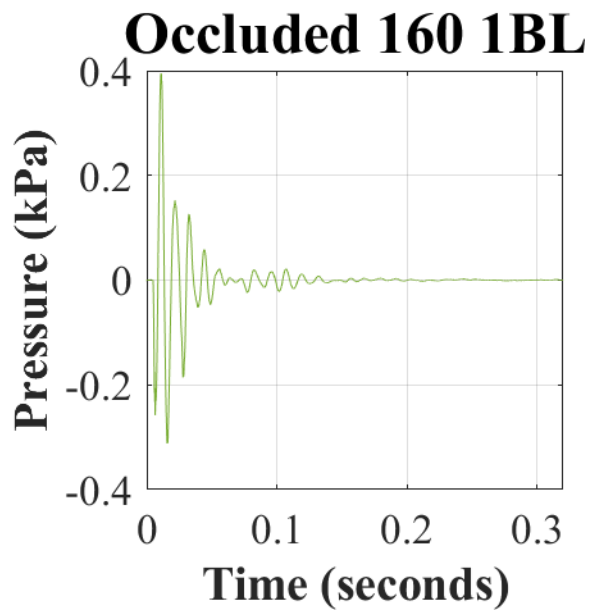
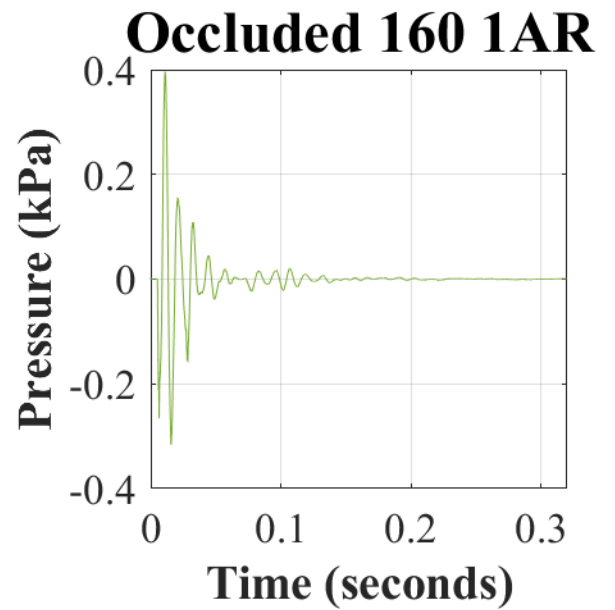
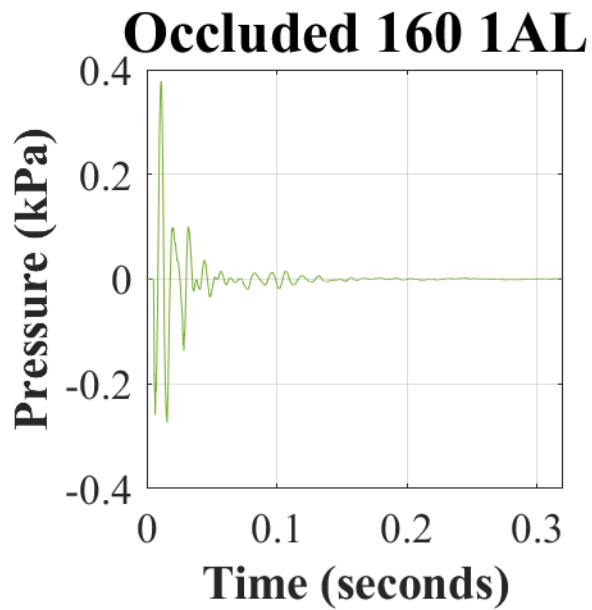


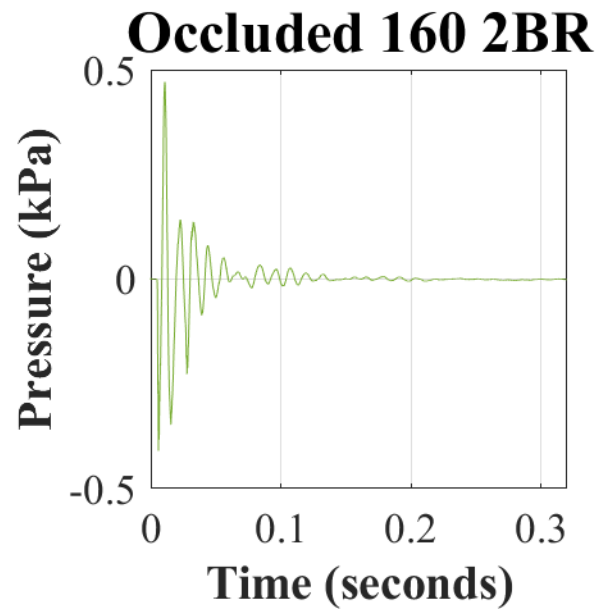
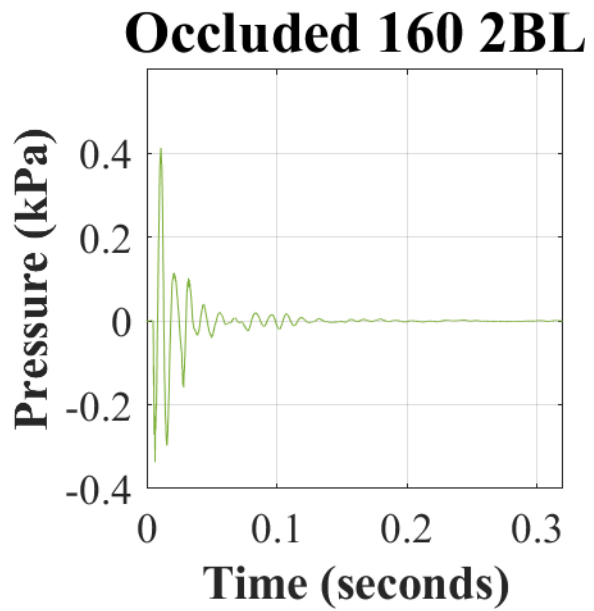
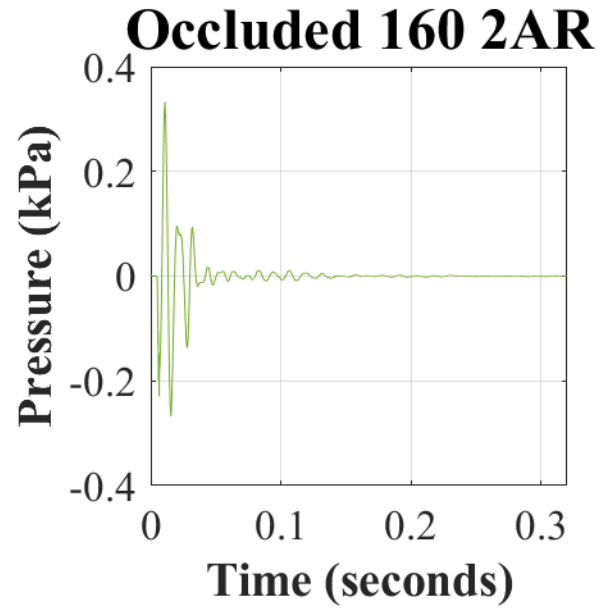
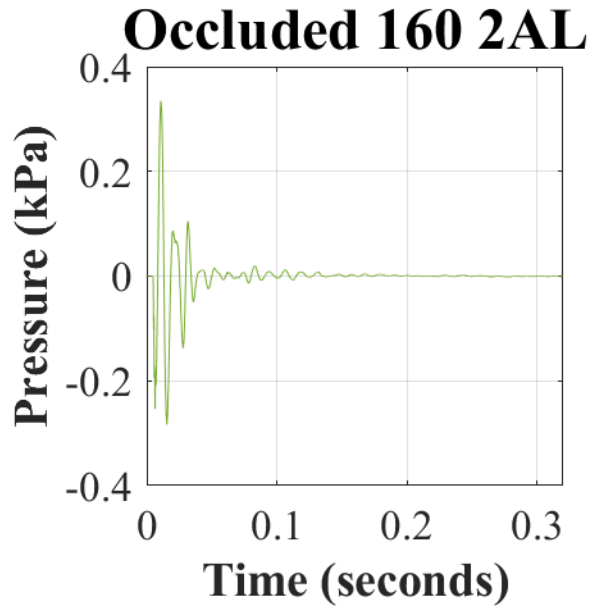


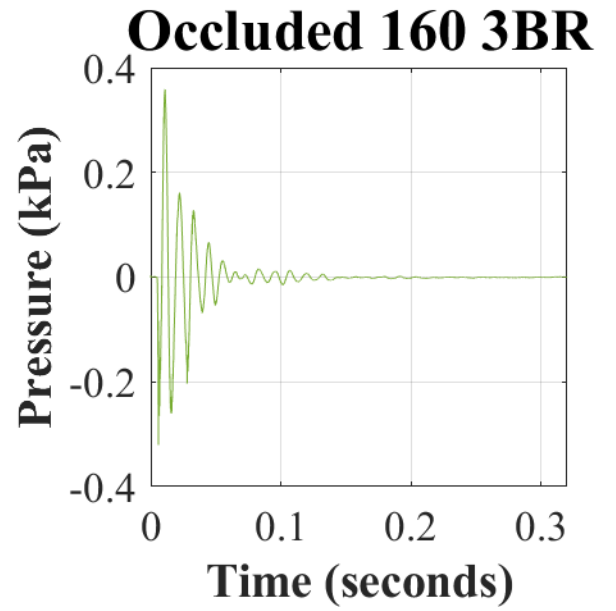
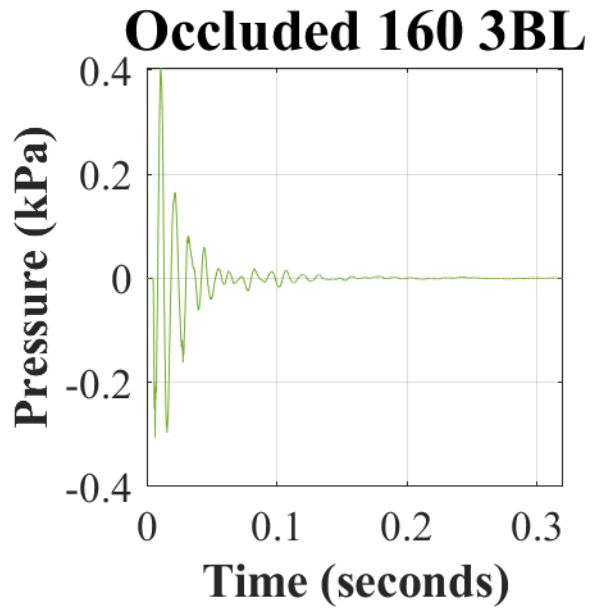
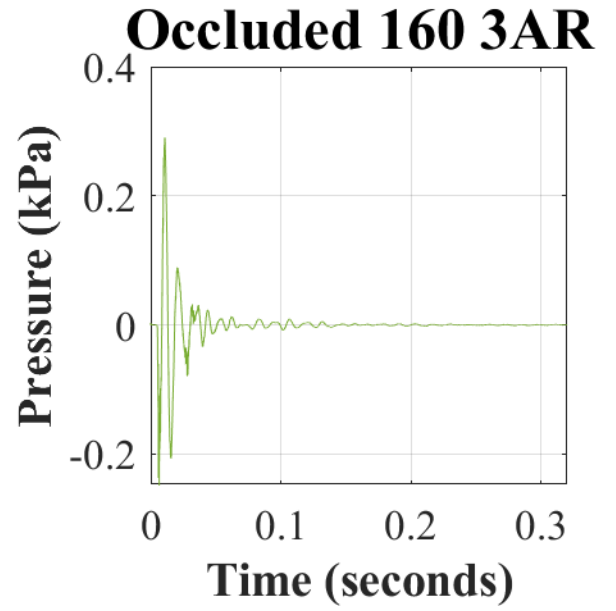
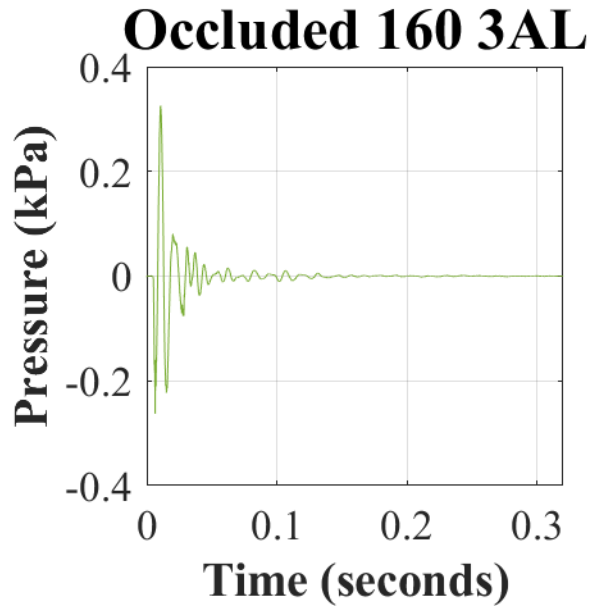


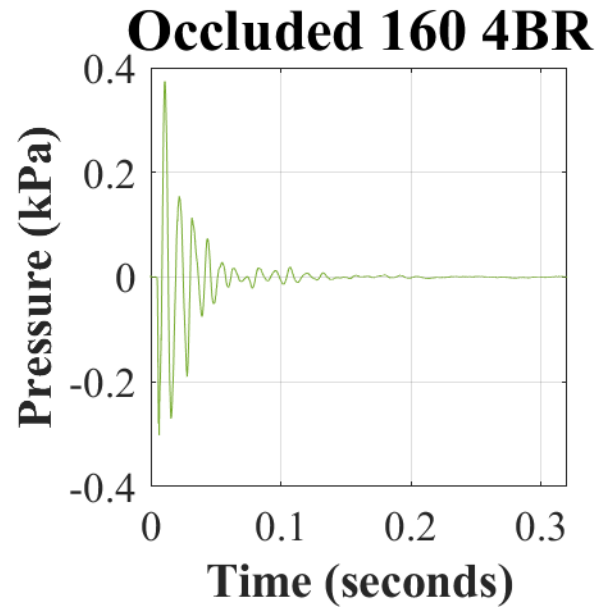
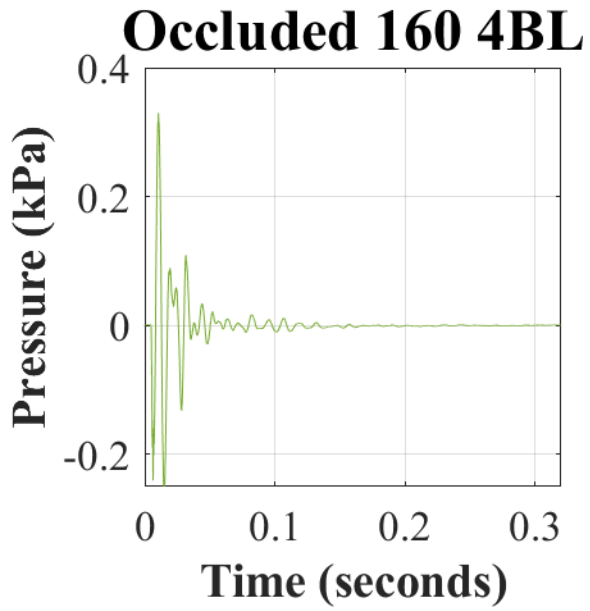
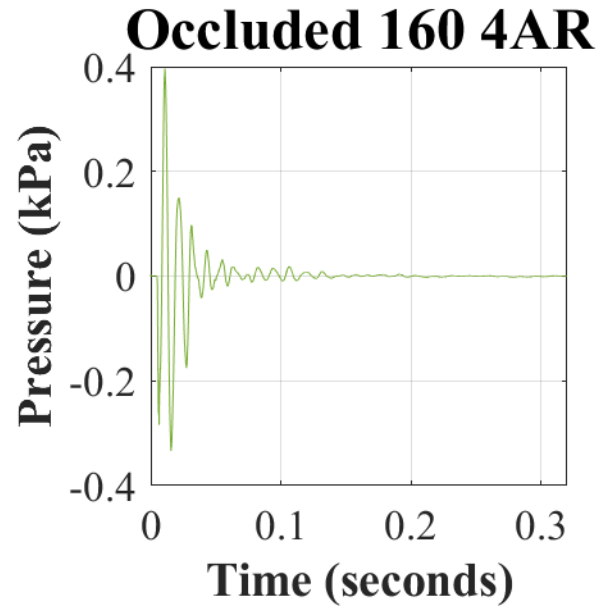
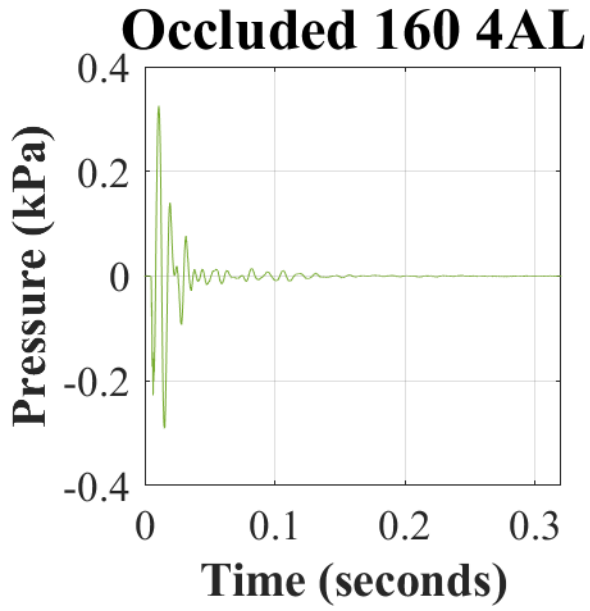
Note. The naming convention for all unoccluded waveforms is “Unoccluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the HPD doffed), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., 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).

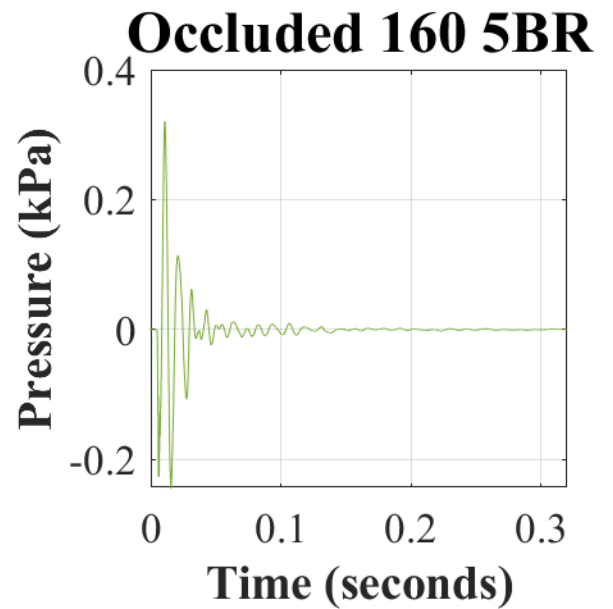
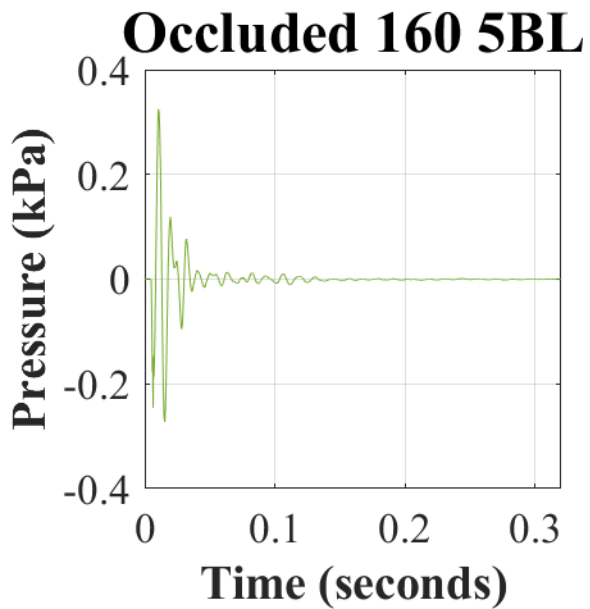
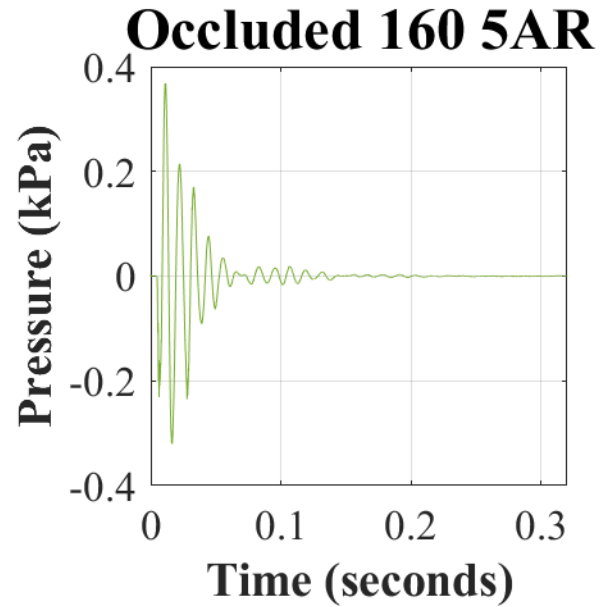
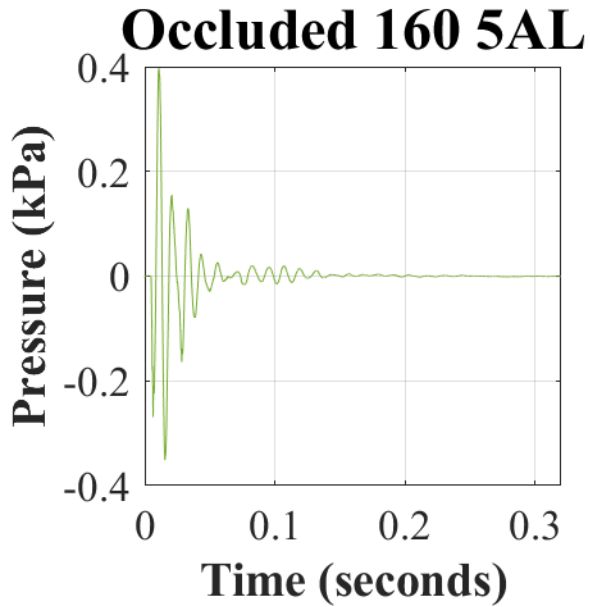
Appendix C. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 160 dBp with the ComTac™ V (OFF).





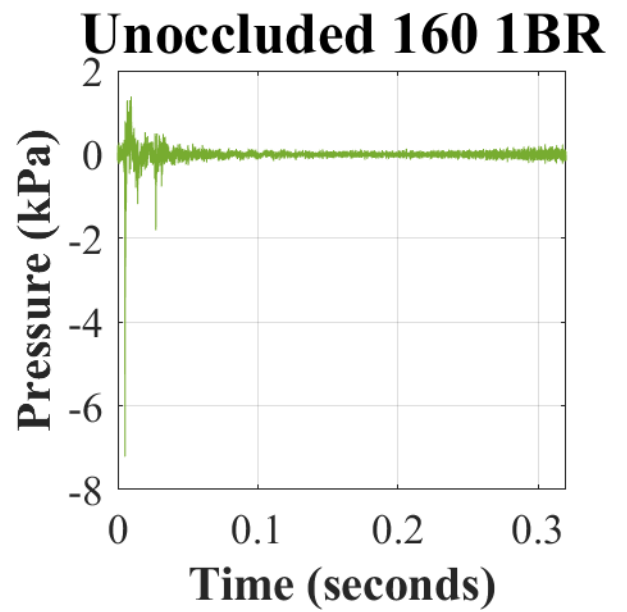
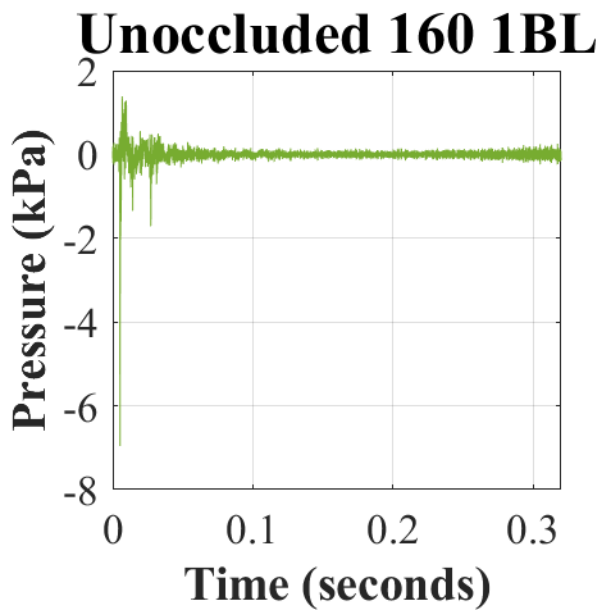
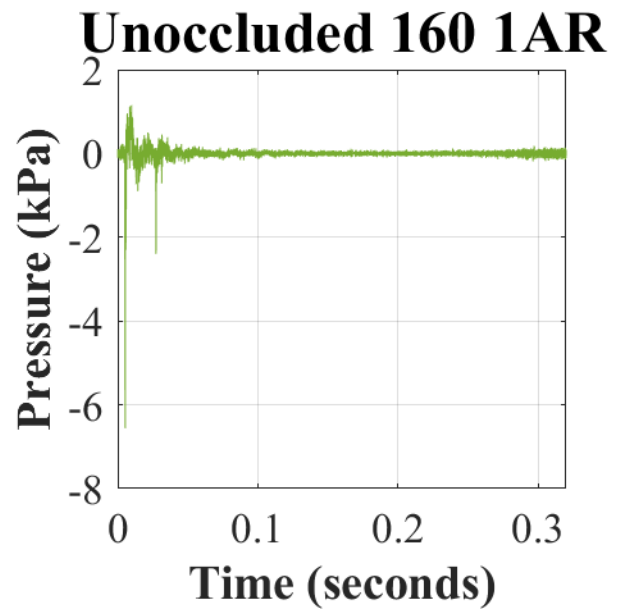
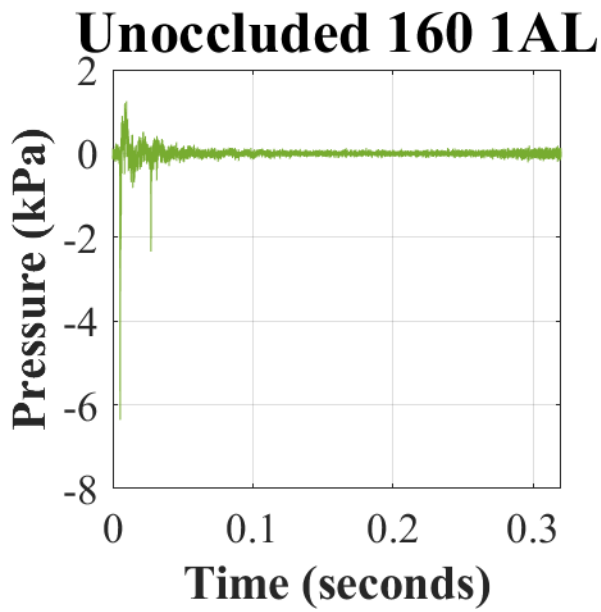




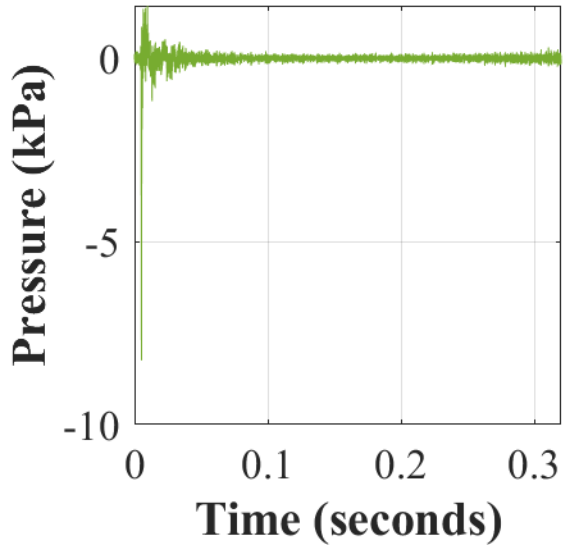


Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or 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).

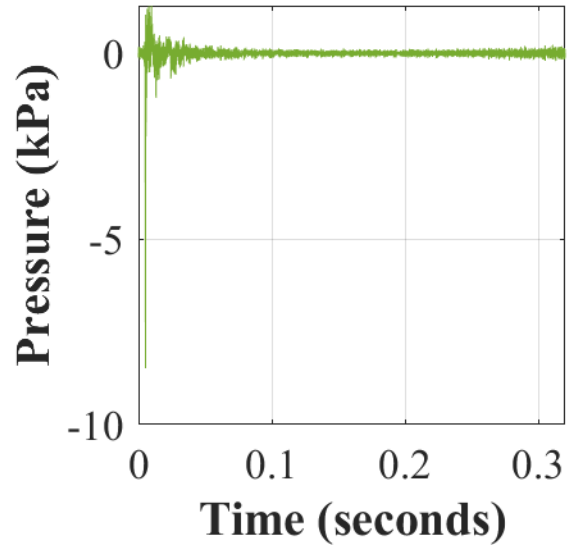
Appendix D. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 160 dBp with the ComTac™ V (OFF).



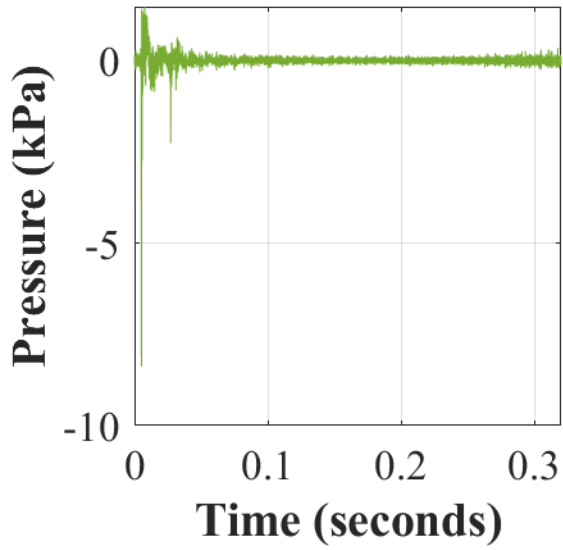
Unoccluded 160 2AL



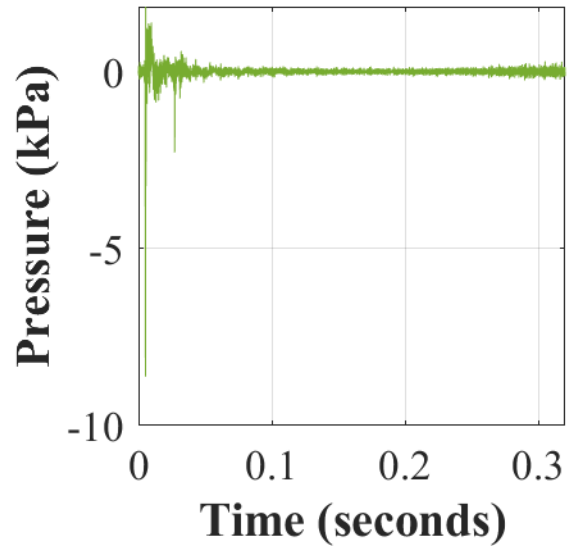
Unoccluded 160 2AR

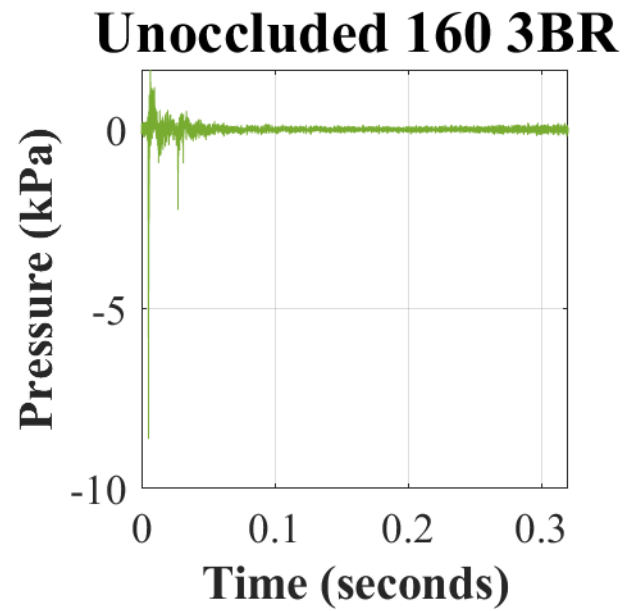
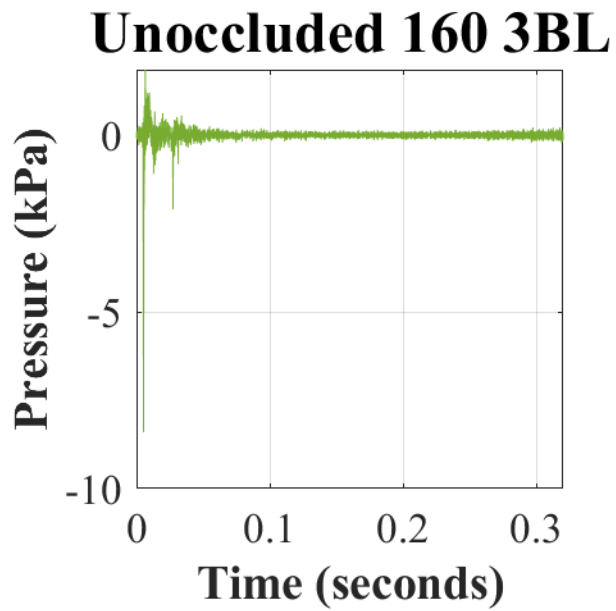
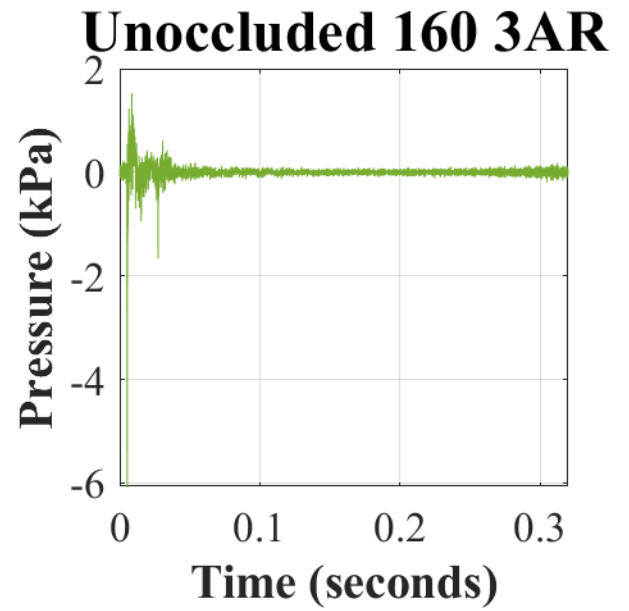
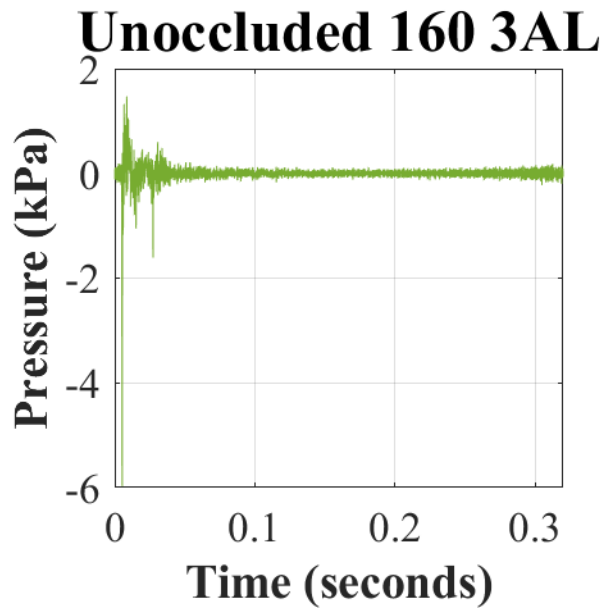


