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Impulse Assessment of the 3M™ PELTOR™ ComTac™ III 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 the 3M™ PELTOR™ ComTac™ III Hearing Defender (neckband model) Headset (ComTac™ III; Model: MT17H682BB-09 CY) in two test modes: passive (i.e., turned OFF) and active (i.e., turned on and set to MAX). Testing was done in accordance with the American National Standards Institute (ANSI) standard S12.42-2010, Methods for the Measurement of Insertion Loss of Hearing Protection Devices in Continuous or Impulsive Noise Using Microphone-in-Real-Ear or Acoustic Test Fixture Procedures. A total of five samples were fitted to an acoustic test fixture two times each for a total of 10 trials per test level in both the passive (i.e., OFF) and active (i.e., on and set to MAX) test modes. No samples of the HPD were rejected. All samples were tested at the nominal levels of 160 and 170 decibel peak (dB_P, re: 20 μPa). As shown in Table 1, the results revealed overall mean IPIL values at 160 dB_P of 26.2 dB SPL in the passive (i.e., OFF) test mode and 27.1 dB SPL in the active (i.e., on at MAX) test mode. In response to the 170 dB_P impulse, the calculated overall mean IPIL value was found to be 28.6 dB SPL in the passive (i.e., OFF) mode and 29.0 dB SPL in the active (i.e., on at MAX) mode. These results suggest that when properly fit and functional, the ComTac™ III Hearing Defender will adequately protect (i.e., reduce exposure to less than 140 dB_P) impulses below 168.6 dB_P in the passive (OFF) mode and below 169.0 dB_P in the active (on at MAX) mode.

Table 1.

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

	160 dB_P	170 dB_P
OFF	26.2 (2.3)	28.6 (1.1)
MAX	27.1 (1.8)	29.0 (1.8)

Introduction

The 3M™ PELTOR™ ComTac™ III Hearing Defender Headset (ComTac™ III; 3M, St. Paul, MN) is a non-communication active earmuff that is powered by two AAA batteries. It utilizes two ear-level independent microphones, along with an active-volume function which amplifies low level sounds (e.g., speech), while loud impulsive noises (i.e., blasts, artillery firing) are attenuated via compression (3M Occupational Health and Environmental Safety Division, 2010). This earmuff-style headset is available as either a headband or neckband model, and can also be mounted on a helmet rail system when used with the 3M™ PELTOR Accessory Rail Connector (ARC) attachment. While 3M™ announced the discontinuation of the ComTac™ III in March 2020 (Thomas, 2020), this product continues to be fielded within the U.S. Navy and U.S. Marine Corps when available. The ComTac™ III has since been replaced with the 3M™ PELTOR™ ComTac™ V Headset. Additional work at NSMRL is underway to assess the impulse attenuation provided by the ComTac™ V Hearing Defender Headset (Silvia et al., 2021).

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

To determine if the issued HPD will reduce the noise exposure below the 140 dBp limit, the impulse peak insertion loss (IPIL) value of the issued and/or used HPD should be subtracted from the impulse noise level (Department of Defense, 2015). The IPIL value is the standard metric (ANSI/ASA S12.42) used to determine the amount of protection afforded by a HPD in response to impulse noise. At present, the IPIL value of the ComTac™ III Hearing Defender at 160 and 170 dBp is unknown. The current effort determined the IPIL values for the ComTac™ III Hearing Defender Headset in both the passive (i.e., OFF) and active (i.e., turned on and set to MAX) test modes. In addition to reporting an overall device IPIL, ear-specific IPILs are reported for the tested nominal levels.

Methods

Facility & Personnel

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

Equipment

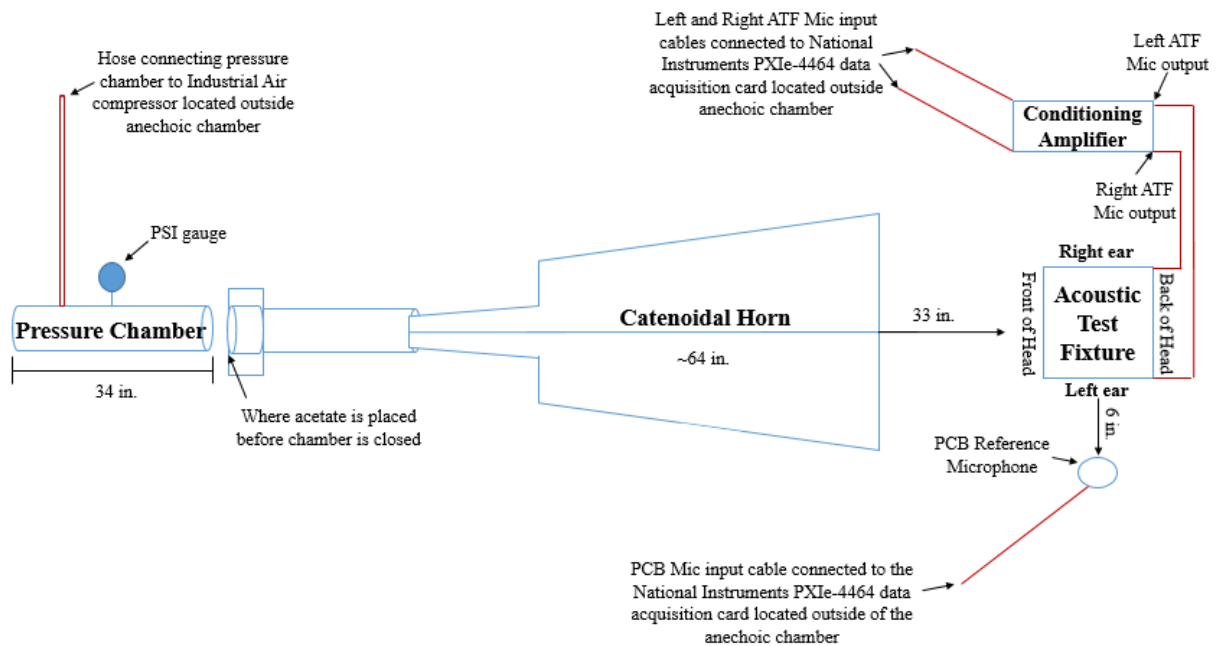
Hardware. Acoustic impulses were generated by NSMRL's 4 inch (in., 10.2 centimeters (cm)) shock tube (B/C Precision, Inc., Greendale, IN). The shock tube pressure chamber is approximately 34 in. (86.4 cm) long, with an inner diameter of 4 in. (10.2 cm). A 64 in. (162.6 cm) long catenoidal tube horn consisting of four welded

steel flat-projection sheets forming a square cross section was connected to the shock tube using a PVC 4.5 in. (11.4 cm) coupler. An industrial air compressor (ILA#1883054; Industrial Air Corporation, Memphis, TN) supplied pressurized air (900 kilopascal) to the shock tube. For each trial, a 7 in. (17.8 cm) by 7 in. (17.8 cm), acetate sheet (Grafix Plastic, Maple Heights, OH) was used as a membrane between the pressurized chamber and the catenoidal tube horn to enable pressurization of the air chamber. Each acetate sheet was 0.002 in. (2 mil) thick.

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

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

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



Data Acquisition System. The data acquisition system (NI chassis PXIe-1071 with NI PXIe-4460 and NI PXIe-4464; National Instruments Corp., Austin, TX) was

controlled by a standalone laptop computer running project specific software (LabVIEW; National Instruments Corp., Austin, TX). The data acquisition system was connected to the laptop using an MXI cord and host interface card (NI PXIe-8360). The software controlled the acquisition of waveforms from the three source microphones (left ATF microphone, right ATF microphone, and a reference microphone) at a sampling rate of 204.8 k samples/second during each impulse recording. Pre-trigger settings were 1024 samples per 0.005 seconds, with a trigger level of 110 dB SPL. Each recording was 0.3 seconds in duration.

Rather than using an ANSI/ASA S12.42-2010 standardized in-line analog external Bessel filter (6th order, corner frequency 20.0 kHz [3 dB down]) to filter impulses during data acquisition, anti-alias filtering was accomplished by an analog filter and a digital filter. First, an electronic analog anti-aliasing filter (corner frequency of 93.0 kHz [3 dB down]) was applied to all waveforms by the National Instruments data acquisition system during data collection. This deviation was made due to equipment and software limitations.

The custom-written software program saved all recorded waveforms as files (.tdms), which were exported and converted to data files using an additional custom software programming script. The script compiled the reference PCB microphone, left ATF microphone, and right ATF microphone channels into a file (.mat) that saved variables for input to analysis script (MATLAB) similar to the script provided in Annex H of the ANSI/ASA S12.42-2010 standard. Minor alterations were made to the analysis script in order to accept 160 decibel peak (dBp) and 170 dBp data (see Data Analysis below).

Hearing Protection Device Samples. Five samples of the ComTac™ III Hearing Defender Headset (Manufacturer Product Number: MT17H682BB-09 CY) with gel ear cushions and neckband were tested in accordance with (IAW) ANSI/ASA S12.42-2010. Each sample (i.e., one headset) was randomly assigned and labeled with a number 1 through 5.

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Figure 2.
ComTac™ III Hearing Defender Headset (Neckband Model).



Procedure

Since the ComTac™ III employs active technology, this device was tested in both the passive (OFF) and active modes (i.e., the headset turned on and the equipment volume set at its maximum limit (MAX)). Per ANSI/ASA S12.42, each sampled HPD was fitted to the ATF twice, resulting in two trials (trials A and B) per sample, and 10 total trials per nominal level test condition (160 and 170 dBP) for each HPD mode. No samples of the HPD were rejected.

To achieve an appropriate fit that would provide maximum attenuation, each sample was expertly fitted to the ATF following the instructions provided on the device packaging. The manufacturer fitting guidelines stated that all samples should be inspected for any wear, cracks, or damage prior to use. Once inspected, earmuffs were placed over the ears to encompass the pinnae, and the neckband adjusted to just rest on the neck of the ATF.

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

Impulse noises were presented to the ATF in the occluded (i.e., HPD donned) and unoccluded (i.e., HPD doffed) test configurations. For all occluded measures, the earmuffs were fitted on the ATF IAW the specifications outlined in ANSI/ASA S12.42-2010. Each HPD sample was exposed to two impulses at each tested nominal level. Adequate pressure for each impulse was determined by increasing pressure (measured in pounds per square inch [psi]) to a point within a pre-specified range necessary for producing either 160 dBP (19.5 to 22.1 psi, 134 to 152 kilopascals (kPa)) or 170 dBP (28.5 to 29.5 psi, 197 to 203 kPa) nominal level impulses using the NSMRL 4 in. (10.2 cm) acoustic shock tube. The acetate was then punctured 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 and 150 dBP, six calibration impulses were generated at the 160 dBP nominal level in the unoccluded (i.e., without HPD) test configuration. Three of these impulses were generated pre-, and three were generated post-testing at 160 dBP. Calibrations were not completed at the 170 dBP nominal level due to exposure limitations of the ATF right and left microphones.

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

Data Analysis

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

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

Deviating from ANSI/ASA S12.42-2010, a second digital Butterworth filter (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 which was omitted due to equipment limitations.

Results

The calculated overall mean (standard deviation (SD)) IPIL value of the ComTac™ III in the passive (i.e., OFF) test mode was 26.2 (2.2) at 160 dBP and 28.6 (1.1) dBP at the 170 dBP nominal level (see Table 2). Calculated IPIL values for all sample trials in the OFF mode ranged between 22.7 to 29.4 dB at 160 dBP and 26.7 to 30.2 dB at 170 dBP.

Table 2.

Mean (SD) IPIL values (in dB) for Tested ComTac™ III (OFF) Samples.

	160 dBP		170 dBP	
	<i>Right</i>	<i>Left</i>	<i>Right</i>	<i>Left</i>
HPD 1, Trial A	27.5	29.4	29.2	27.7
HPD 1, Trial B	22.9	22.7	28.5	31.5
HPD 2, Trial A	23.3	23.3	29.5	28.5
HPD 2, Trial B	24.9	28.6	28.3	30.2
HPD 3, Trial A	24.0	25.7	29.5	27.9
HPD 3, Trial B	27.2	27.2	29.2	29.6
HPD 4, Trial A	27.0	27.0	28.9	28.3
HPD 4, Trial B	29.4	27.0	28.0	27.3
HPD 5, Trial A	28.1	28.8	27.8	27.8
HPD 5, Trial B	25.2	24.7	26.7	27.5
Ear Specific Mean (SD)	26.0 (2.2)	26.4 (2.3)	28.6 (0.9)	28.6 (1.4)
Level Overall Mean (SD)	26.2 (2.2)		28.6 (1.1)	

As shown in Table 3, the calculated mean (SD) IPIL value in the active (i.e., MAX) test mode was 27.1 (1.8) dB at 160 dBP and 29.0 (1.1) dB at 170 dBP nominal levels. All tested sample trials in the MAX mode ranged between 23.2 to 29.9 dB at 160 dBP and between 25.6 to 32.1 dB at 170 dBP.

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Table 3.*Mean (SD) IPIL values (in dB) for Tested ComTac™ III (MAX) Samples.*

	160 dBP		170 dBP	
	<i>Right</i>	<i>Left</i>	<i>Right</i>	<i>Left</i>
HPD 1, Trial A	28.0	25.5	32.1	28.4
HPD 1, Trial B	29.9	25.5	30.2	28.9
HPD 2, Trial A	23.2	25.4	31.6	28.1
HPD 2, Trial B	28.7	26.6	29.7	27.8
HPD 3, Trial A	29.6	27.6	30.2	29.6
HPD 3, Trial B	28.4	28.0	30.6	27.0
HPD 4, Trial A	26.1	24.5	29.3	26.3
HPD 4, Trial B	27.6	26.0	28.0	25.6
HPD 5, Trial A	28.9	26.4	29.4	27.2
HPD 5, Trial B	28.9	26.2	31.3	28.2
Ear Specific Mean (SD)	27.9 (2.0)	26.2 (1.1)	30.2 (1.2)	27.7 (1.2)
Level Overall Mean (SD)	27.1 (1.8)		29.0 (1.8)	

The measured clamping force of the ComTac™ III (neckband model) ranged from 2.3 to 2.5 lbf, with a mean (SD) of 2.4 (0.1) lbf (as shown in Table 4).

Table 4.*Mean (SD) Band Force (lbf) for Tested ComTac™ III Samples.*

	Band Force
HPD 1	2.4
HPD 2	2.4
HPD 3	2.3
HPD 4	2.3
HPD 5	2.5
MEAN (SD)	2.4 (0.1)

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

Discussion

As required by ANSI/ASA S12.42-2010, when measuring the IPIL of an active HPD, the ComTac™ III was tested in both the passive and active modes. As an active device, the limiting circuit of the ComTac™ III will automatically turn off the amplifier when a signal exceeds 82 dB (A-weighted; dBA) (3M Personal Safety Division, 2015). Once the amplifier is turned off, the headset then acts as a passive HPD, attenuating all

incoming noise above 82 dBA. Therefore, when the active technology is functional and the ear cups are fitted properly, it is anticipated that the passive (i.e., OFF) and active (i.e., MAX) test modes will perform similarly. A possible mode of failure is the limiting circuit not turning off fast enough, allowing some of the impulse noise to be amplified and actively passed through the device. To test for this possibility, the ComTac™ III Hearing Defender Headset was tested both powered off and with the unit powered on and volume set to its maximum setting.

As anticipated, the calculated mean IPIL values were greater at the 170 dBP nominal level than at the 160 dBP nominal level for both tested HPD modes. The difference in overall mean IPIL values was as much as 2.4 dB when the HPD was turned off, and 1.9 dB when the HPD was turned on with the gain set to MAX. Across ears, the individual trial mean IPIL values were found to vary as much as 6.7 dB at 160 dBP and 3.5 dB at 170 dBP in the OFF test mode, while all individual trial mean IPILs in the MAX test mode varied 6.7 dB at 160 dBP and 6.5 dB at 170 dBP. This may be due to a combination of inherent variance within the impulse system and/or variability in fit as a result of each HPD sample being fitted twice.

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

Conclusions

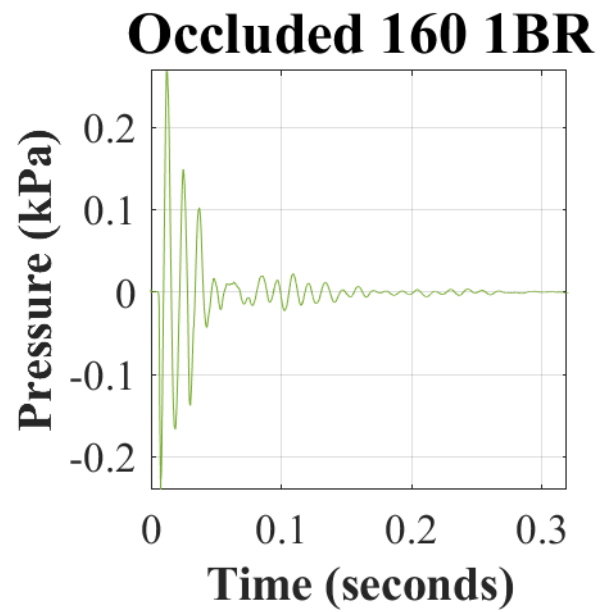
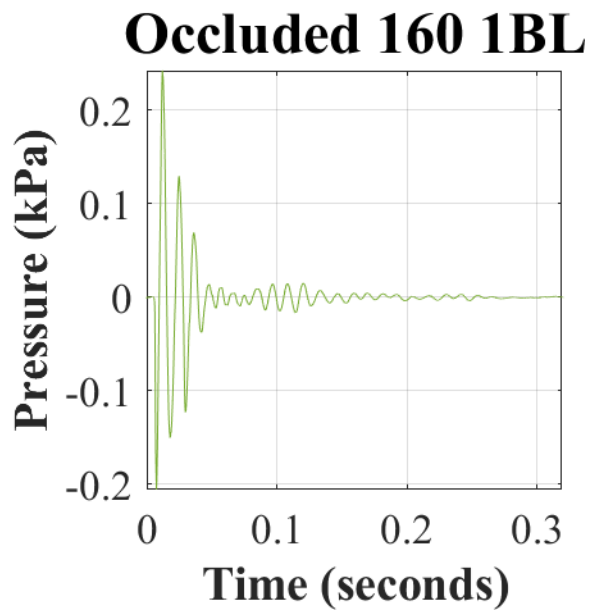
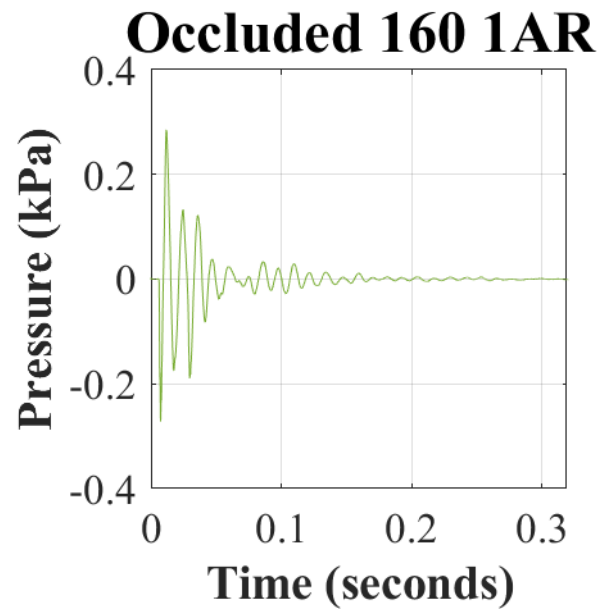
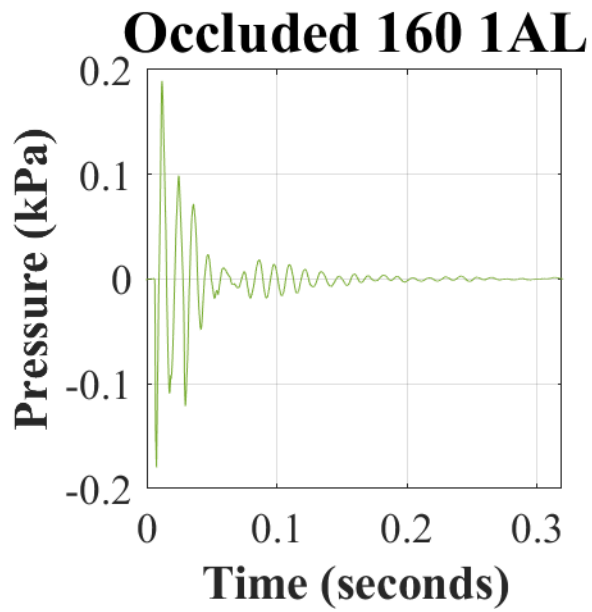
This report described the determination of the mean impulse peak insertion loss (IPIL) values provided by the ComTac™ III Hearing Defender Headset at the nominal levels of 160 dBP and 170 dBP. The calculated overall mean (SD) impulse peak insertion loss (IPIL) value for the ComTac™ III Hearing Defender in the passive (OFF) mode at 160 dBP was found to be 26.2 (2.2) dB and 28.6 (1.1) dB at 170 dBP. When the ComTac™ III was in the active (turned on, and the volume set to MAX) mode, the overall mean (SD) IPIL value at 160 dBP was 27.1 (1.8) dB and at 170 dB it was 29.0 (1.8) dB.