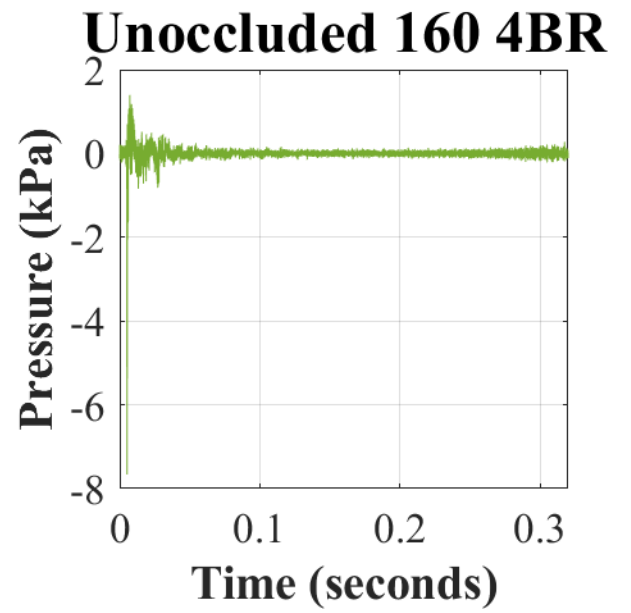
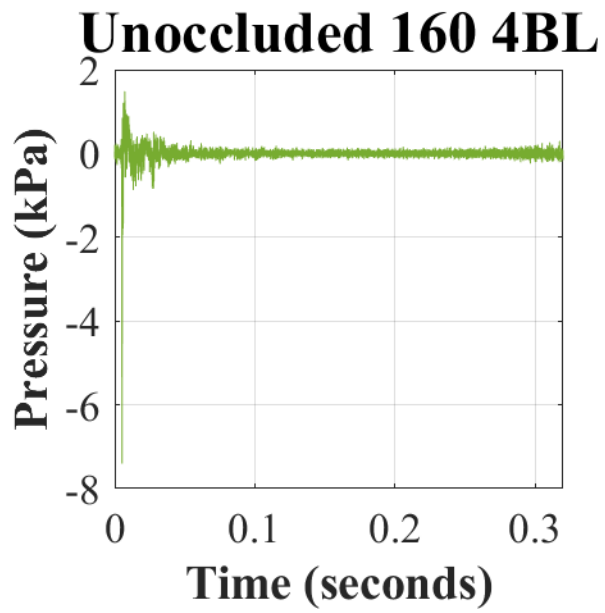
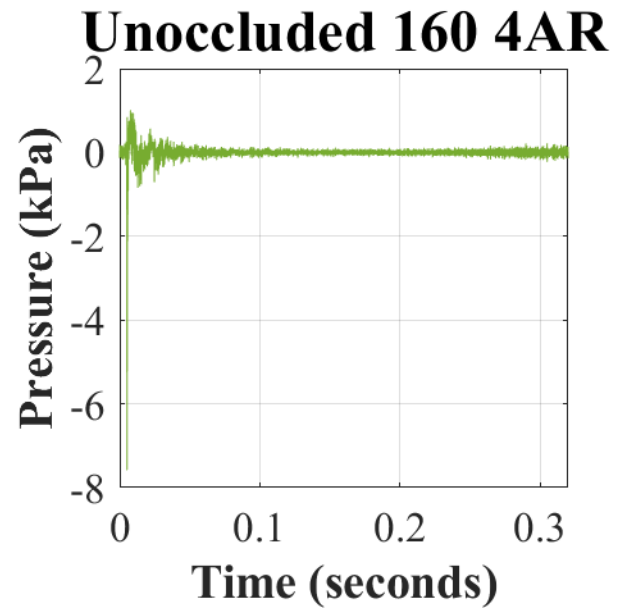
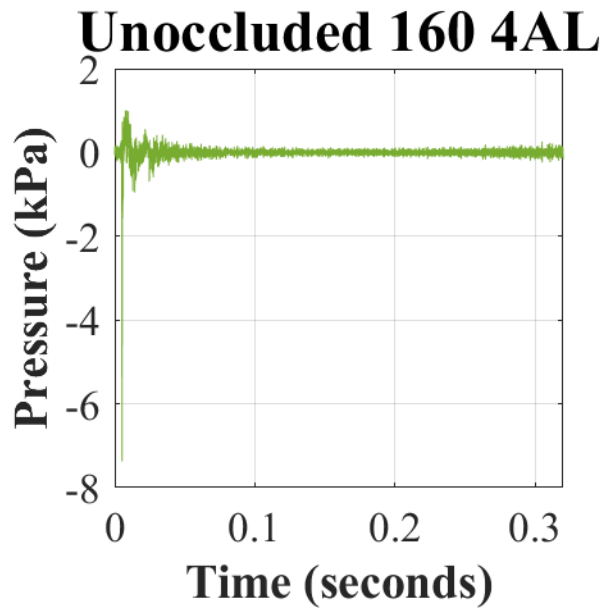
Unoccluded 160 2BL

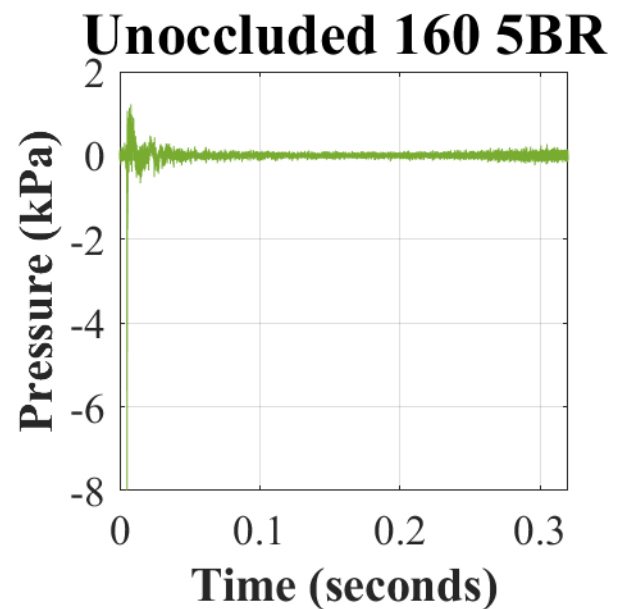
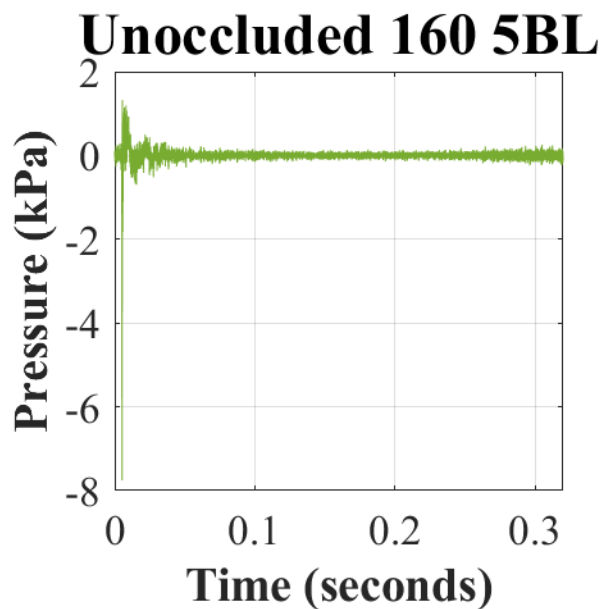
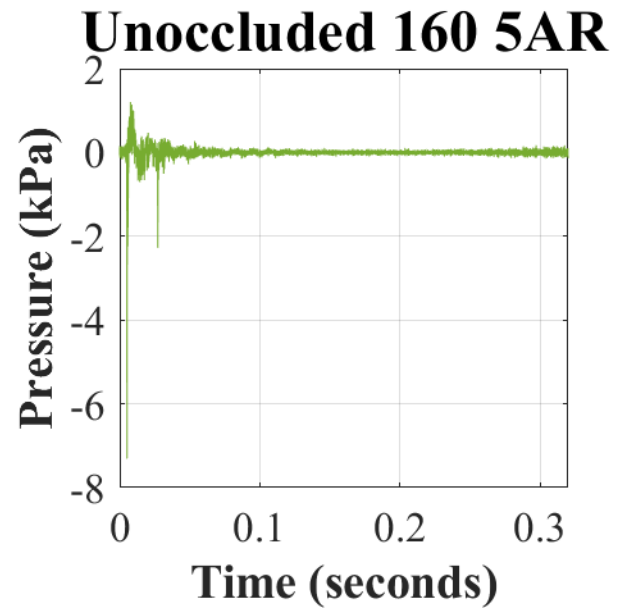
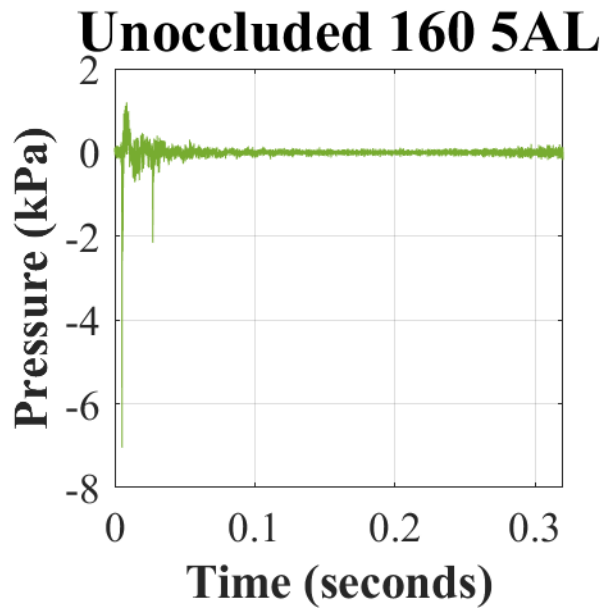


Unoccluded 160 2BR



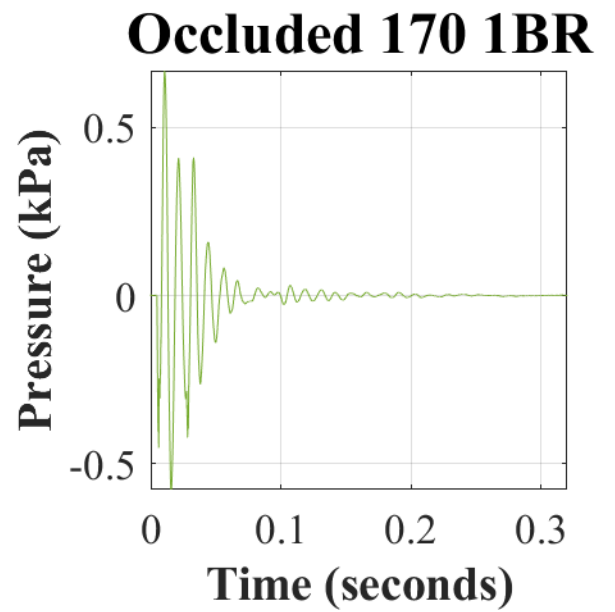
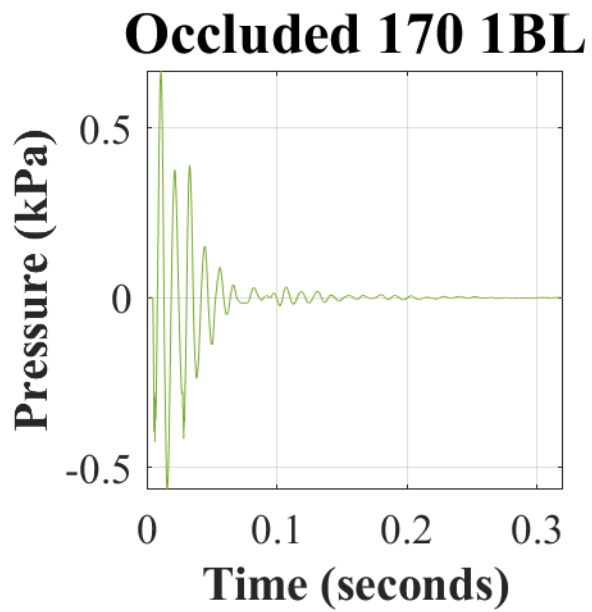
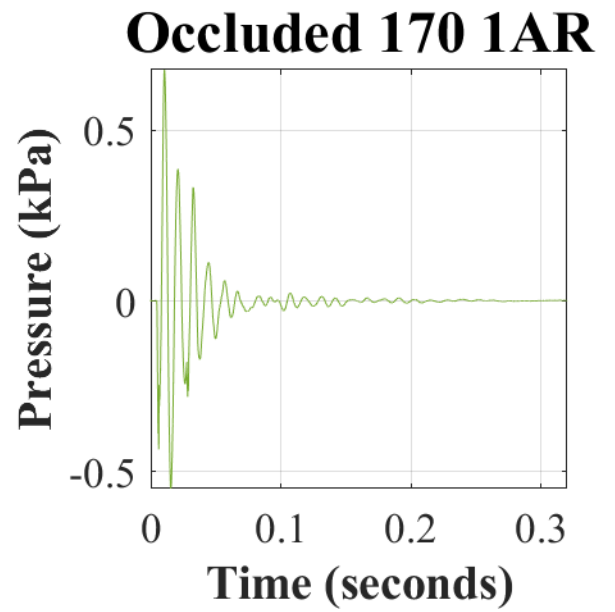
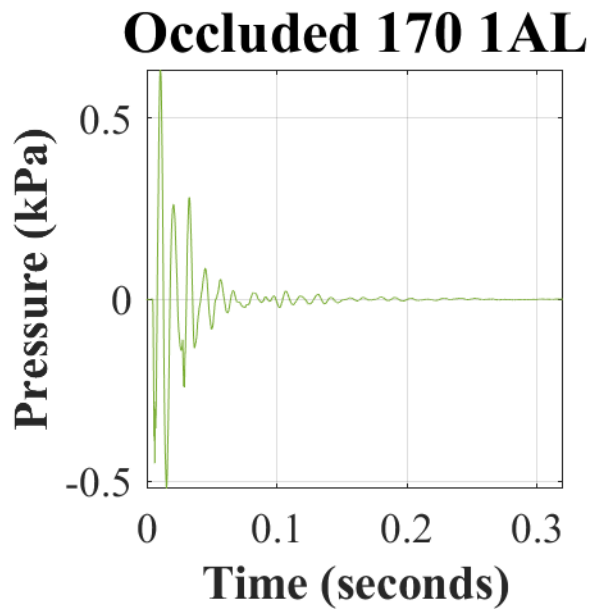




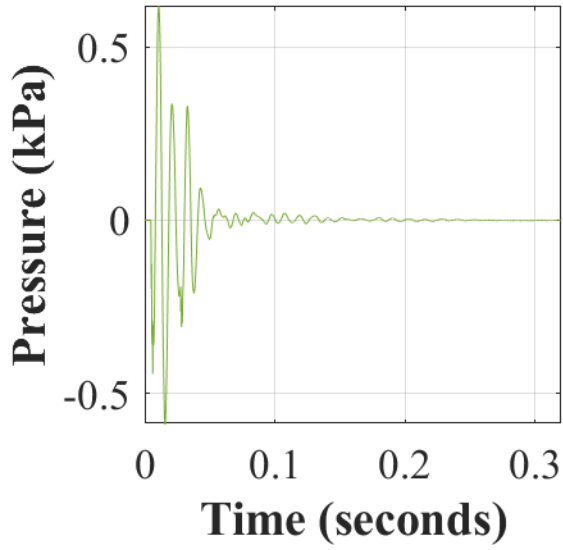


Note. The naming convention for all unoccluded waveforms is “Unoccluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the HPD doffed), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dB), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., 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).

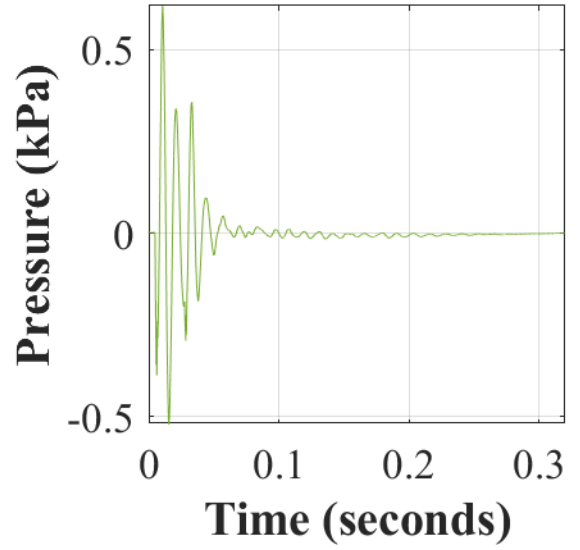
Appendix E. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 170 dBp with the ComTac™ V (OFF).



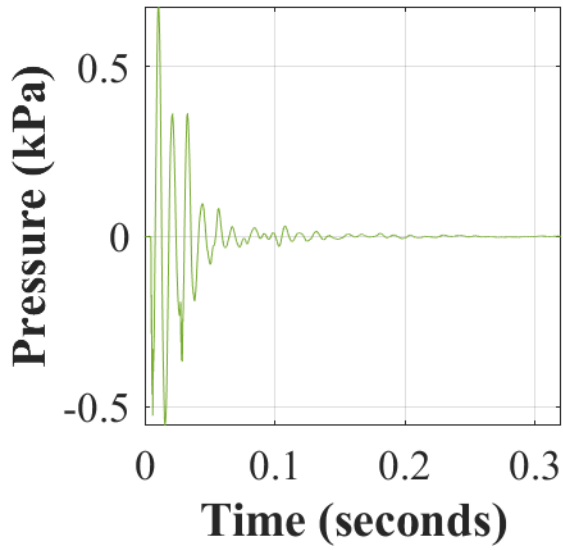
Occluded 170 2AL



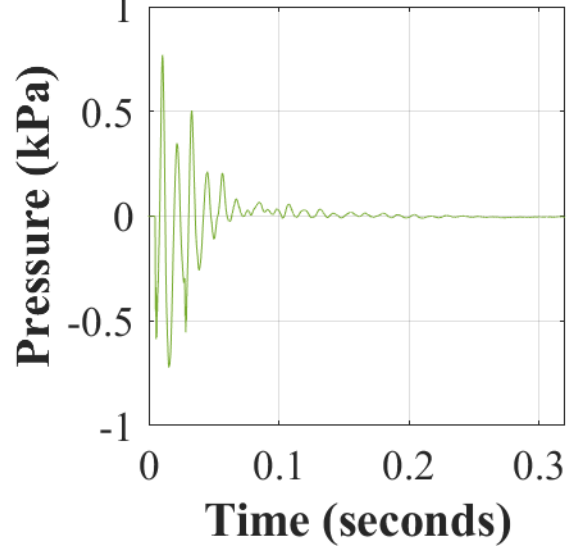
Occluded 170 2AR



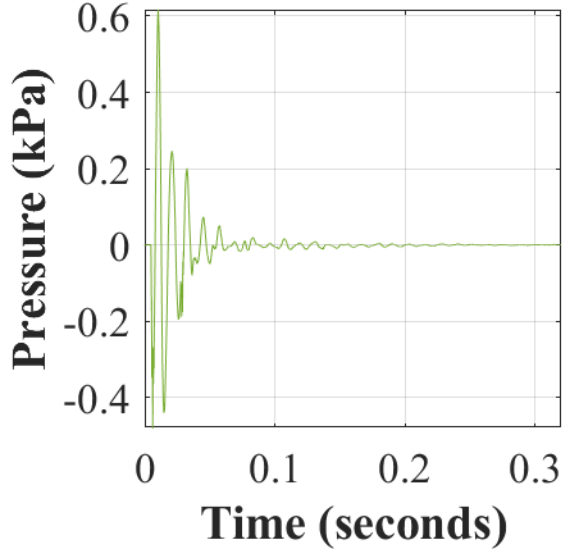
Occluded 170 2BL



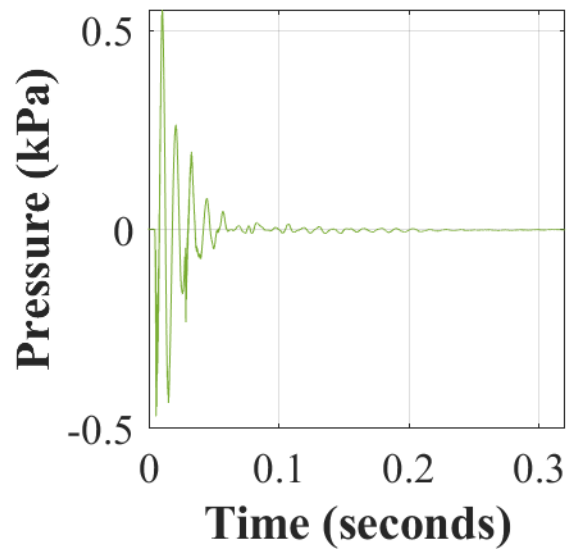
Occluded 170 2BR



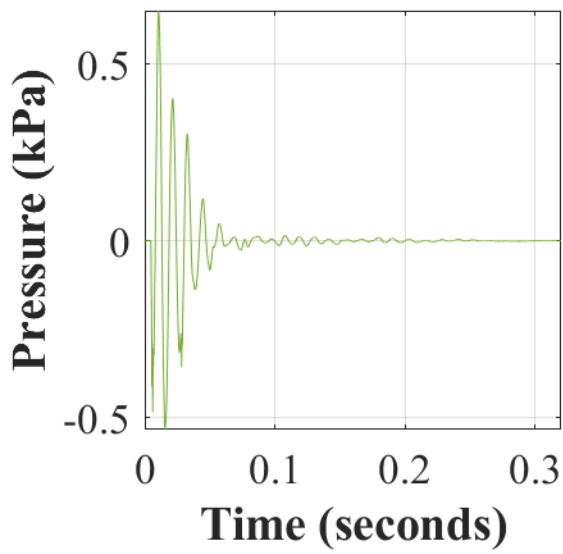
Occluded 170 3AL



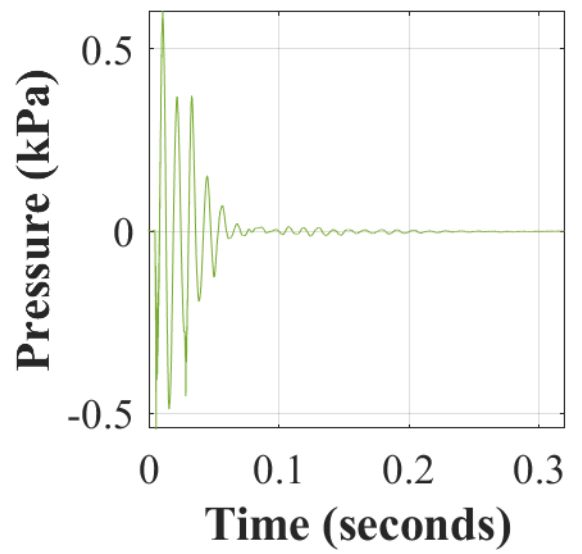
Occluded 170 3AR



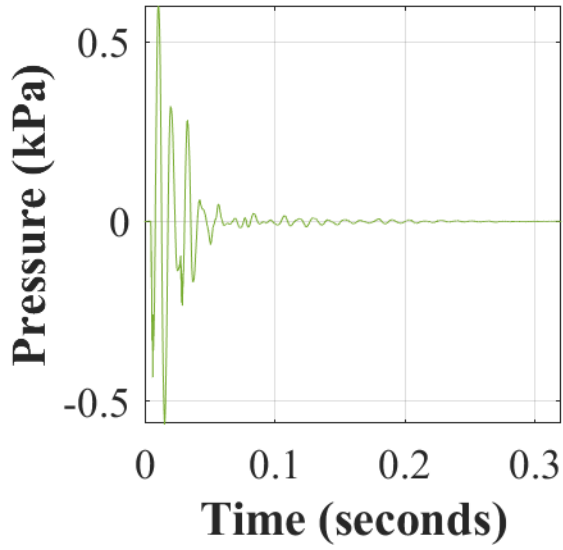
Occluded 170 3BL



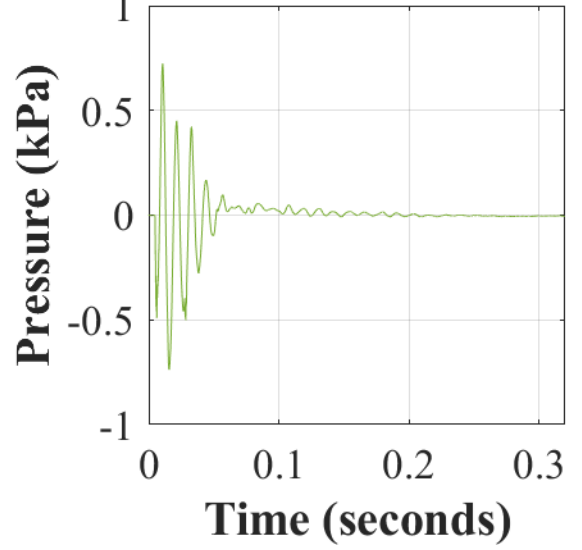
Occluded 170 3BR



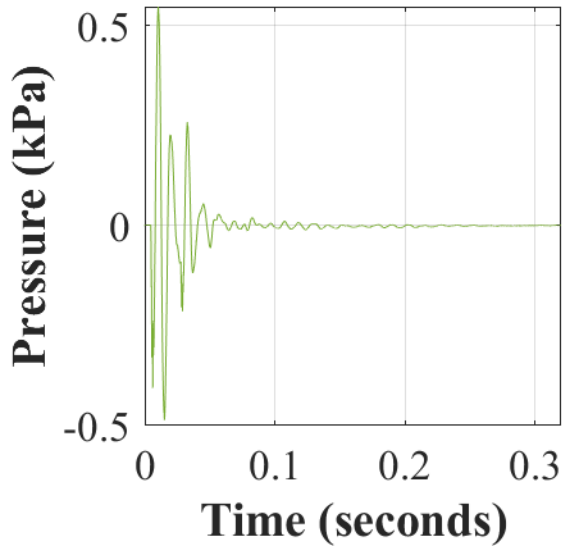
Occluded 170 4AL



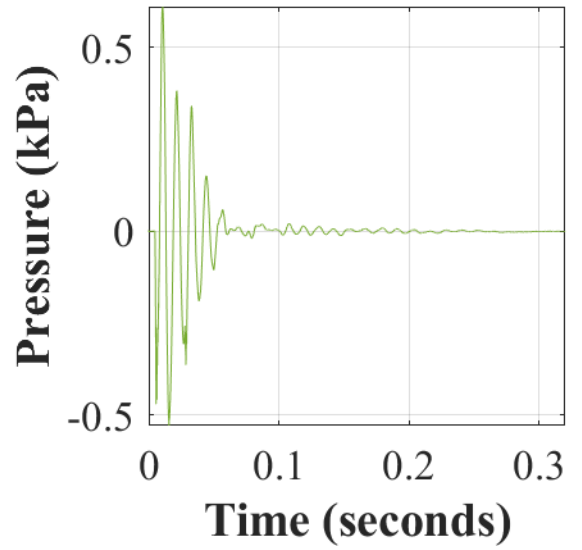
Occluded 170 4AR



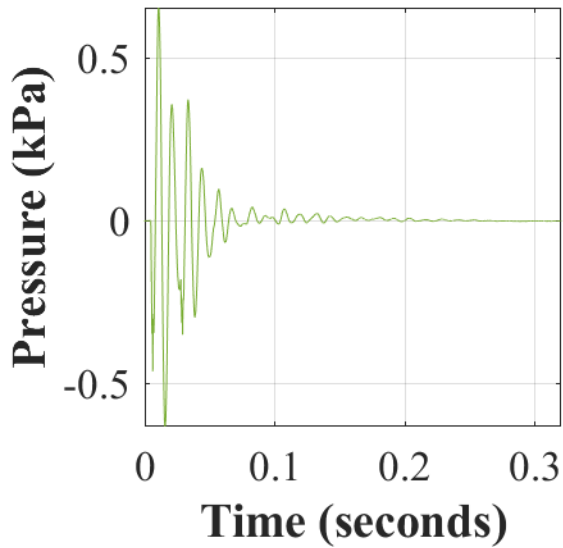
Occluded 170 4BL



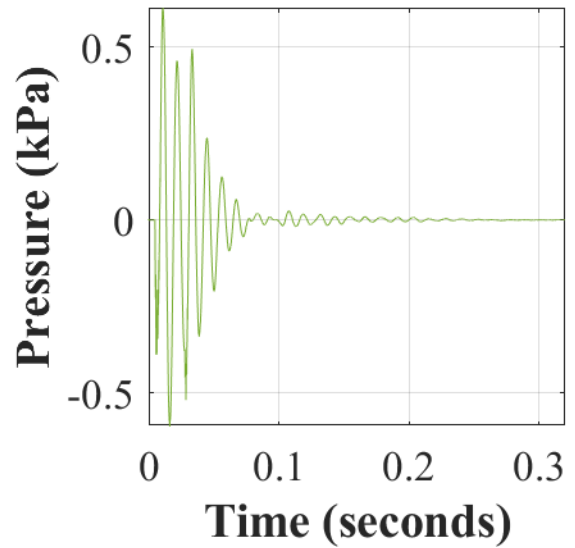
Occluded 170 4BR



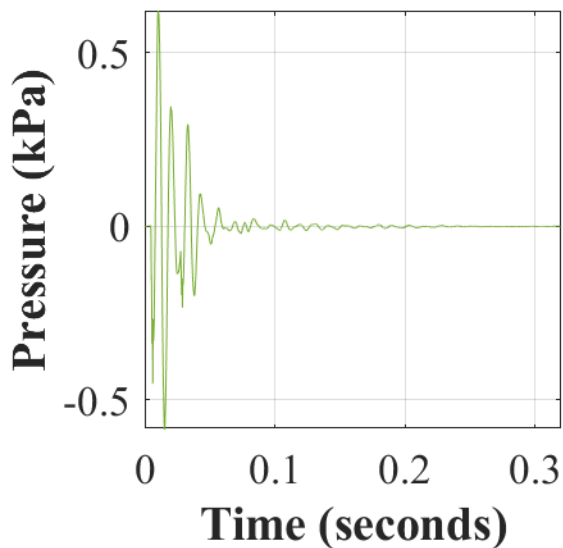
Occluded 170 5AL



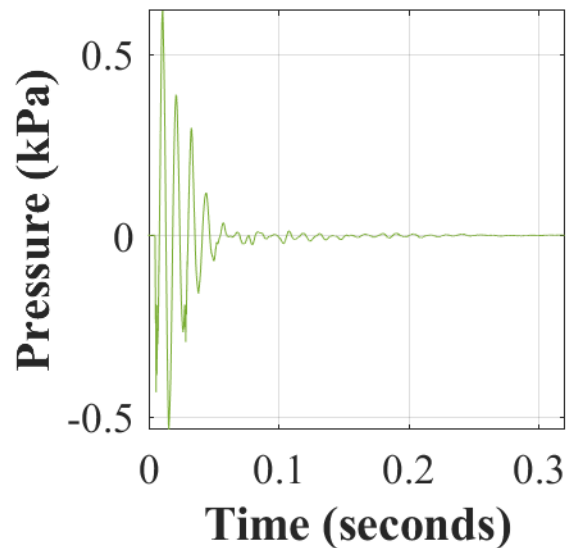
Occluded 170 5AR



Occluded 170 5BL

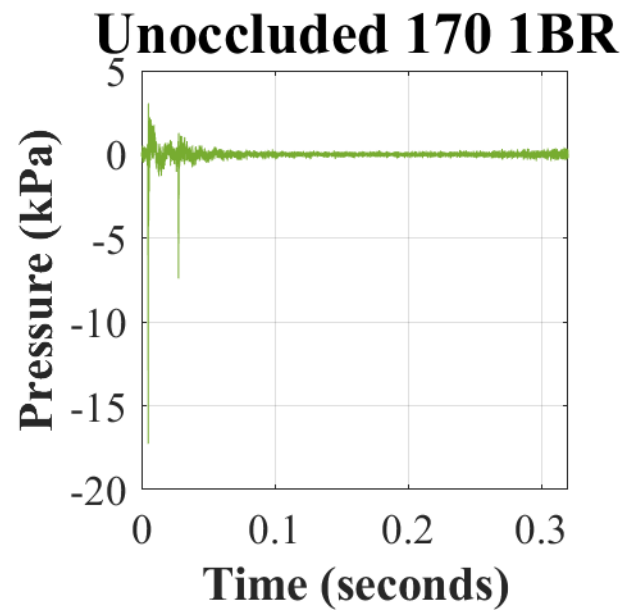
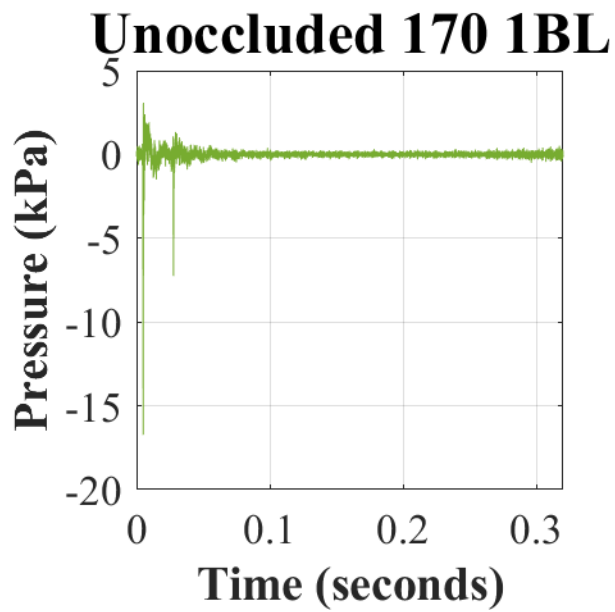
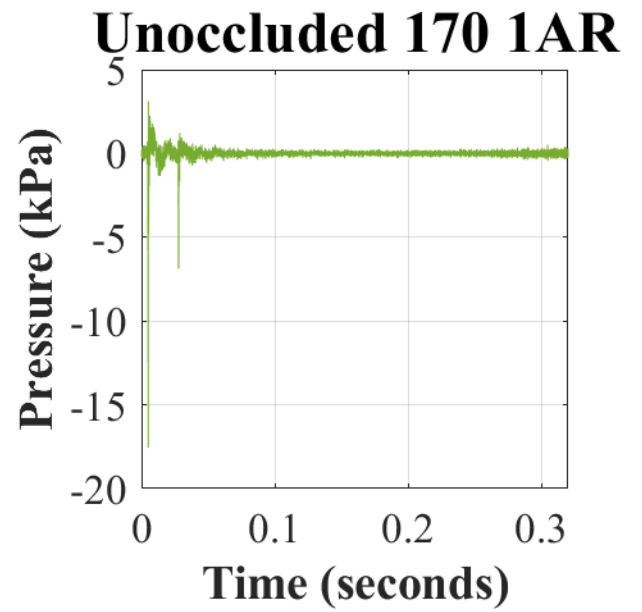
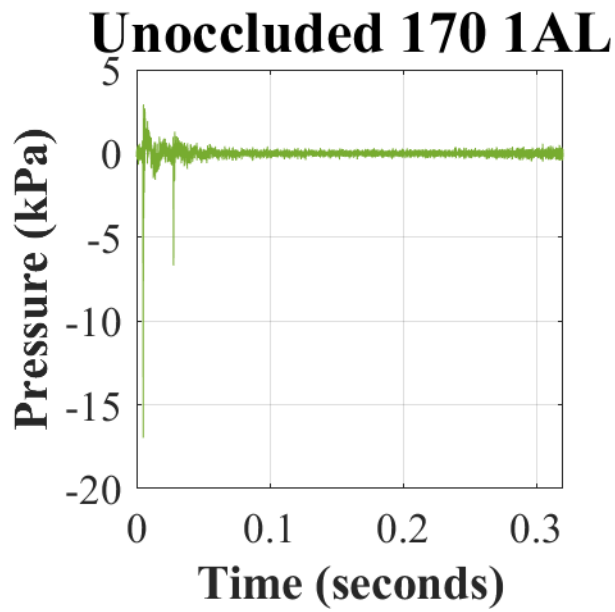


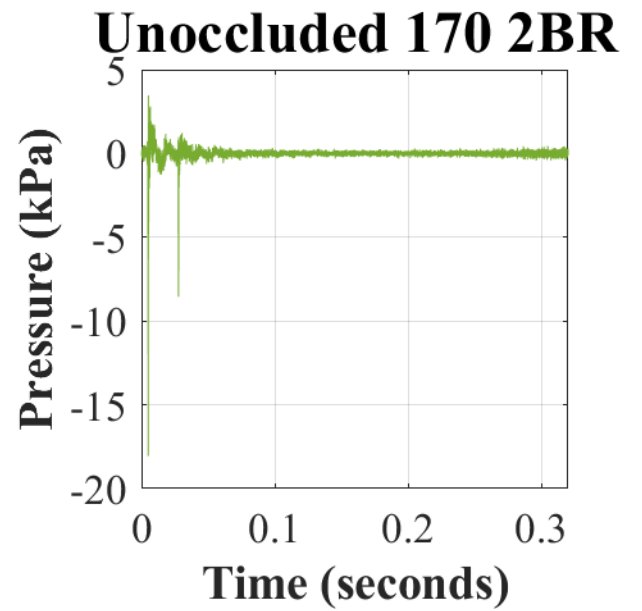
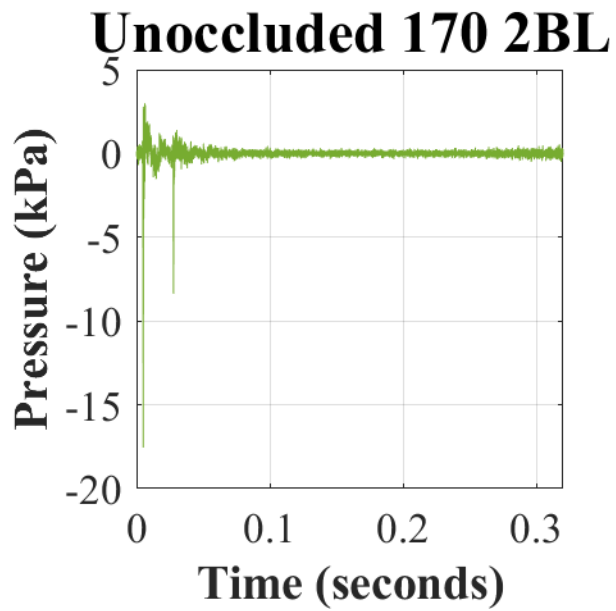
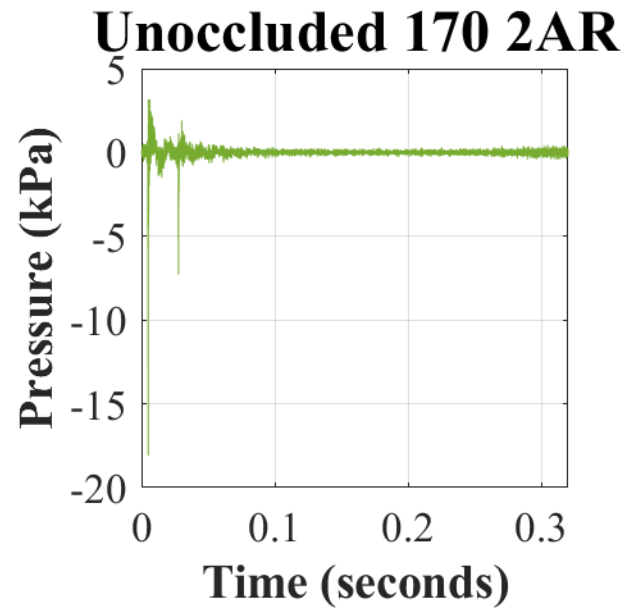
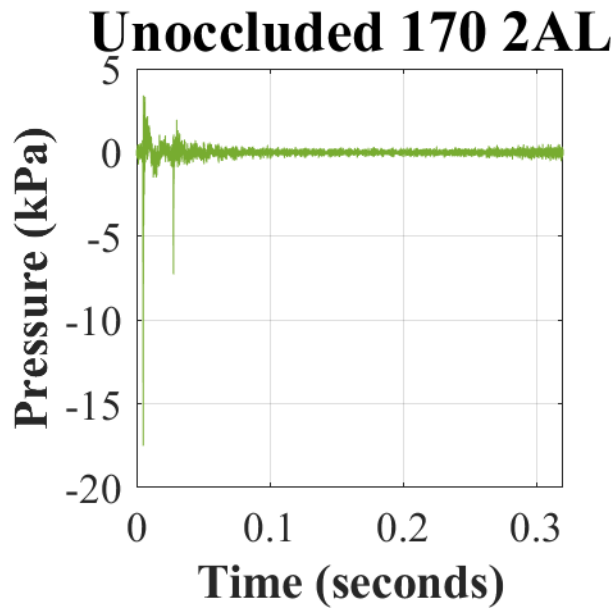
Occluded 170 5BR

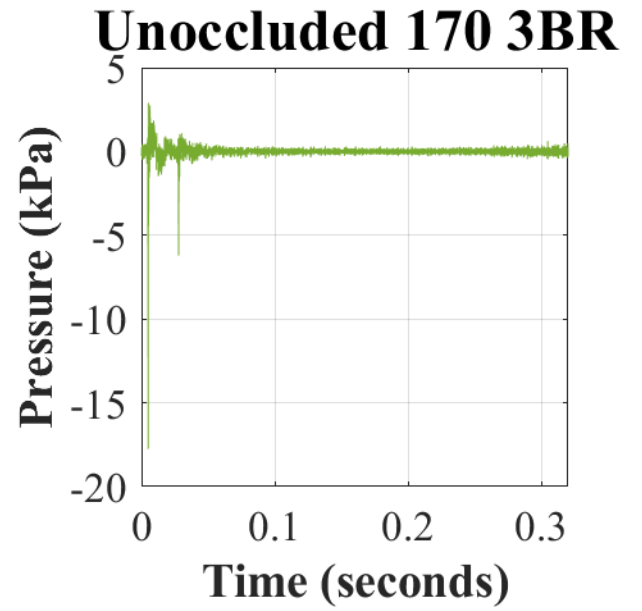
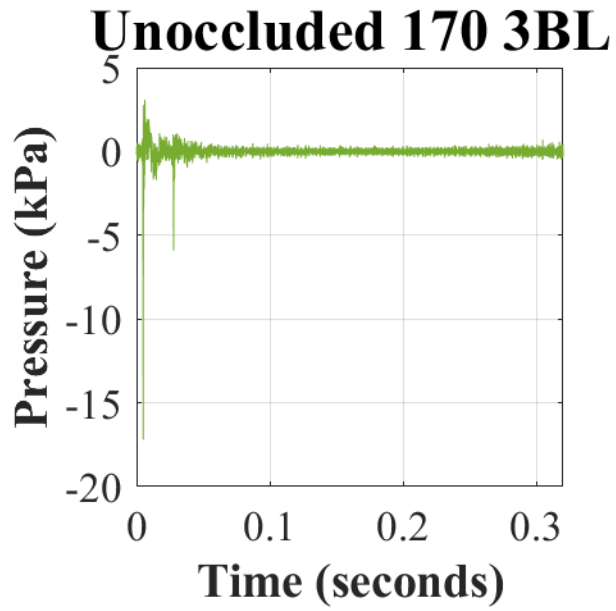
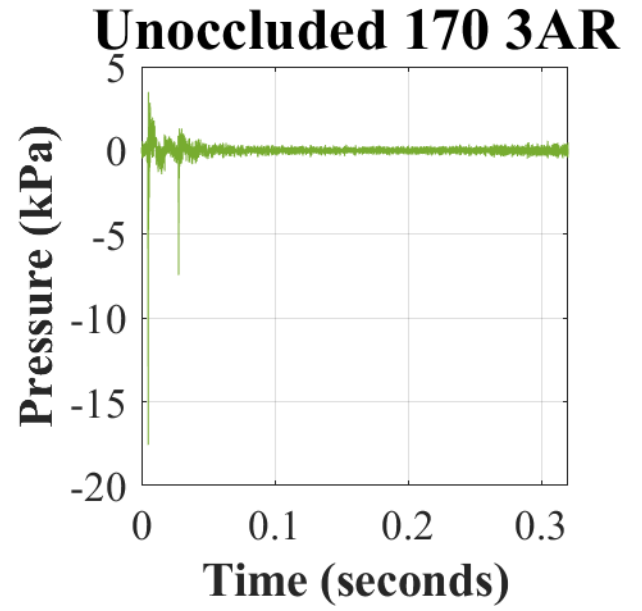
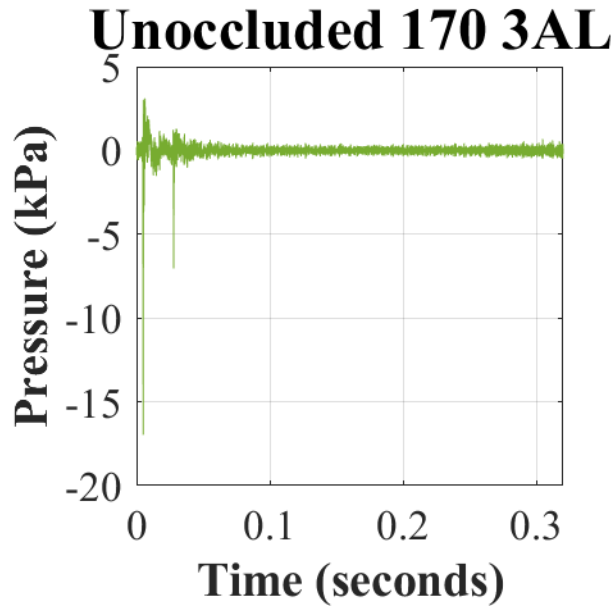


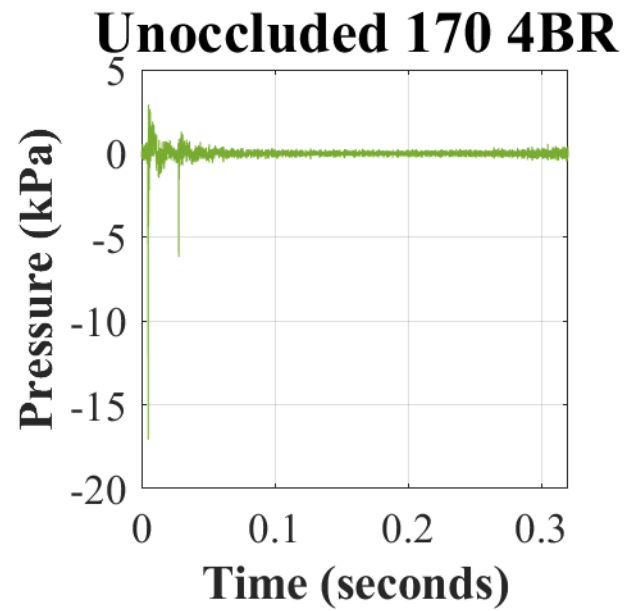
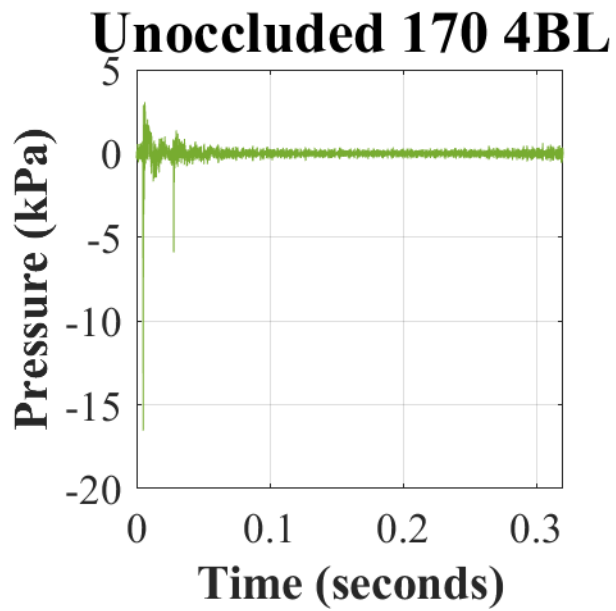
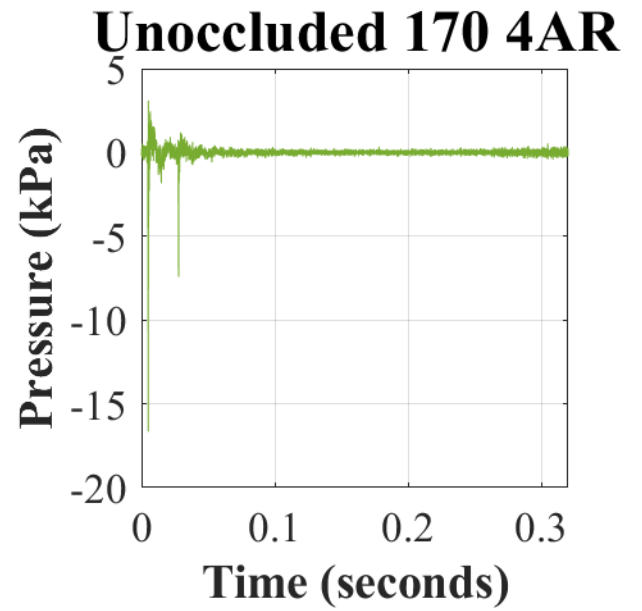
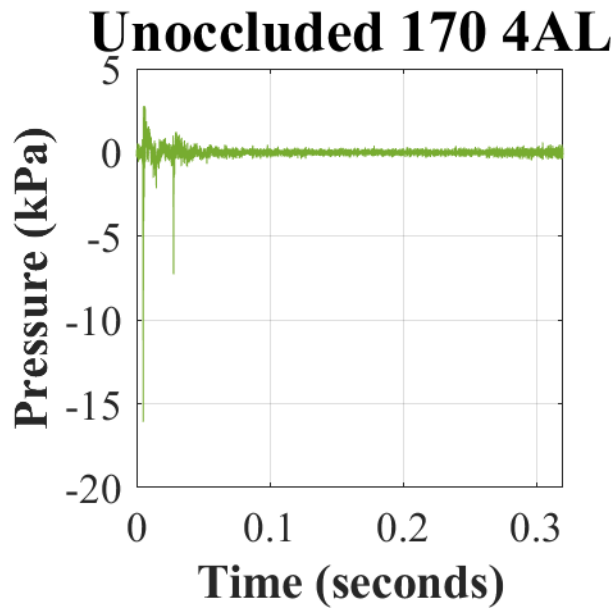
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or 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).

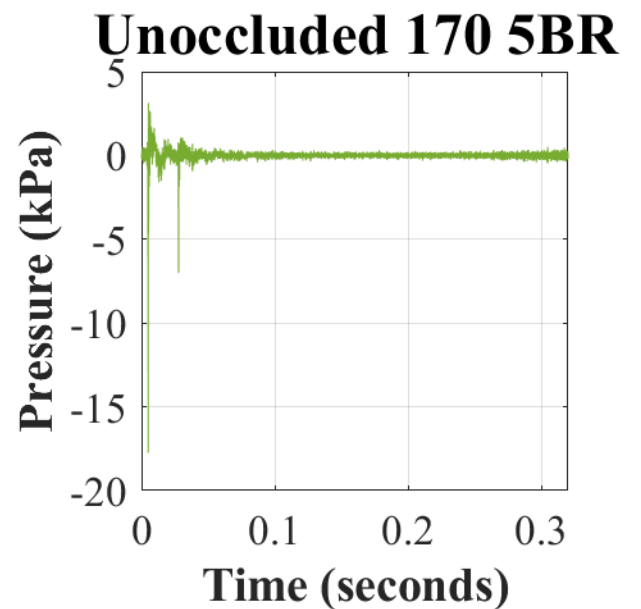
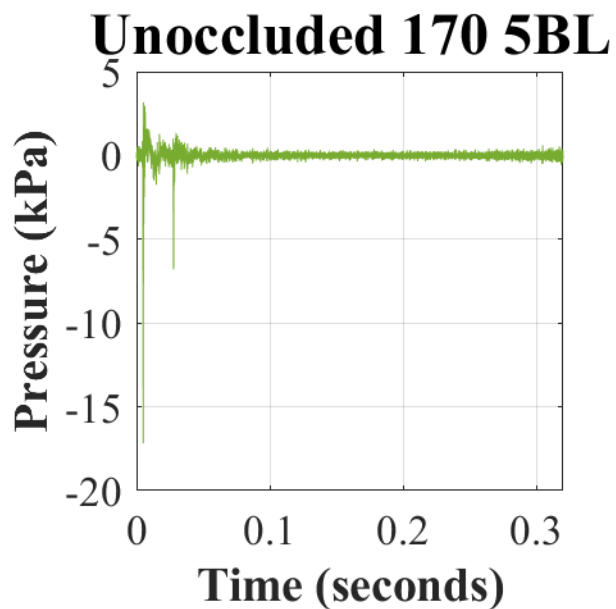
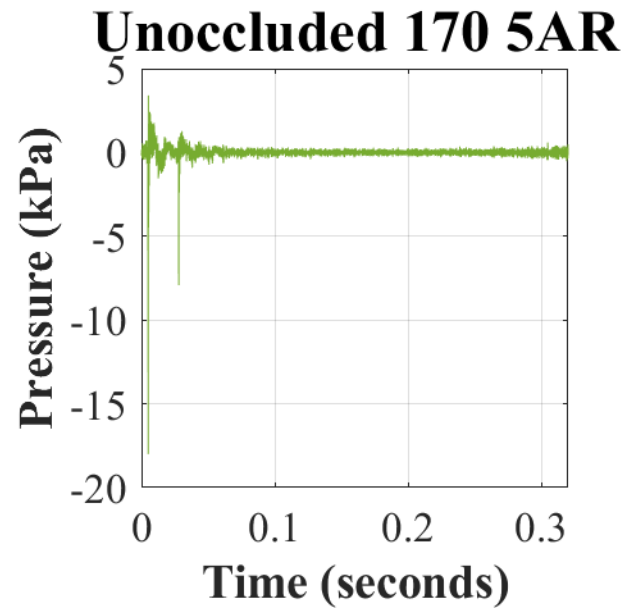
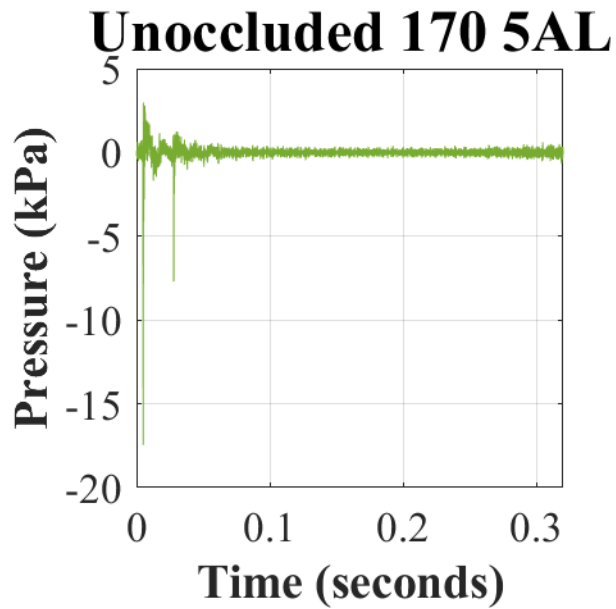
Appendix F. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 170 dBp with the ComTac™ V (OFF).





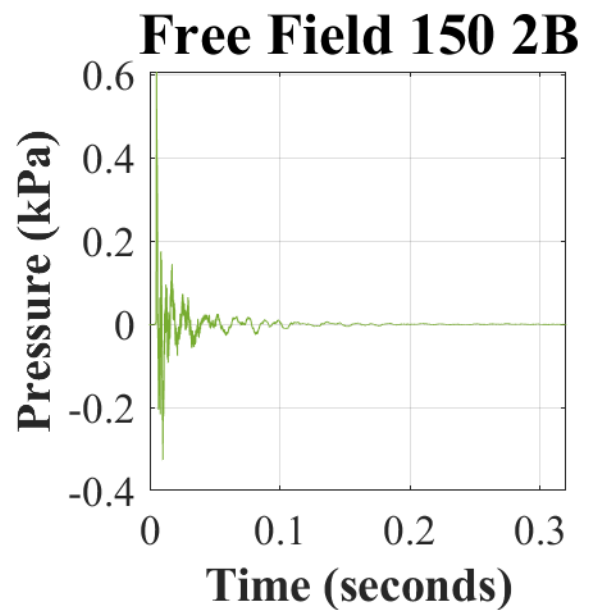
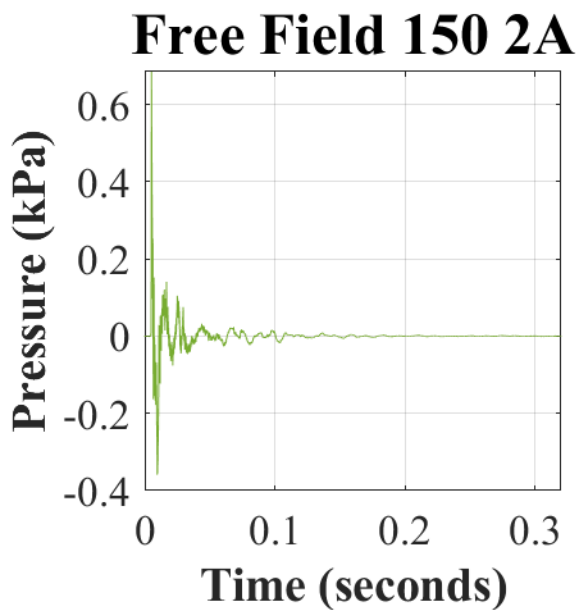
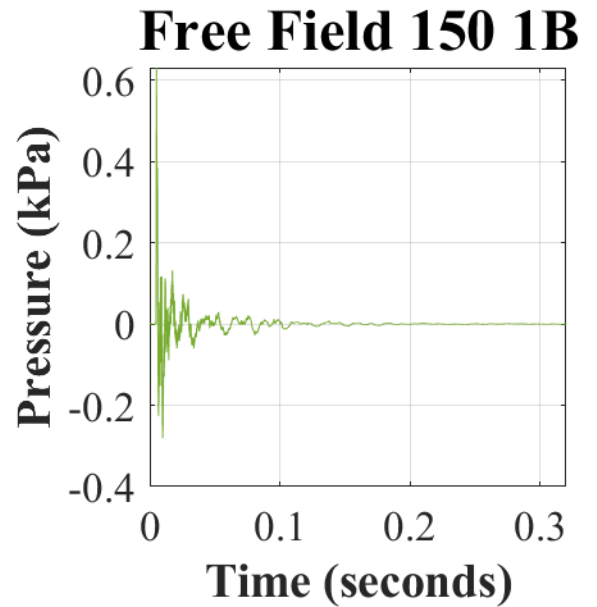
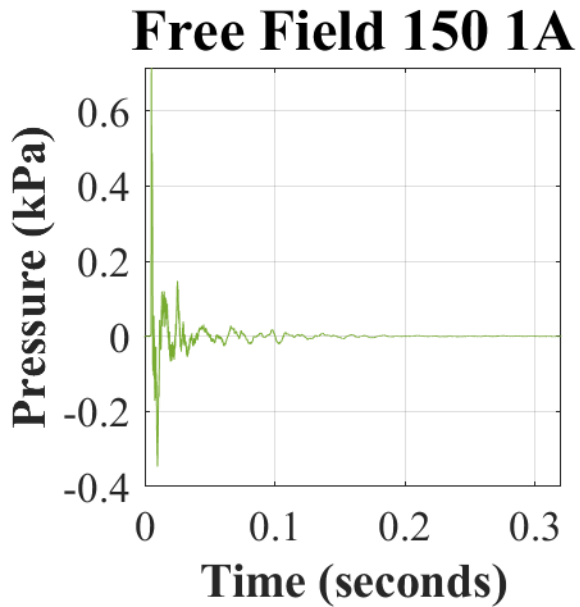




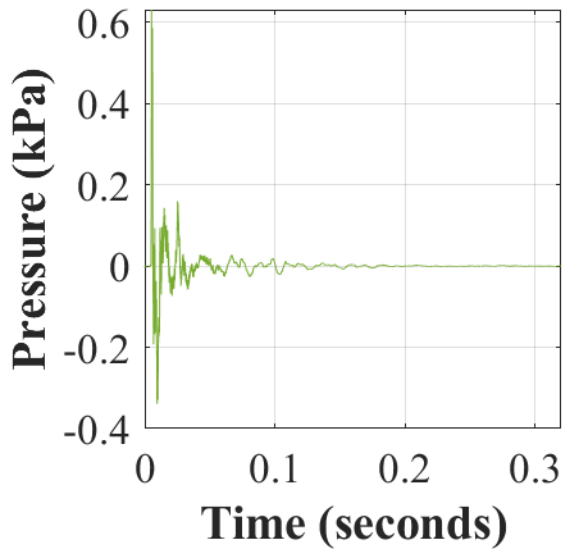


Note. The naming convention for all unoccluded waveforms is “Unoccluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the HPD doffed), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dB), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., 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).

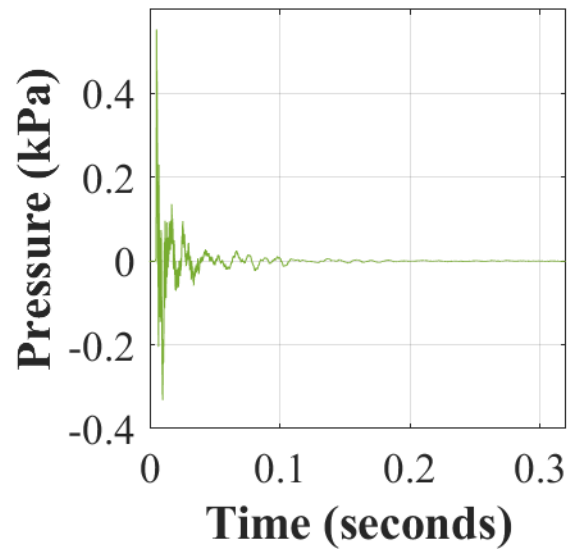
Appendix G. Recorded waveform (in kilopascals [kPa]) over time (in seconds [s]) of the impulse measured with the free-field probe at 150 dBp and the ComTac™ V (OFF) donned.



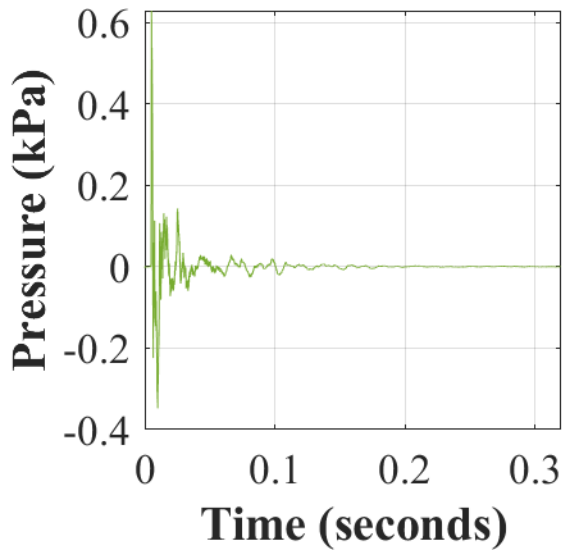
Free Field 150 3A



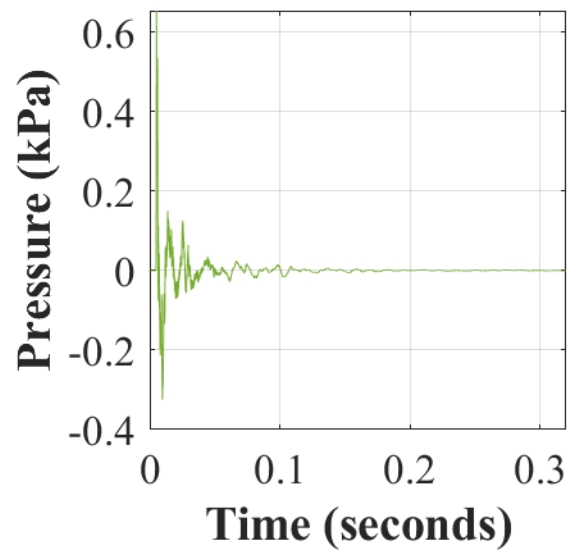
Free Field 150 3B

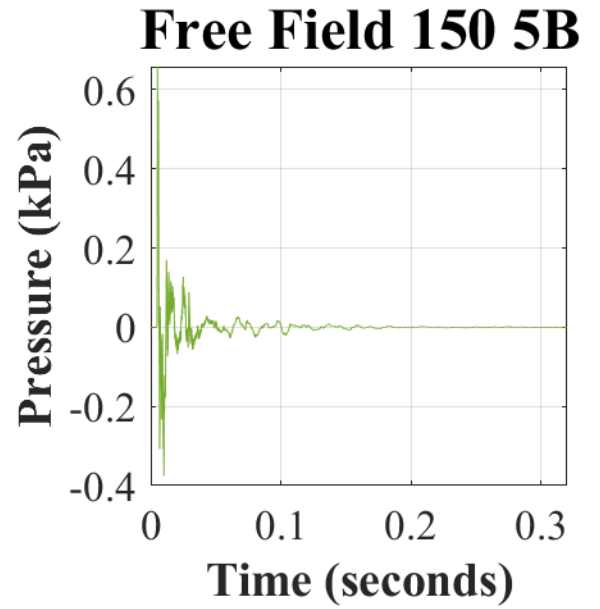
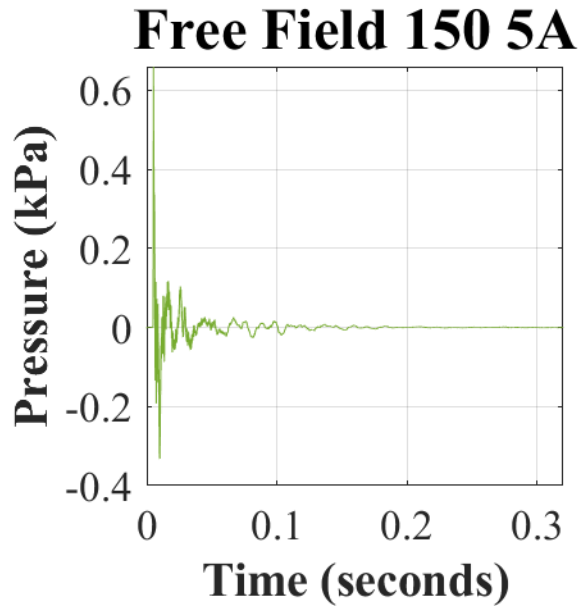


Free Field 150 4A



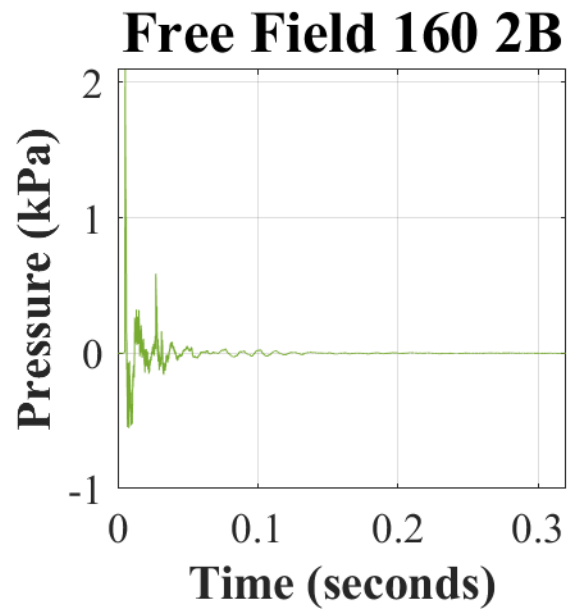
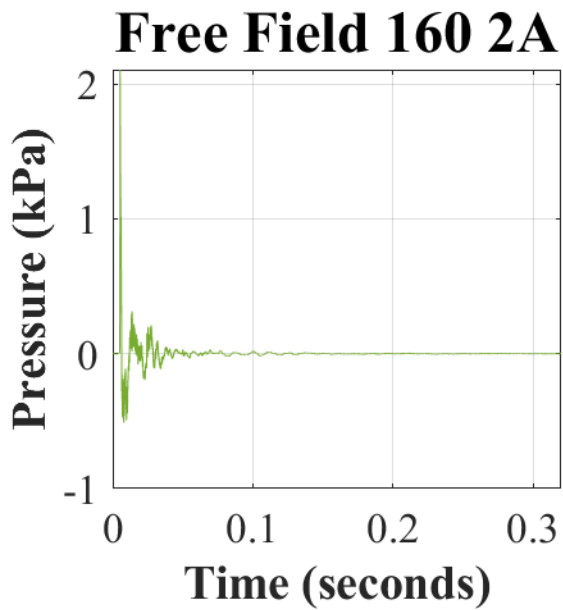
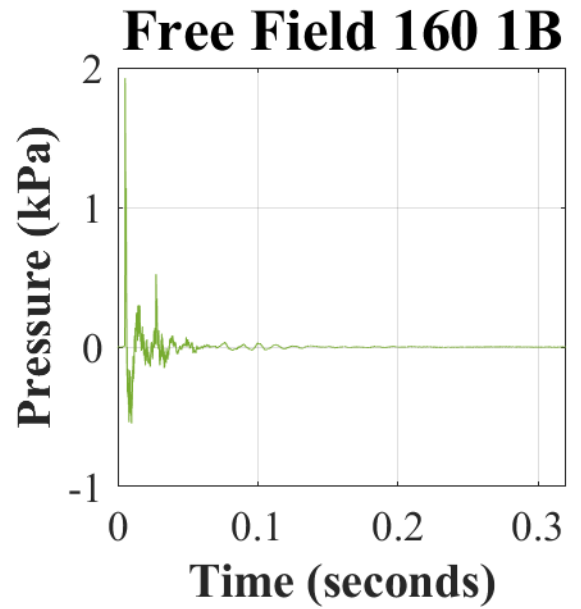
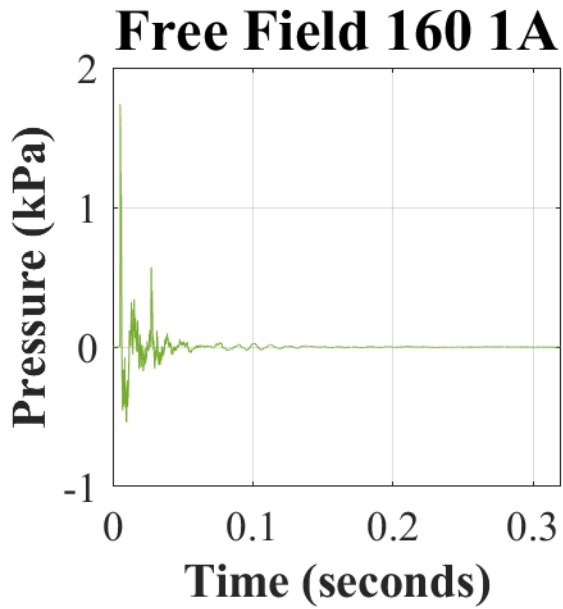
Free Field 150 4B

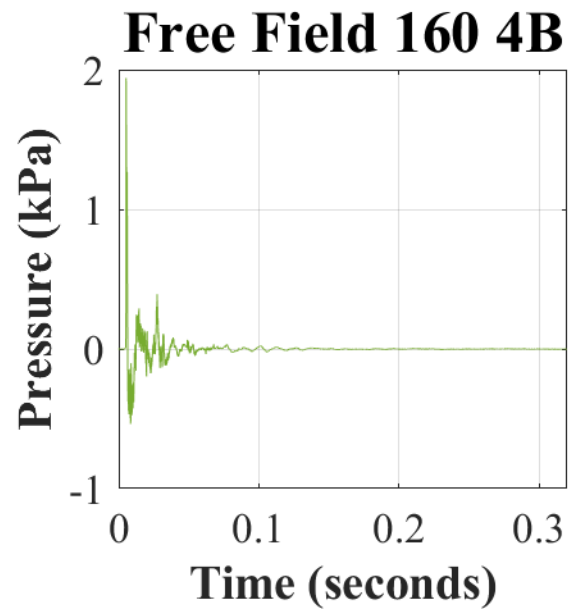
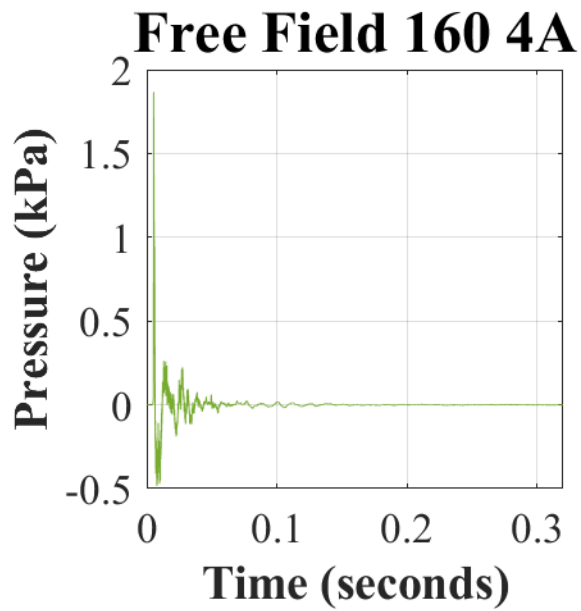
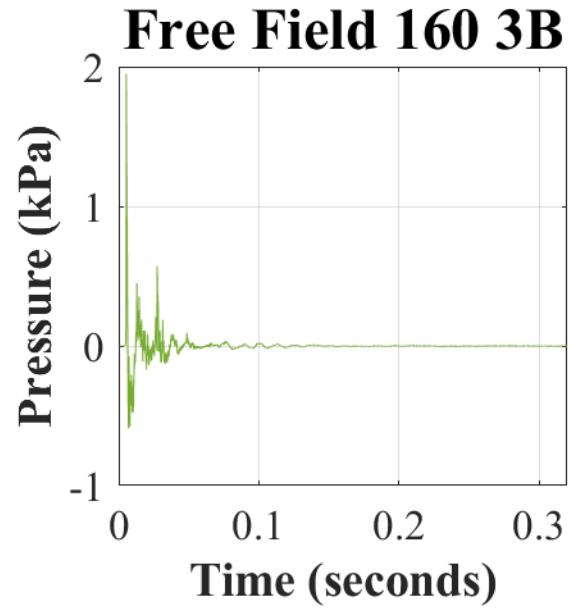
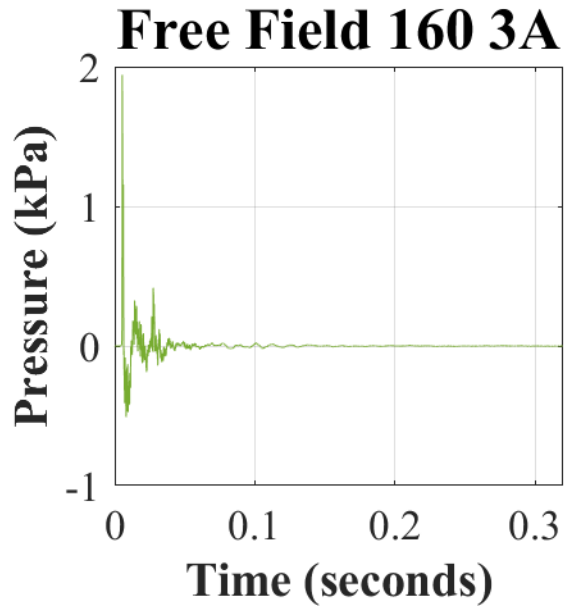