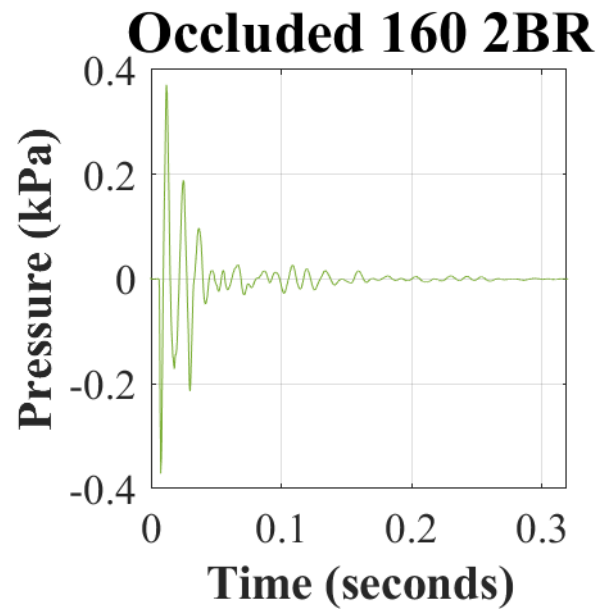
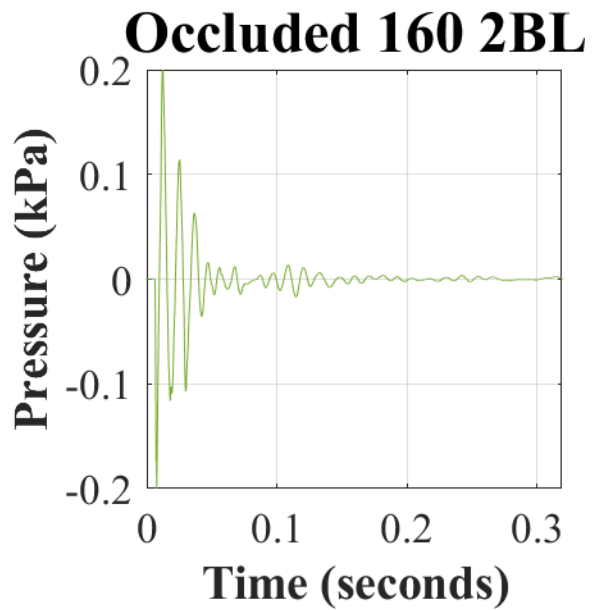
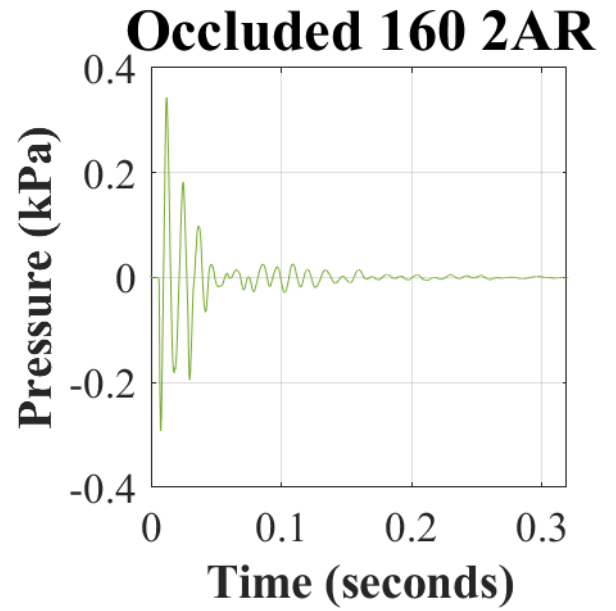
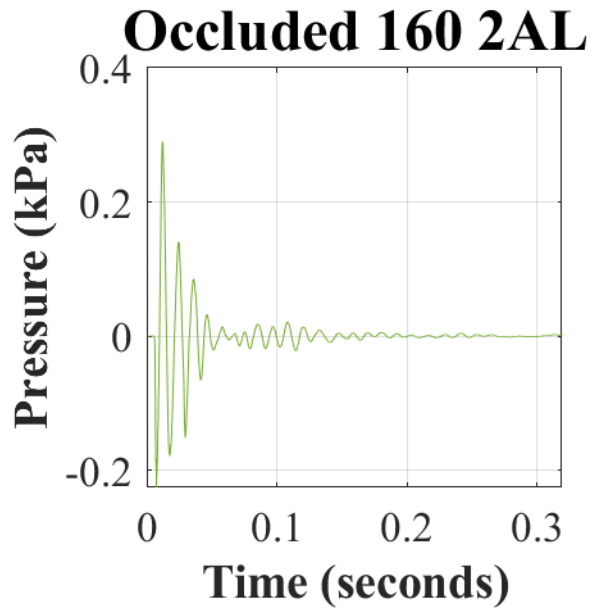
These results imply that when properly fit and functional, the ComTac™ III Hearing Defender Headset will adequately protect (i.e., reduce exposure to less than 140 dBP) impulses below 168.6 dBP in the passive (i.e., OFF) mode and below 169.0 in the active (i.e., MAX) mode.

References

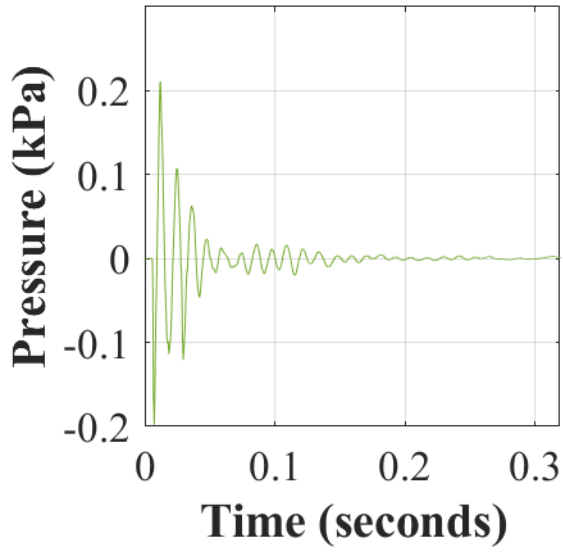
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Appendix A. Recorded occluded (earmuff donned) waveforms (in kilopascals (kPa)) over time (in seconds (s)) in response to 160 dBp with the ComTac™ III (OFF).

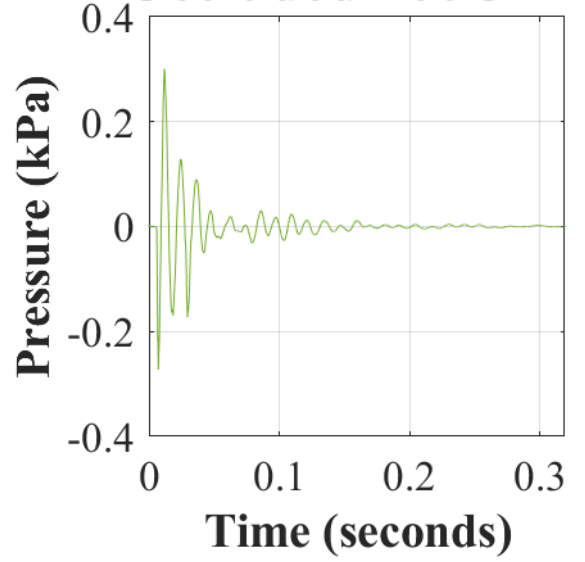




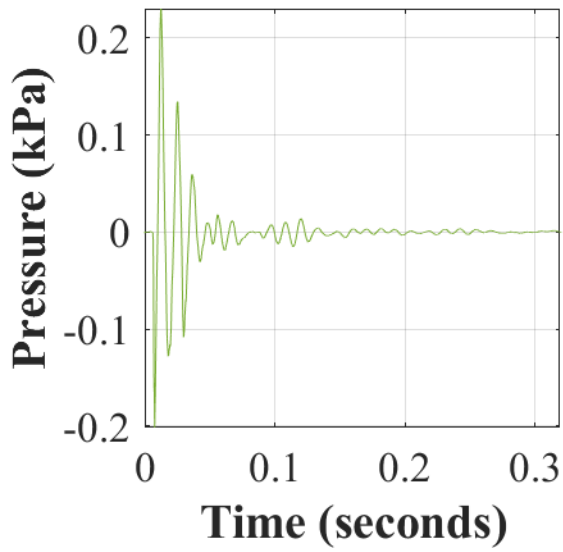
Occluded 160 3AL



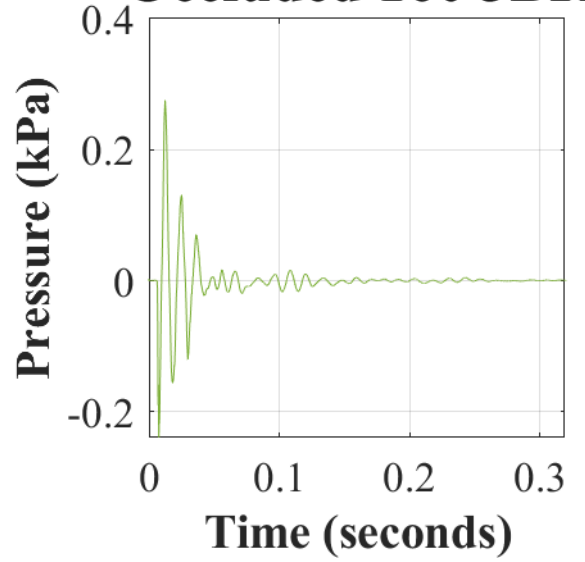
Occluded 160 3AR



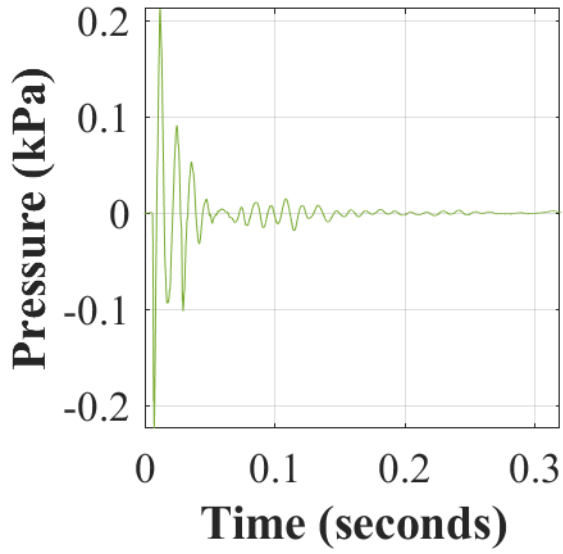
Occluded 160 3BL



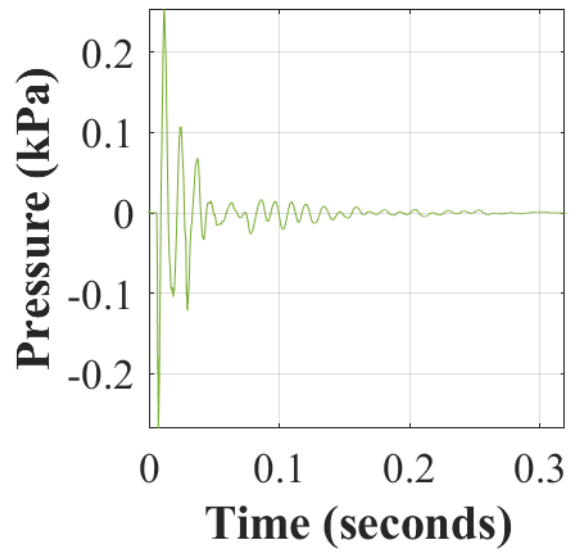
Occluded 160 3BR



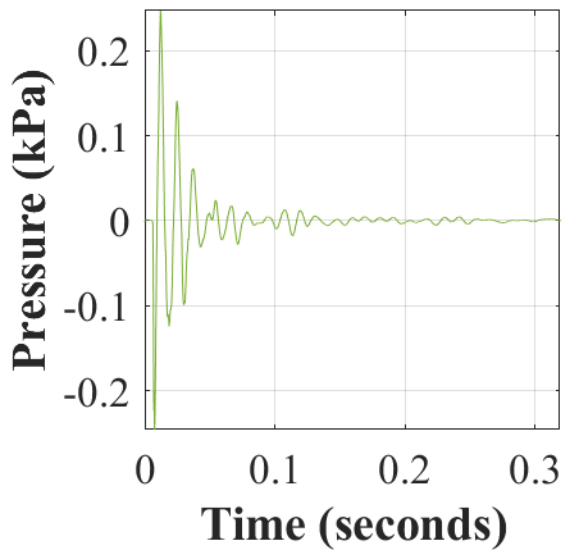
Occluded 160 4AL



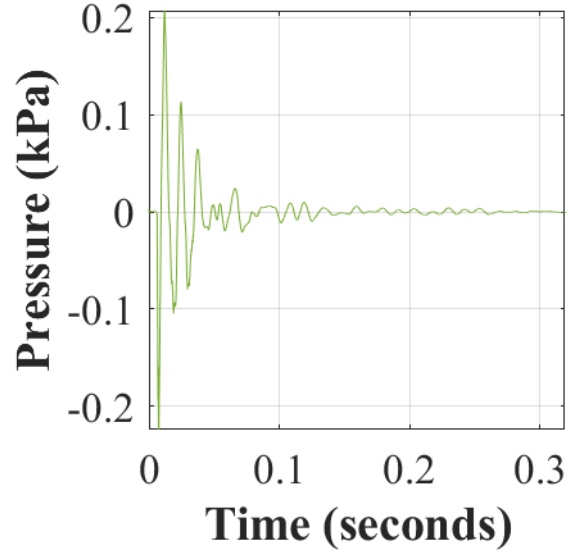
Occluded 160 4AR

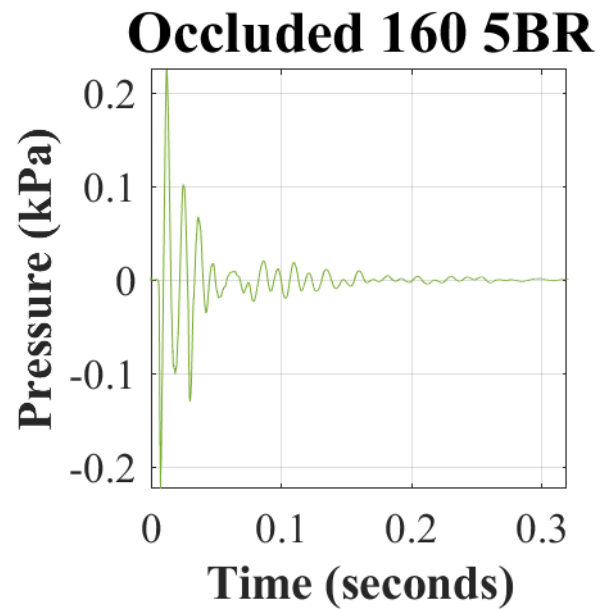
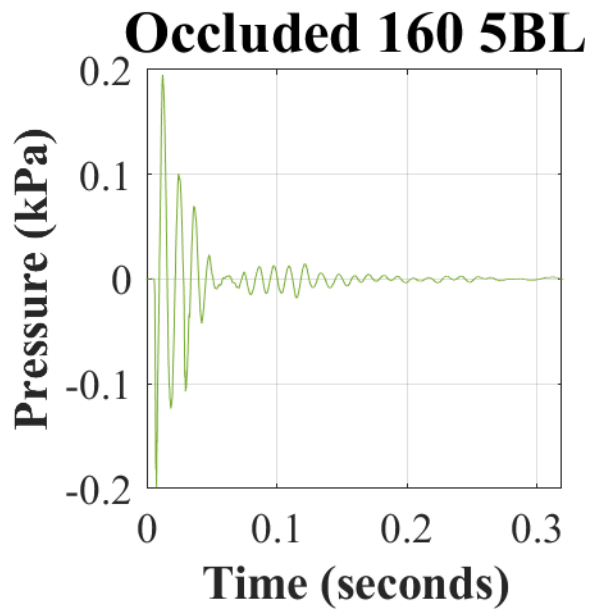
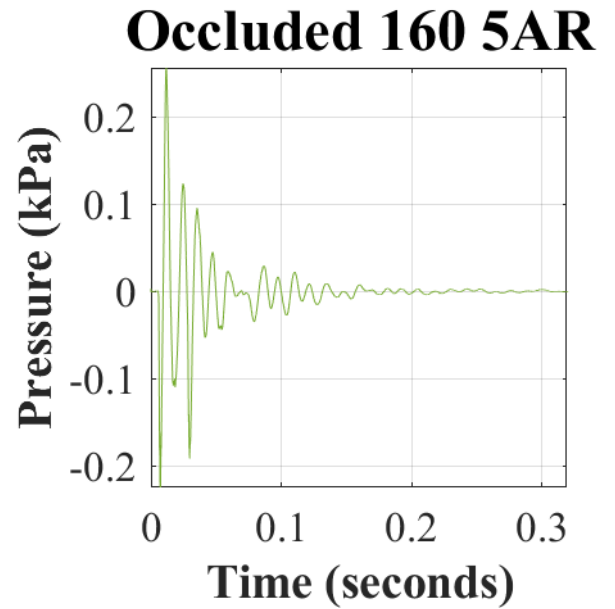
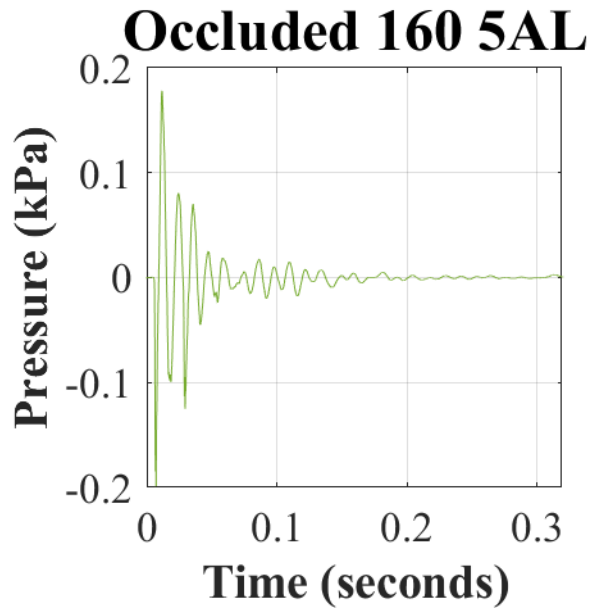