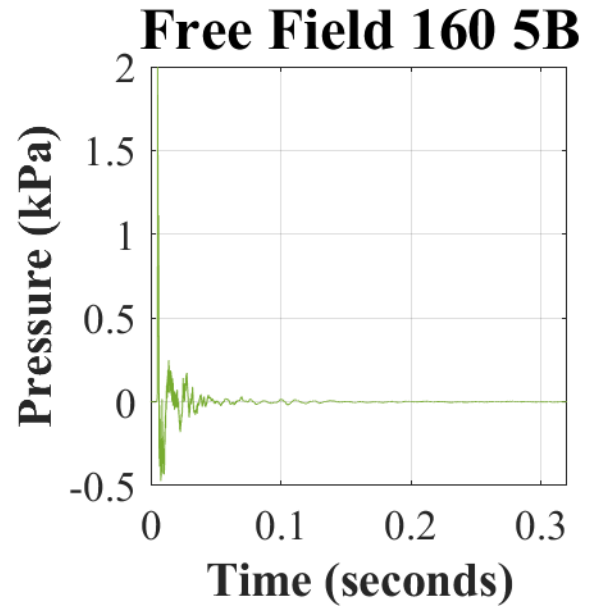
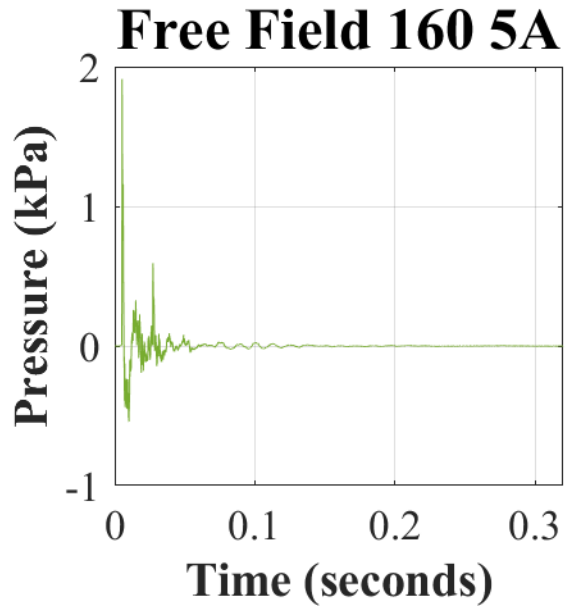


Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (150 dB), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

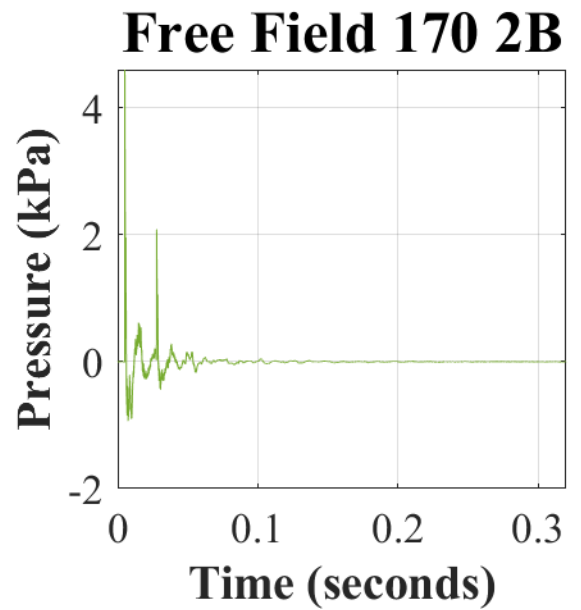
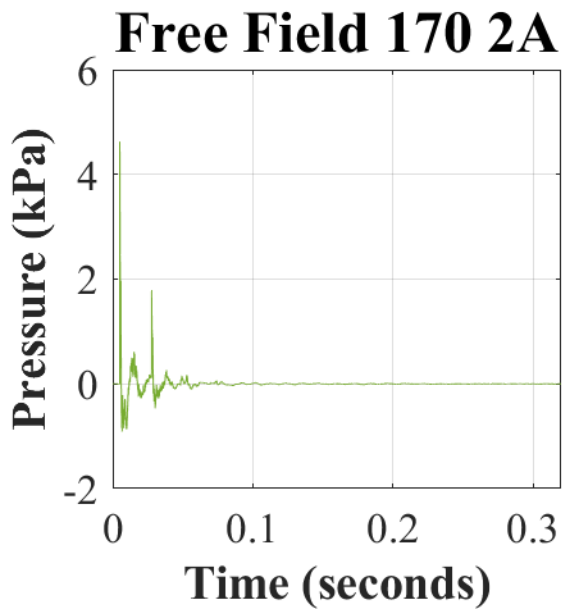
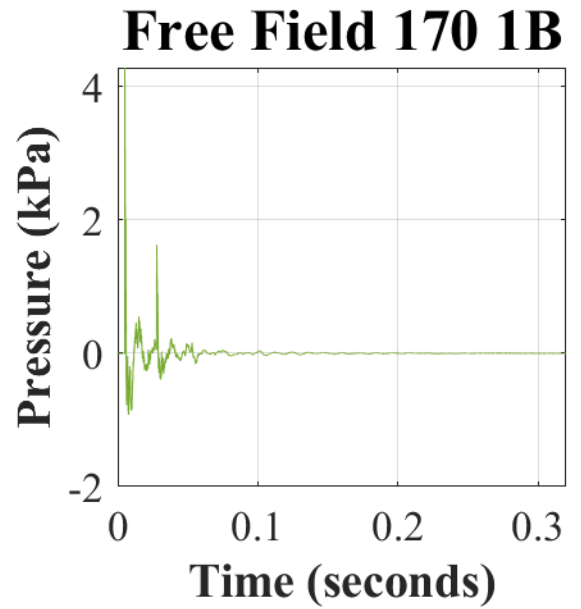
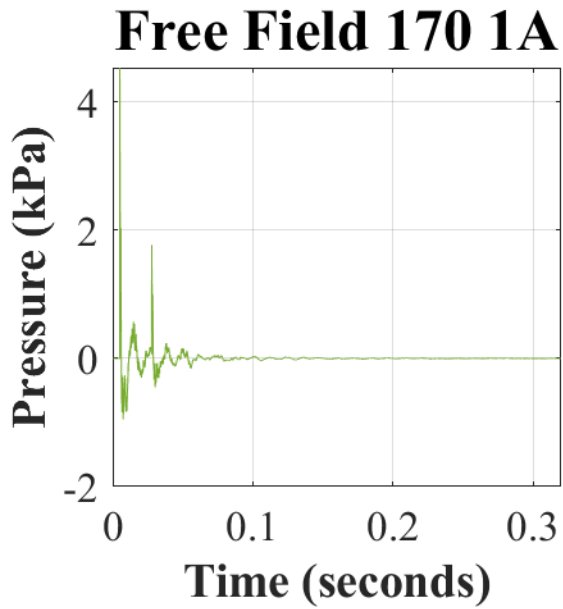




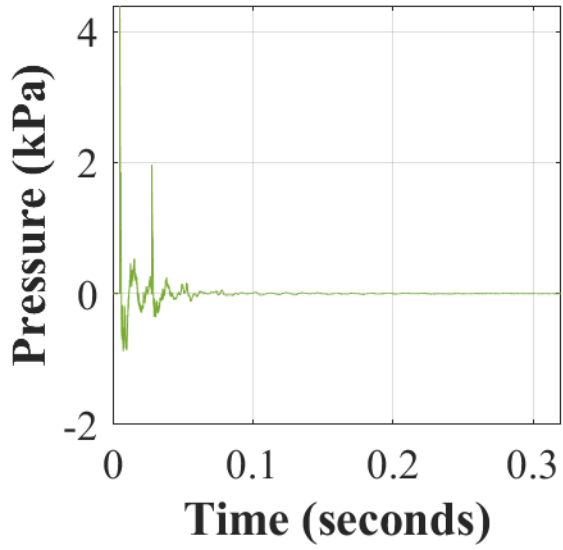


Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (160 dB), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

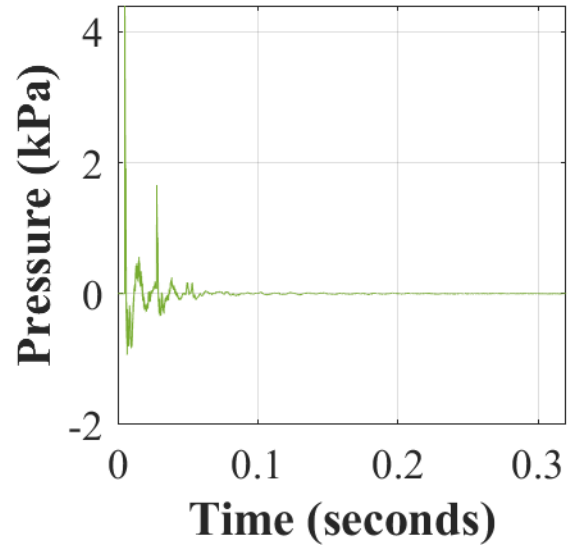
Appendix I. Recorded waveform (in kilopascals [kPa]) over time (in seconds [s]) of the impulse measured with the free-field probe at 170 dBp and the ComTac™ V (OFF) donned.



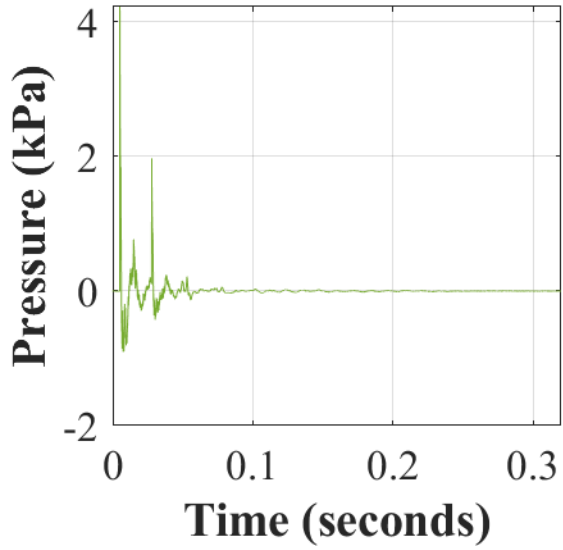
Free Field 170 3A



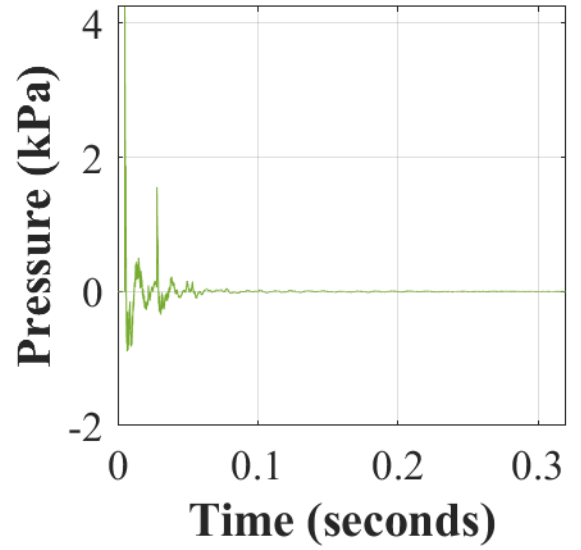
Free Field 170 3B

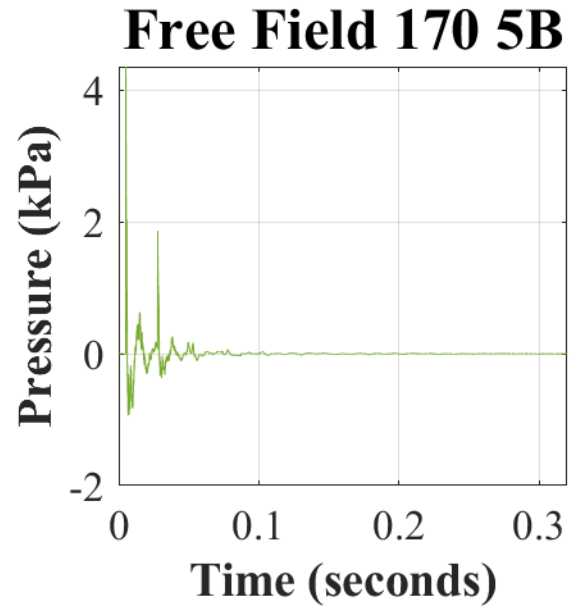
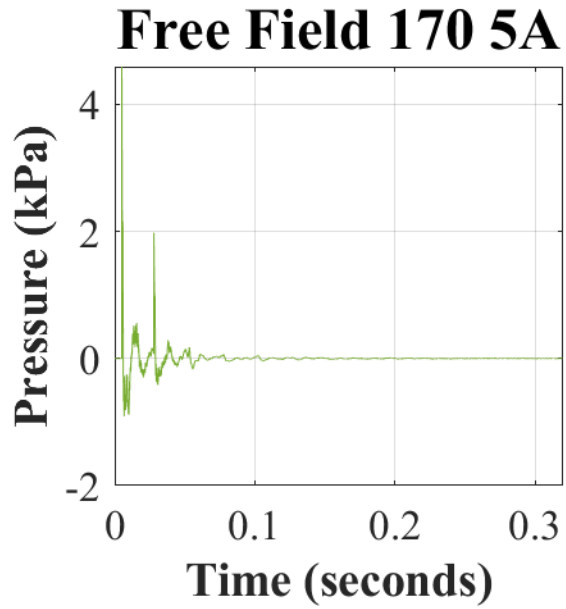


Free Field 170 4A



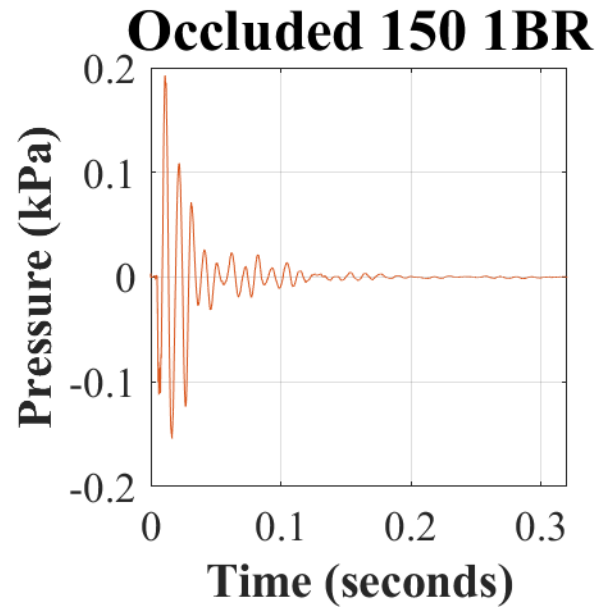
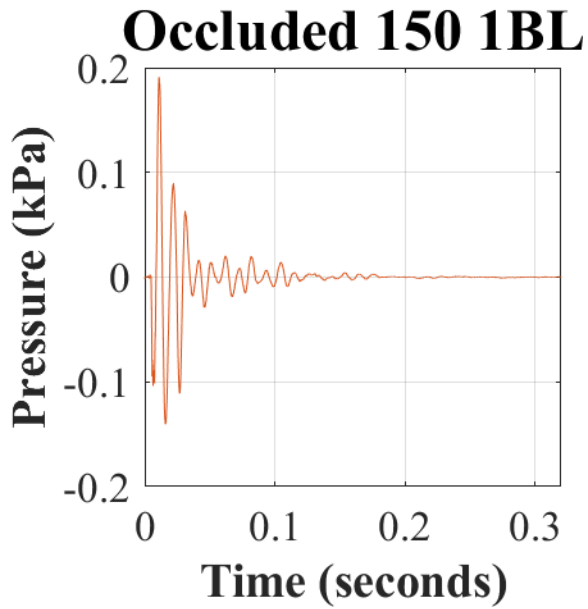
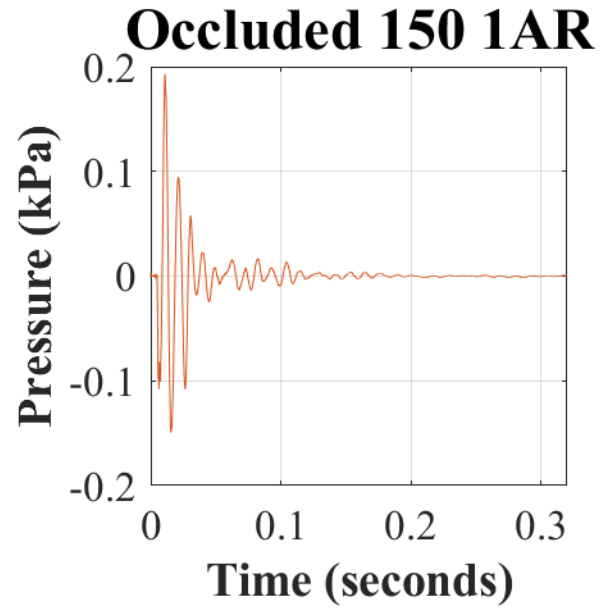
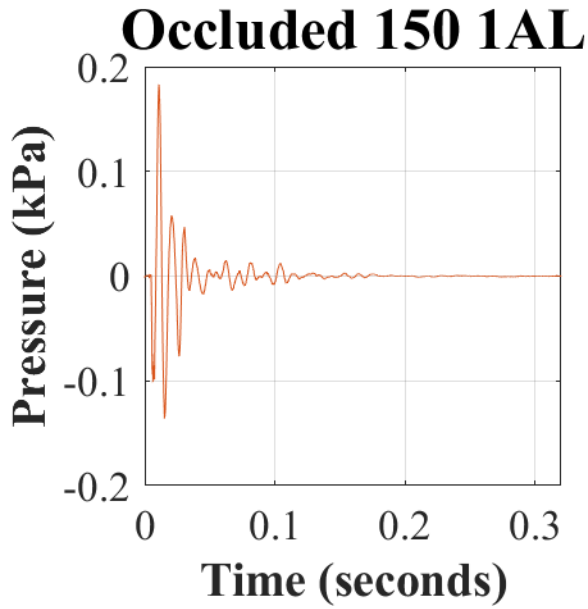
Free Field 170 4B

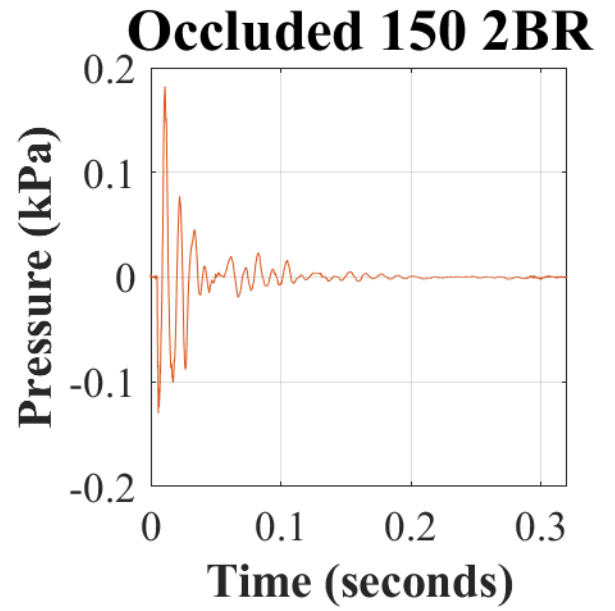
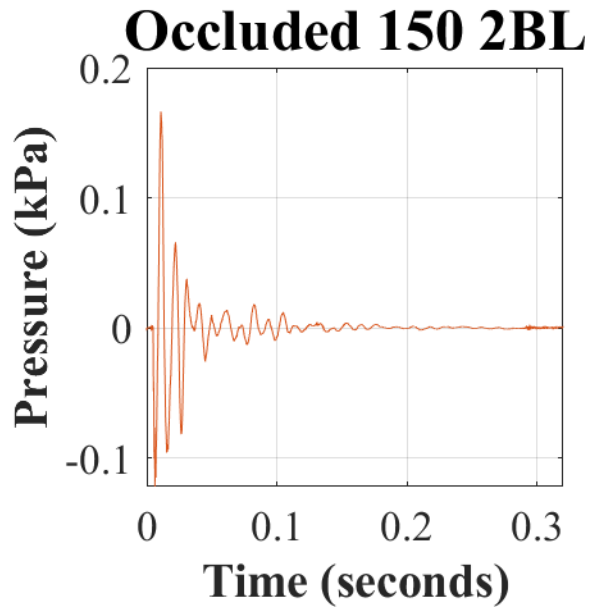
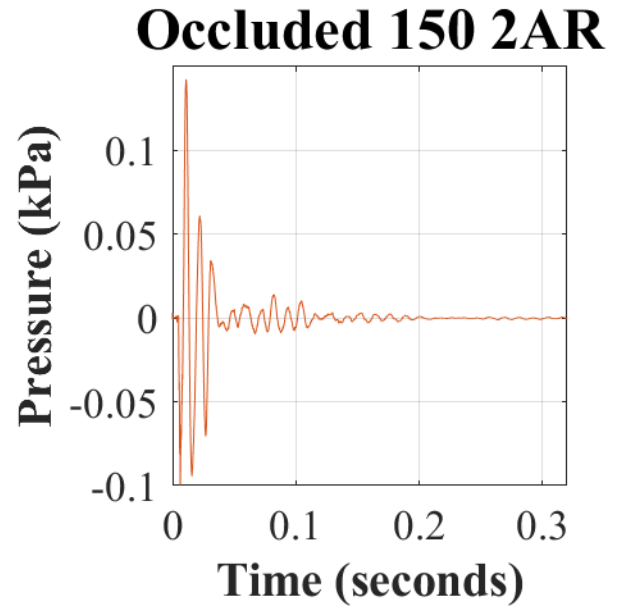
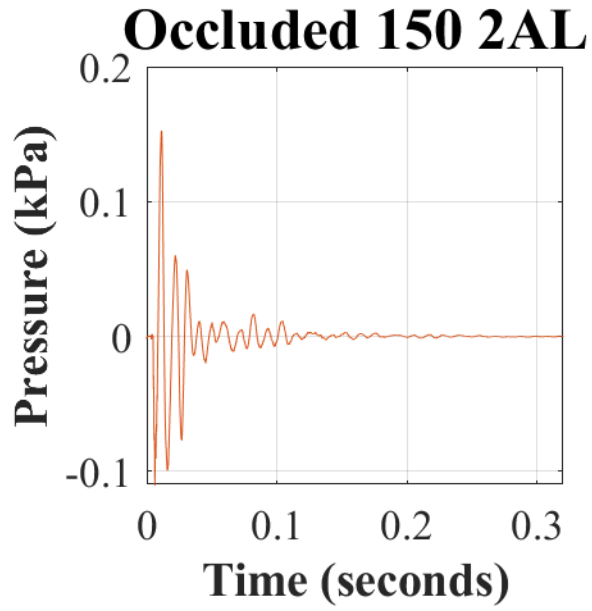


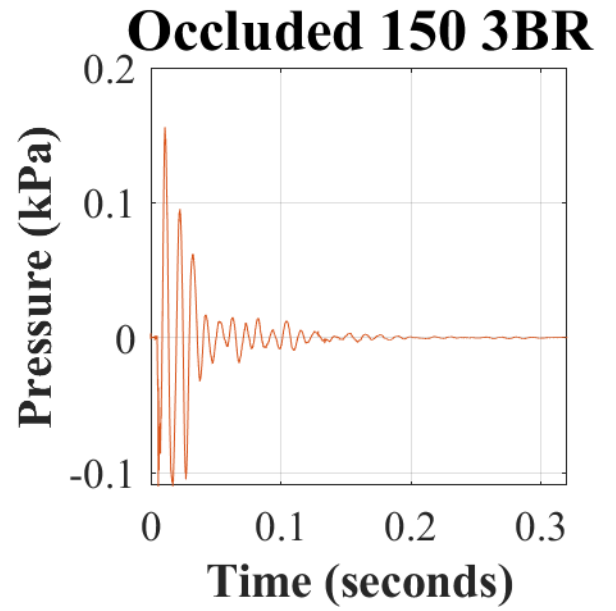
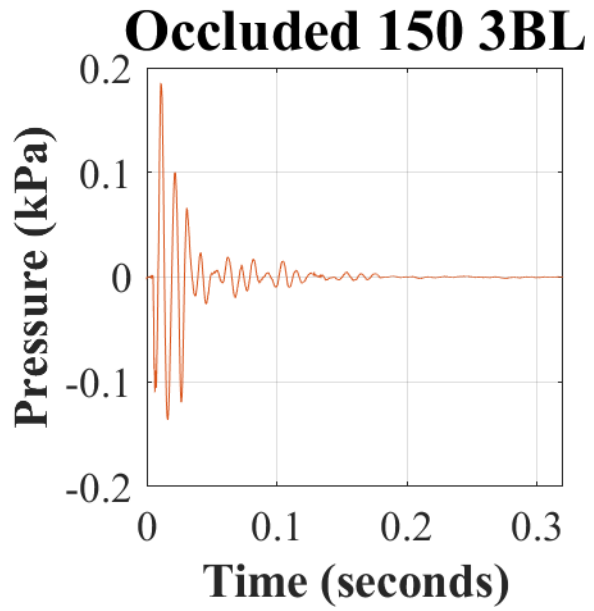
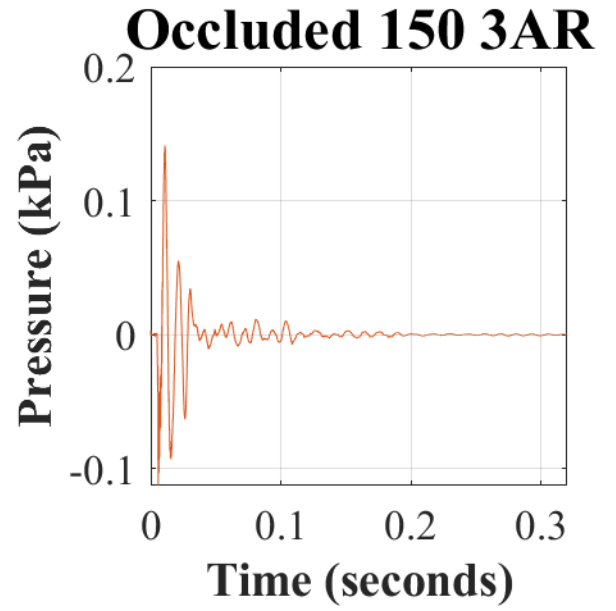
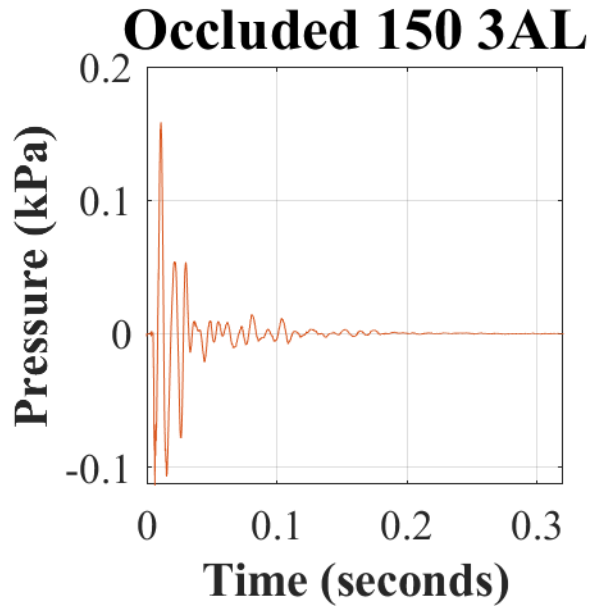


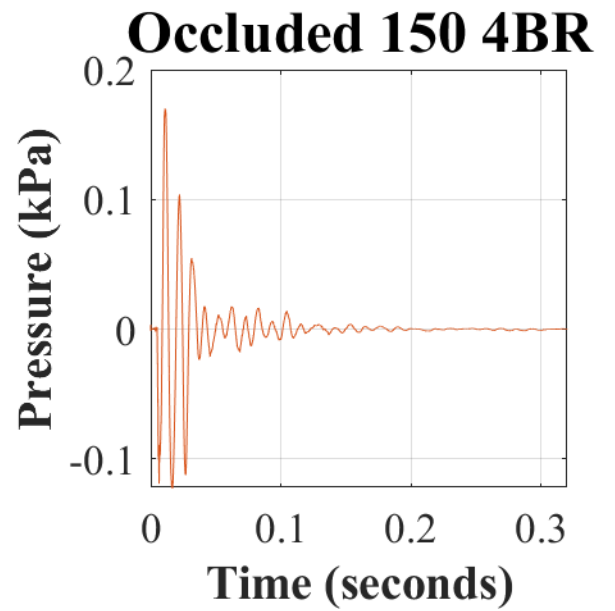
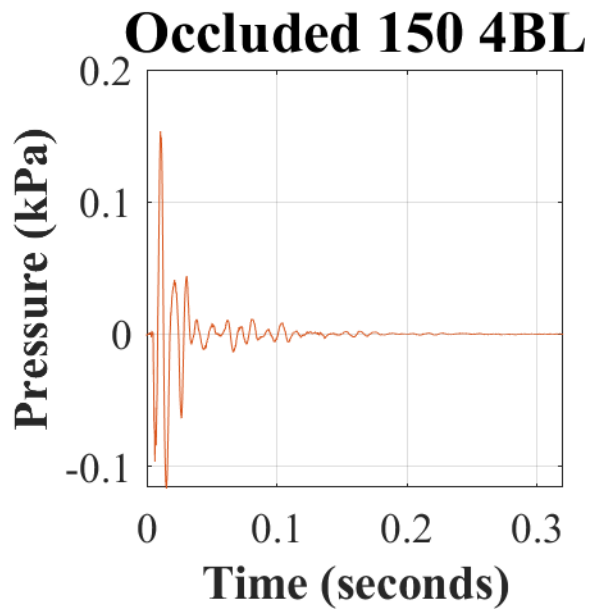
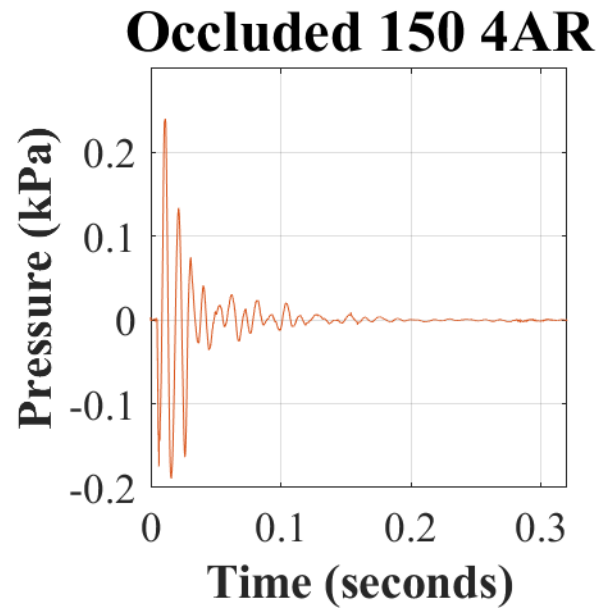
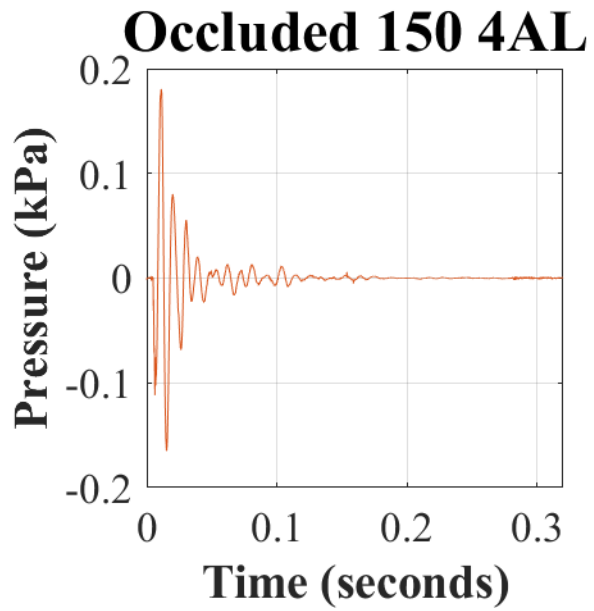
Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (170 dB), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

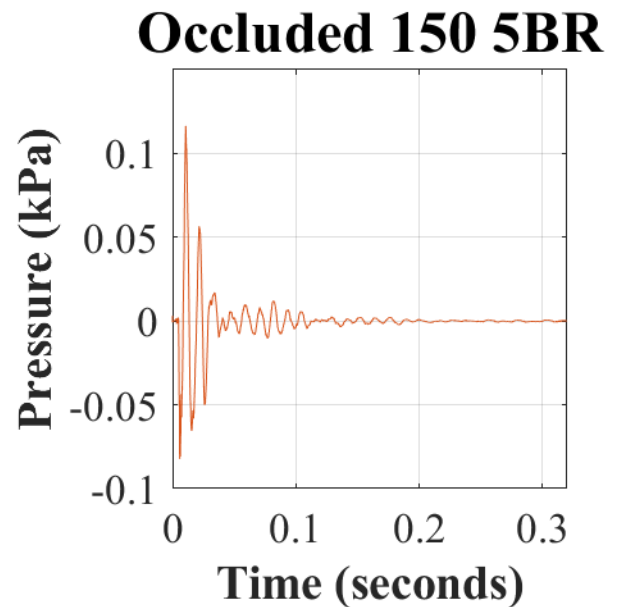
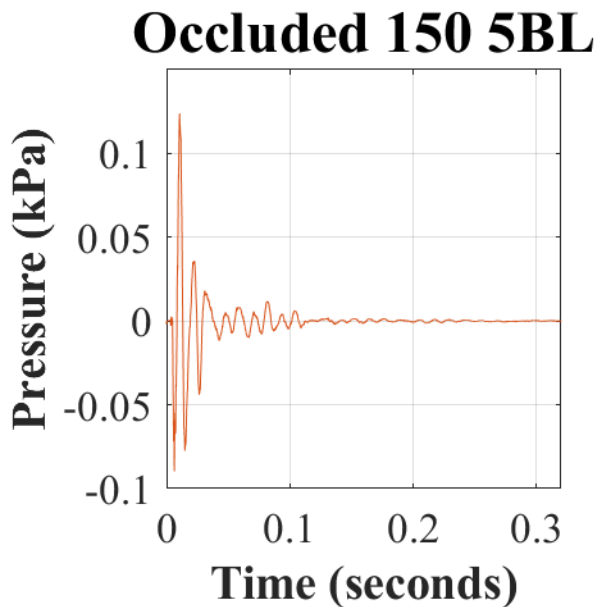
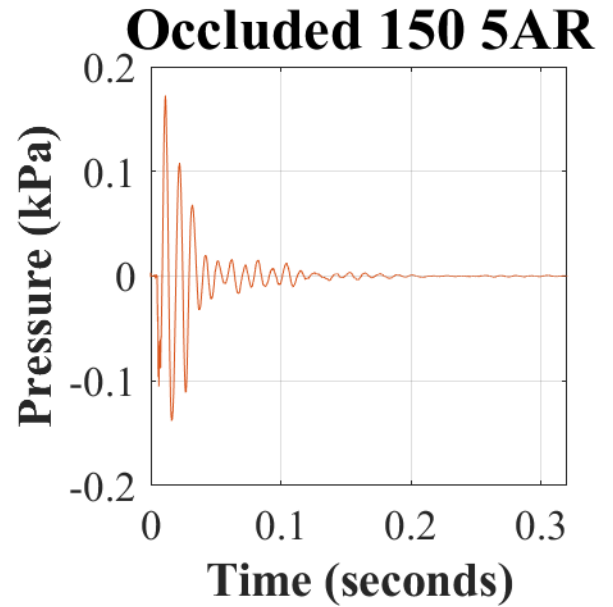
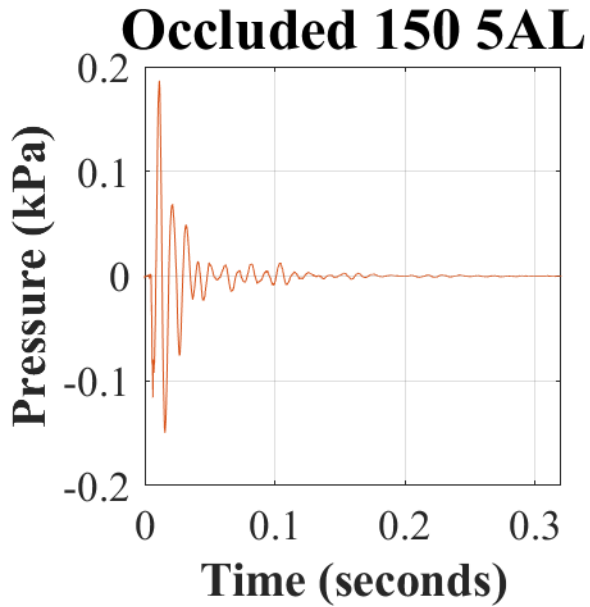
Appendix J. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 150 dBp with the ComTac™ V (MAX).





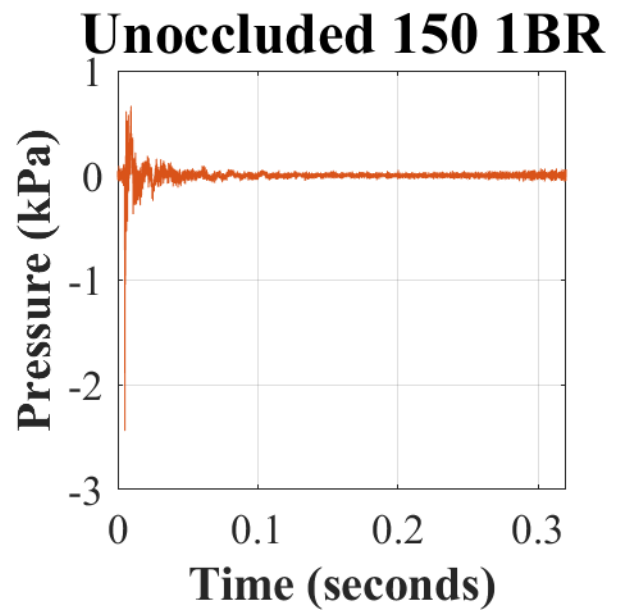
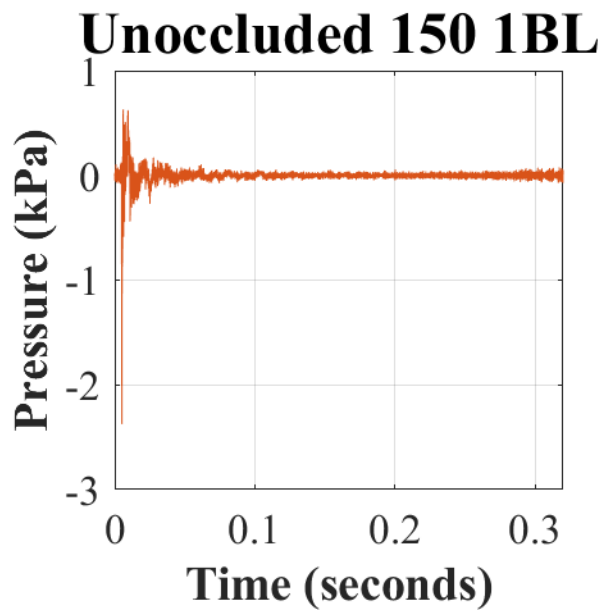
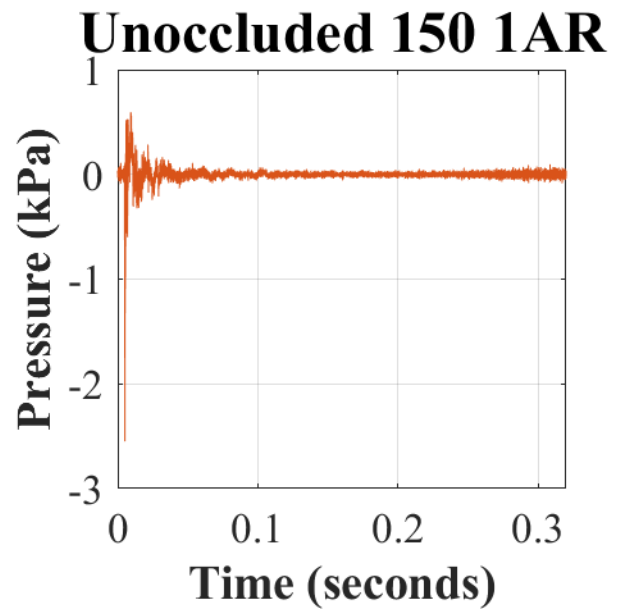
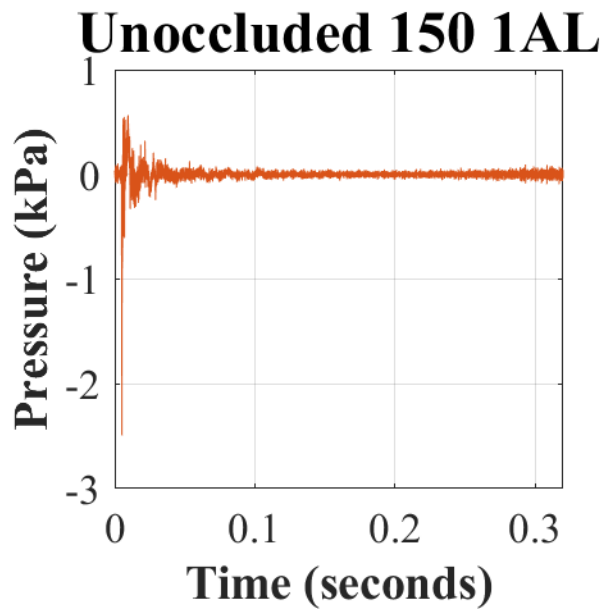


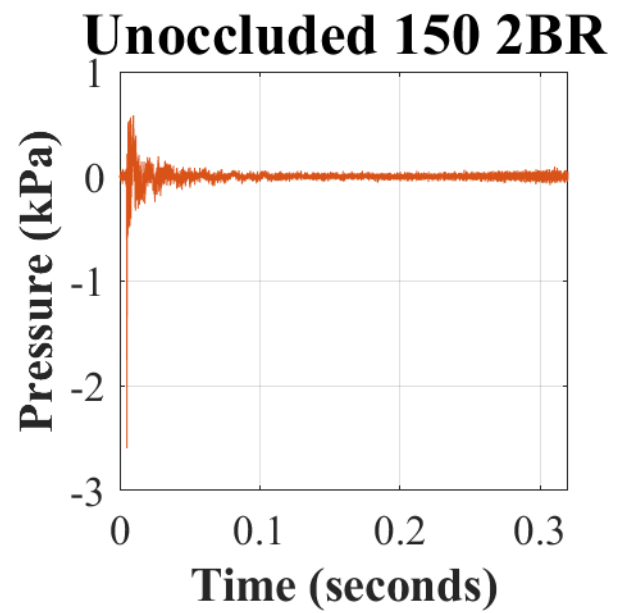
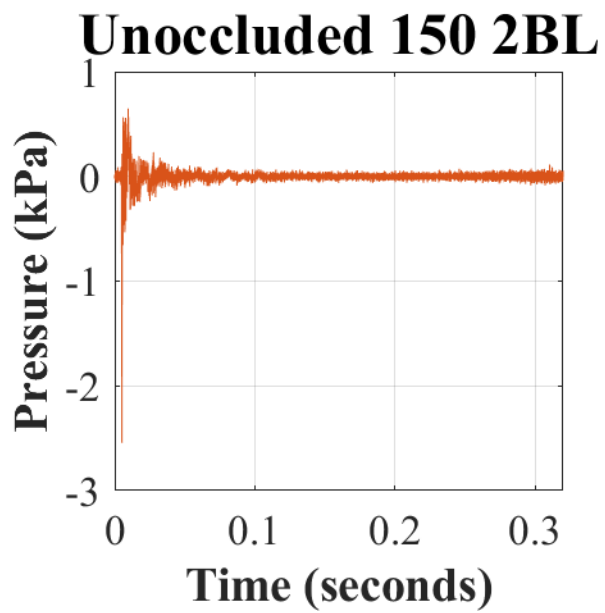
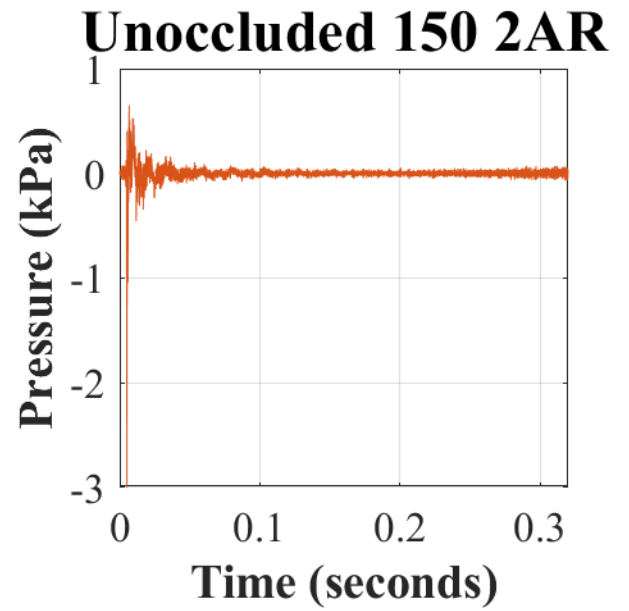
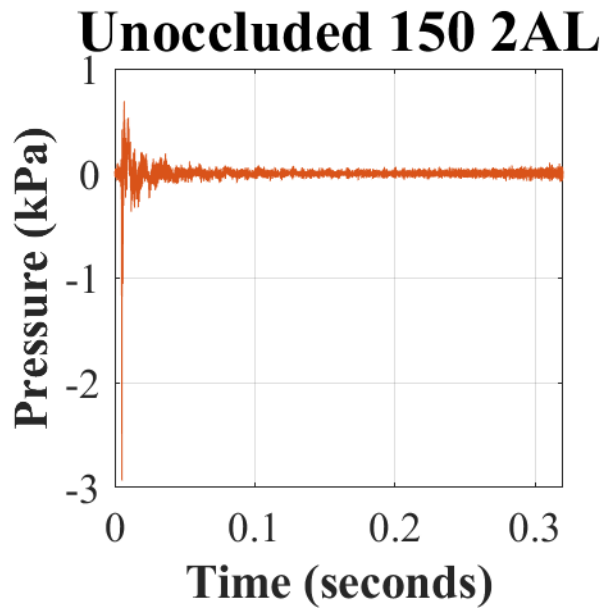


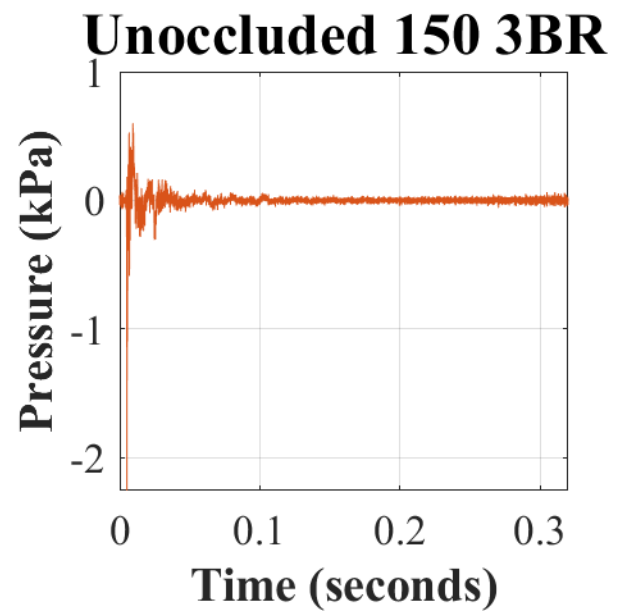
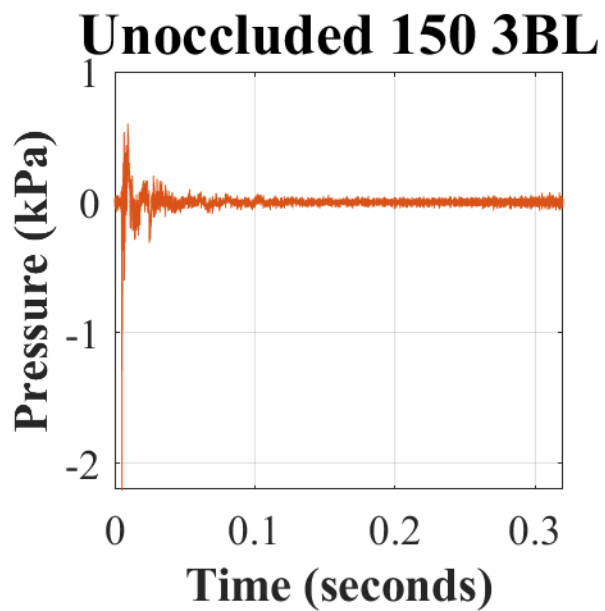
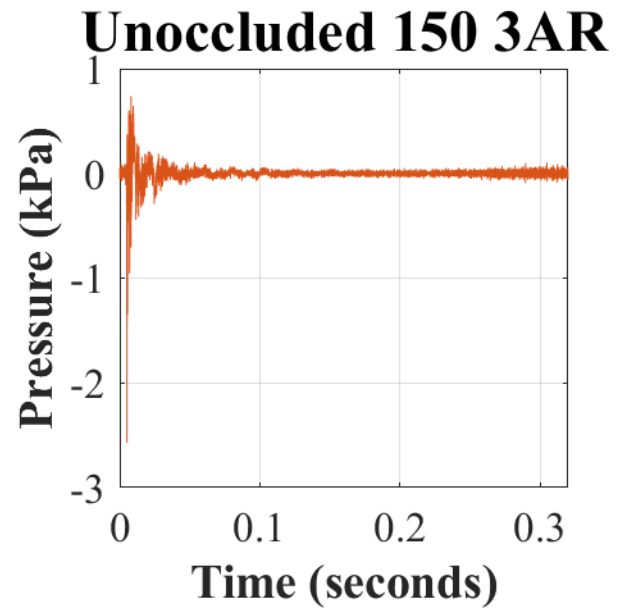
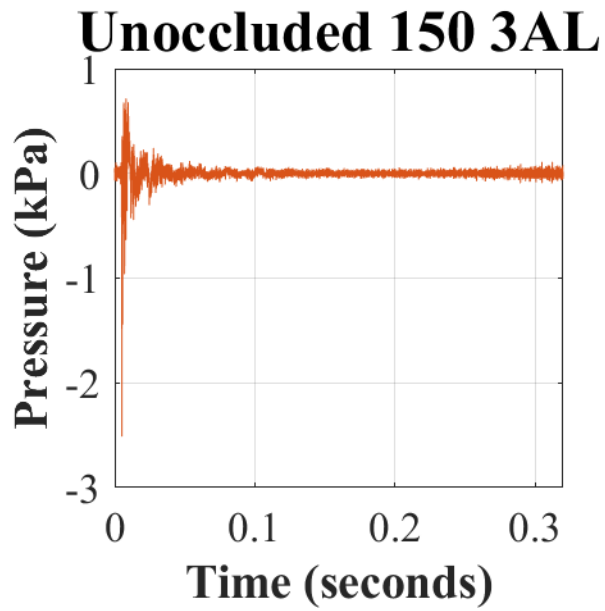


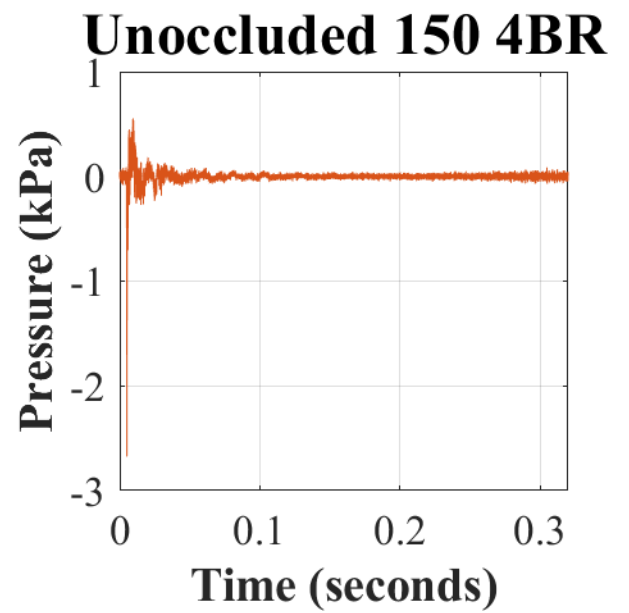
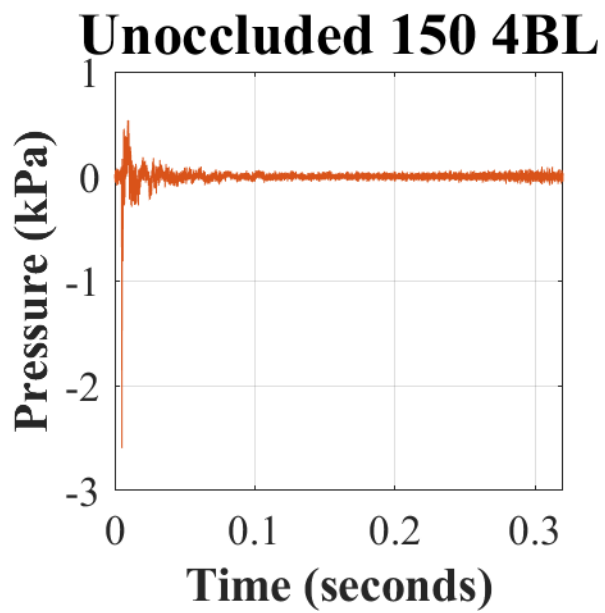
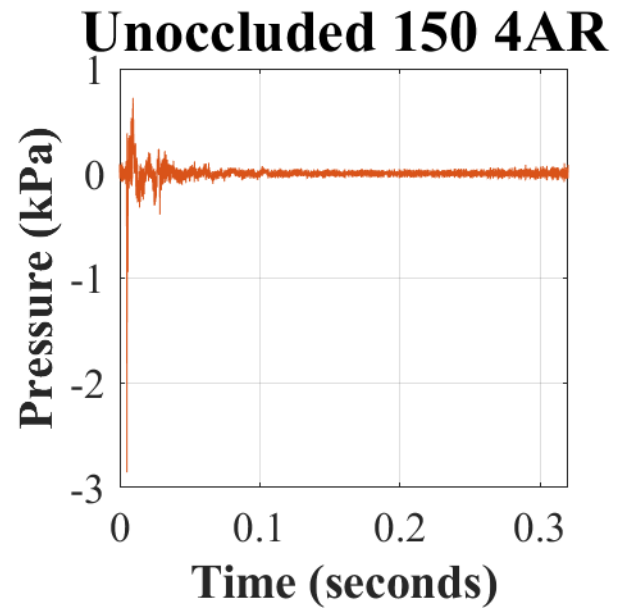
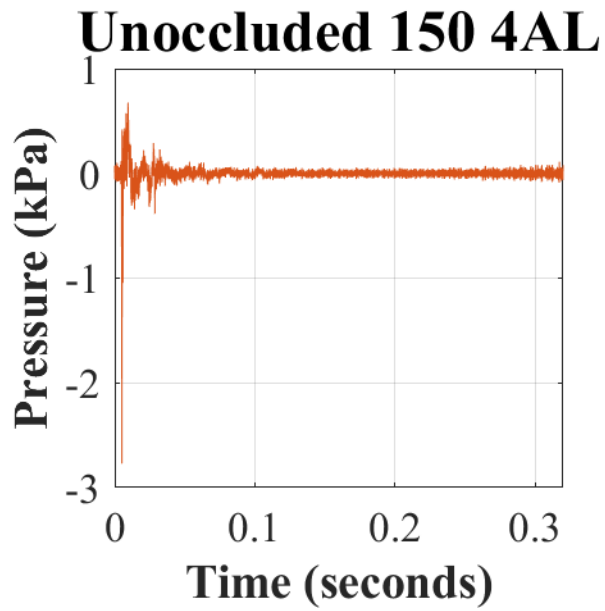
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or 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).

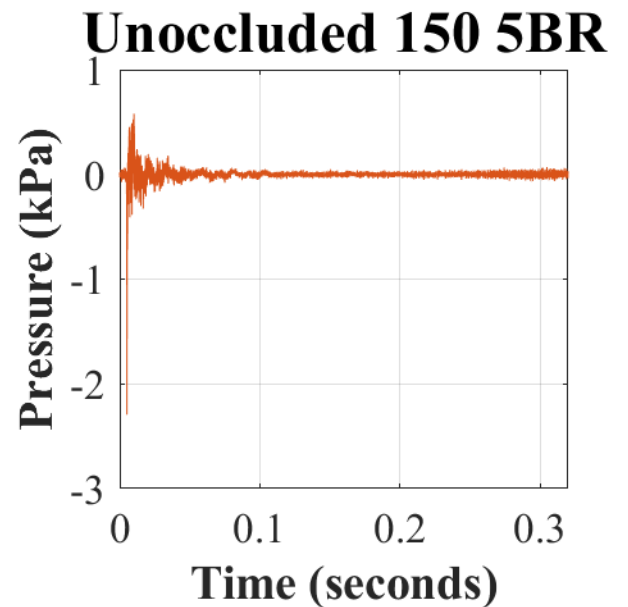
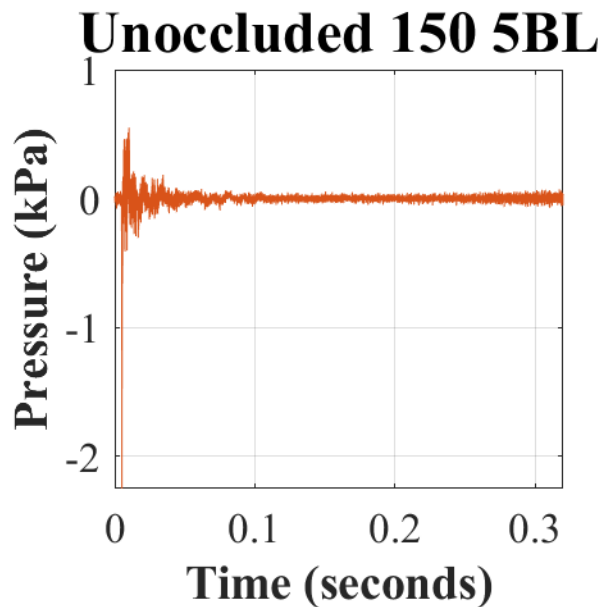
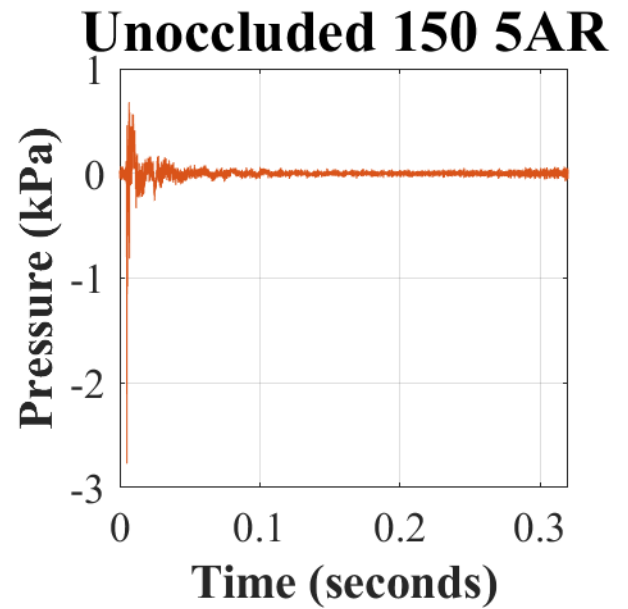
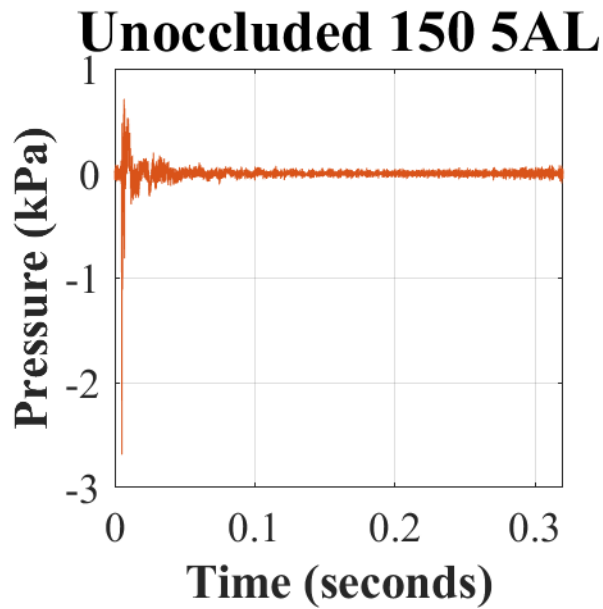
Appendix K. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 150 dBp with the ComTac™ V (MAX).





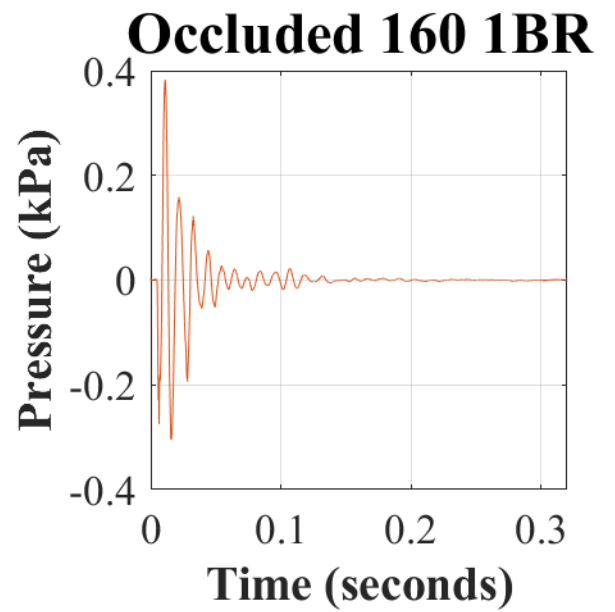
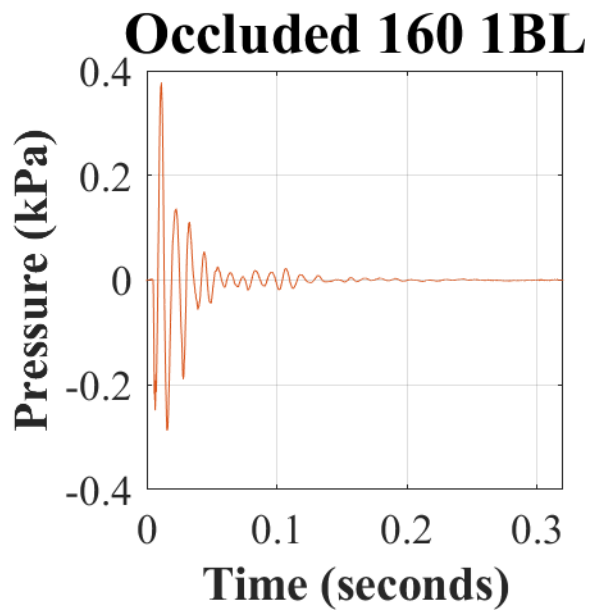
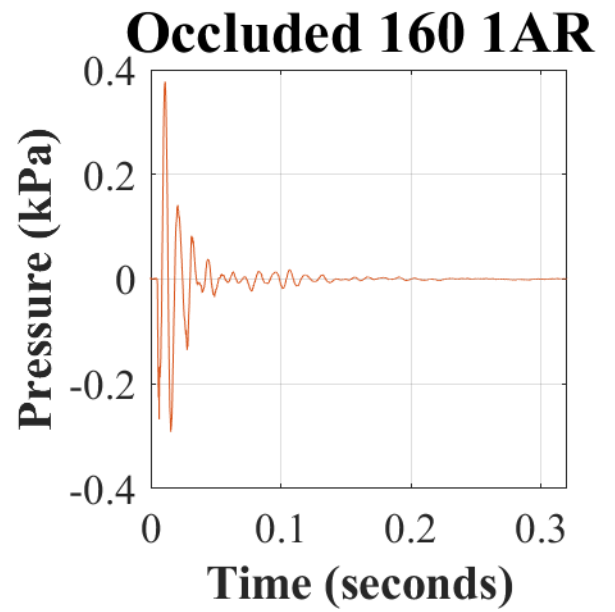
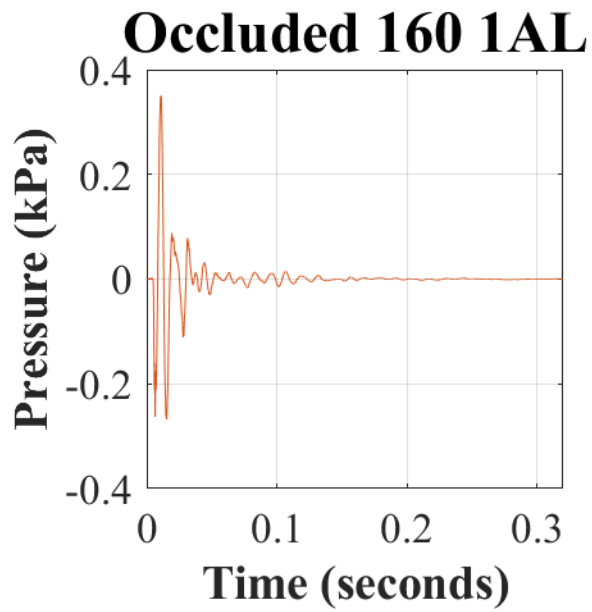


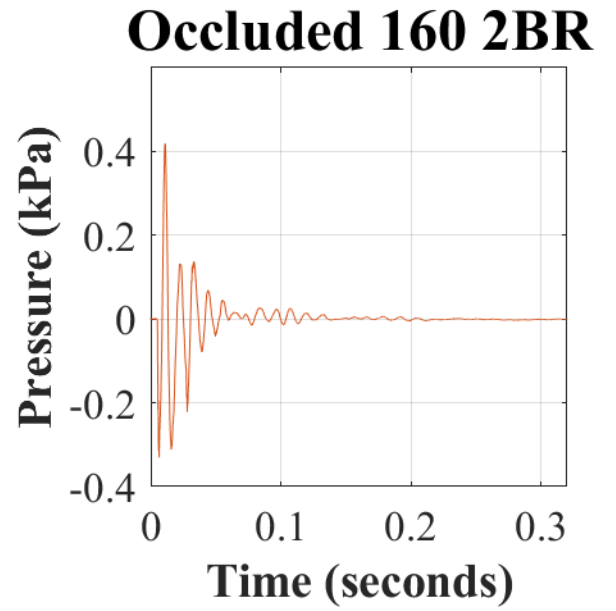
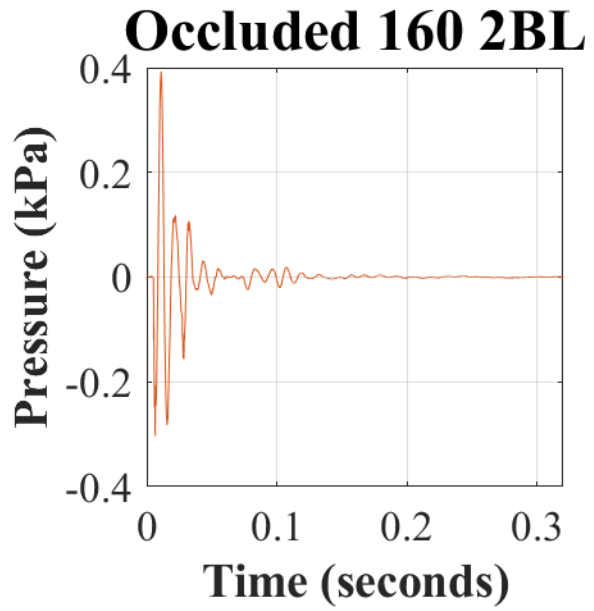
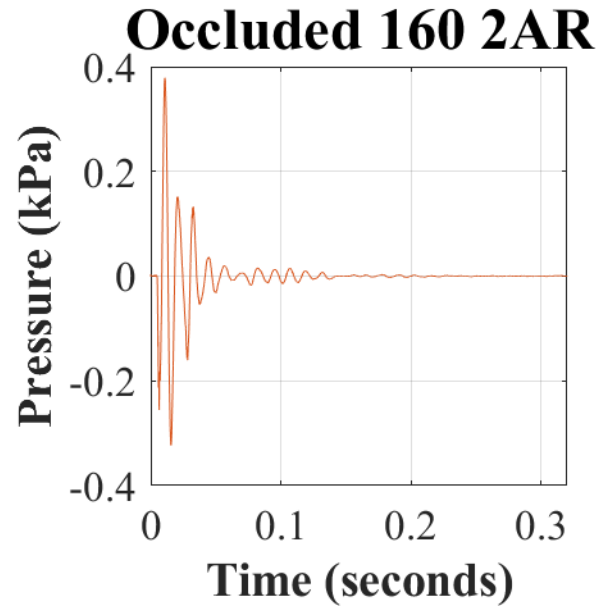
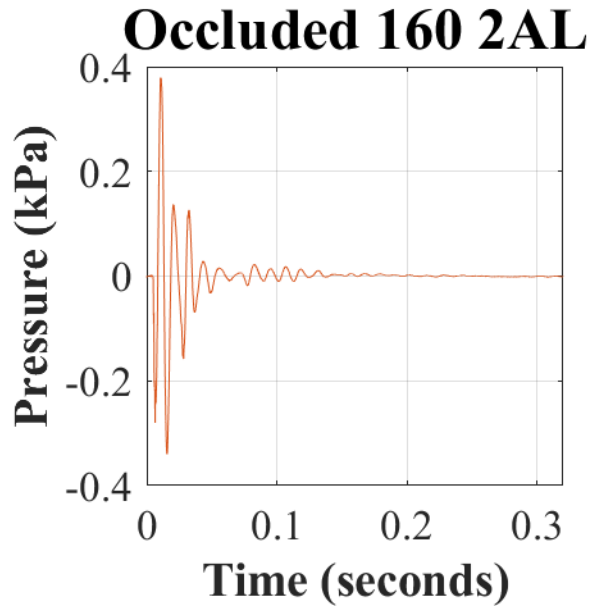


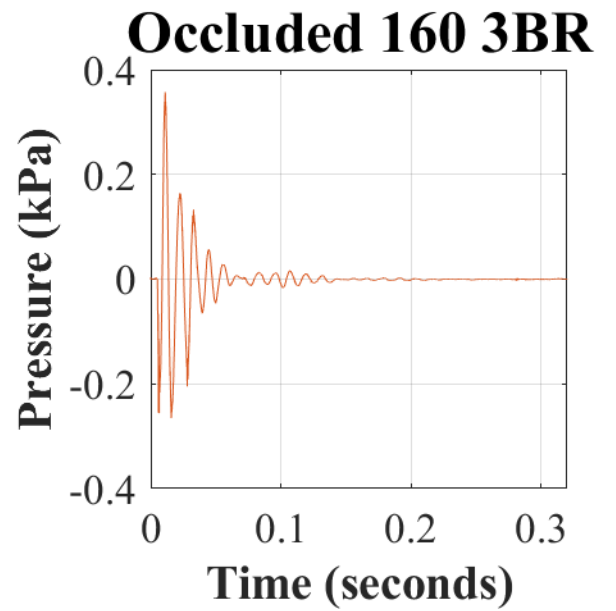
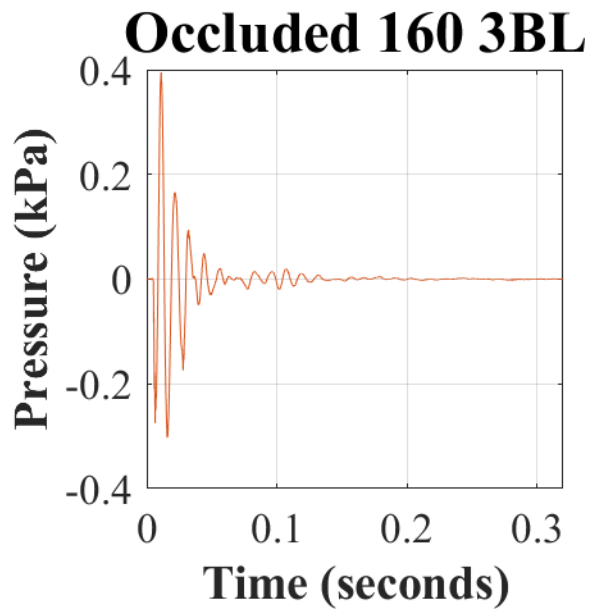
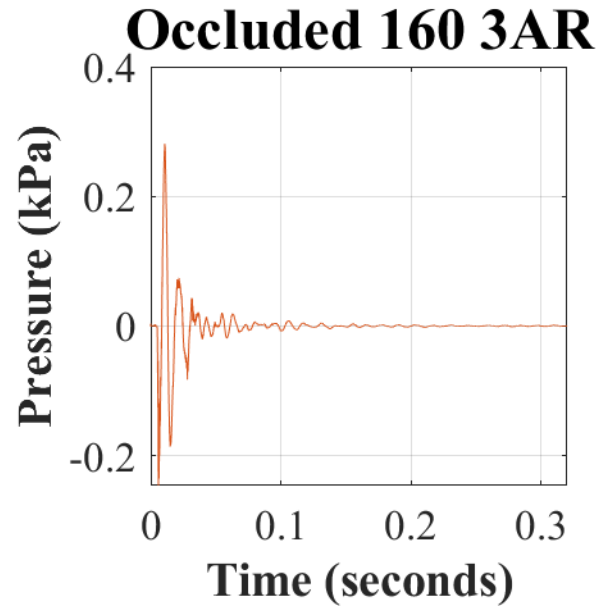
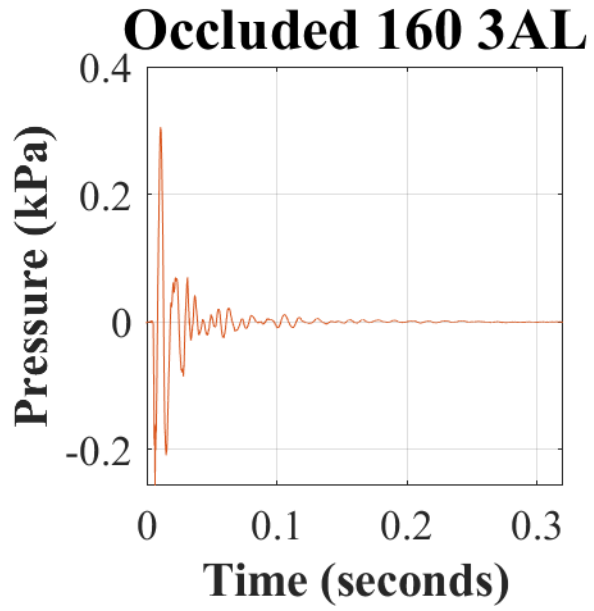


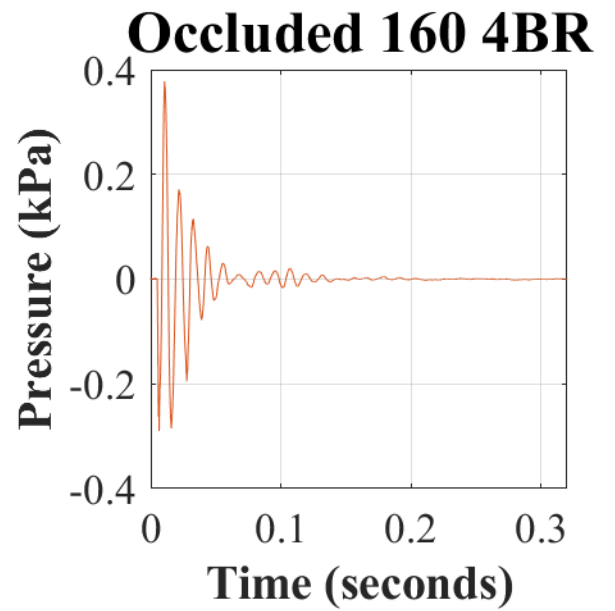
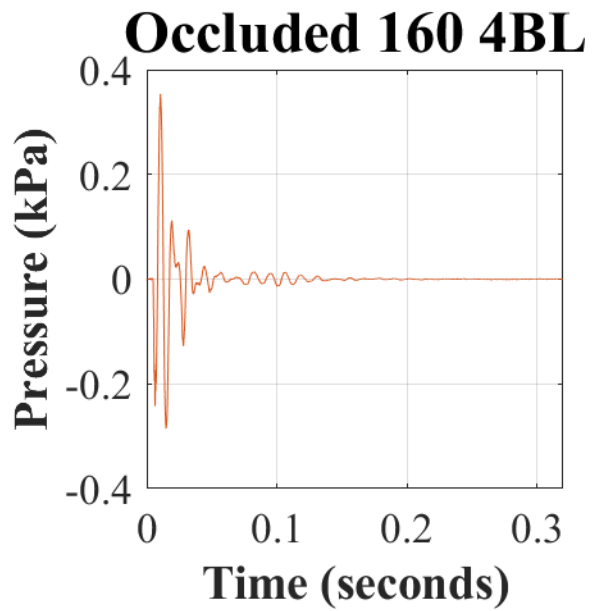
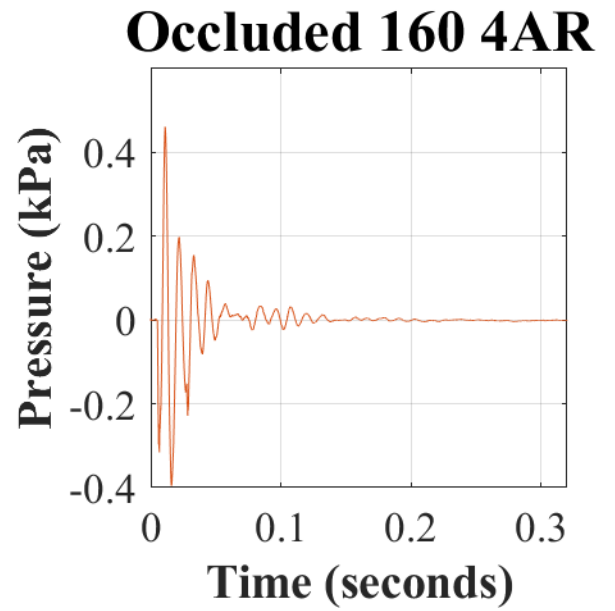
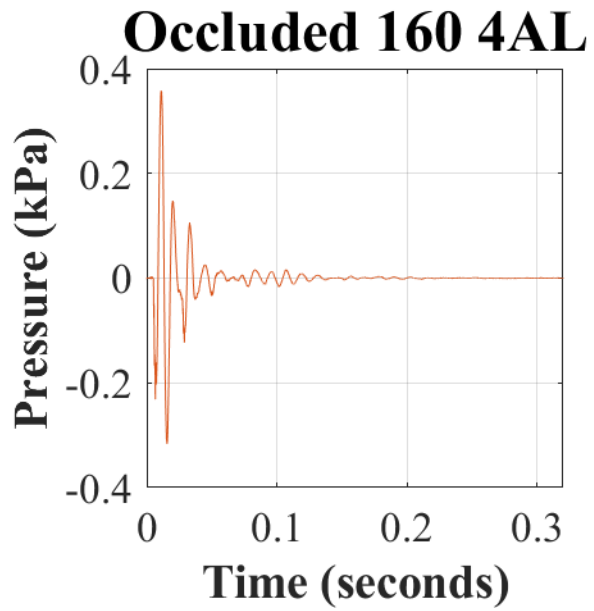
Note. The naming convention for all unoccluded waveforms is “Unoccluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the HPD doffed), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dB), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., 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).