Occluded 160 4BL



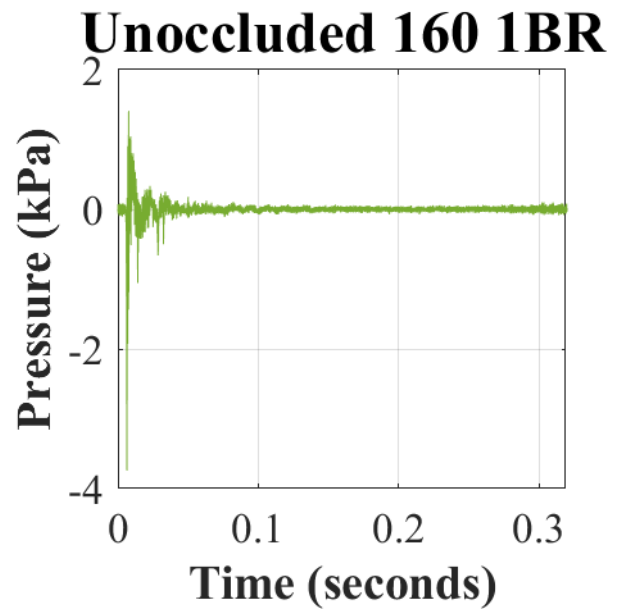
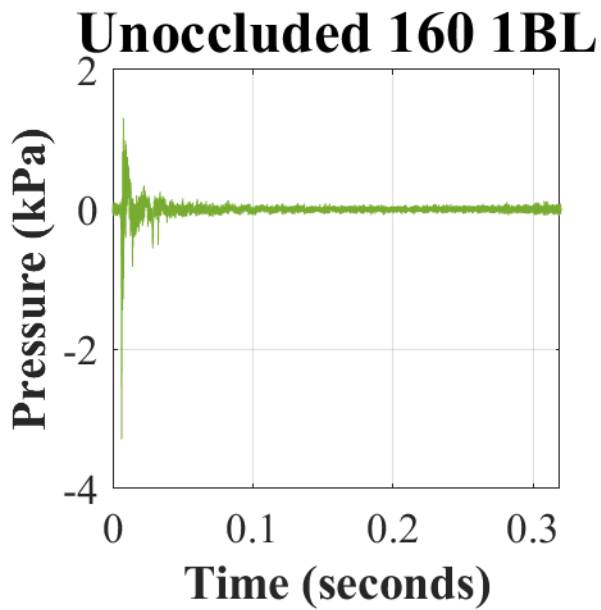
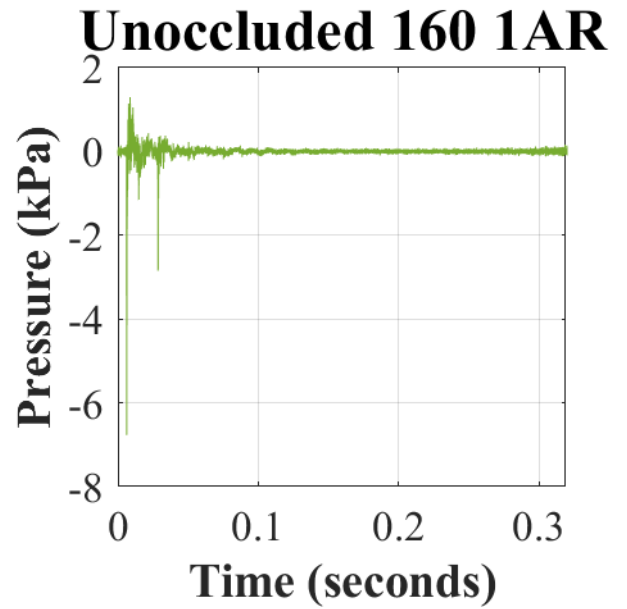
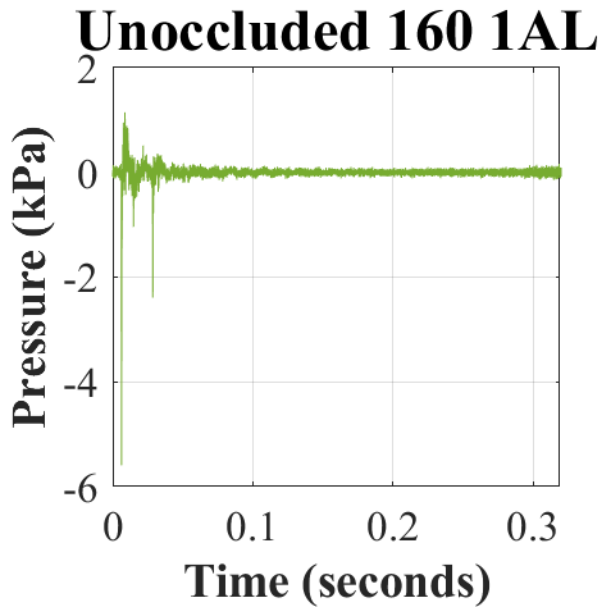
Occluded 160 4BR

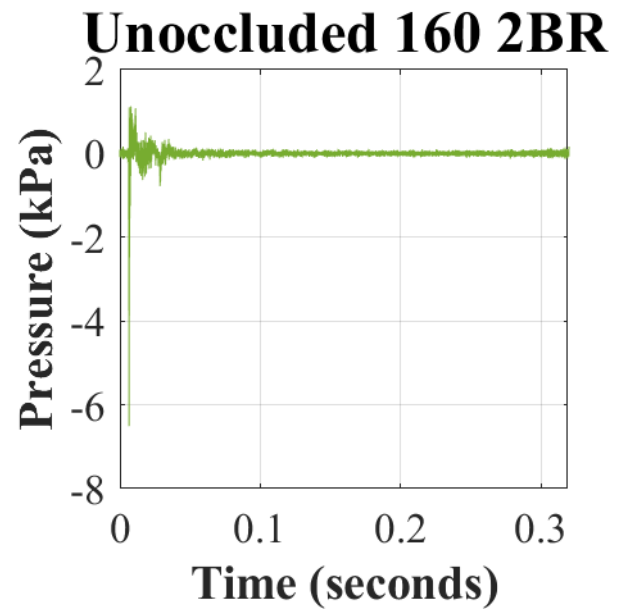
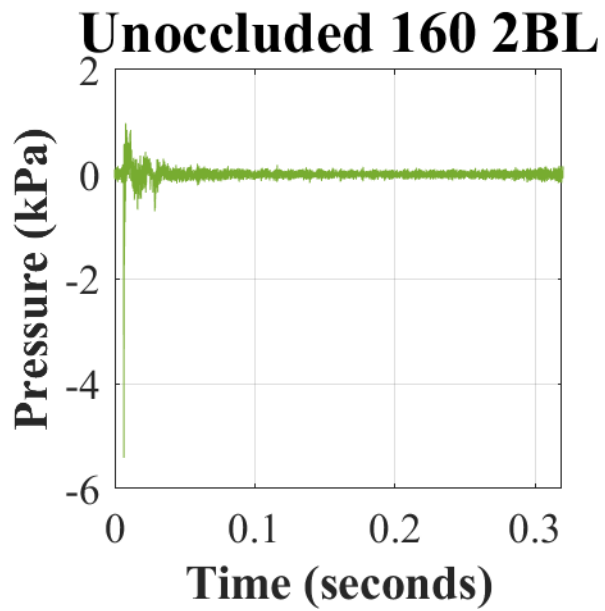
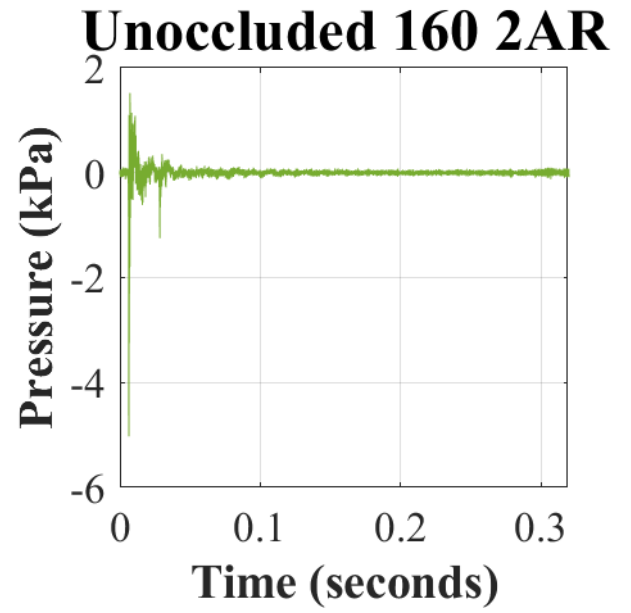
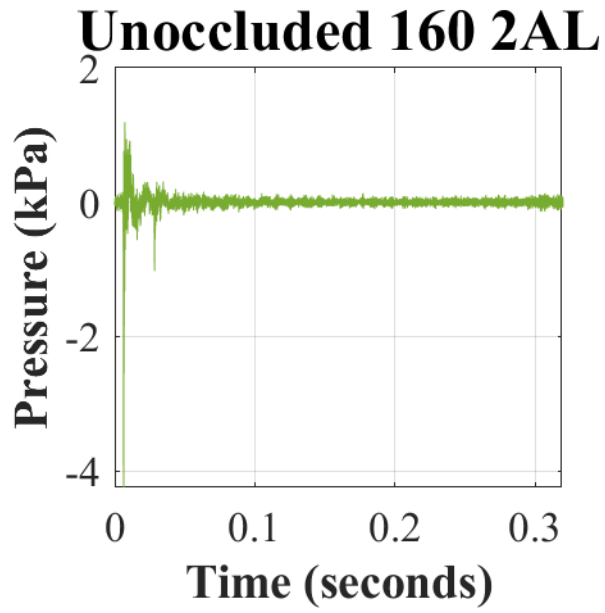


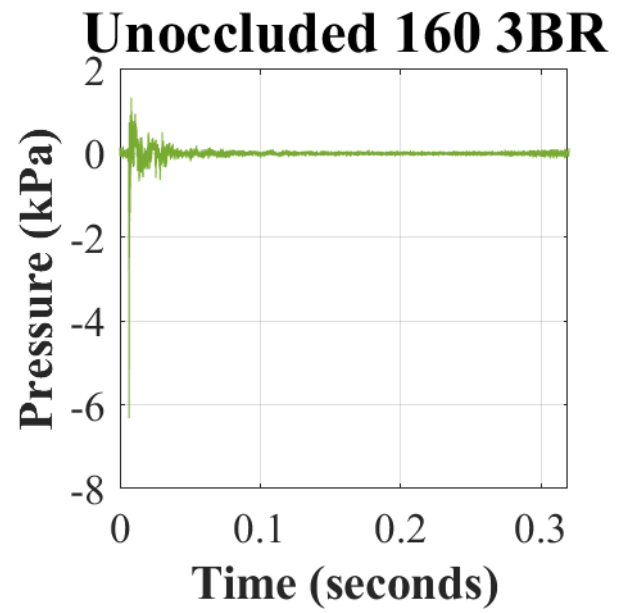
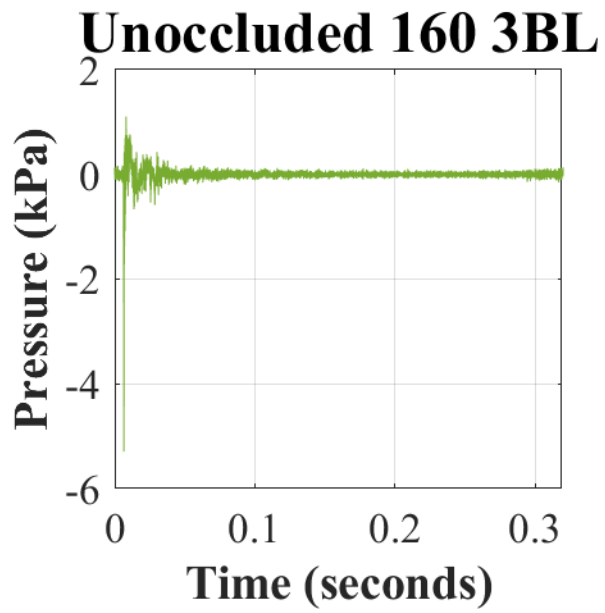
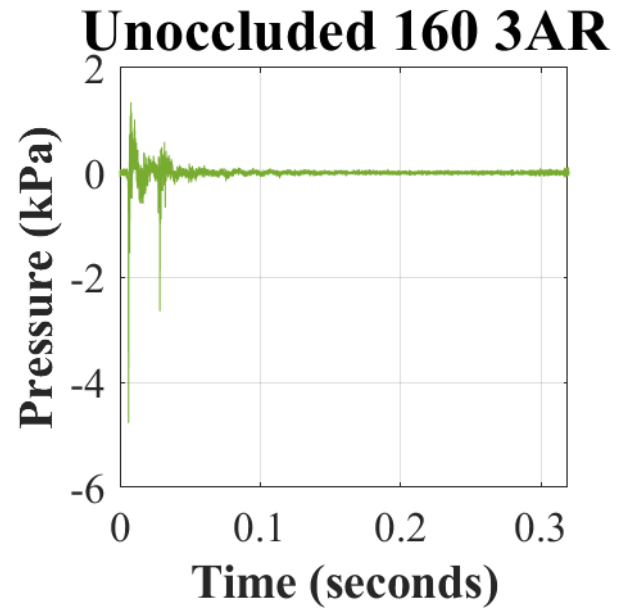
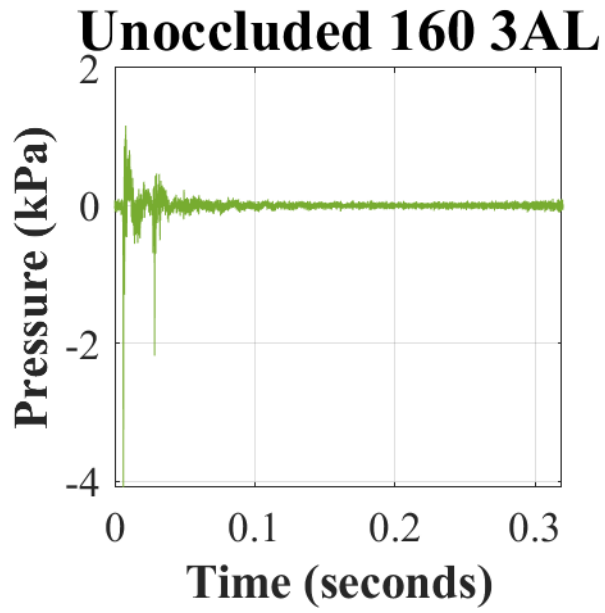


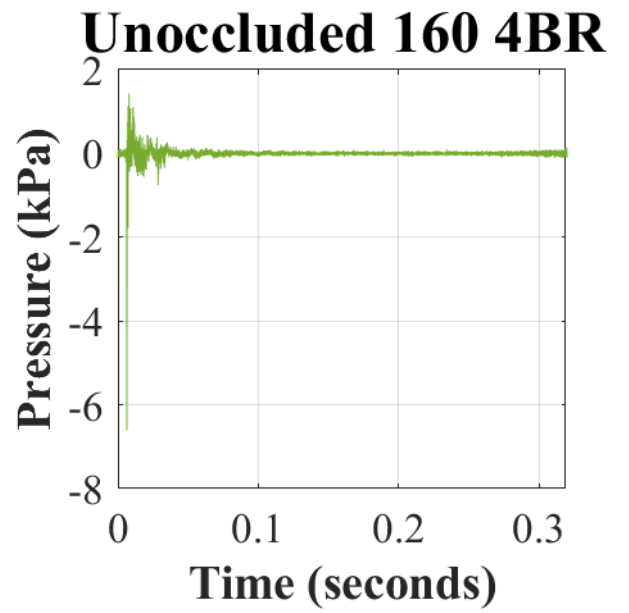
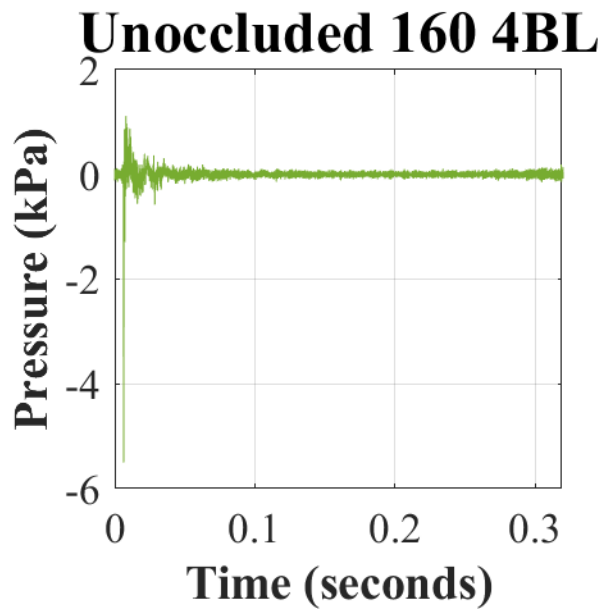
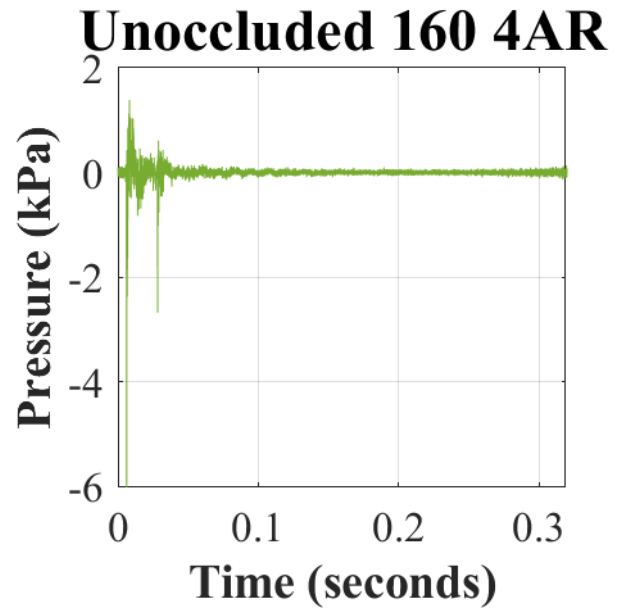
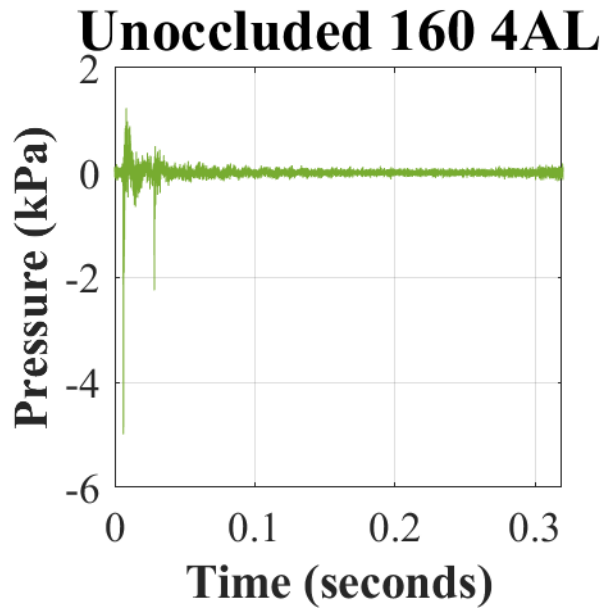
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the earmuff donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B)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

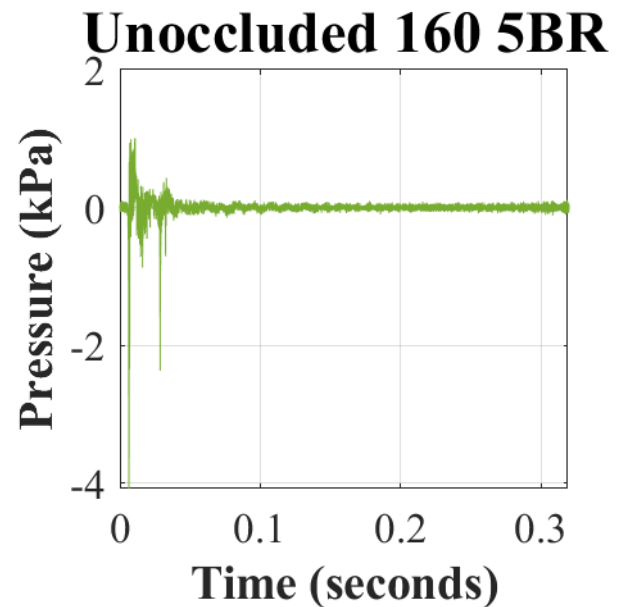
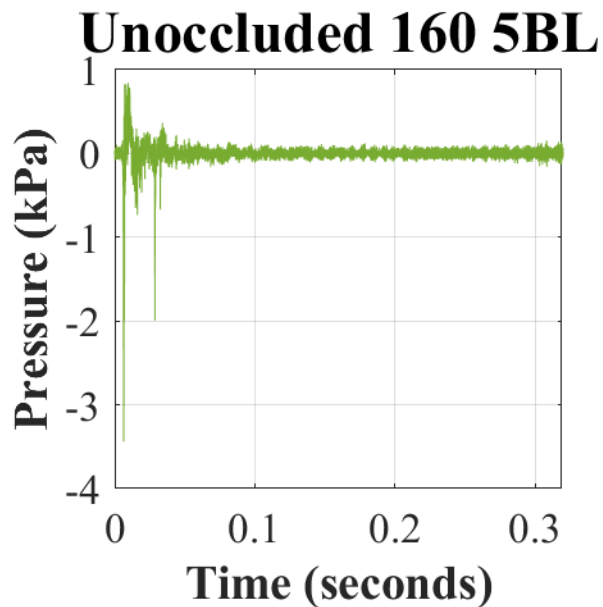
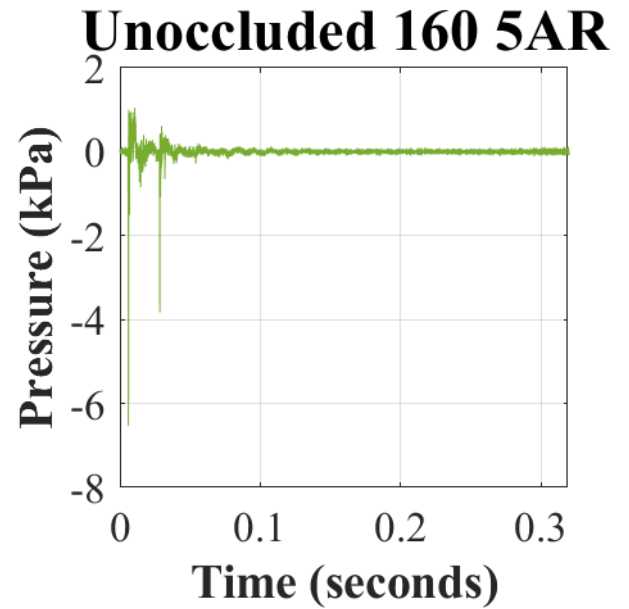
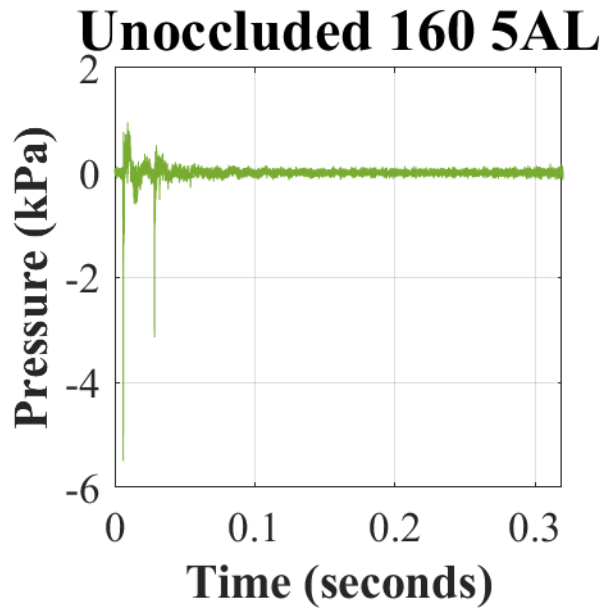
Appendix B. Estimated unoccluded (earmuff doffed) waveforms (in kilopascals (kPa)) over time (in seconds (s)) in response to 160 dBp with the ComTac™ III (OFF).





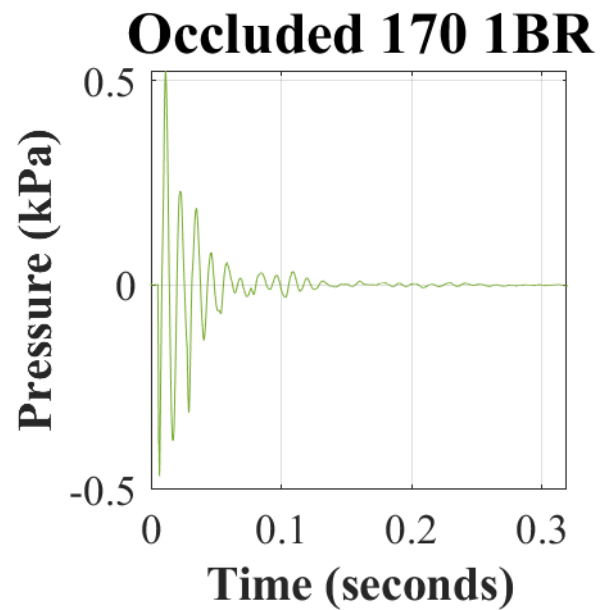
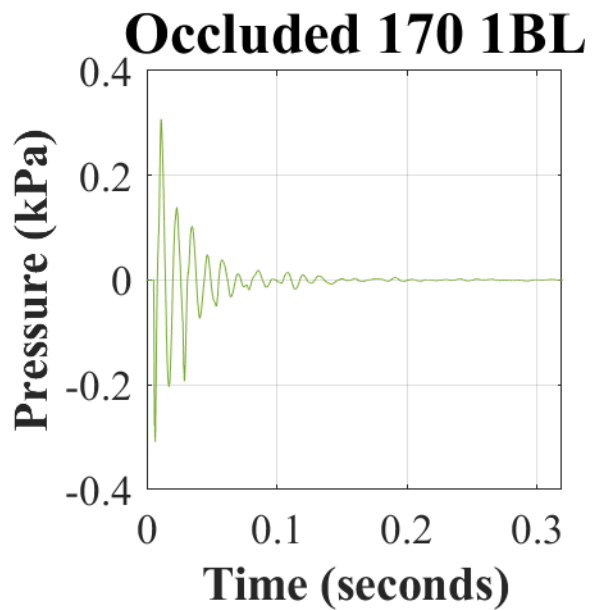
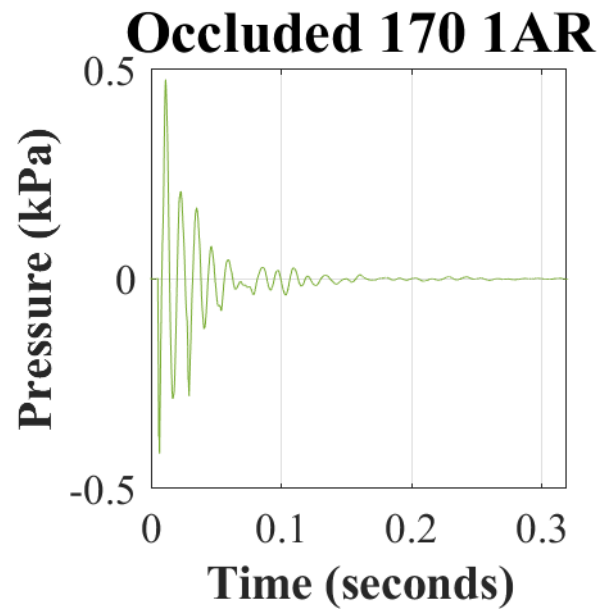
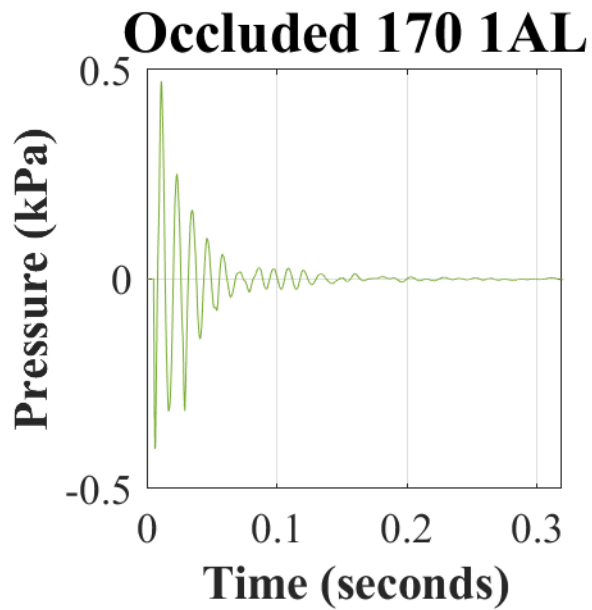




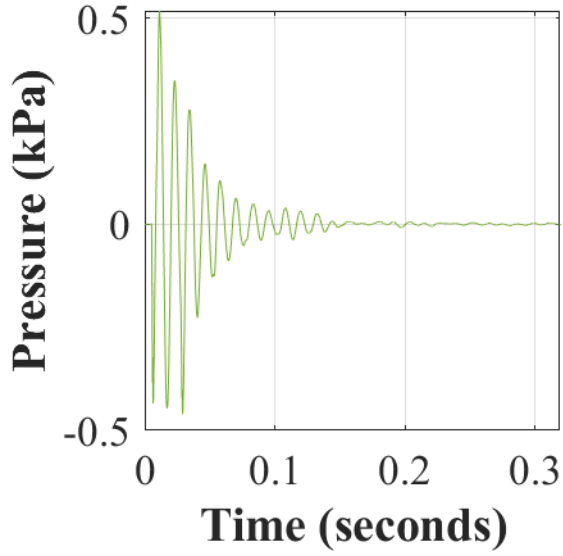


Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the earmuff doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or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

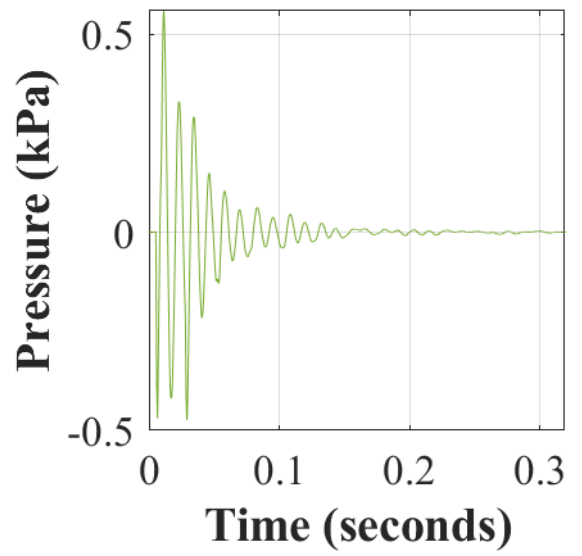
Appendix C. Recorded occluded (earmuff donned) waveforms (in kilopascals (kPa)) over time (in seconds (s)) in response to 170 dBp with the ComTac™ III (OFF).