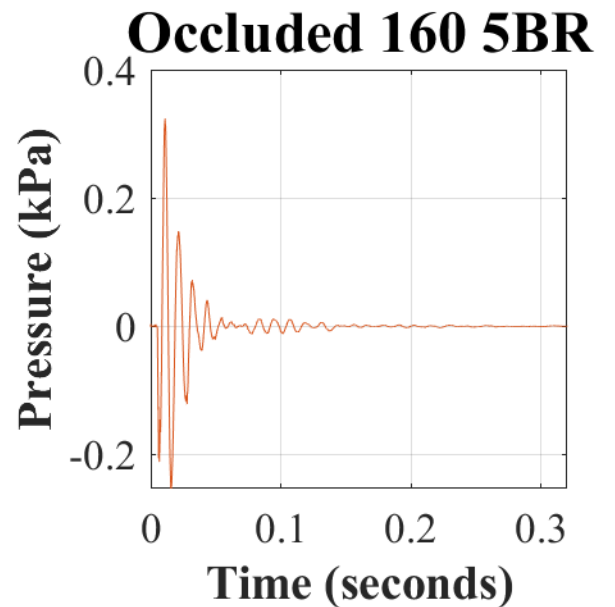
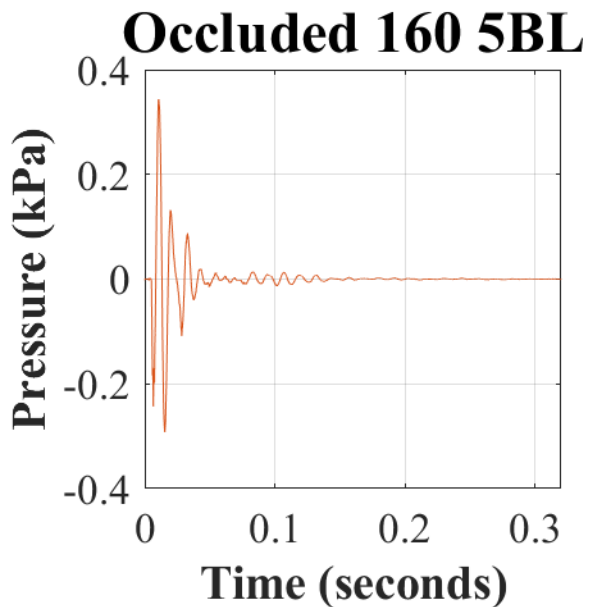
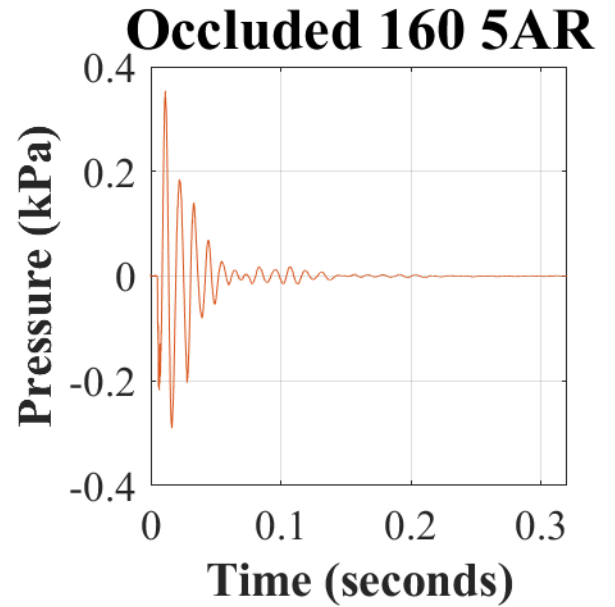
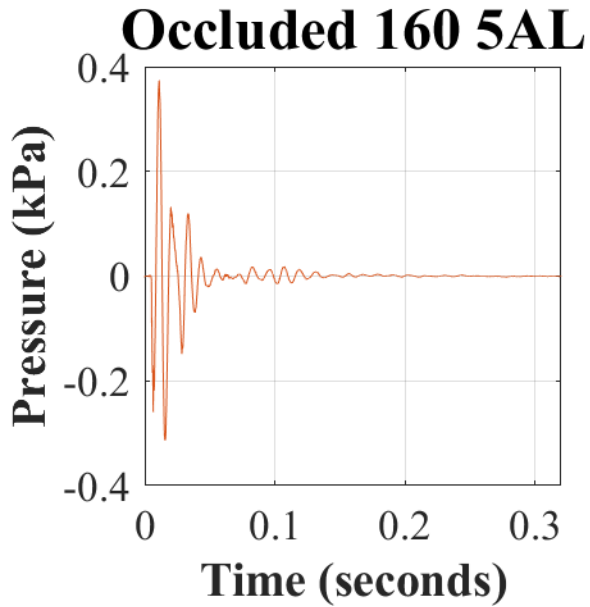
Appendix L. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 160 dBp with the ComTac™ V (MAX).





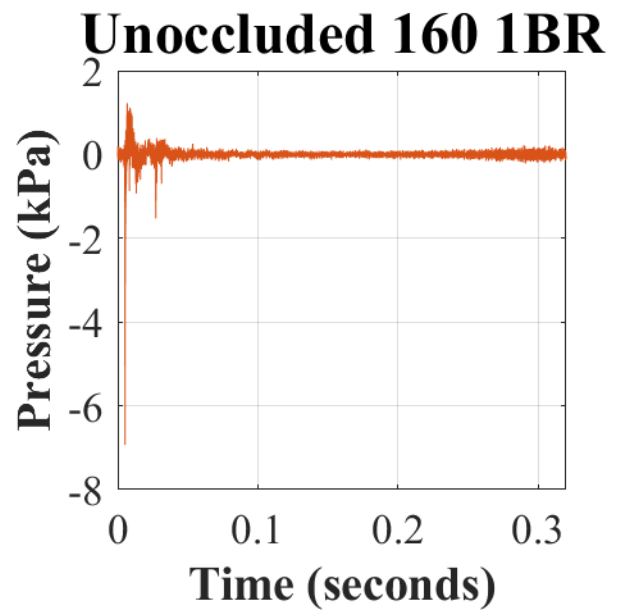
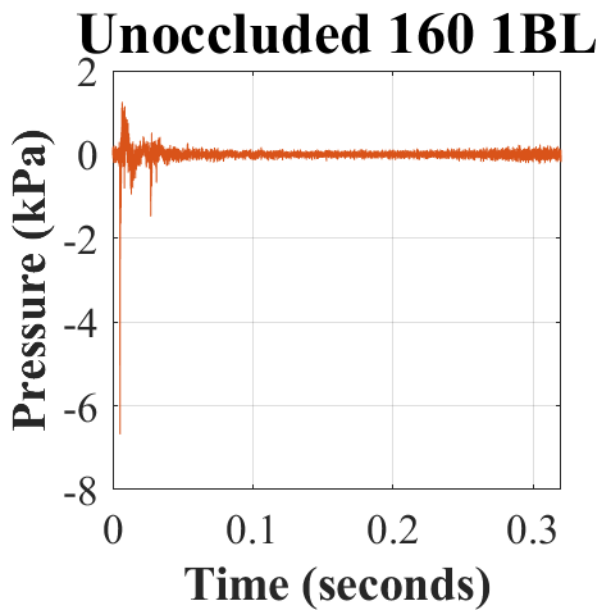
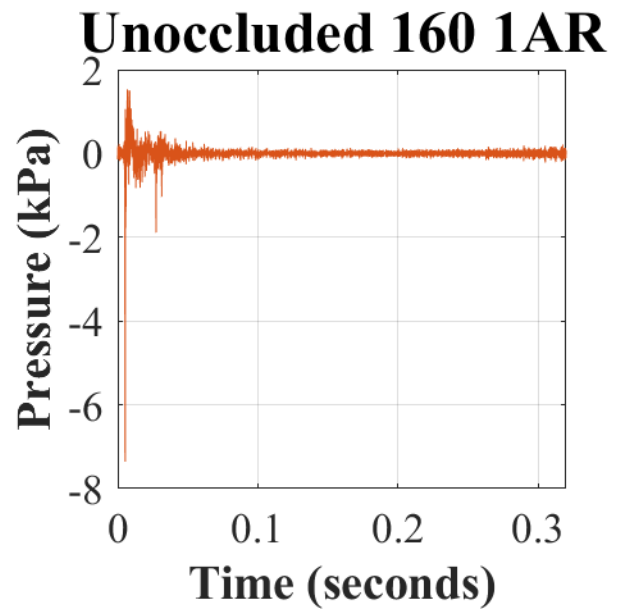
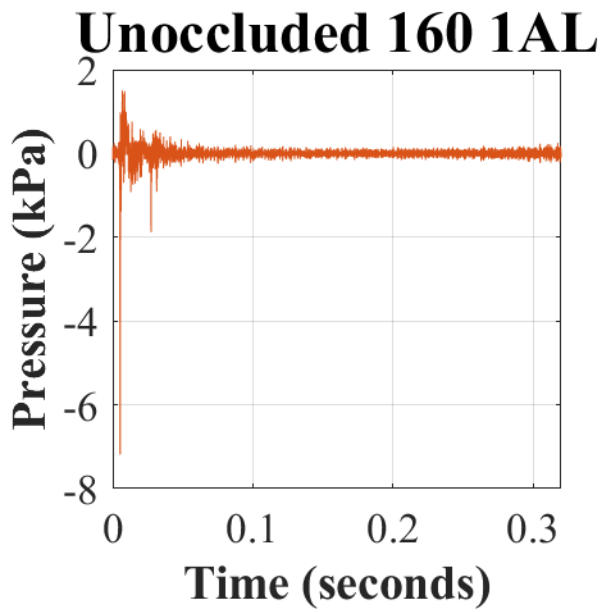


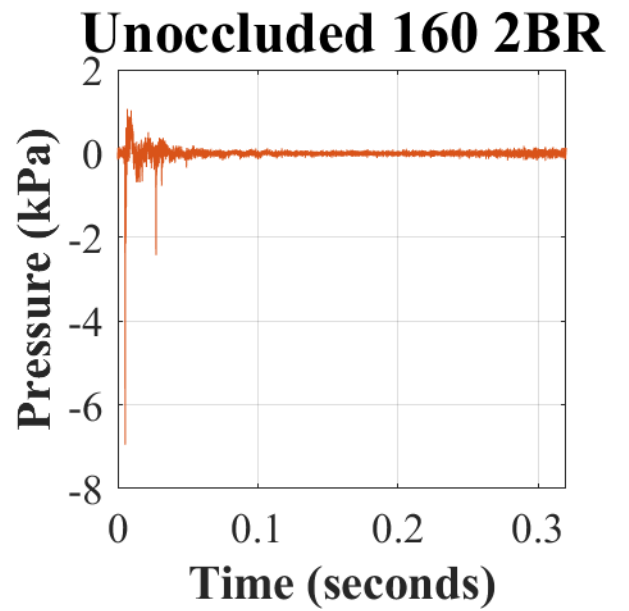
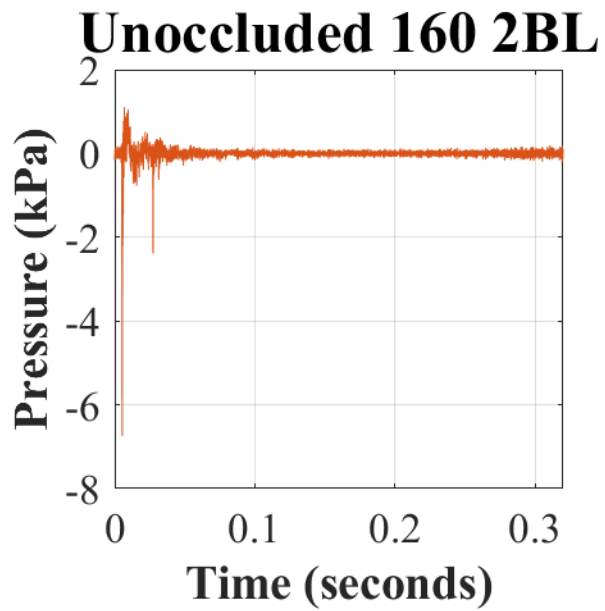
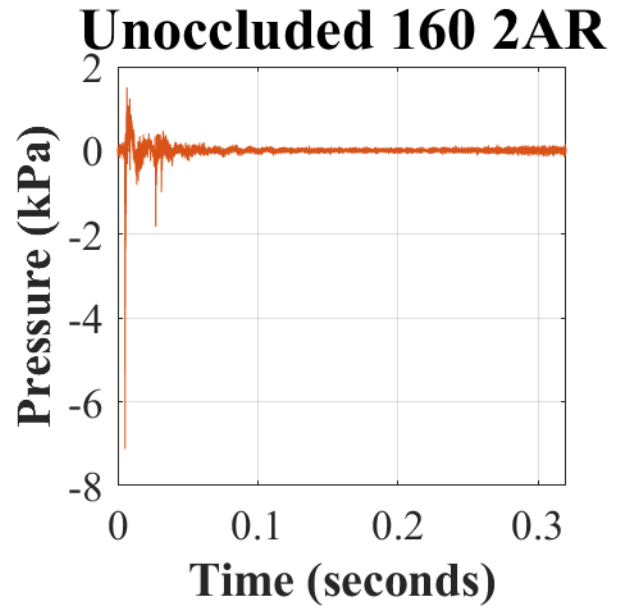
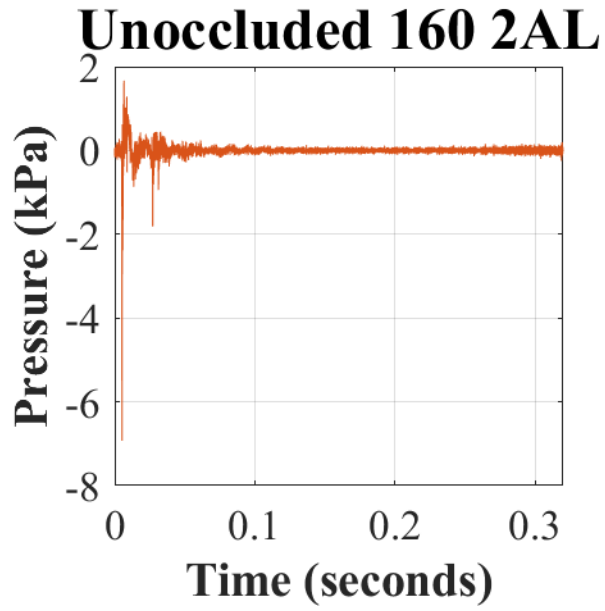


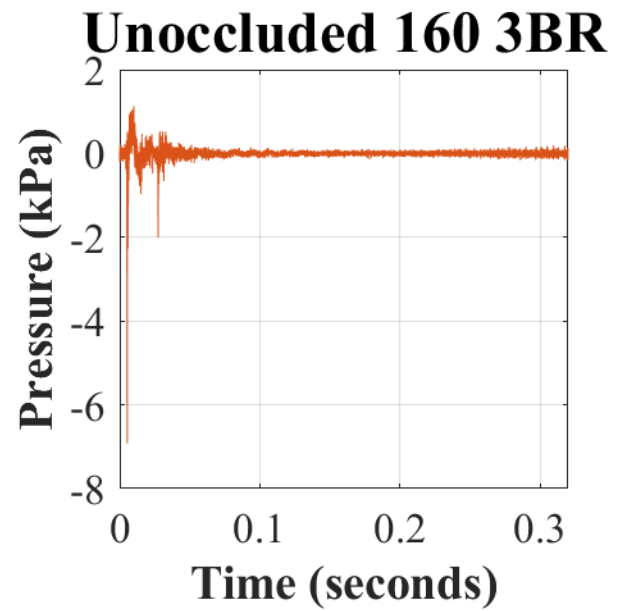
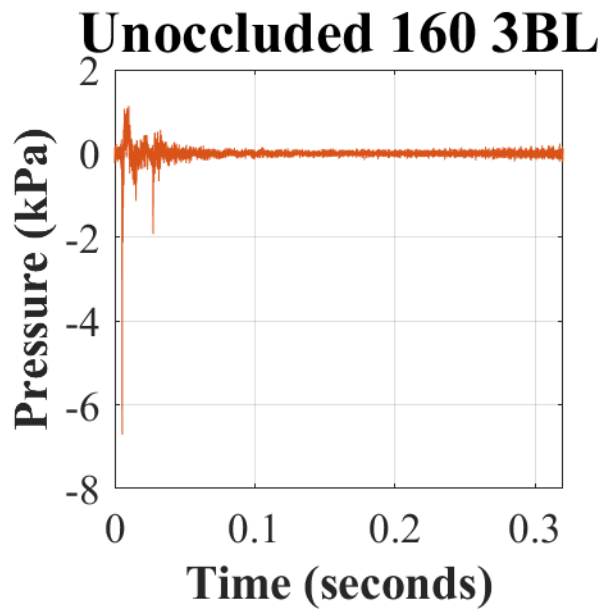
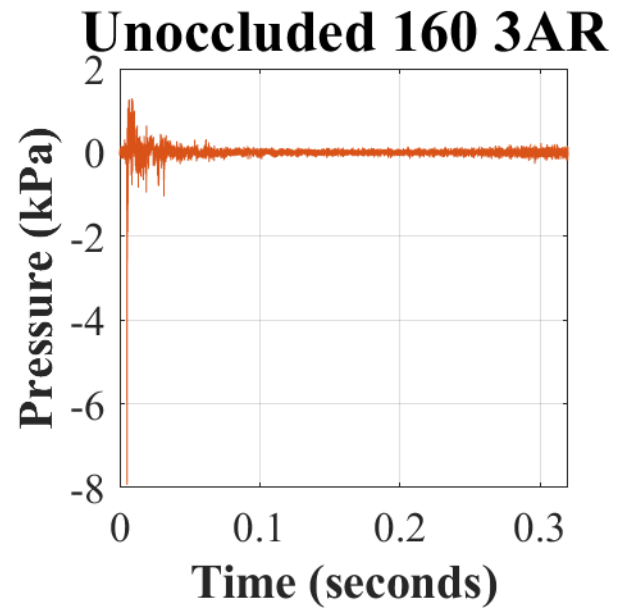
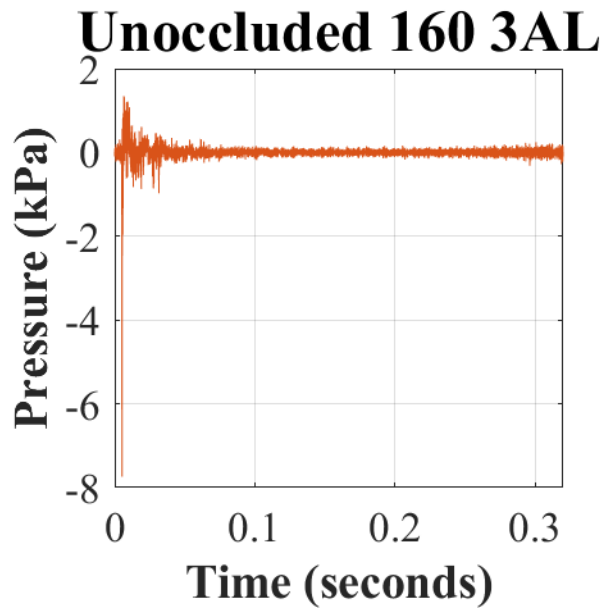


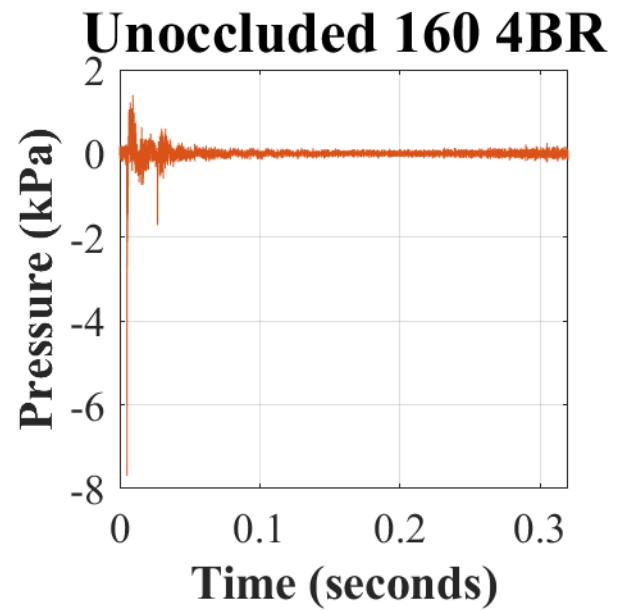
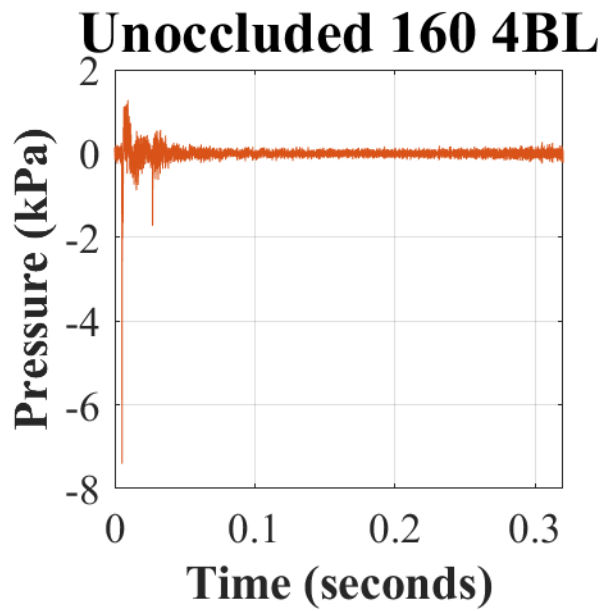
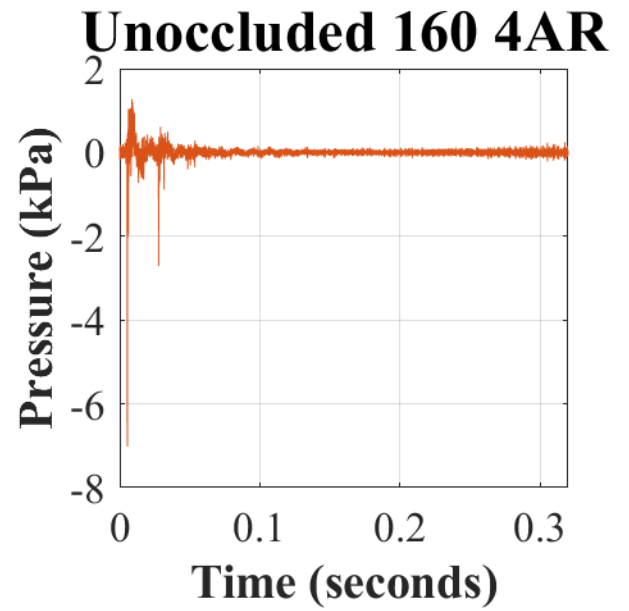
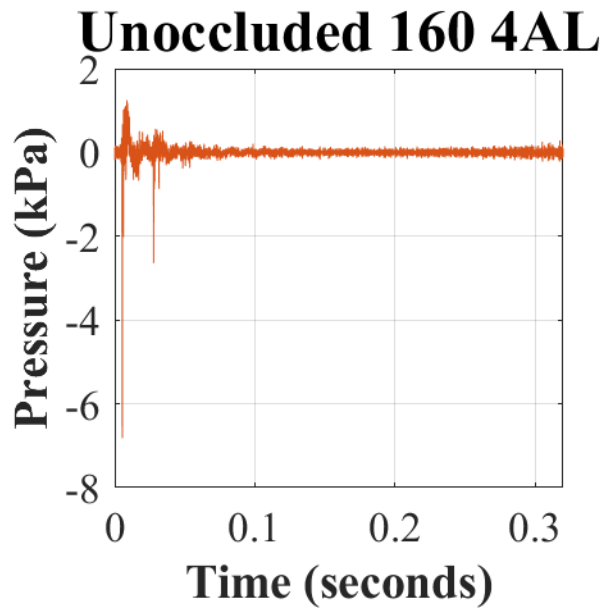
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or 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).

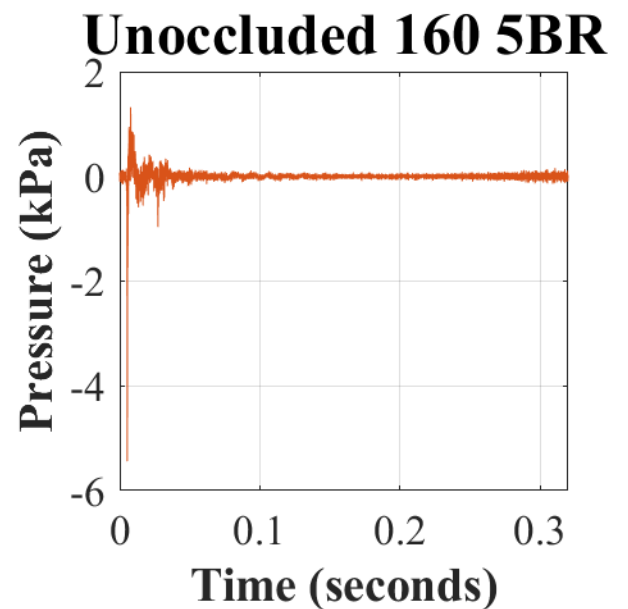
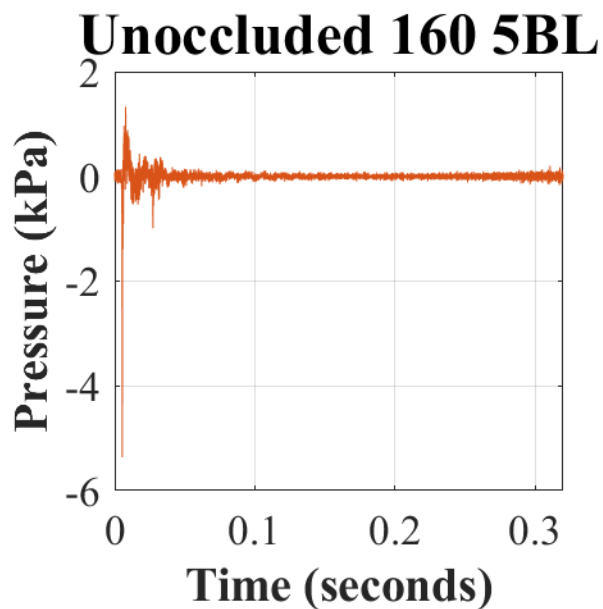
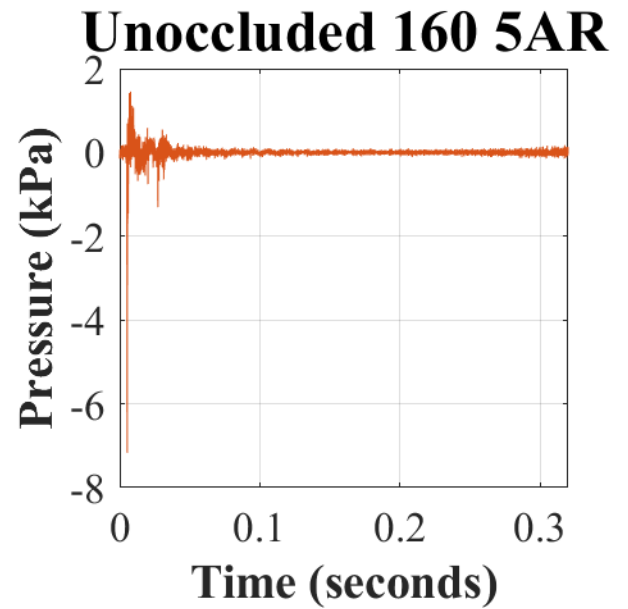
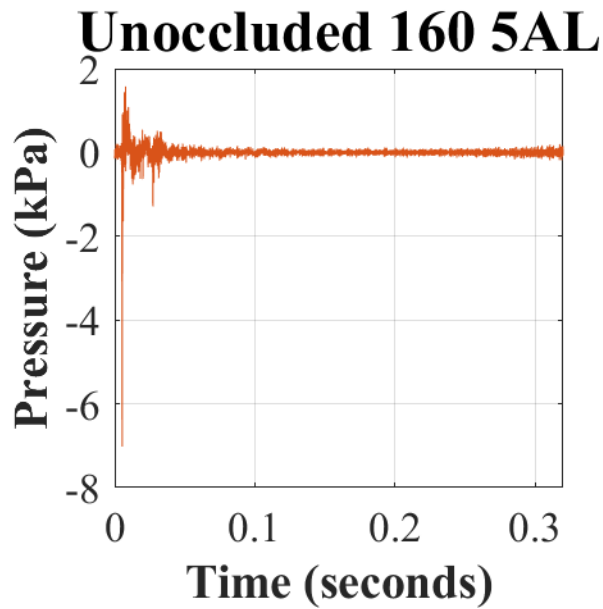
Appendix M. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 160 dBp with the ComTac™ V (MAX).





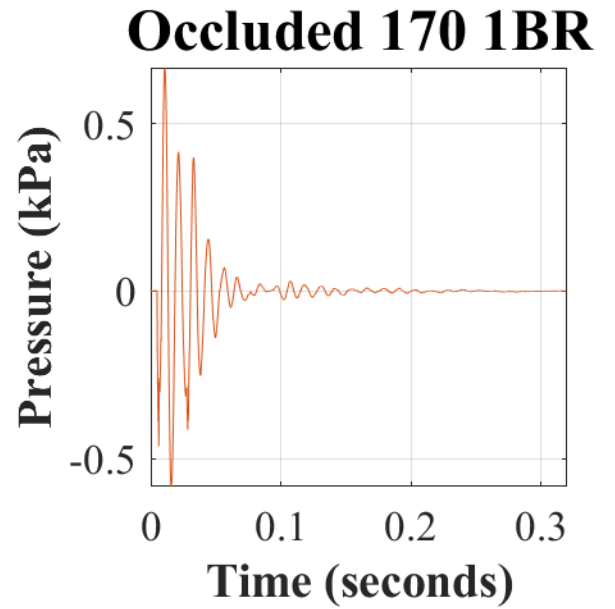
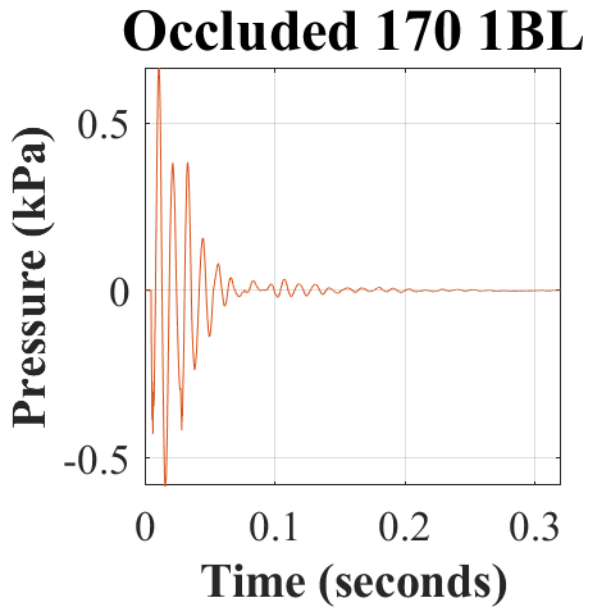
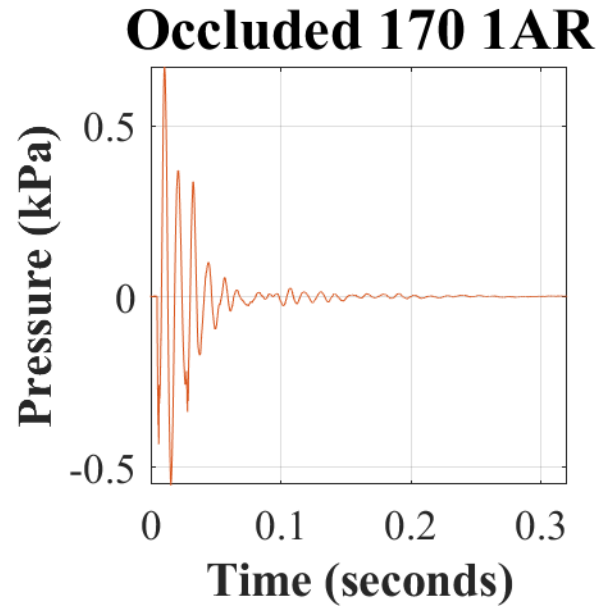
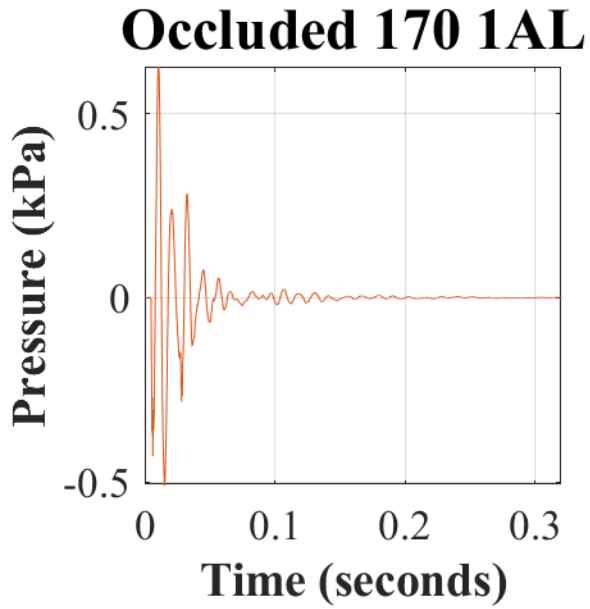




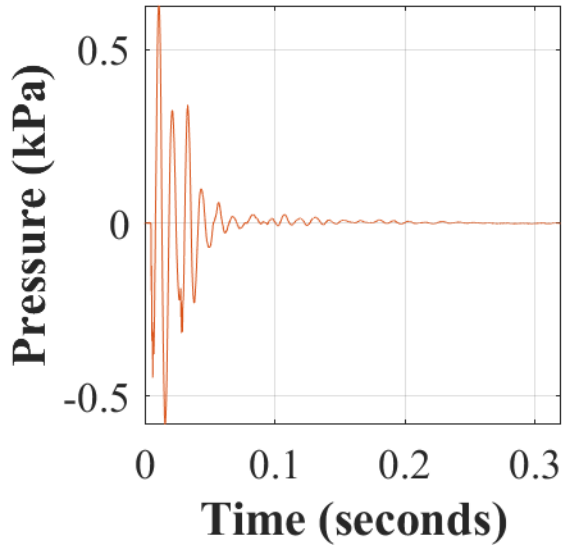


Note. The naming convention for all unoccluded waveforms is “Unoccluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the HPD doffed), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dB), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., 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).

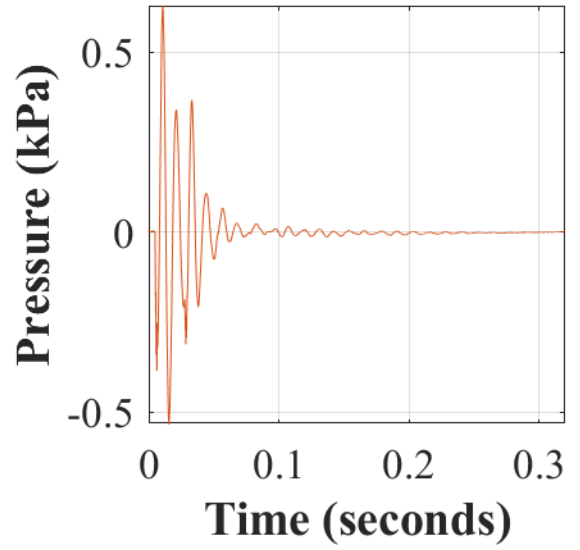
Appendix N. Recorded occluded (closed-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 170 dBp with the ComTac™ V (MAX).



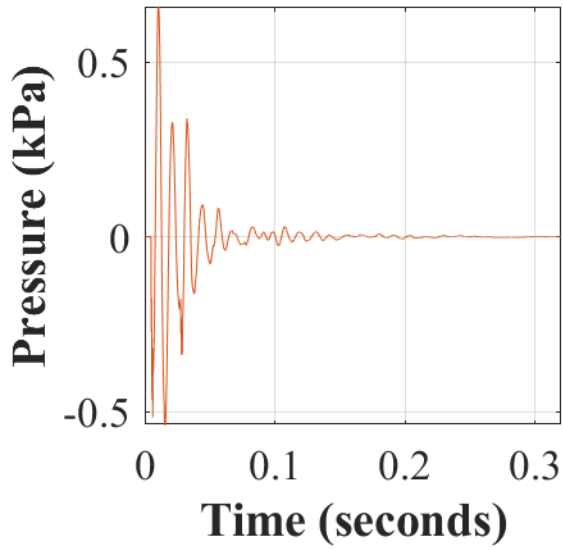
Occluded 170 2AL



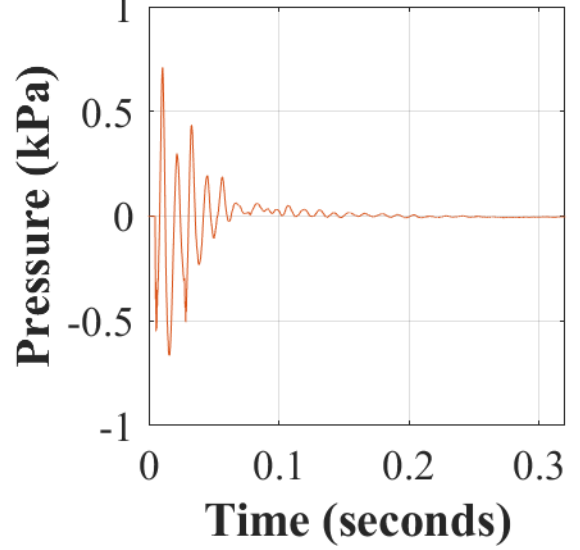
Occluded 170 2AR



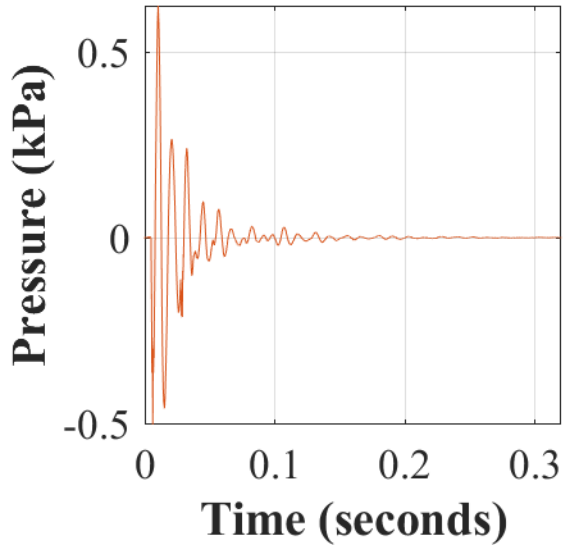
Occluded 170 2BL



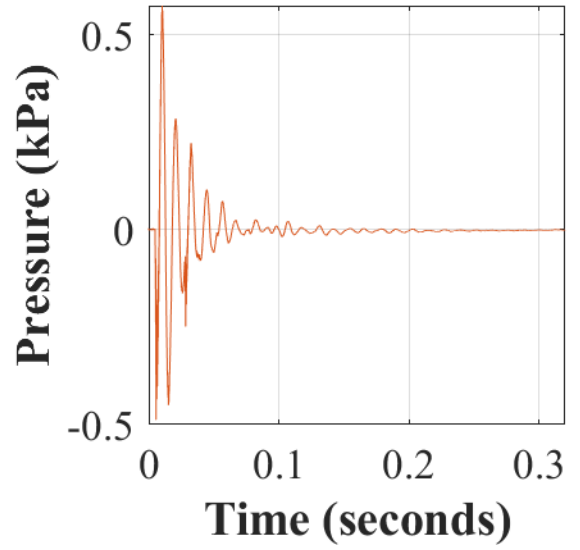
Occluded 170 2BR



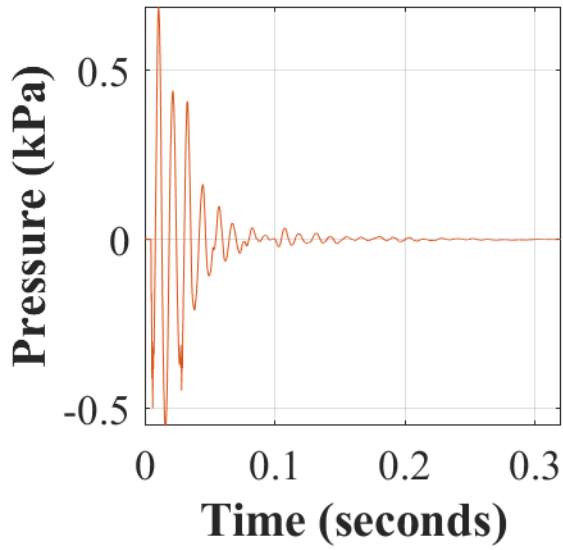
Occluded 170 3AL



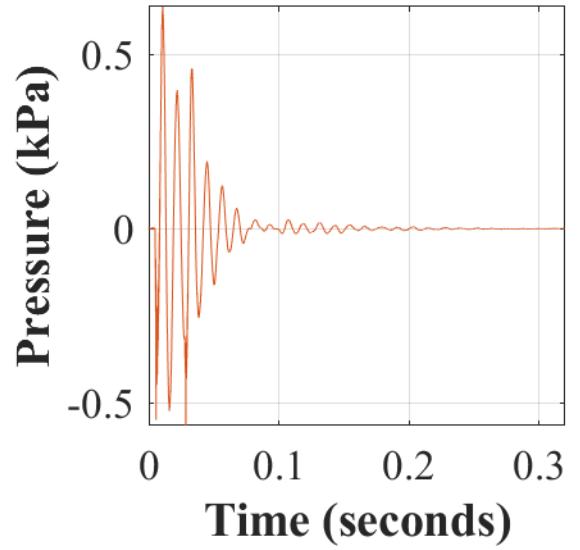
Occluded 170 3AR



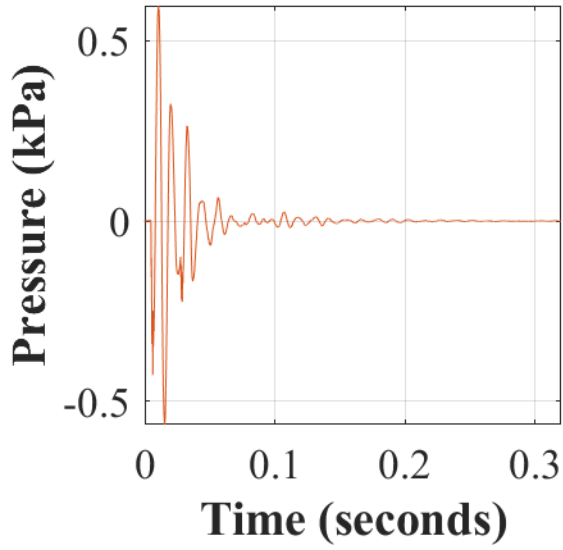
Occluded 170 3BL



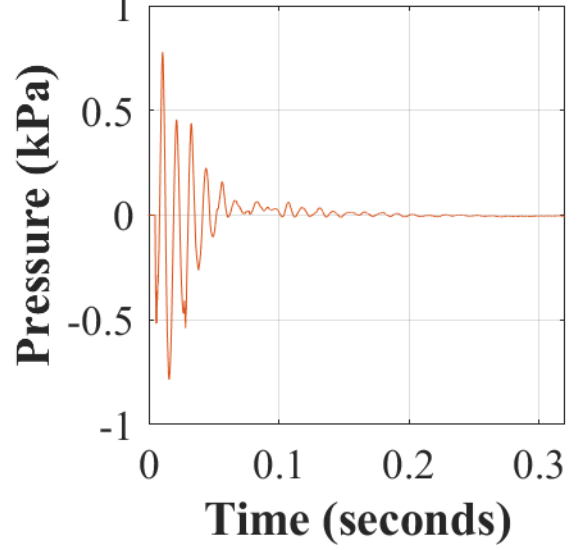
Occluded 170 3BR



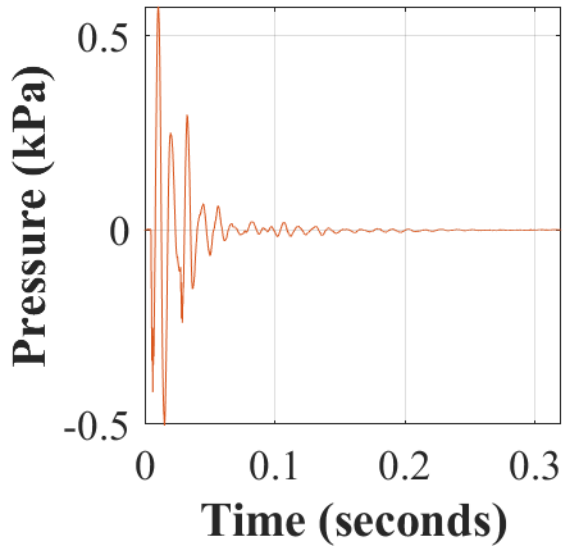
Occluded 170 4AL



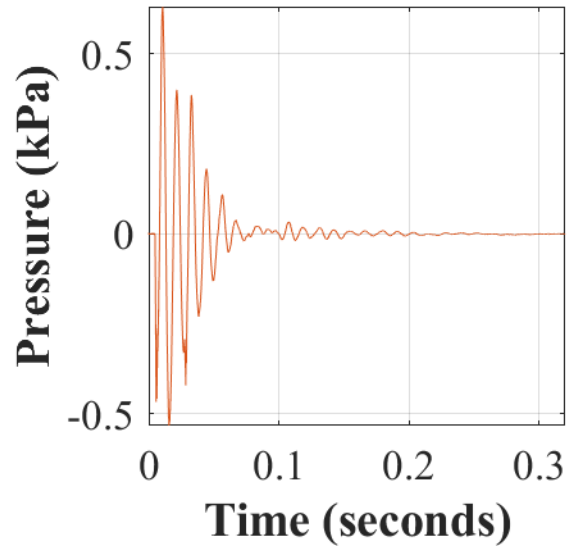
Occluded 170 4AR

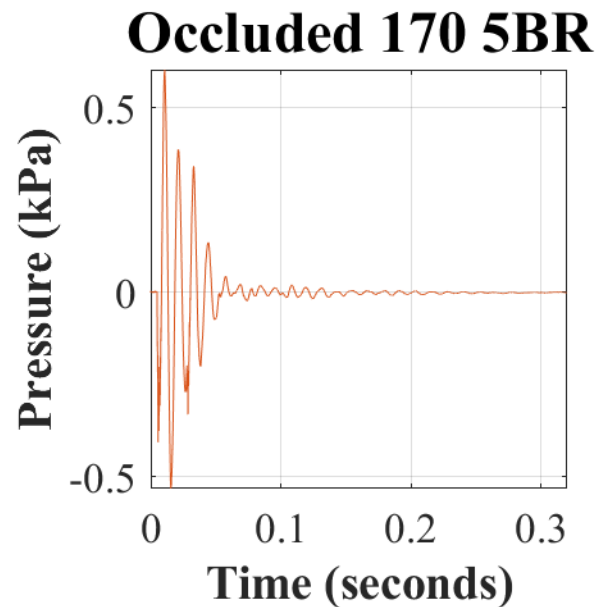
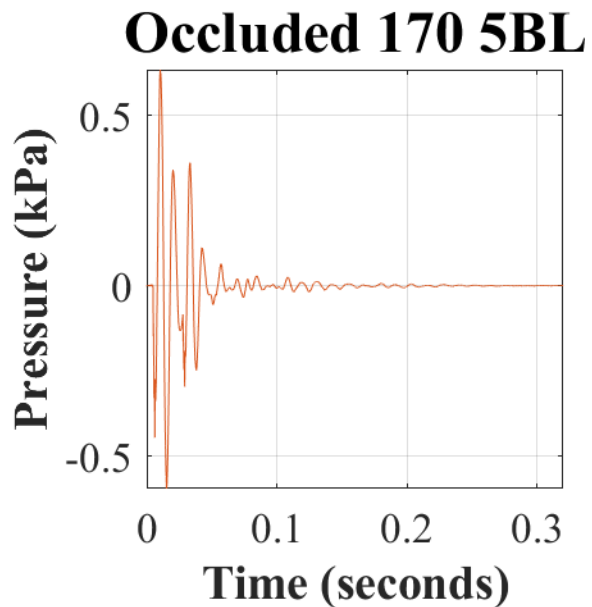
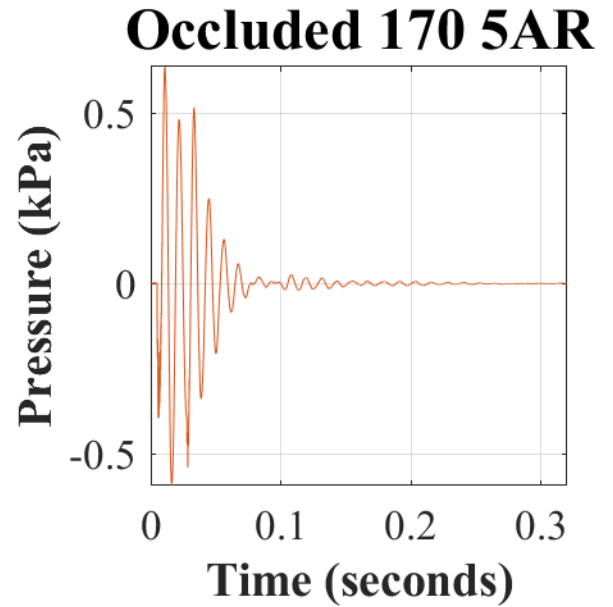
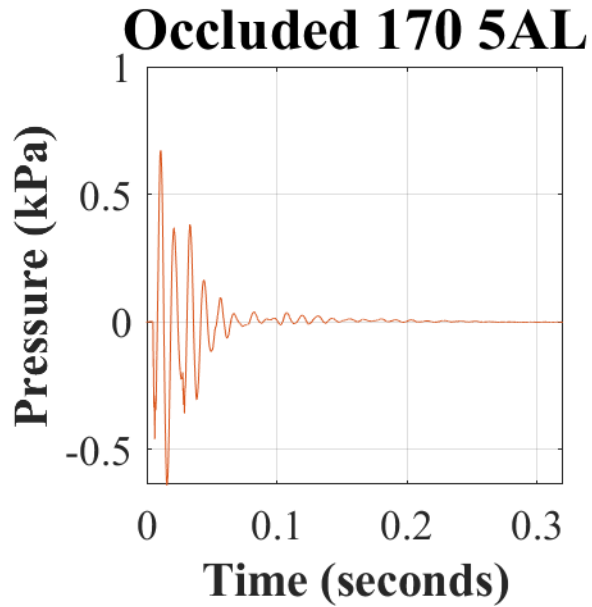


Occluded 170 4BL



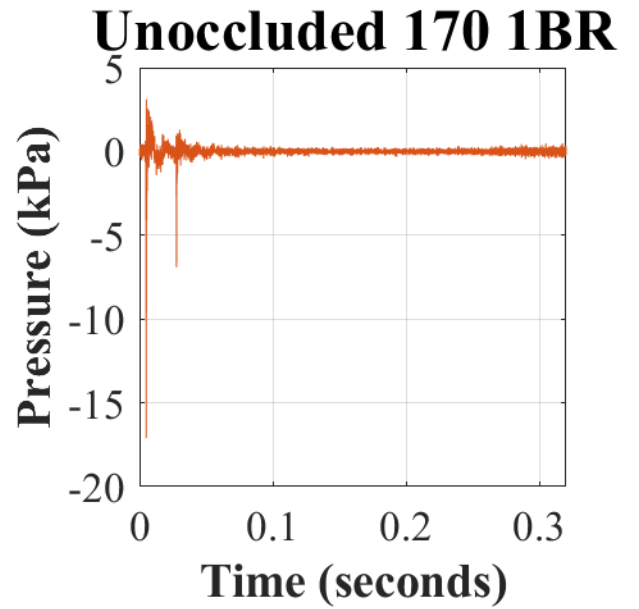
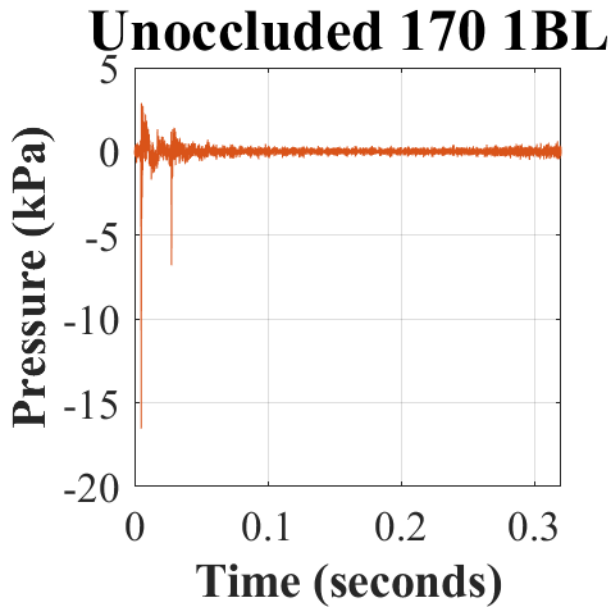
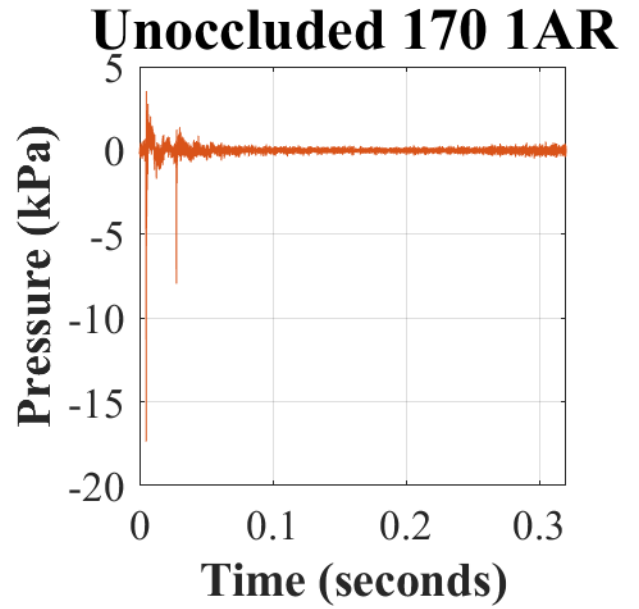
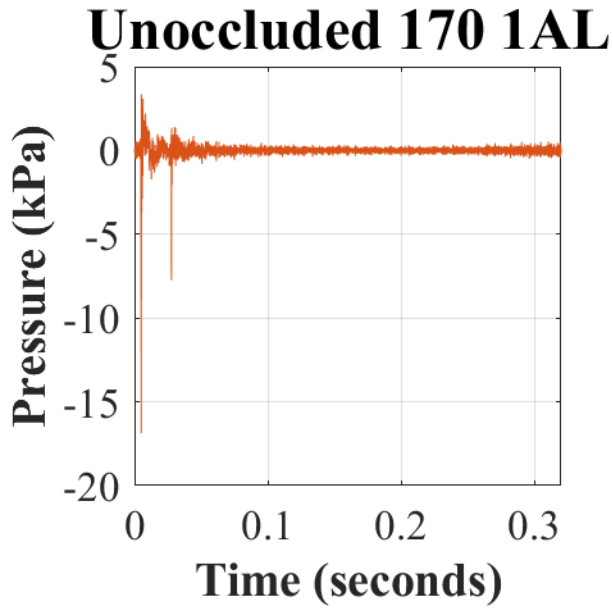
Occluded 170 4BR

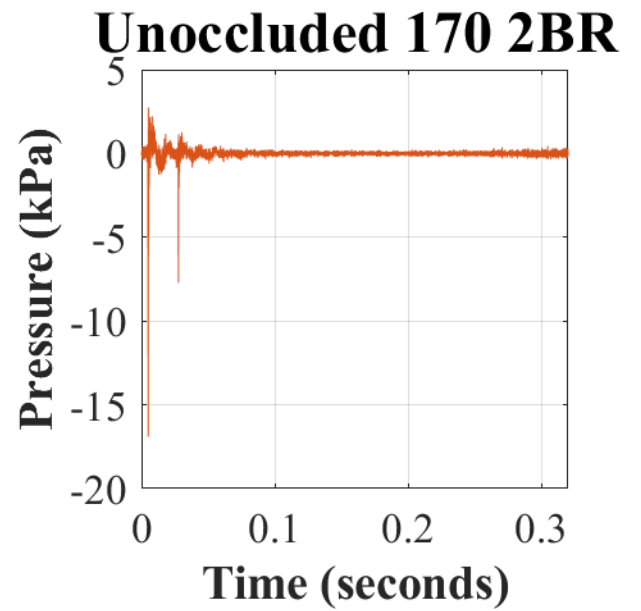
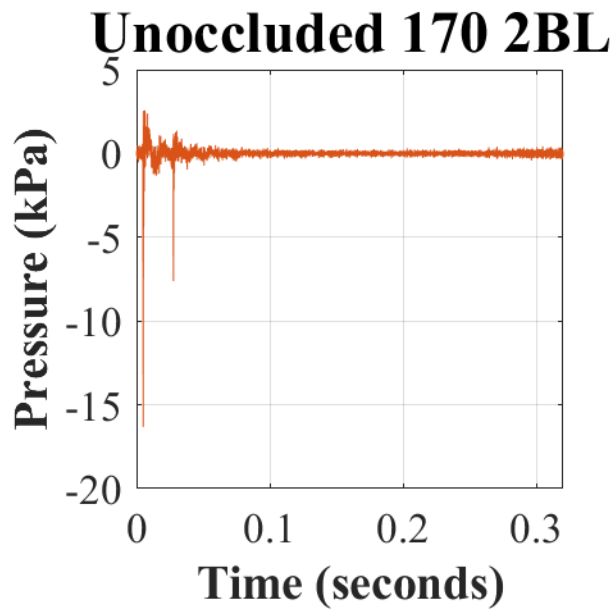
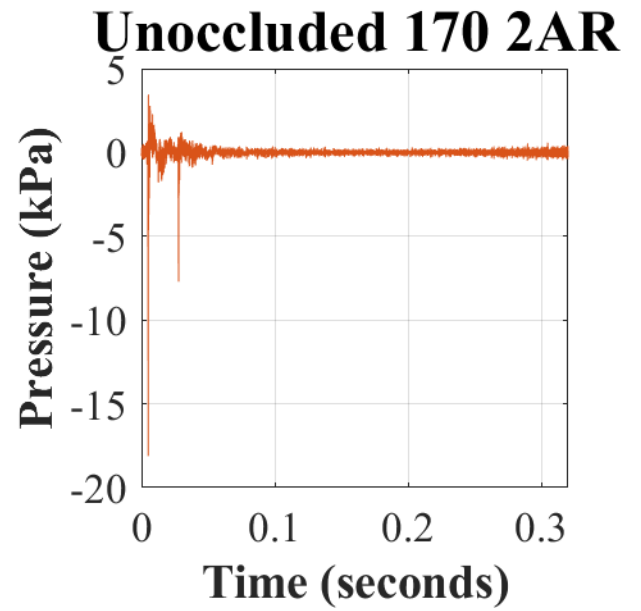
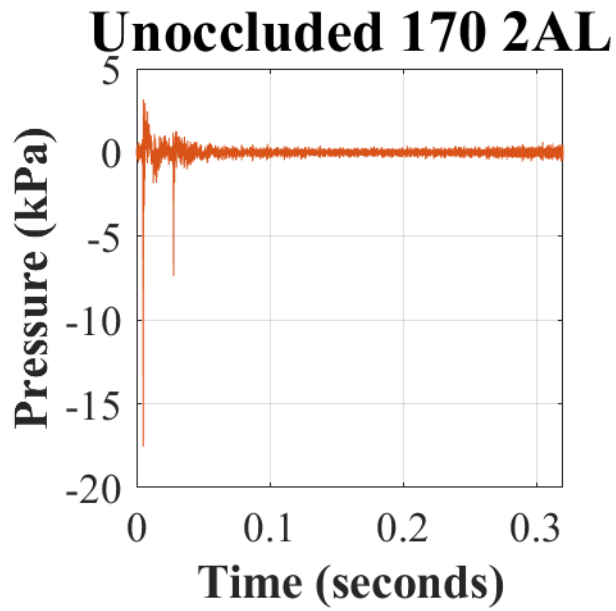


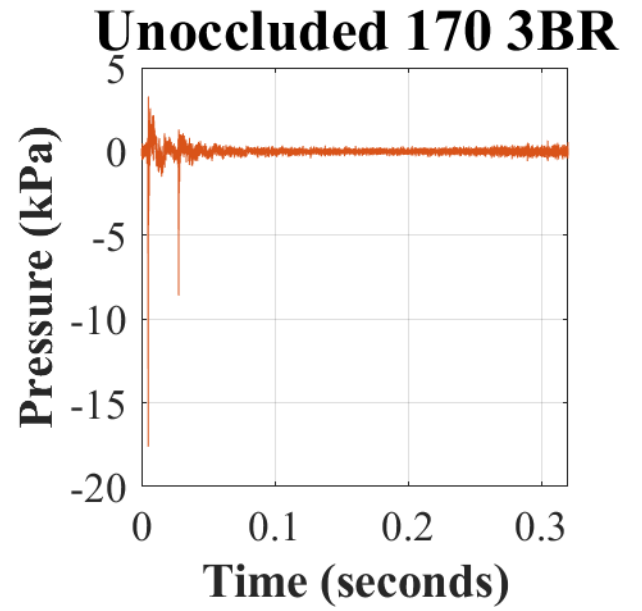
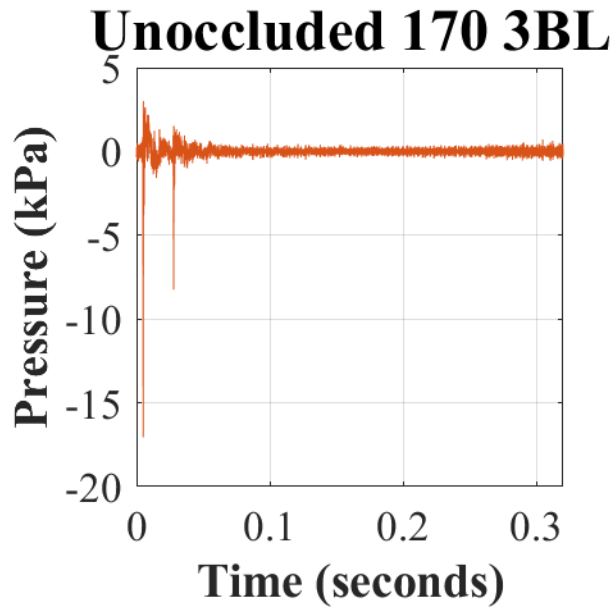
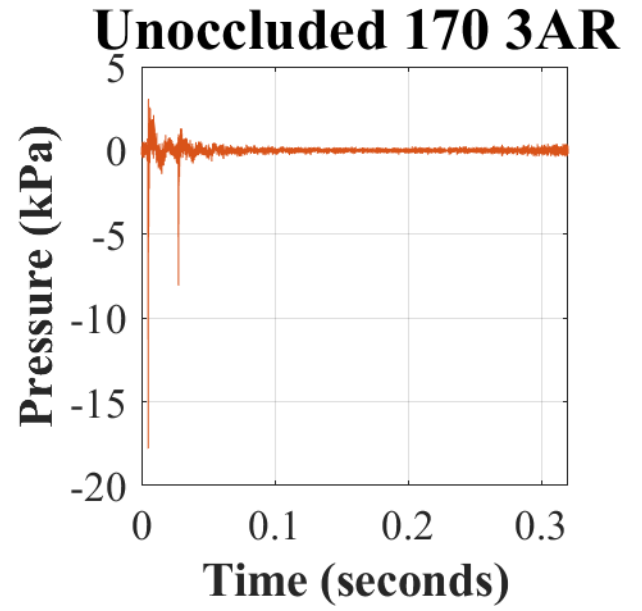
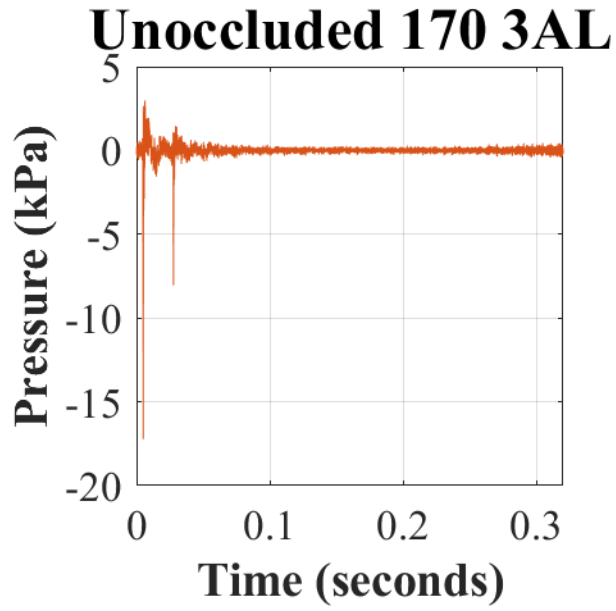


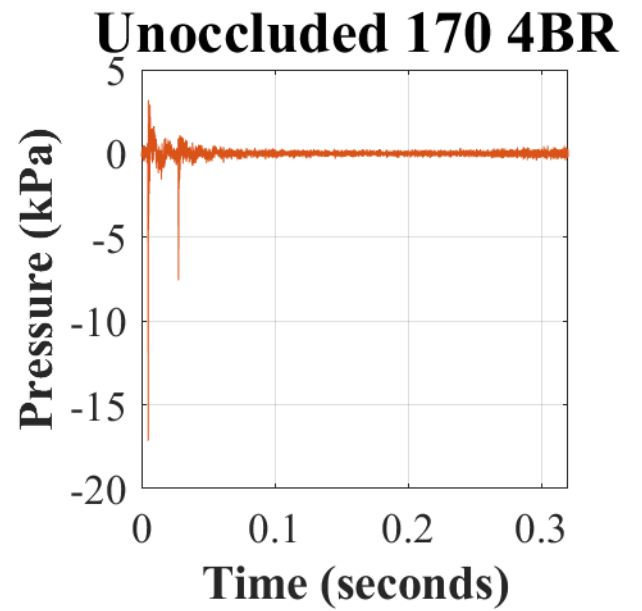
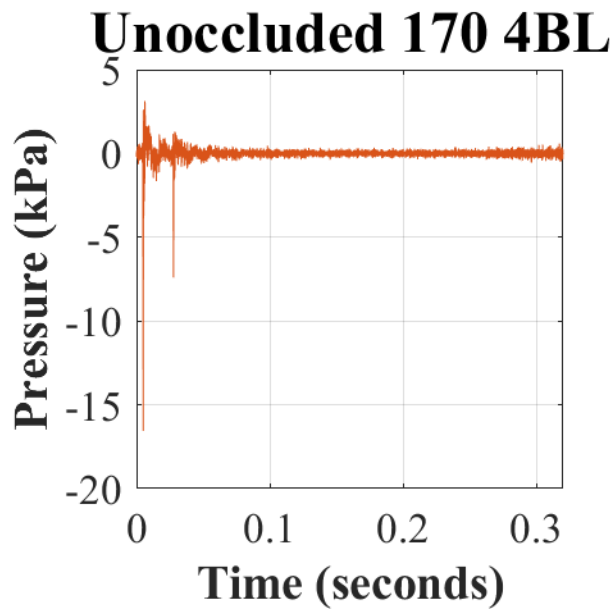
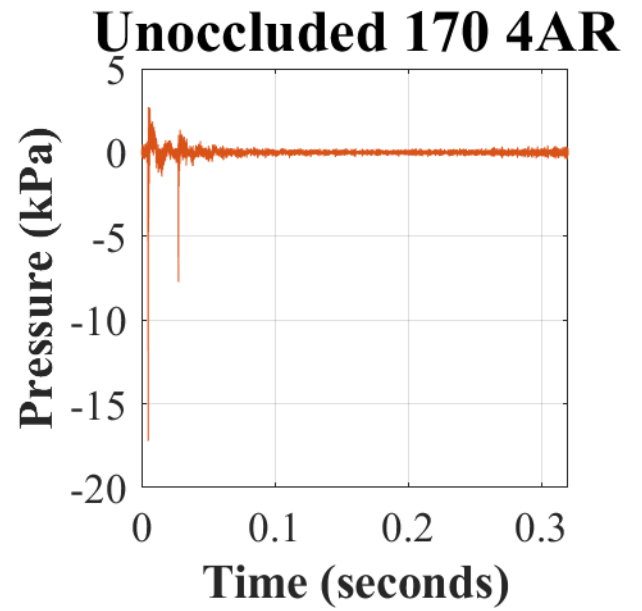
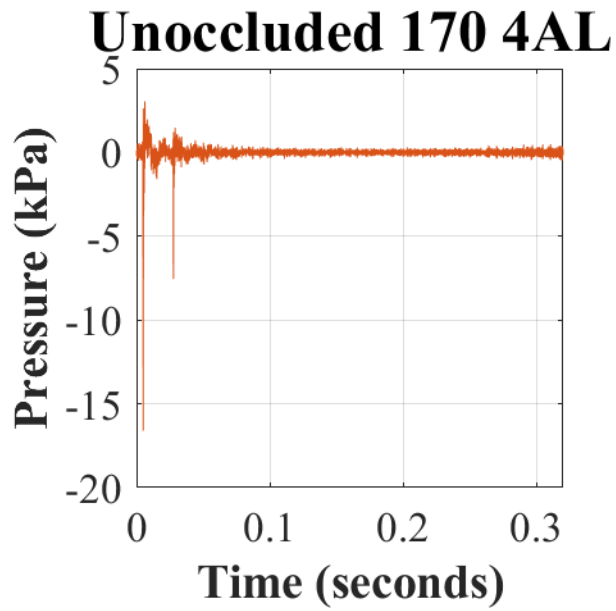
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the HPD donned), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or 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).