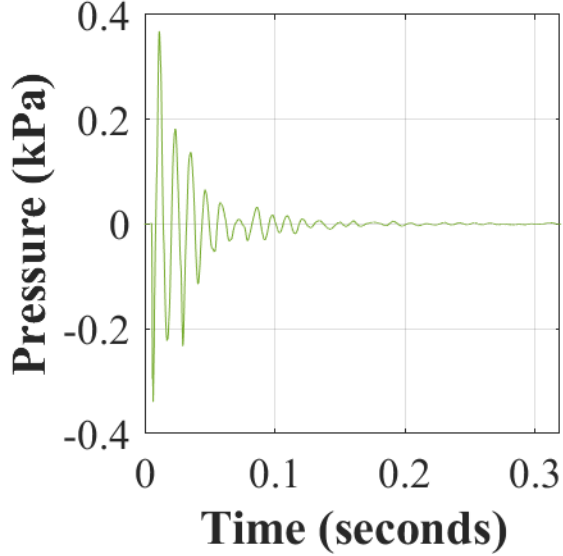
Occluded 170 2AL



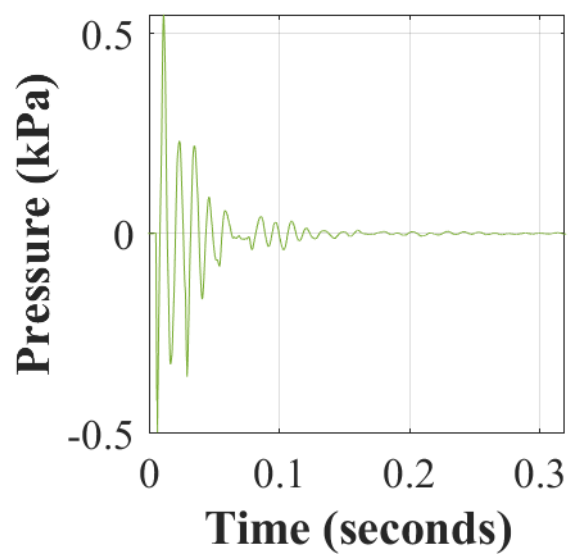
Occluded 170 2AR

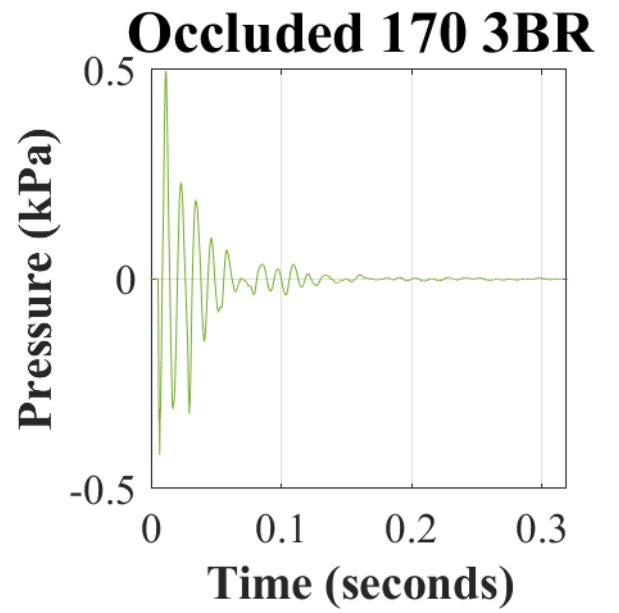
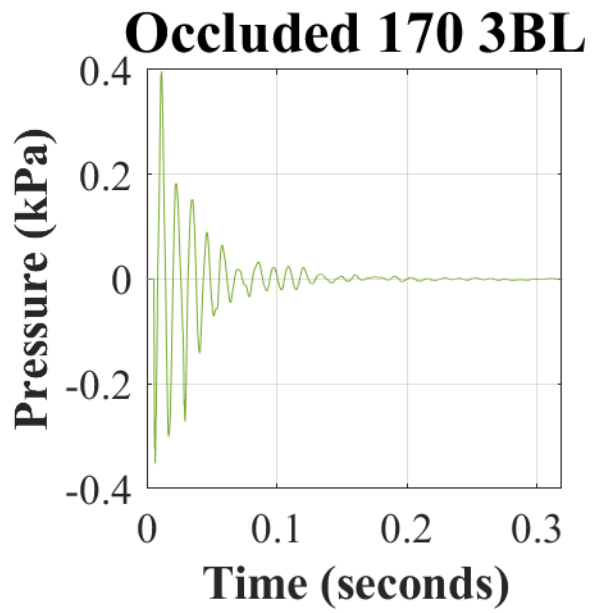
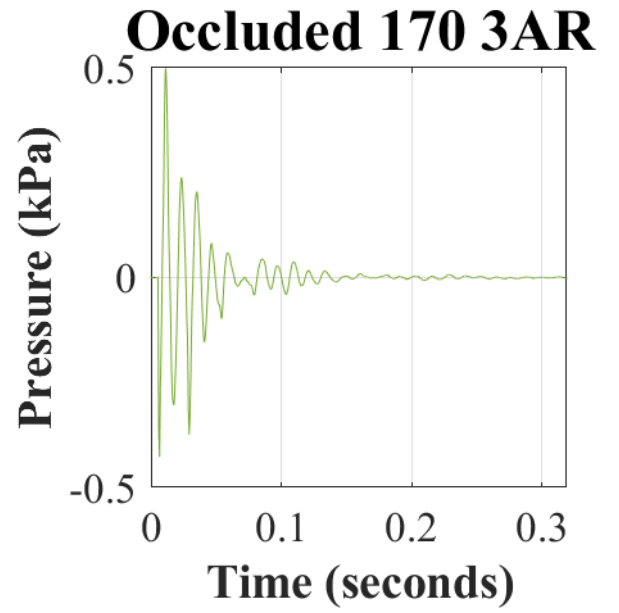
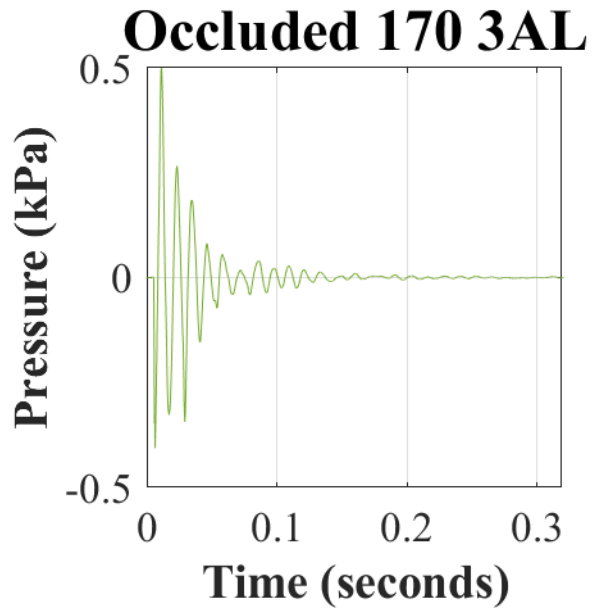


Occluded 170 2BL

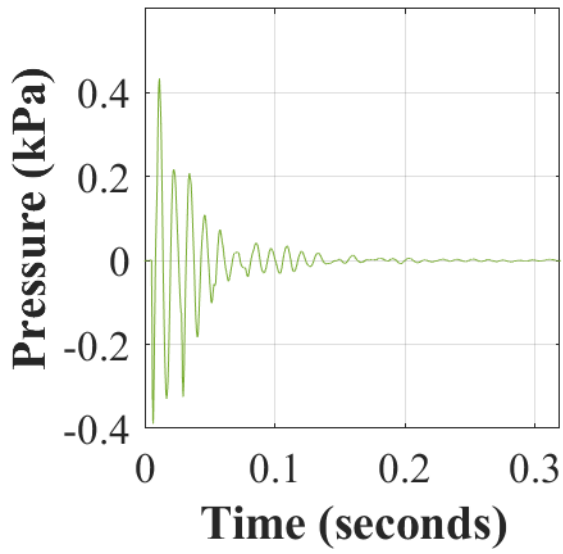


Occluded 170 2BR

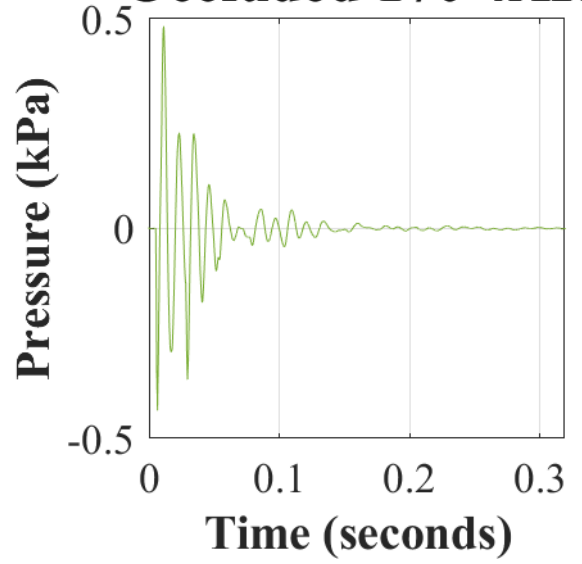




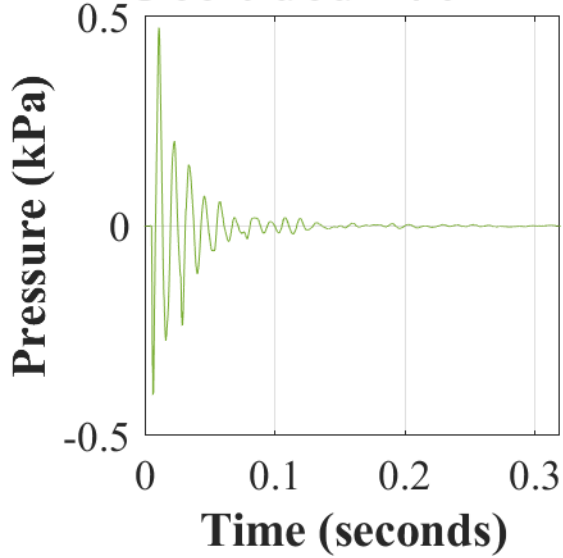
Occluded 170 4AL



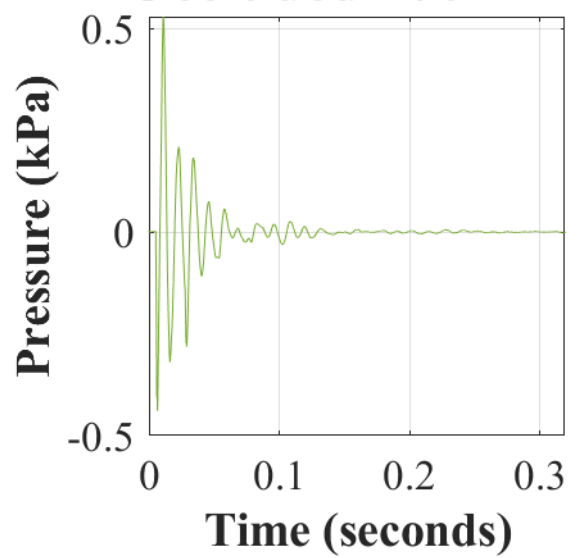
Occluded 170 4AR

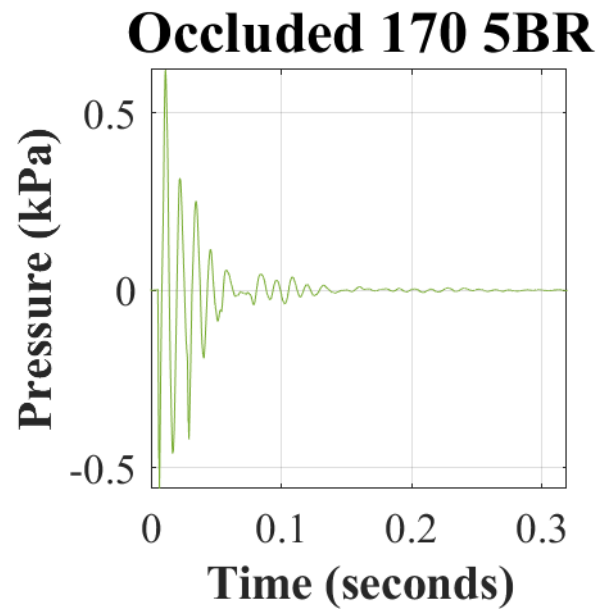
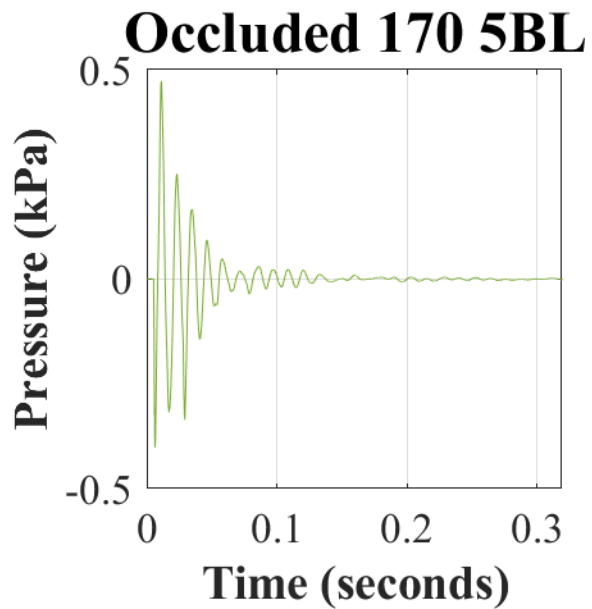
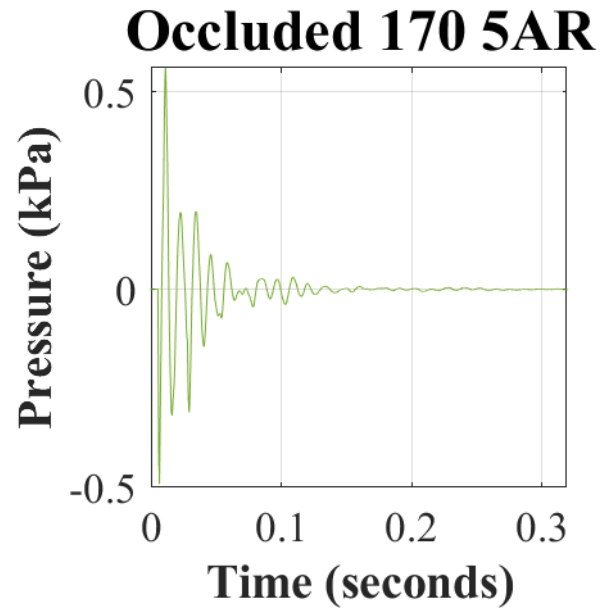
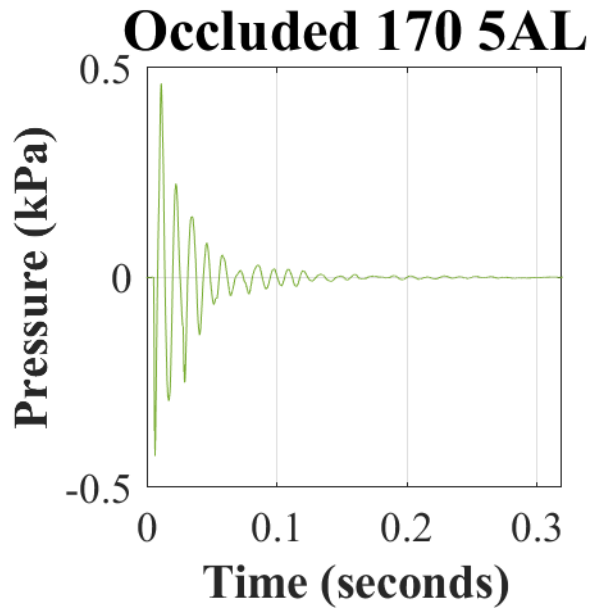


Occluded 170 4BL



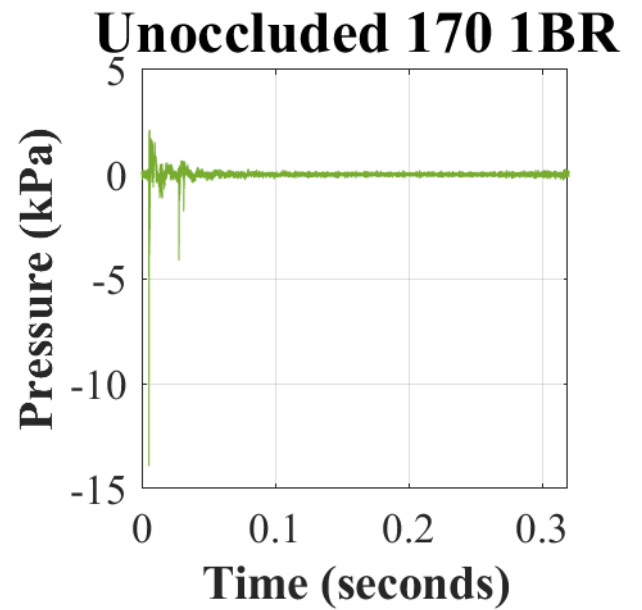
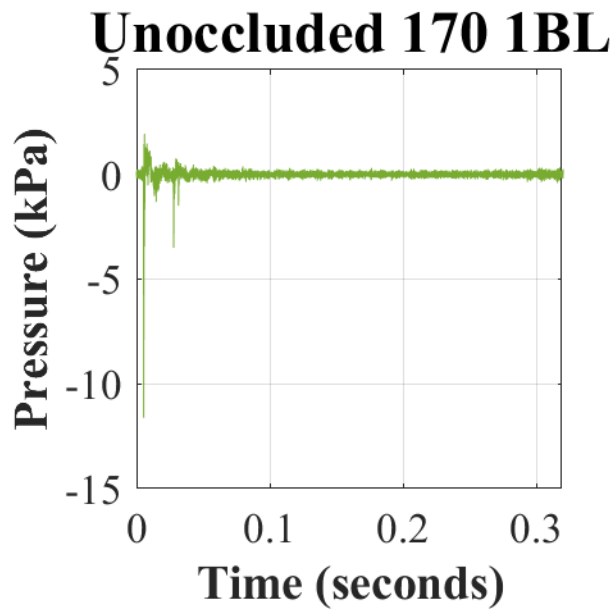
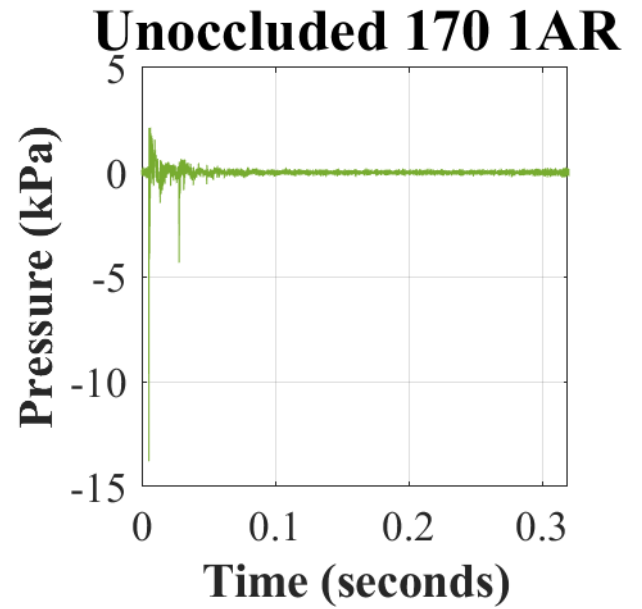
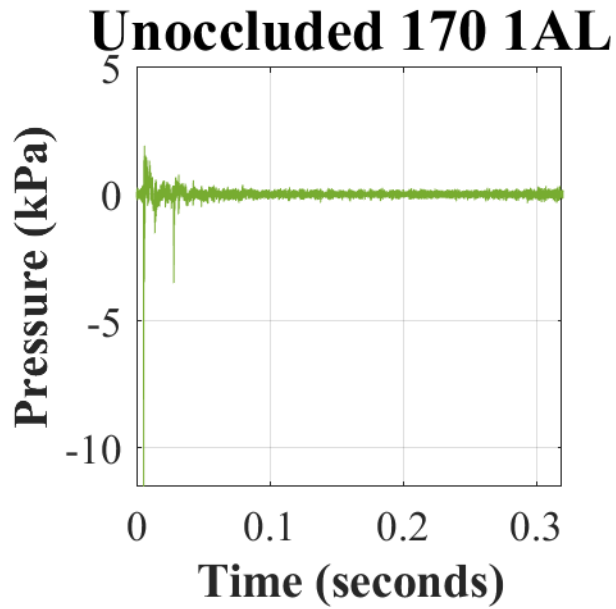
Occluded 170 4BR

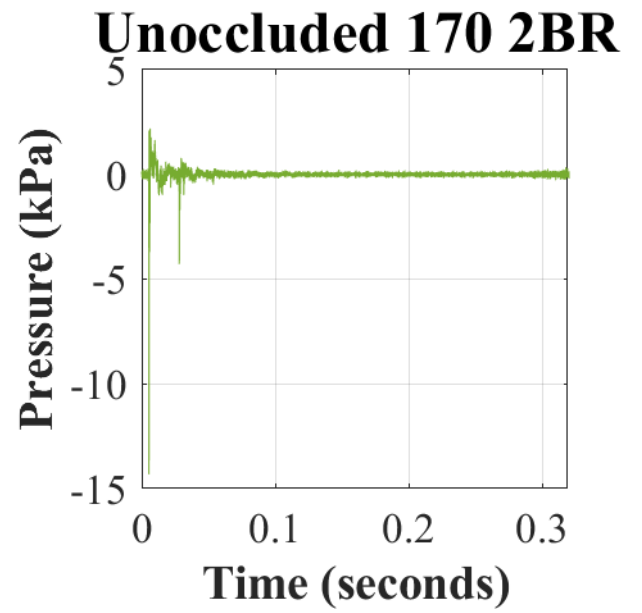
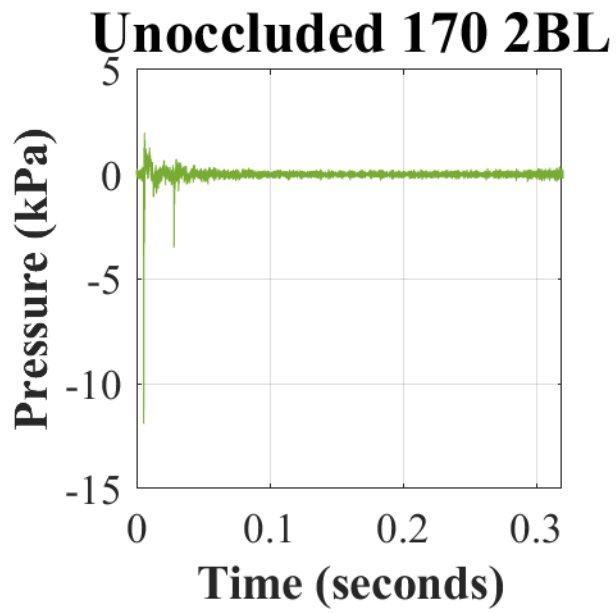
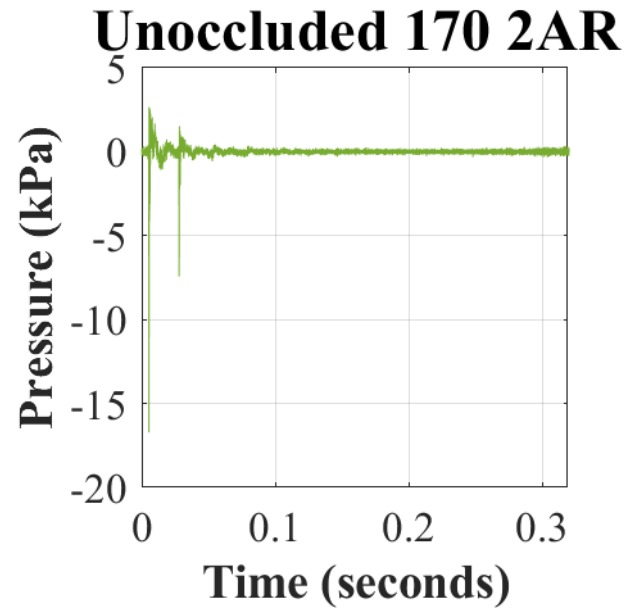
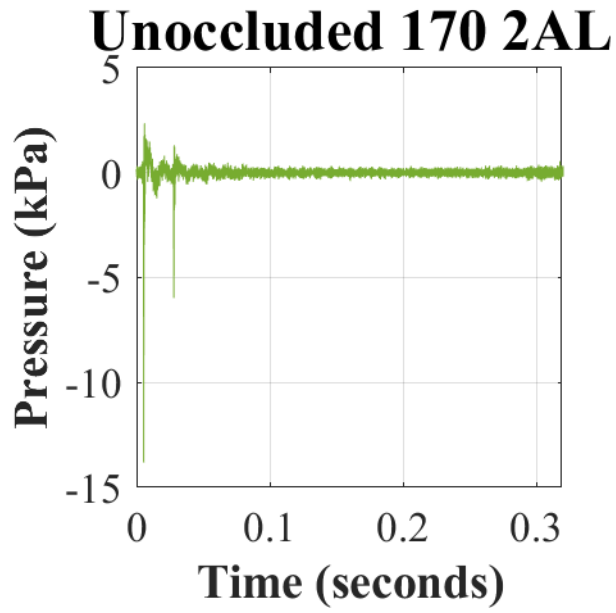


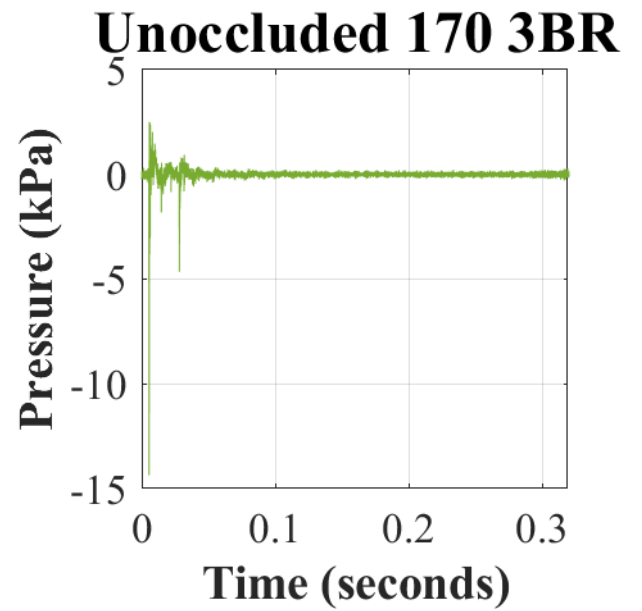
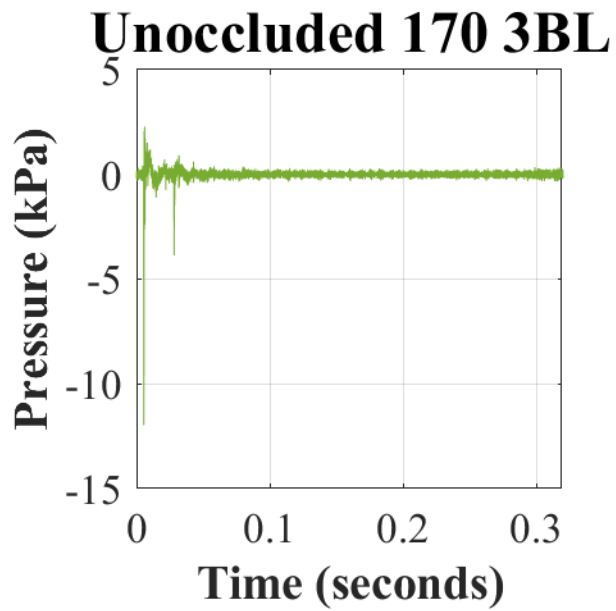
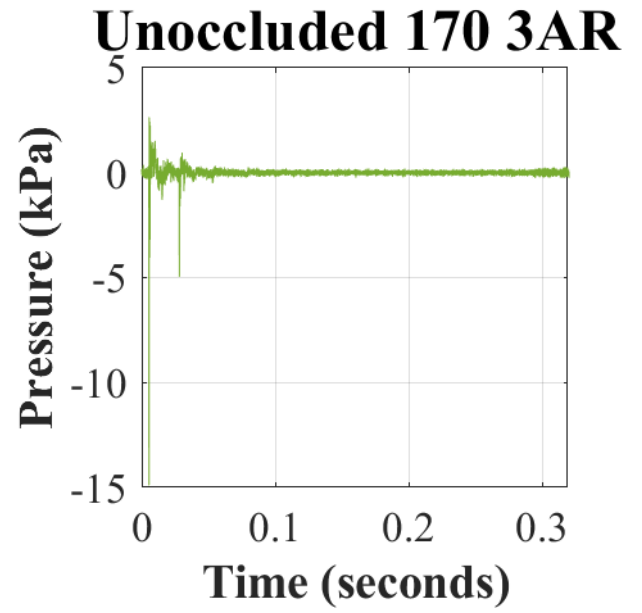
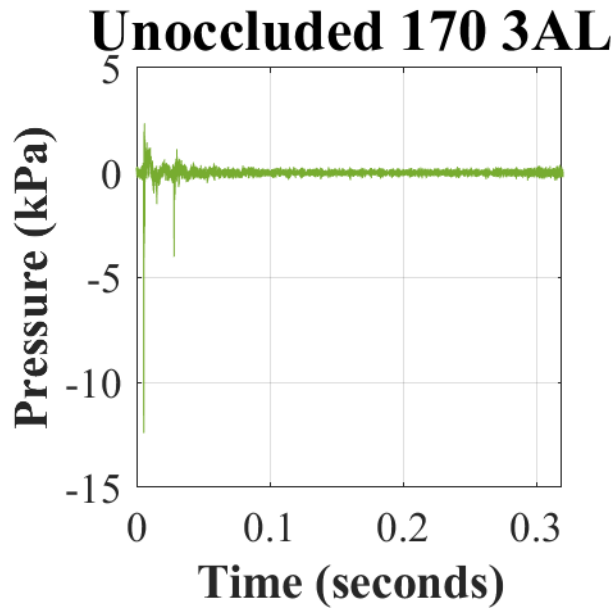


Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the earmuff donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B)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

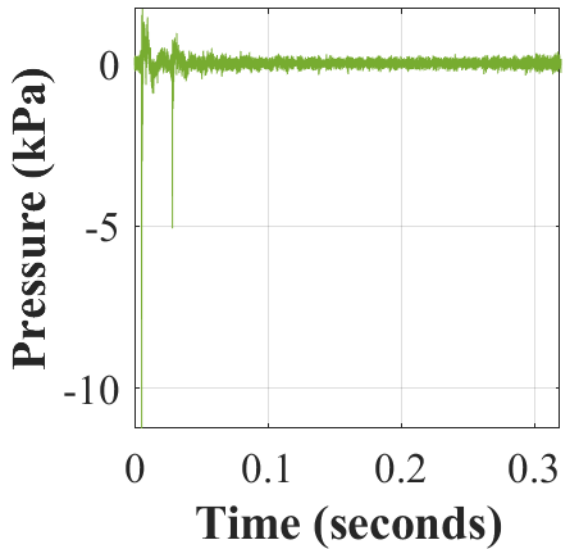
Appendix D. Estimated unoccluded (earmuff doffed) waveforms (in kilopascals (kPa)) over time (in seconds (s)) in response to 170 dBp with the ComTac™ III (OFF).



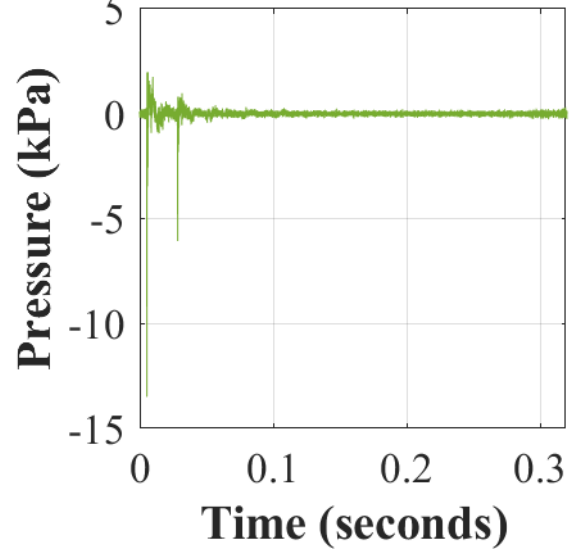




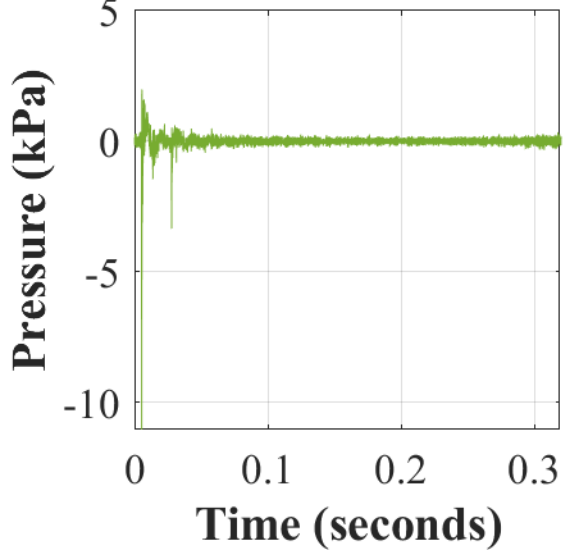
Unoccluded 170 4AL



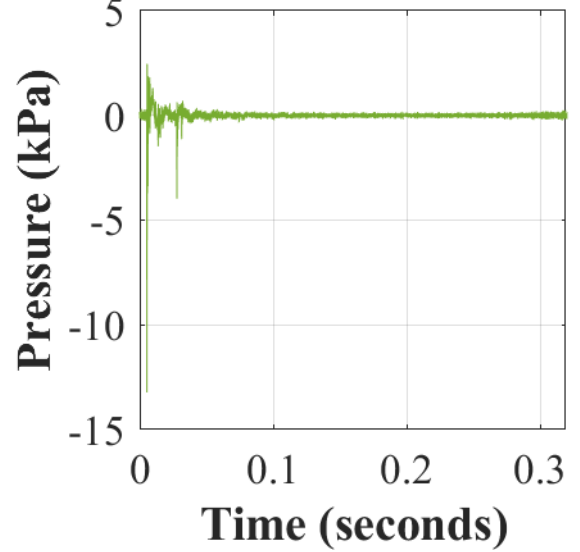
Unoccluded 170 4AR

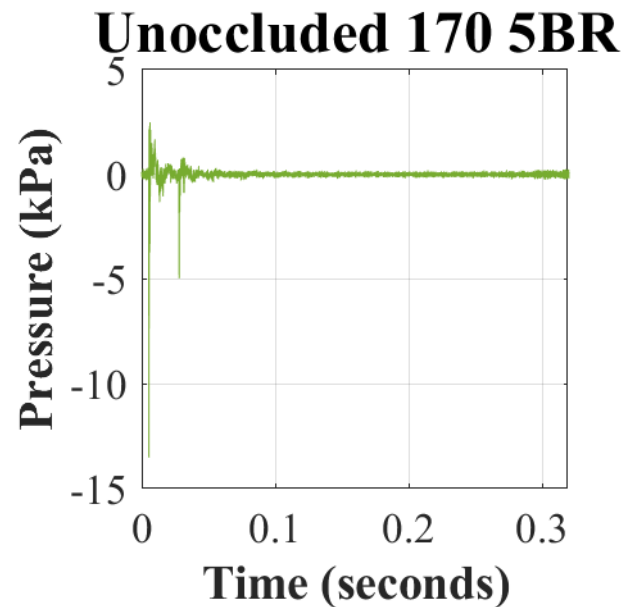
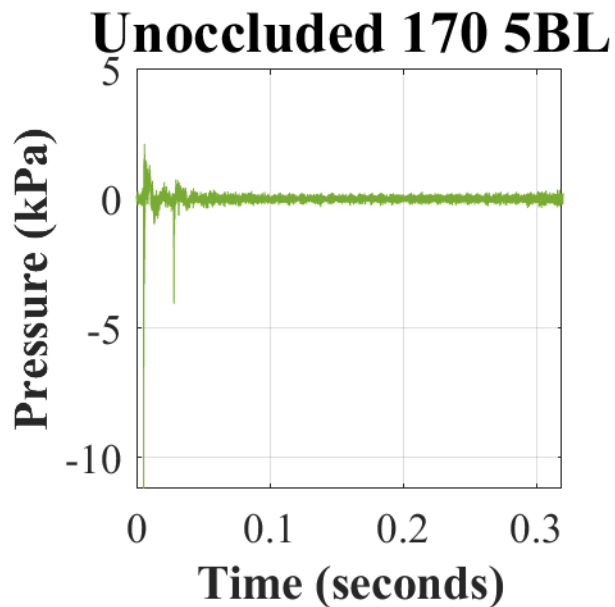
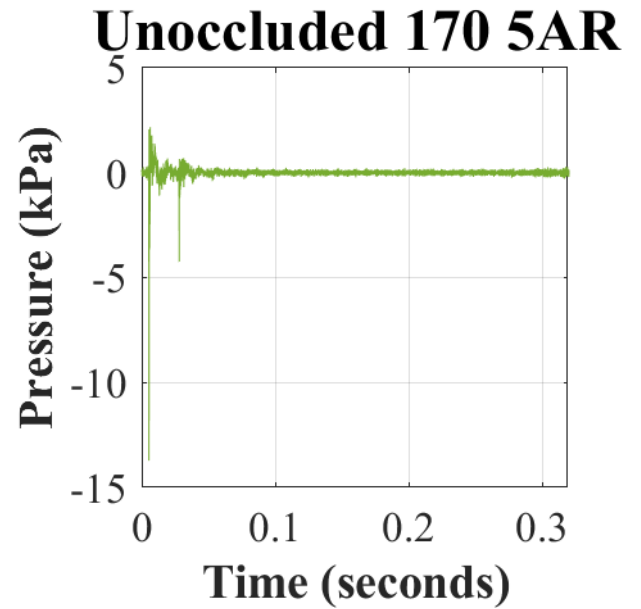
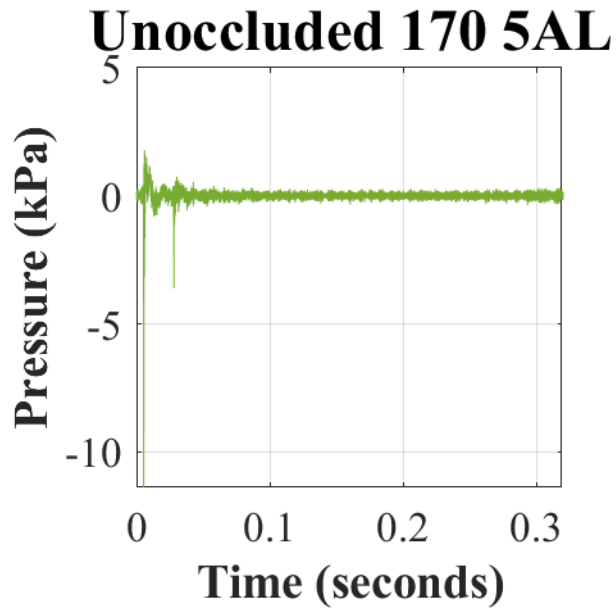