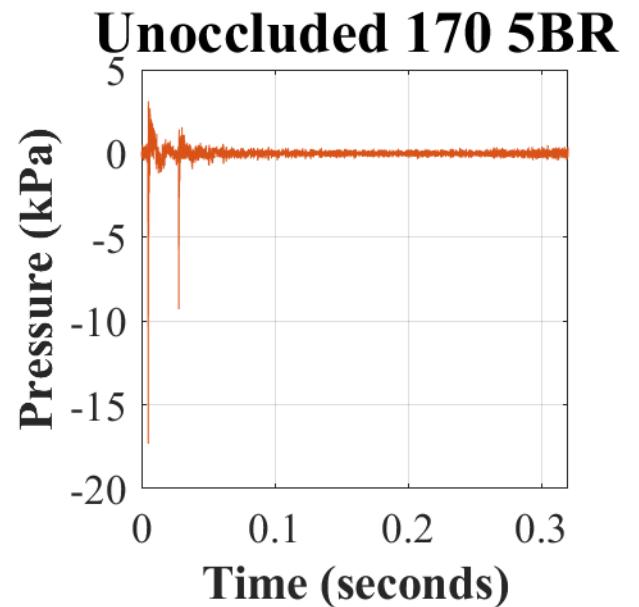
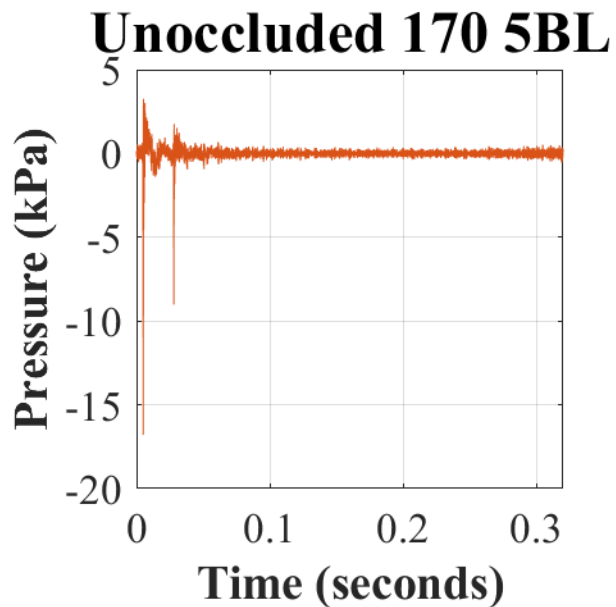
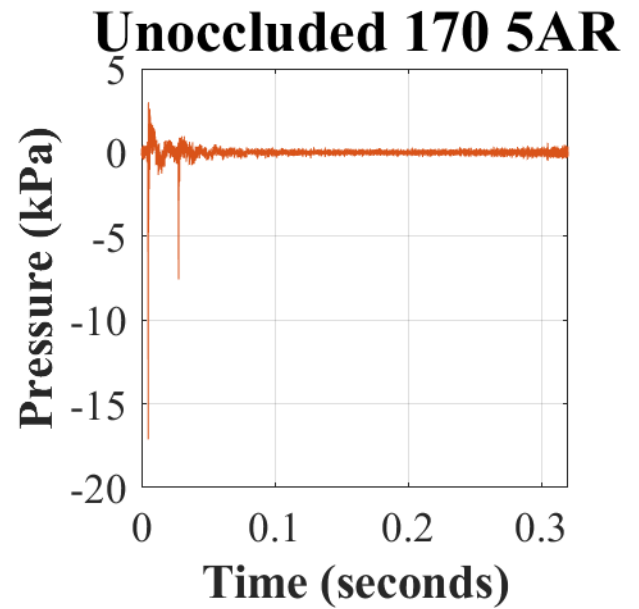
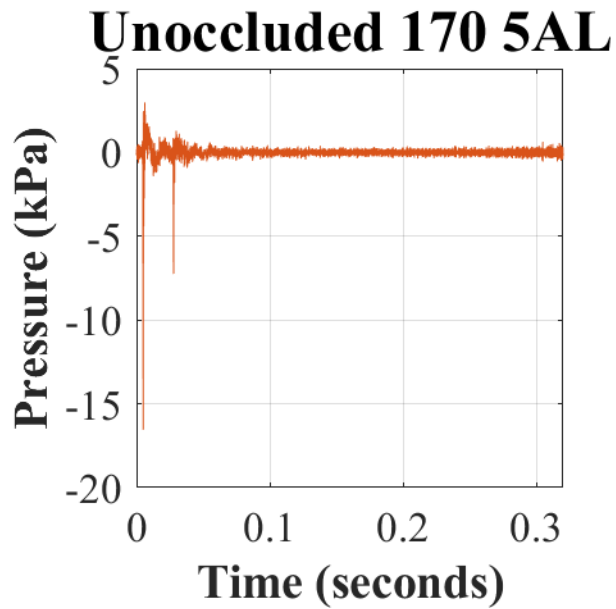
Appendix O. Estimated unoccluded (open-ear) waveforms (in kilopascals [kPa]) over time (in seconds [s]) in response to 170 dBp with the ComTac™ V (MAX).





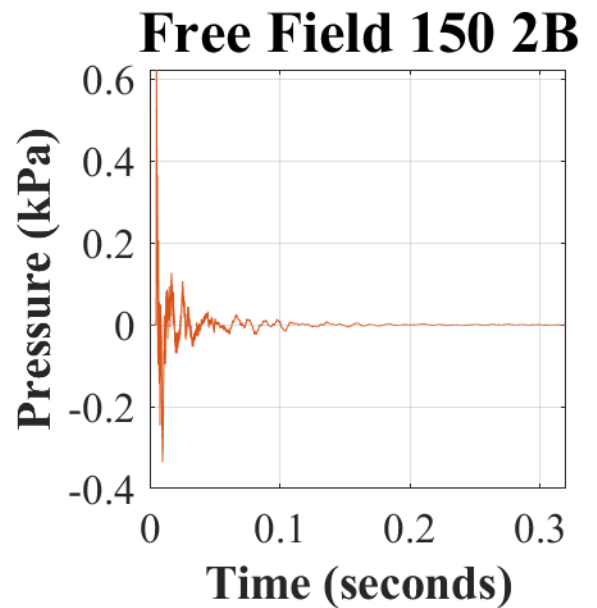
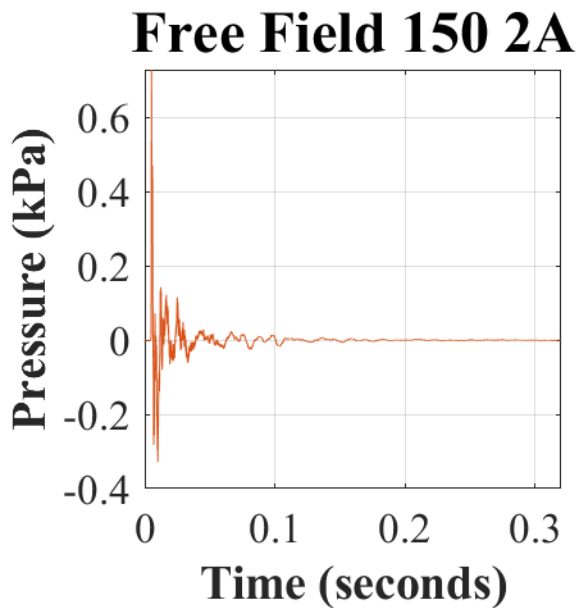
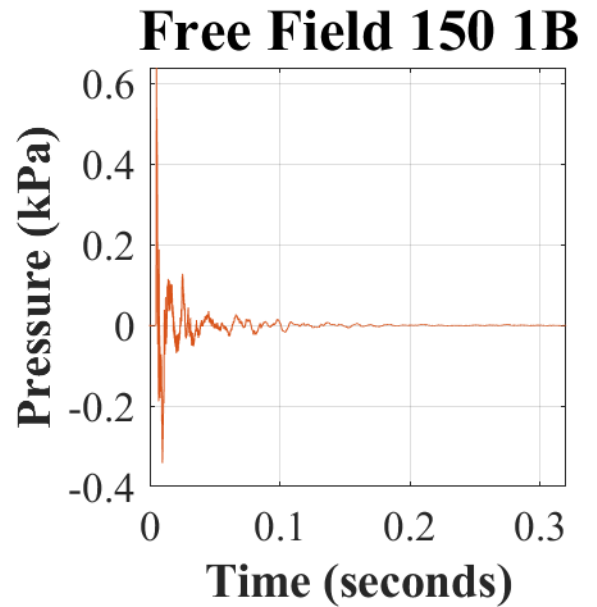
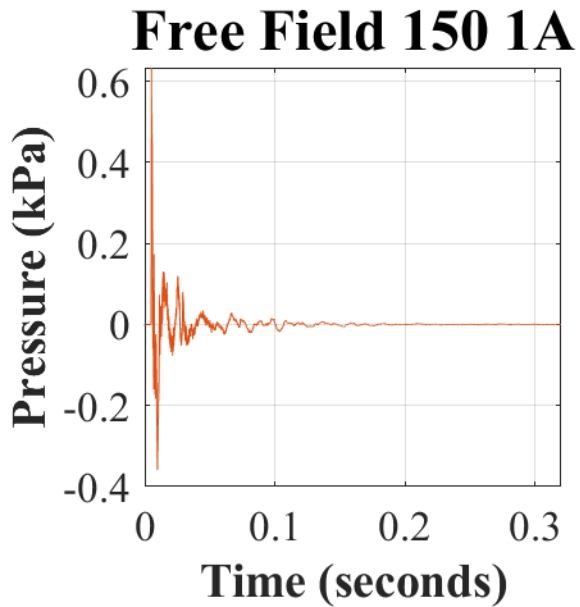




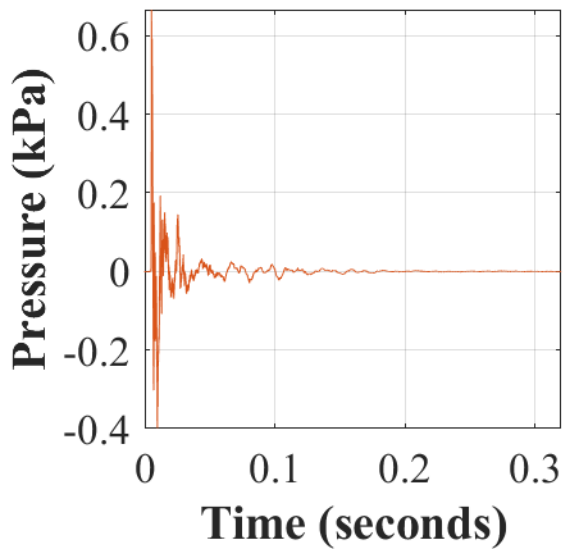


Note. The naming convention for all unoccluded waveforms is “Unoccluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the HPD doffed), ‘LvL’ is the nominal test level (i.e., 150, 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., 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).

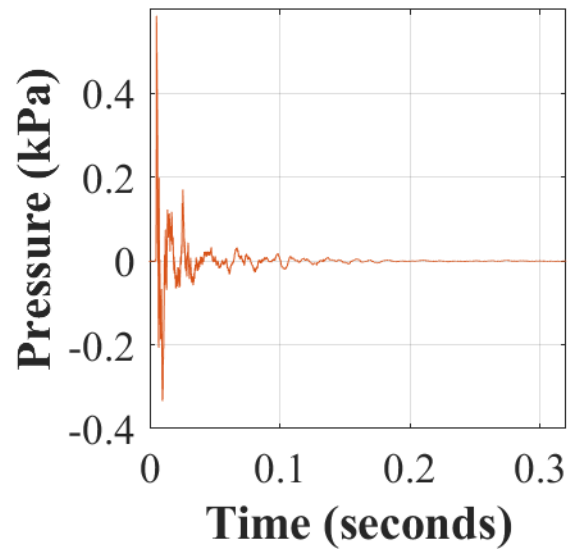
Appendix P. Recorded waveform (in kilopascals [kPa]) over time (in seconds [s]) of the impulse measured with the free-field probe at 150 dBp and the ComTac™ V (MAX) donned.



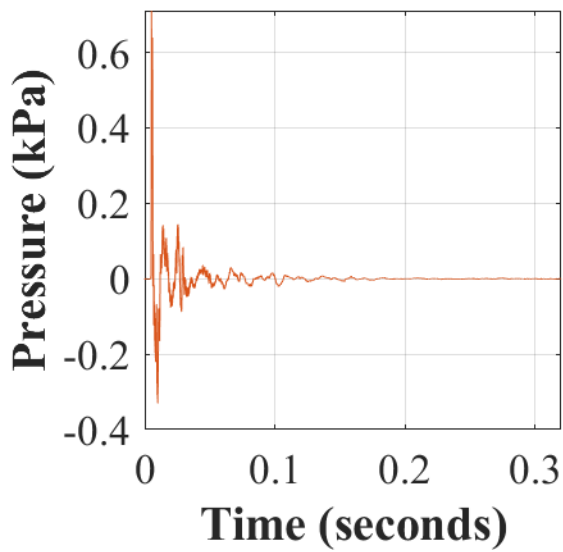
Free Field 150 3A



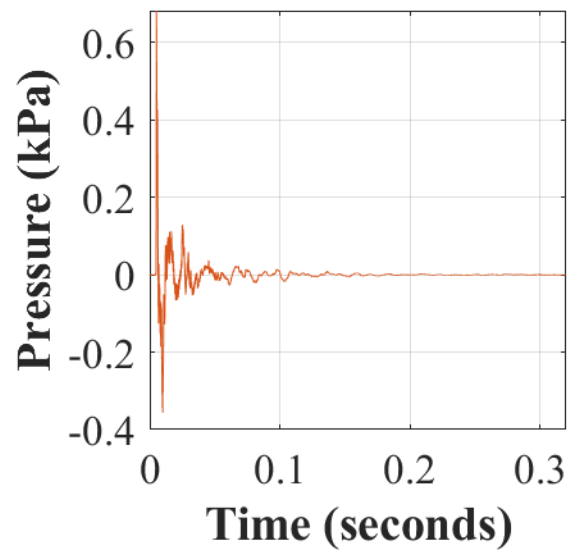
Free Field 150 3B

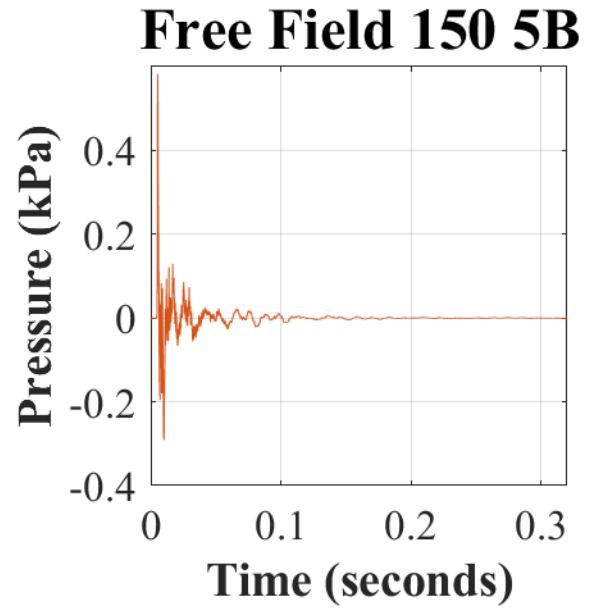
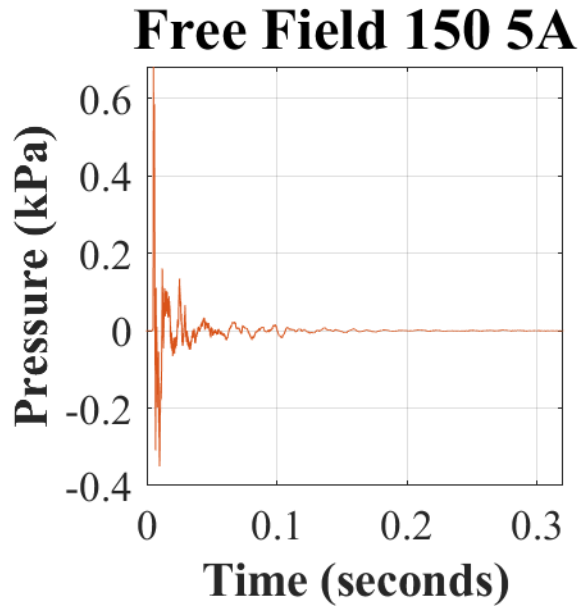


Free Field 150 4A



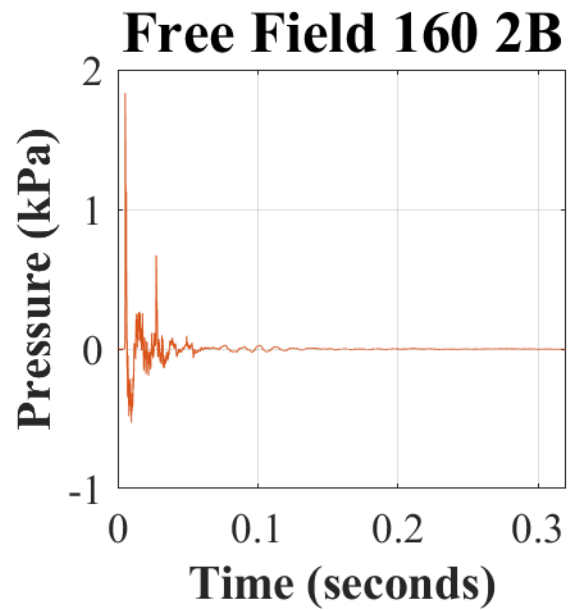
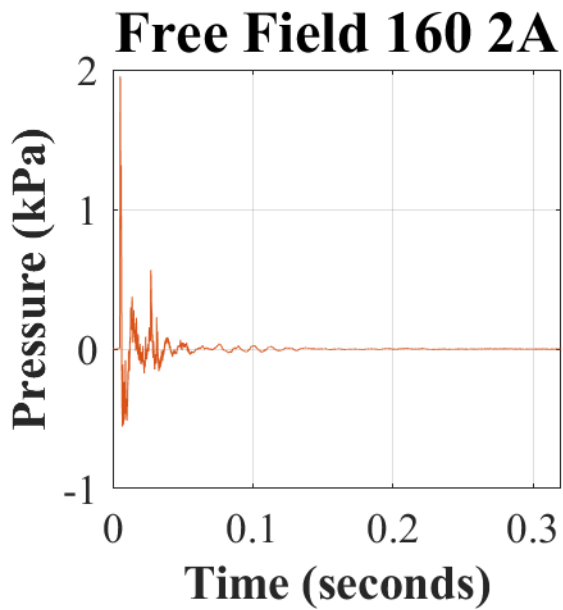
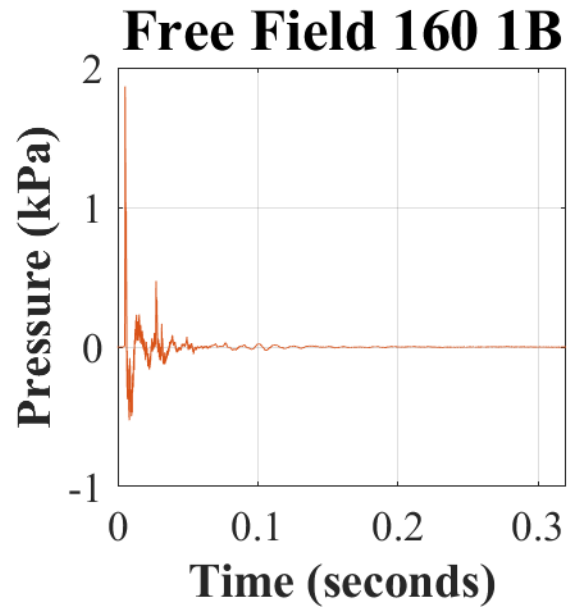
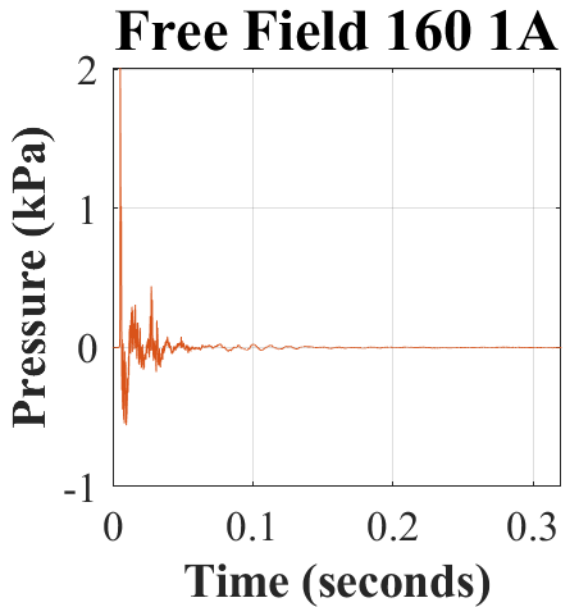
Free Field 150 4B

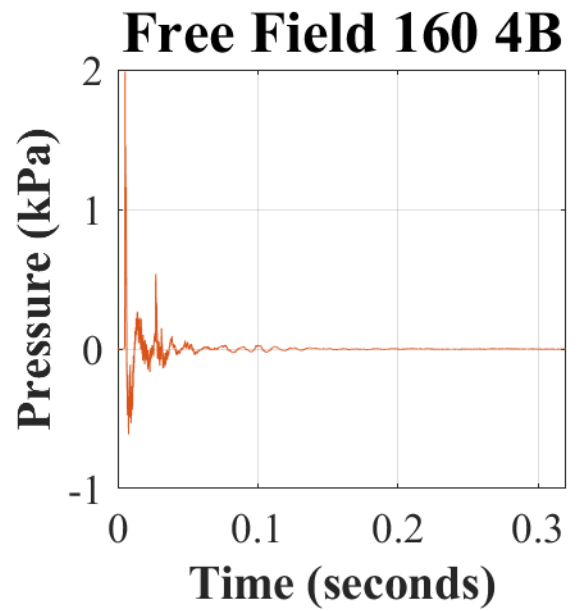
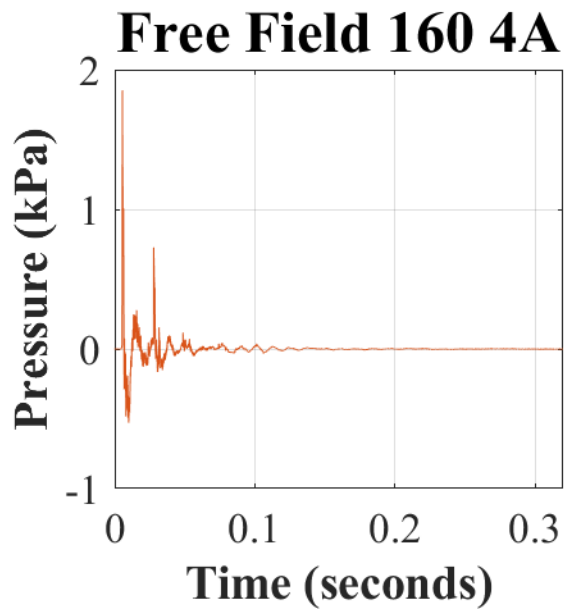
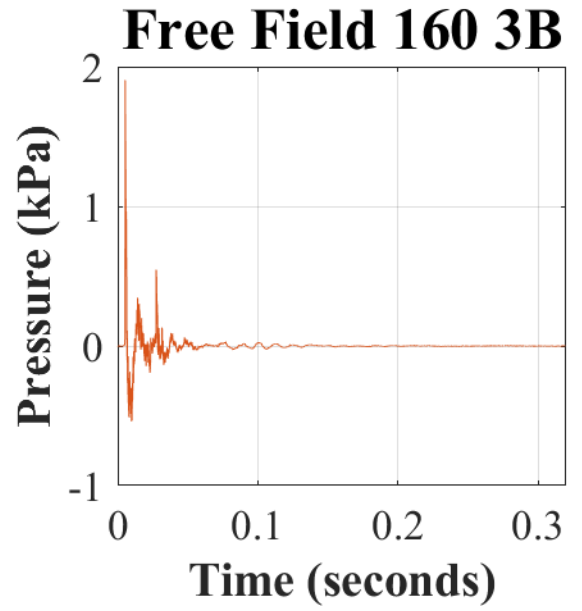
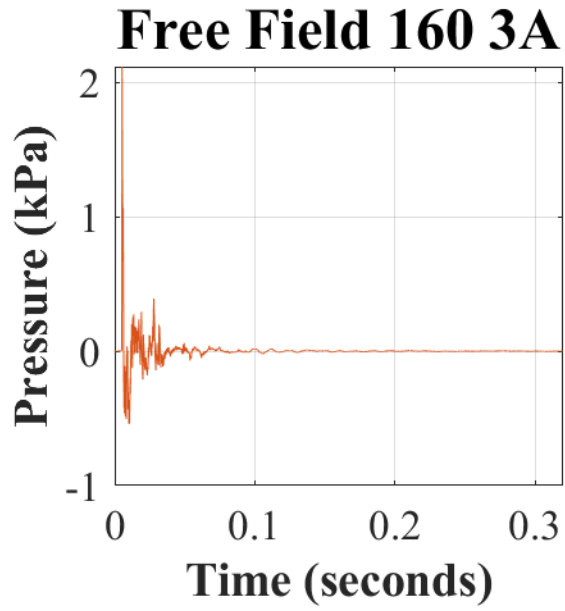


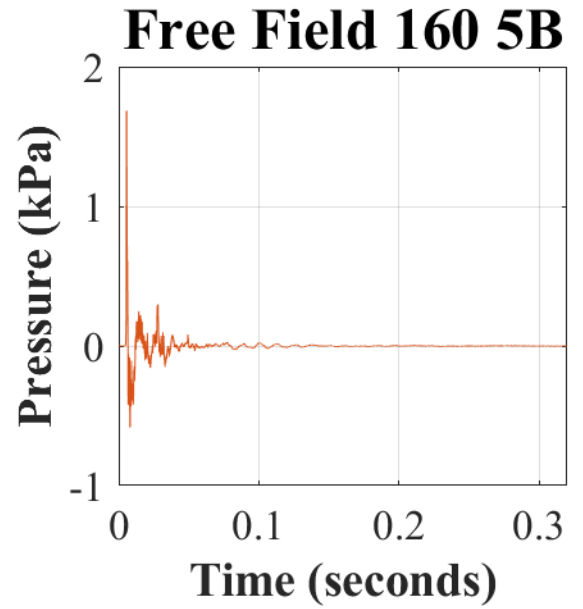
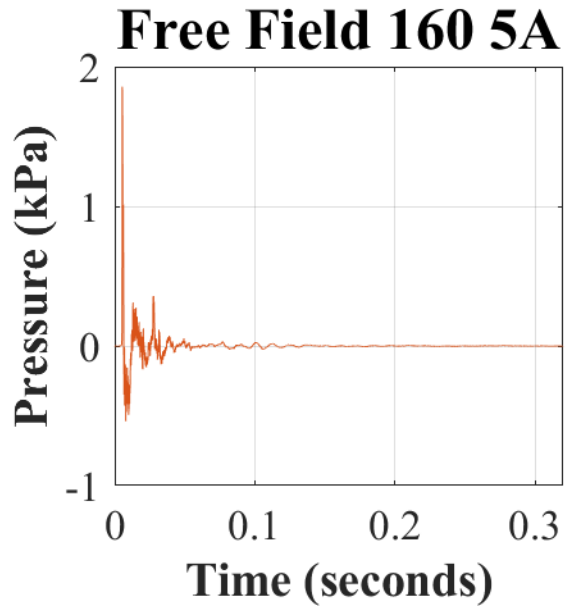


Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (150 dBp), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

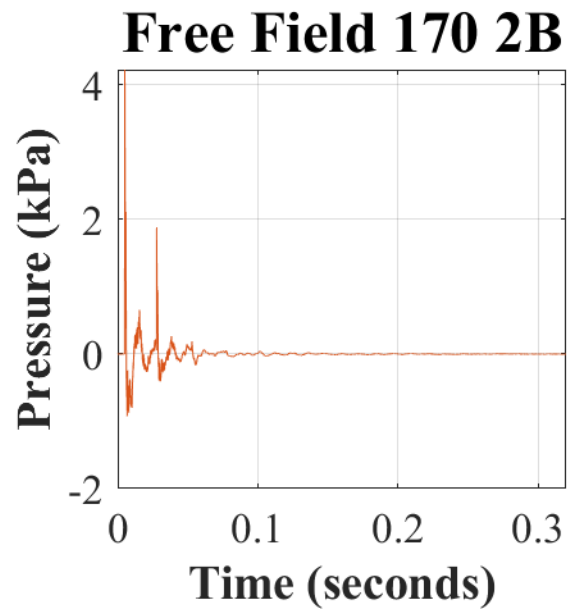
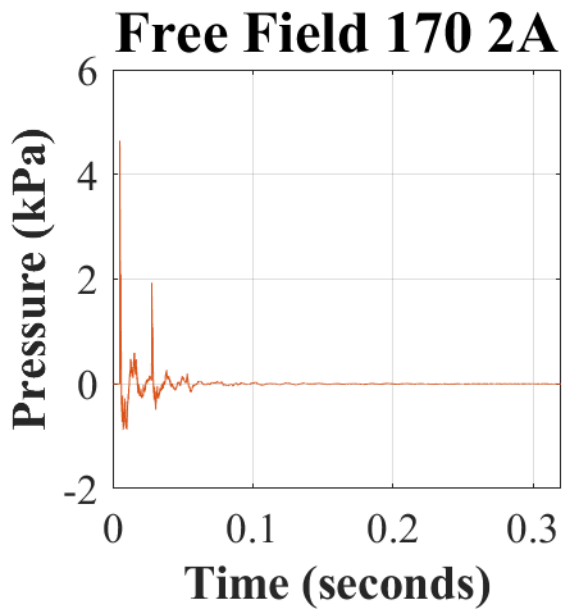
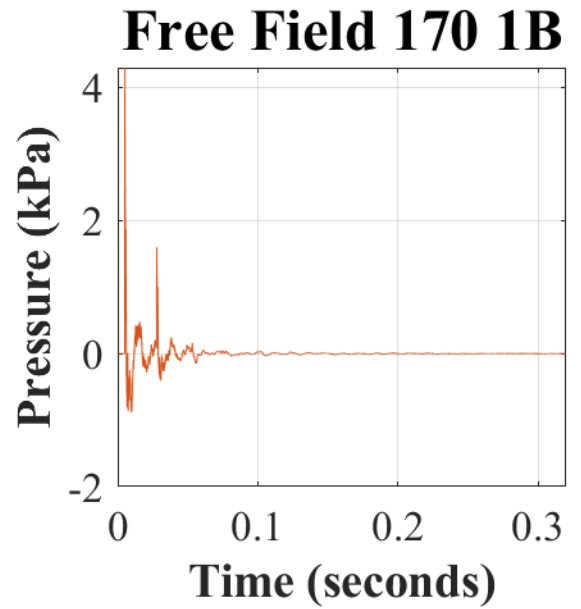
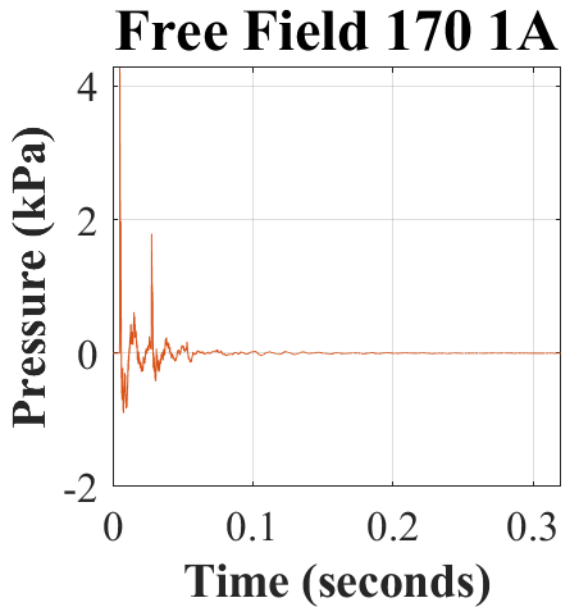




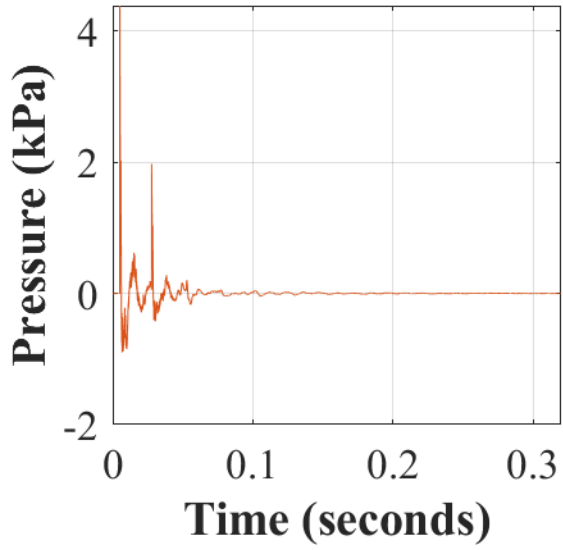


Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (160 dBp), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

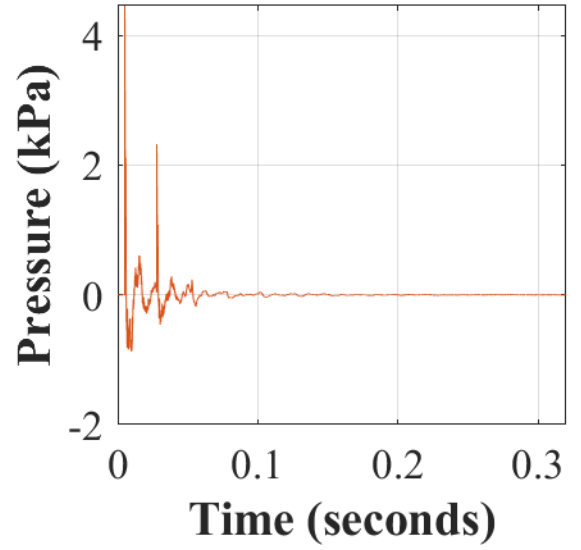
Appendix R. Recorded waveform (in kilopascals [kPa]) over time (in seconds [s]) of the impulse measured with the free-field probe at 170 dBp and the ComTac™ V (MAX) donned.



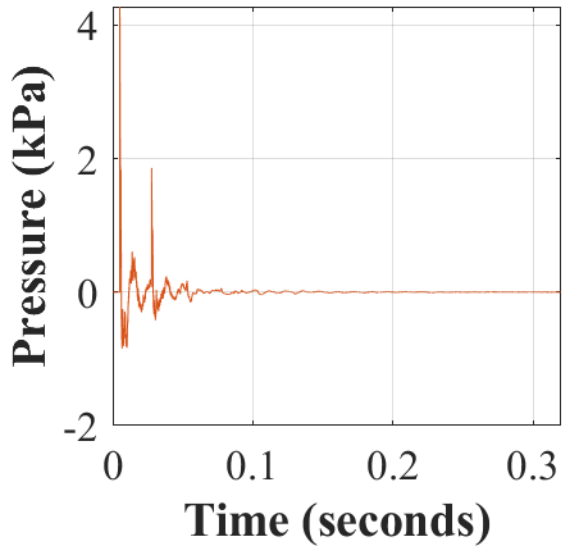
Free Field 170 3A



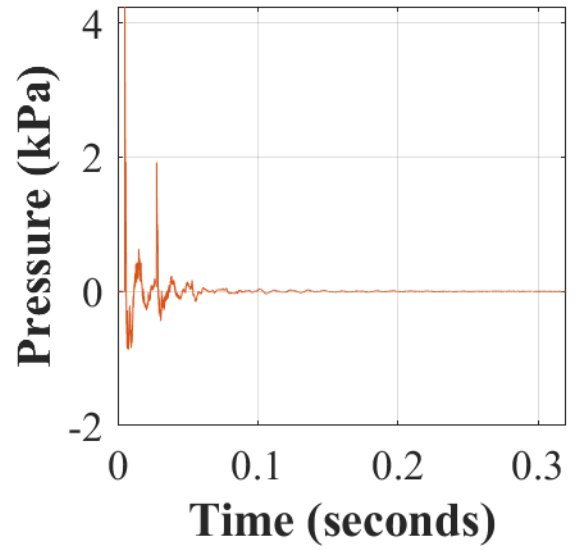
Free Field 170 3B

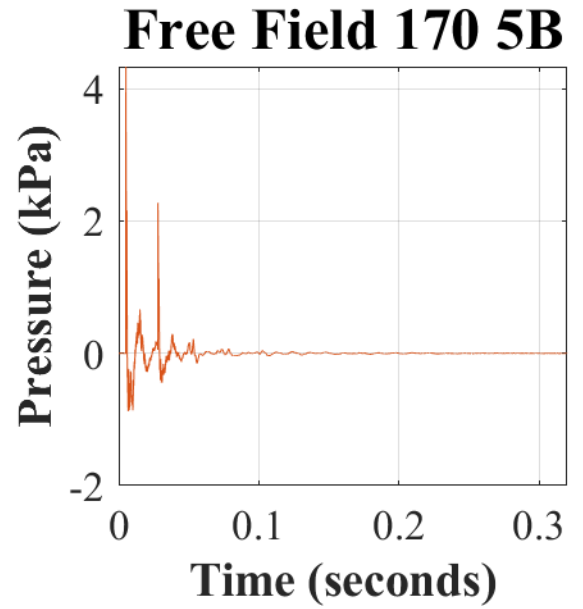
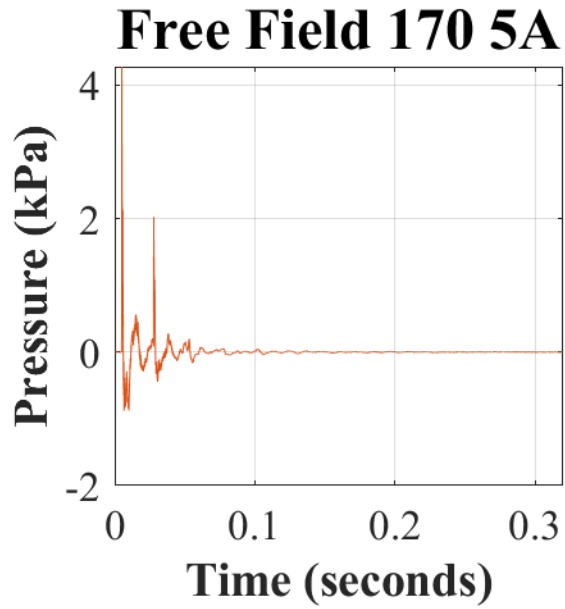


Free Field 170 4A



Free Field 170 4B





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