Unoccluded 170 4BL



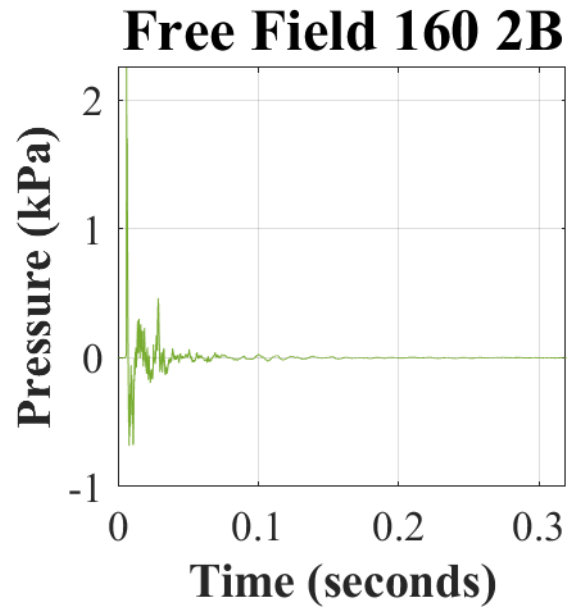
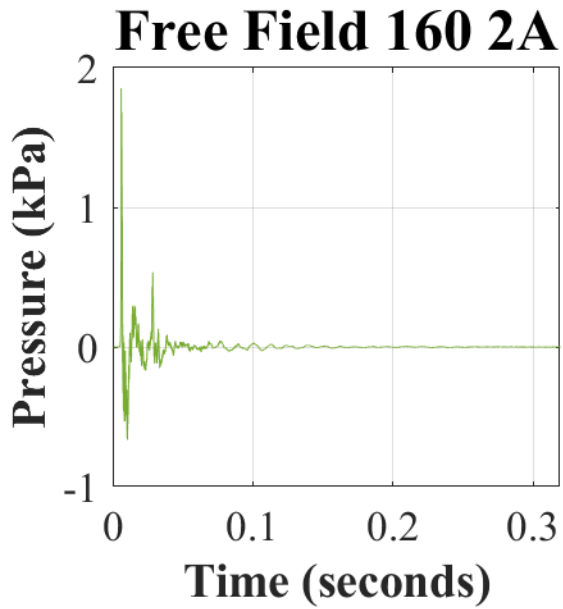
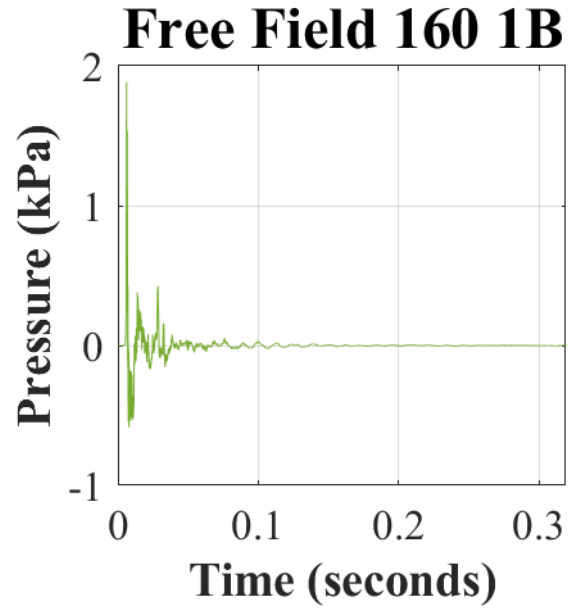
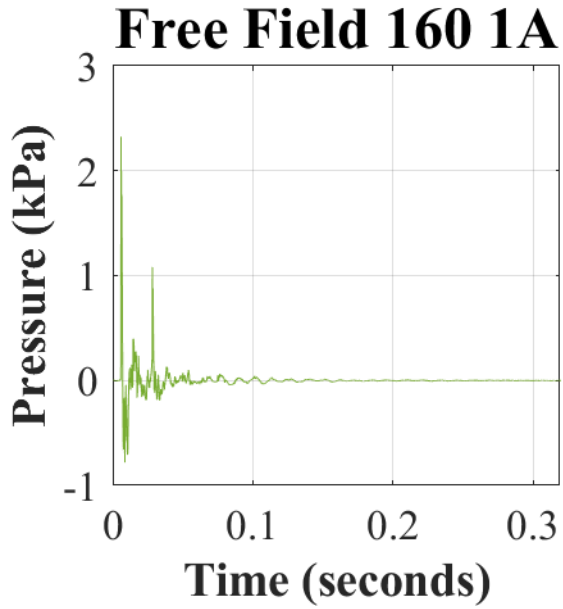
Unoccluded 170 4BR

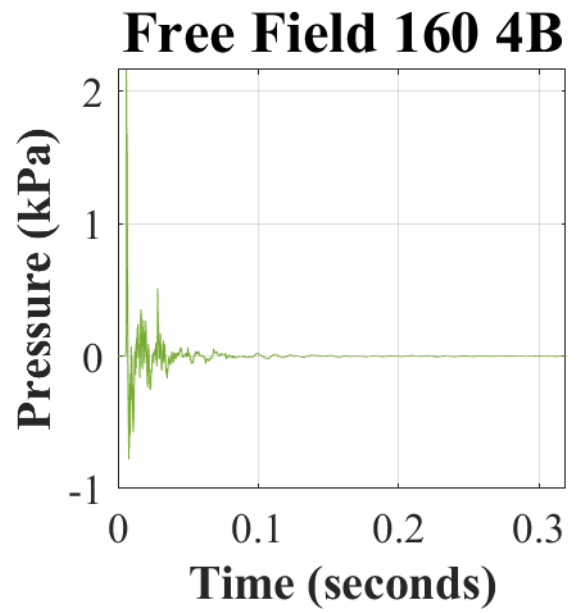
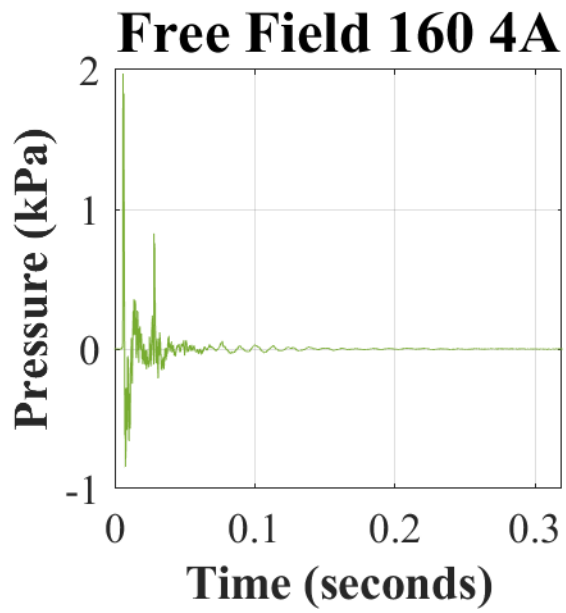
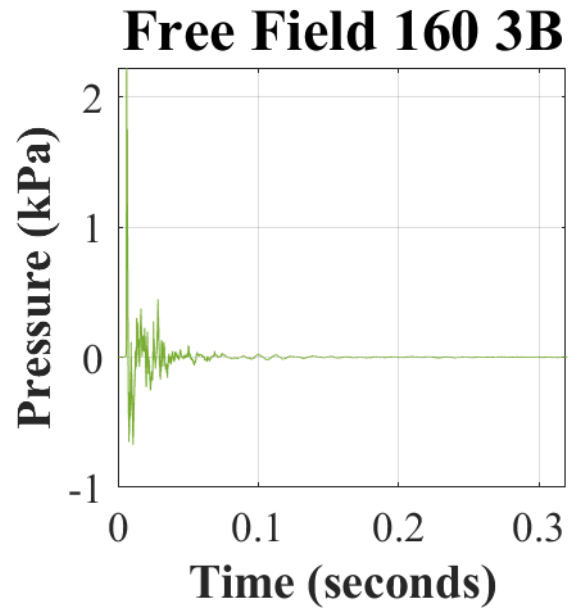
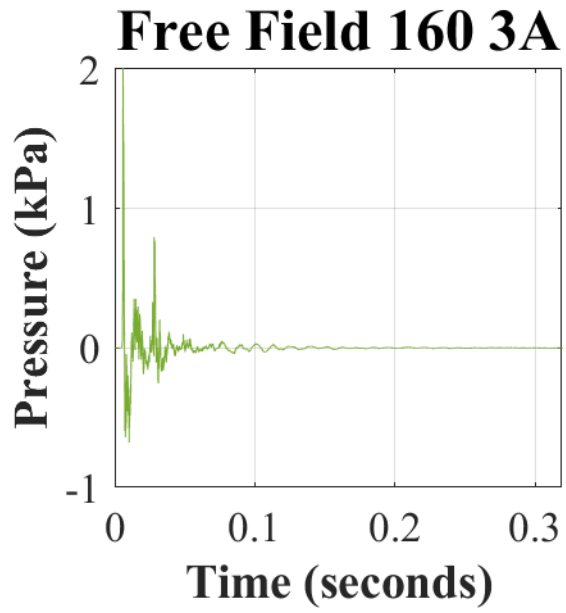


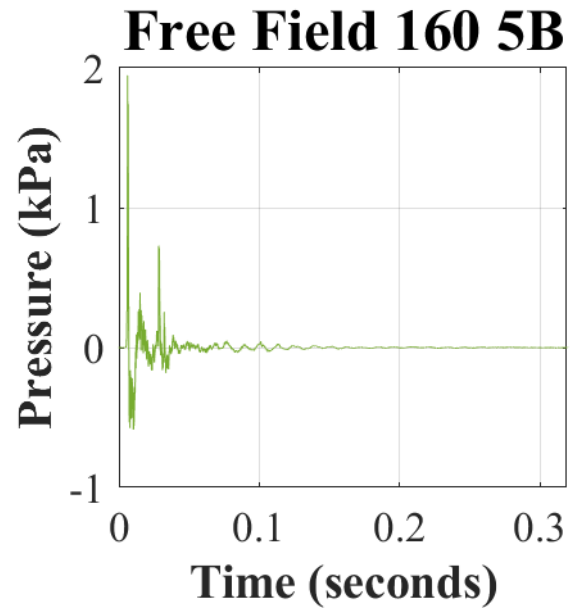
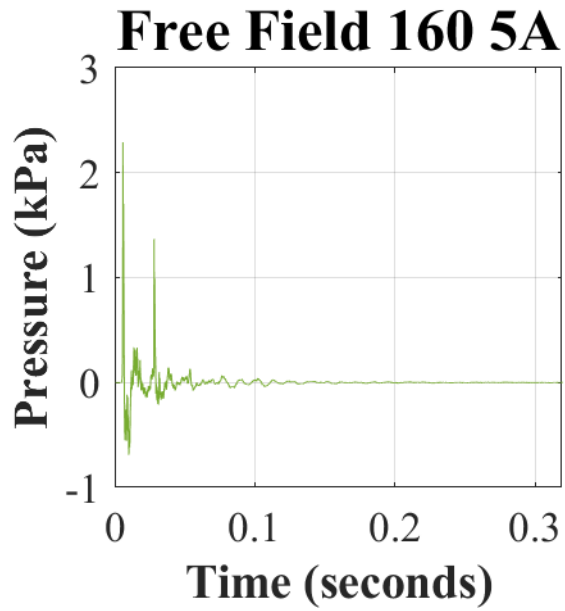


Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the earmuff doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or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

Appendix E. Recorded waveform (in kilopascals (kPa)) over time (in seconds (s)) of the impulse measured with the free-field probe at 160 dBp and the ComTac™ III (OFF) donned.

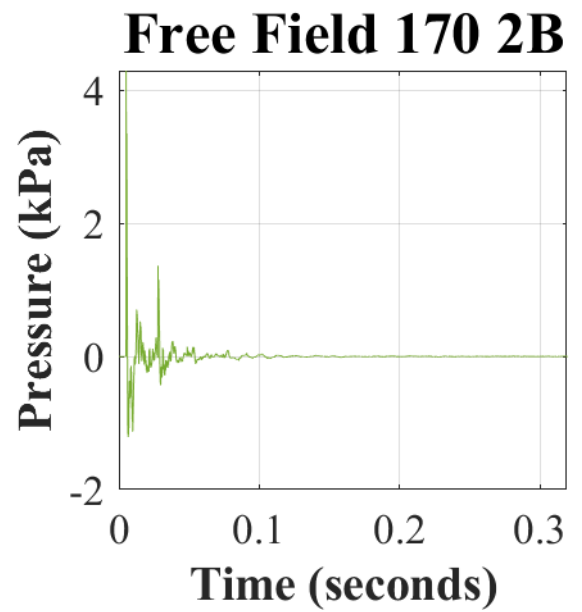
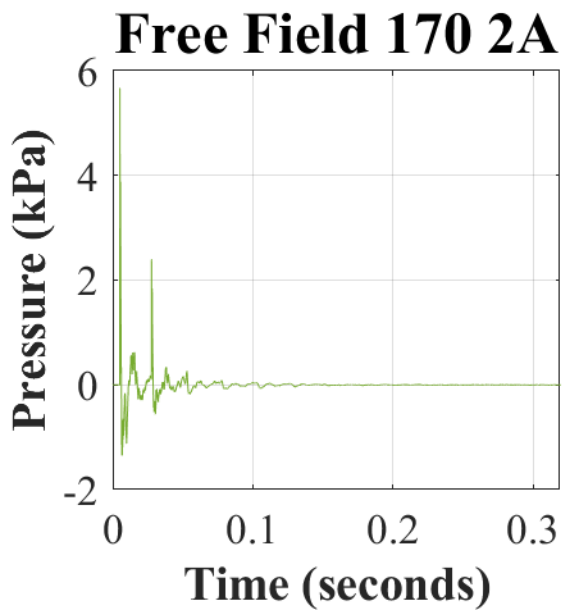
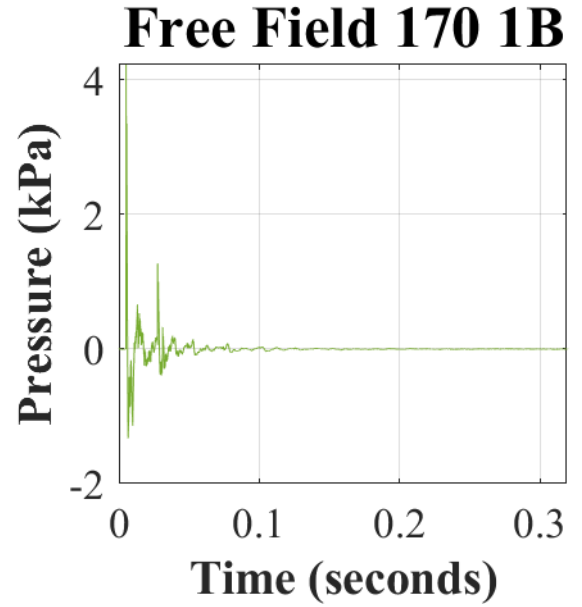
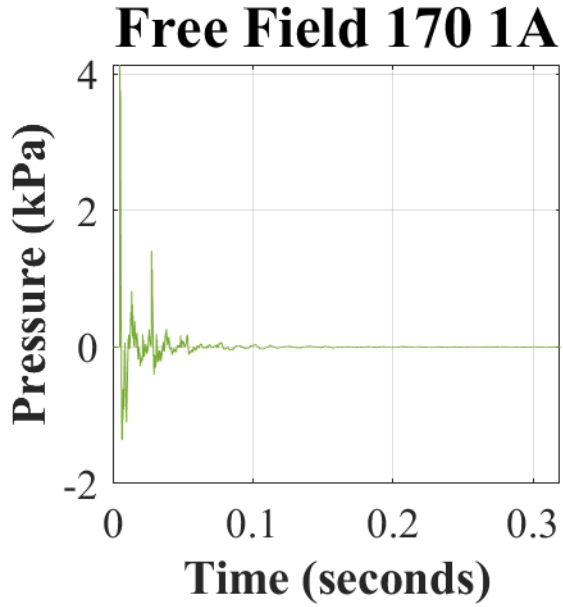


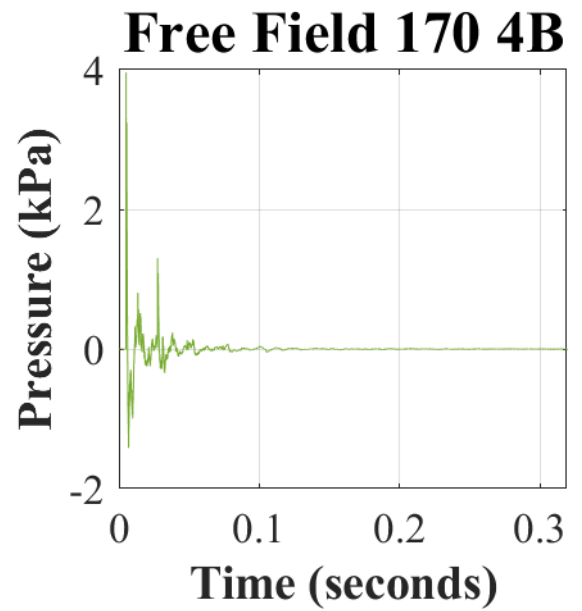
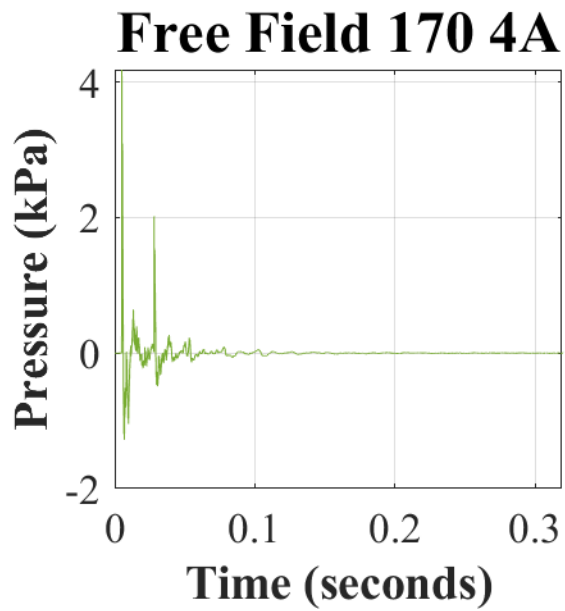
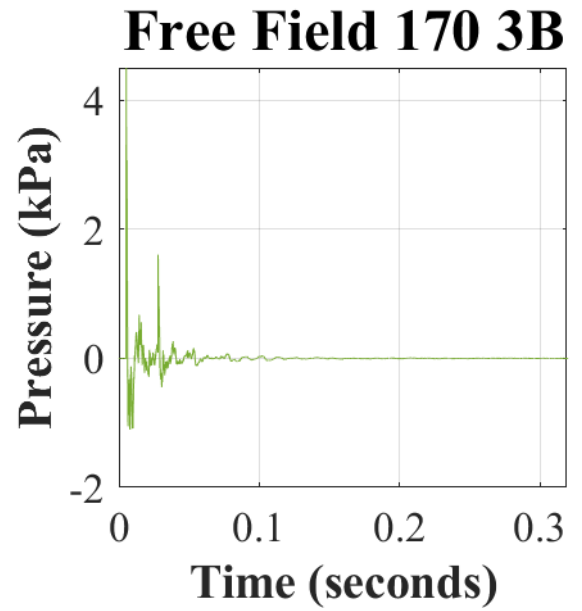
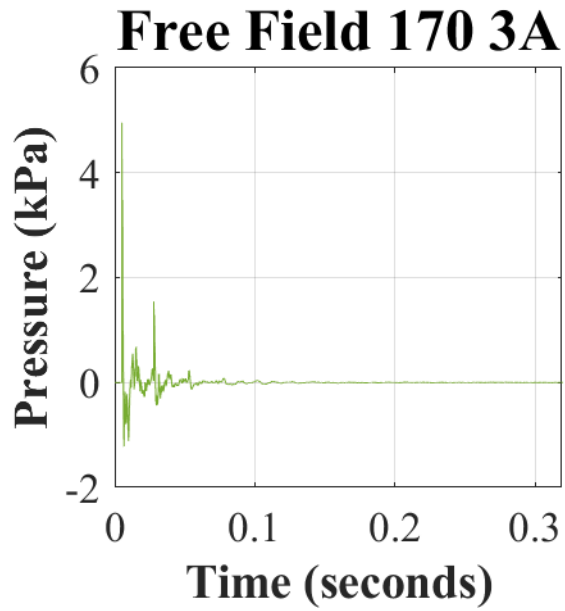


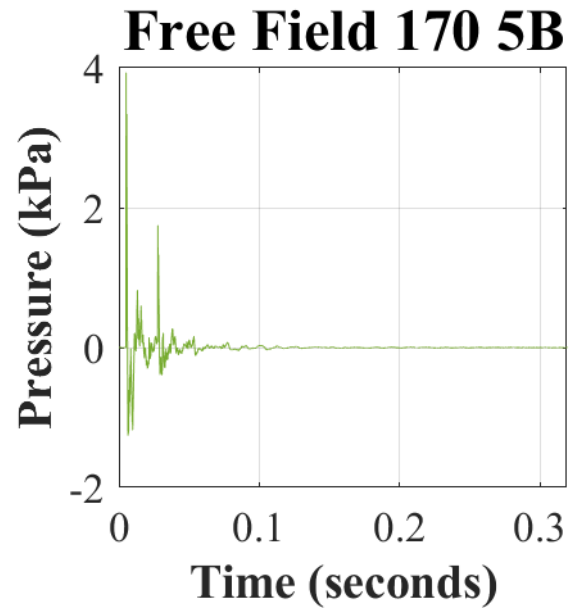
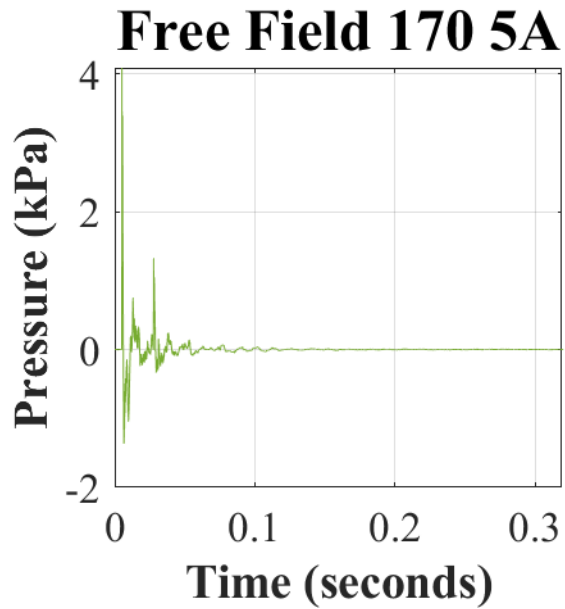


Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (170 dBp), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

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

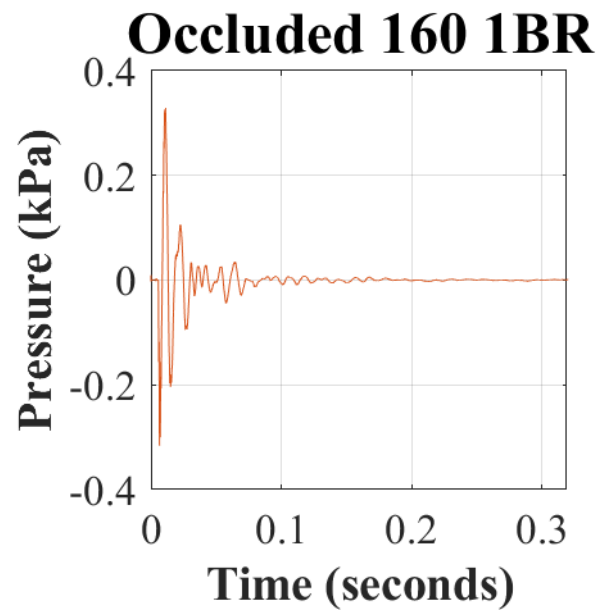
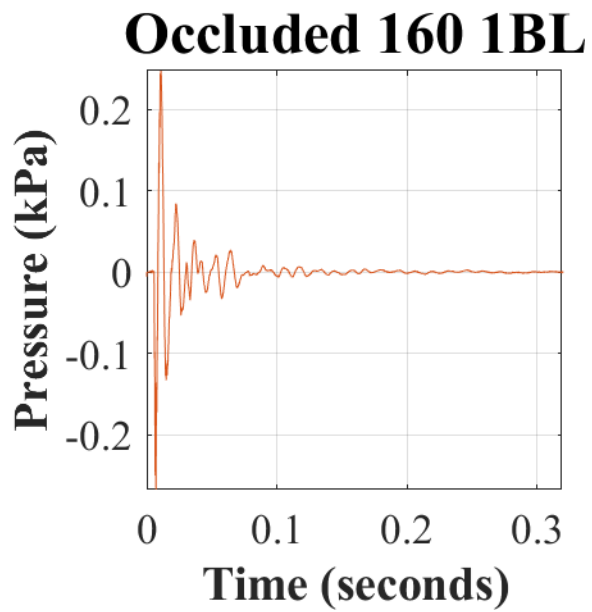
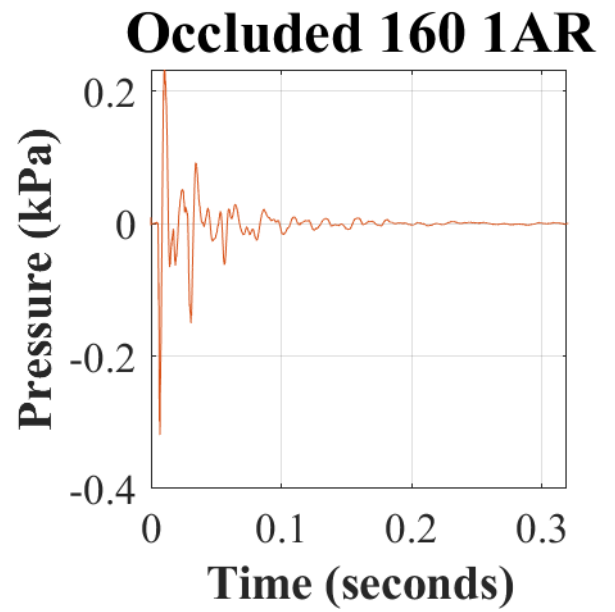
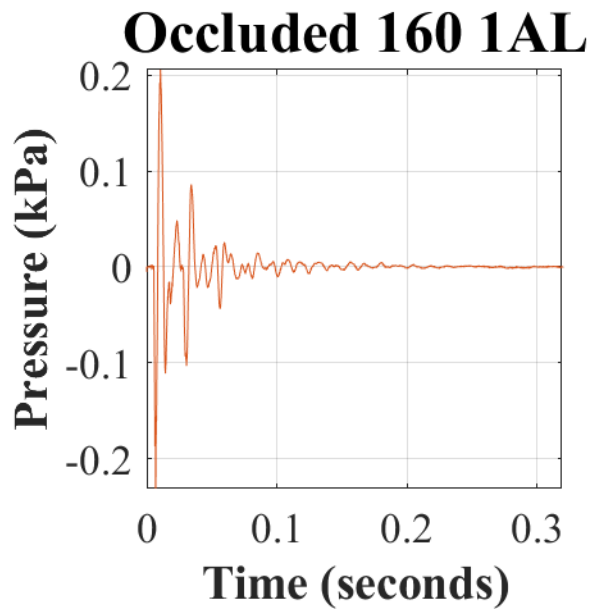




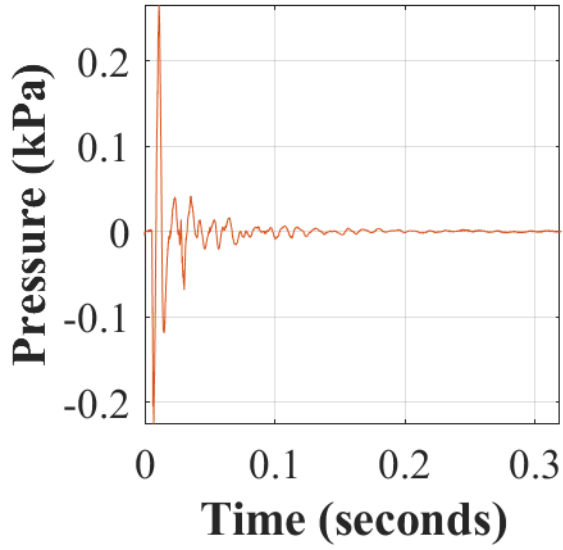


Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (170 dBp), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

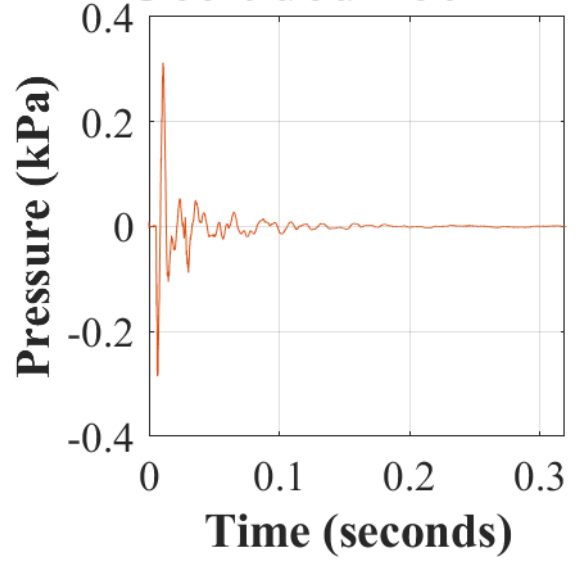
Appendix G. Recorded occluded (earmuff donned) waveforms (in kilopascals (kPa)) over time (in seconds (s)) in response to 160 dBp with the ComTac™ III (MAX).



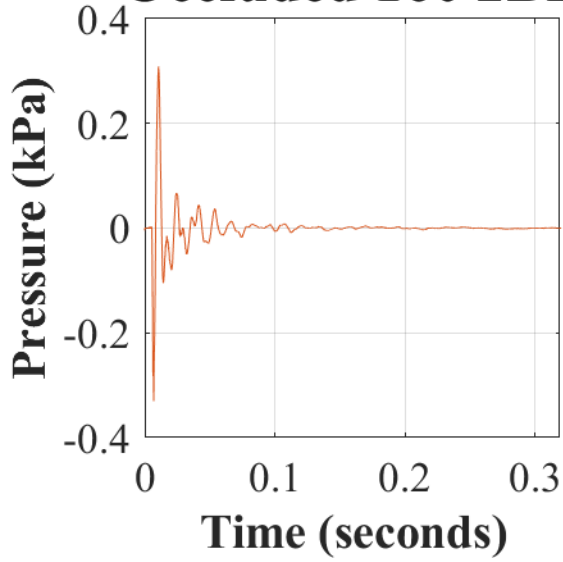
Occluded 160 2AL



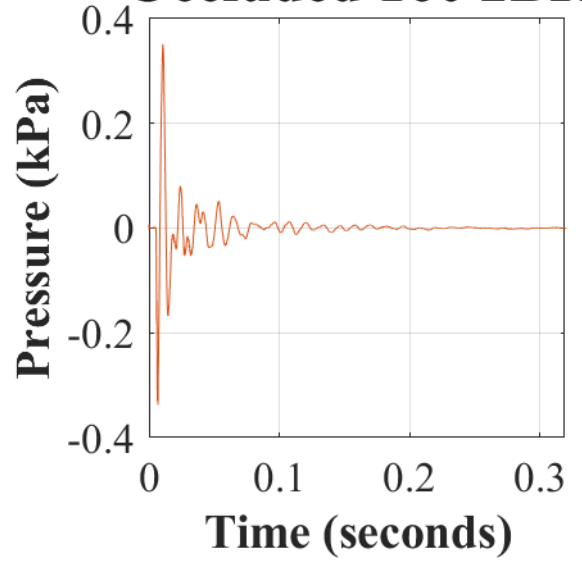
Occluded 160 2AR



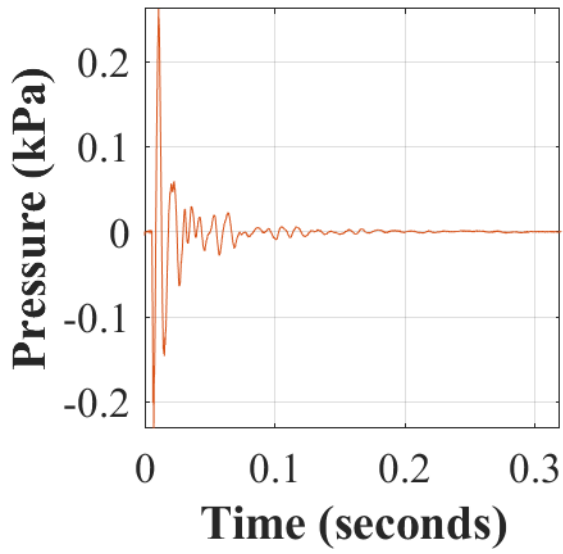
Occluded 160 2BL



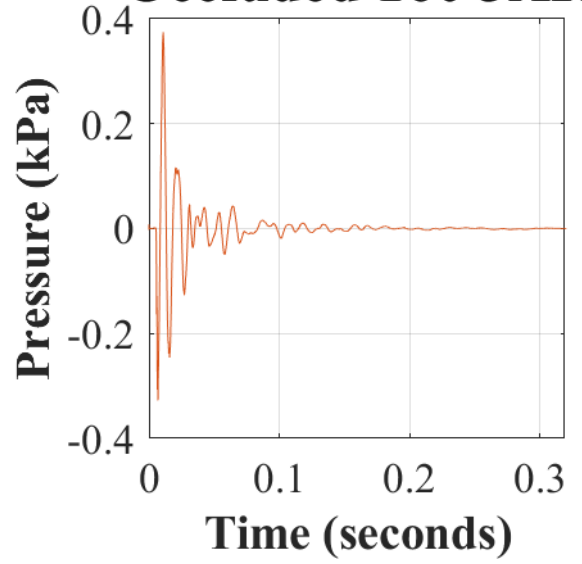
Occluded 160 2BR



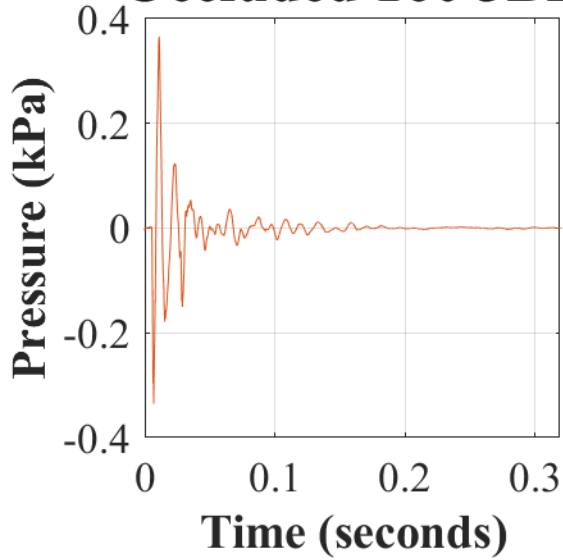
Occluded 160 3AL



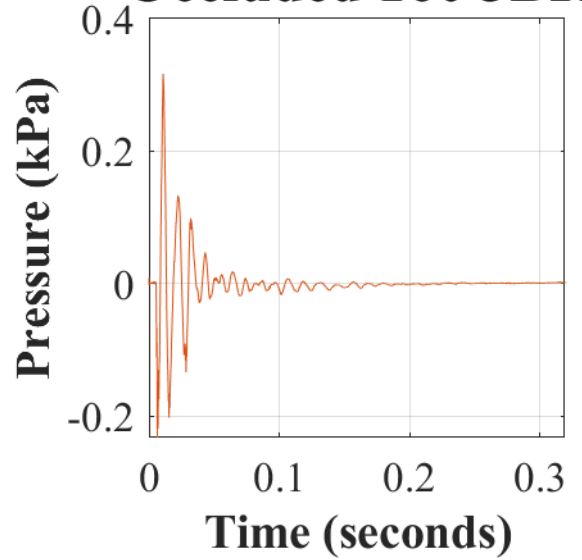
Occluded 160 3AR



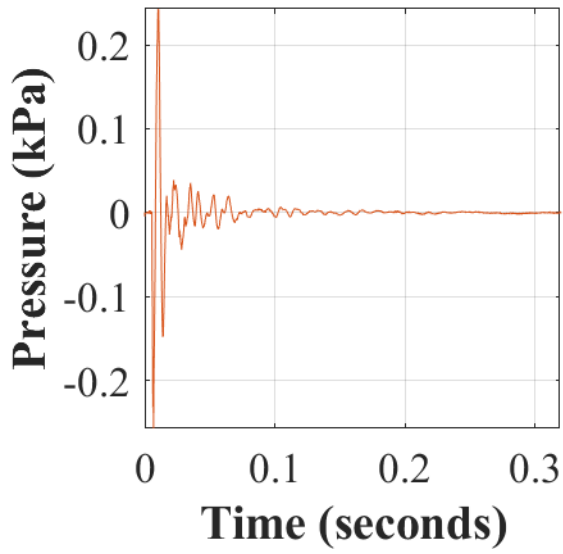
Occluded 160 3BL



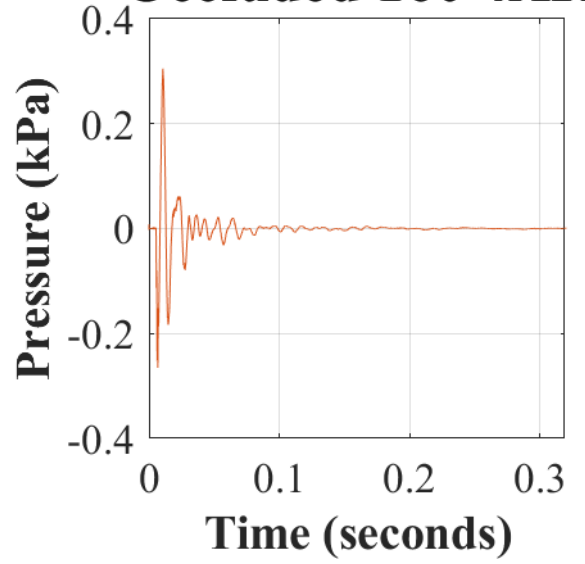
Occluded 160 3BR



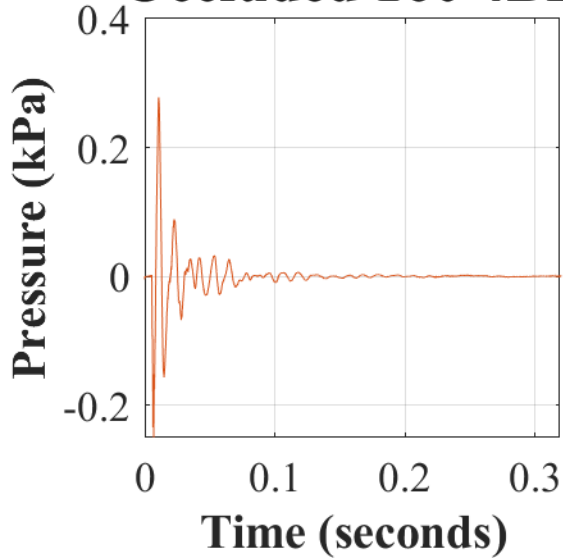
Occluded 160 4AL



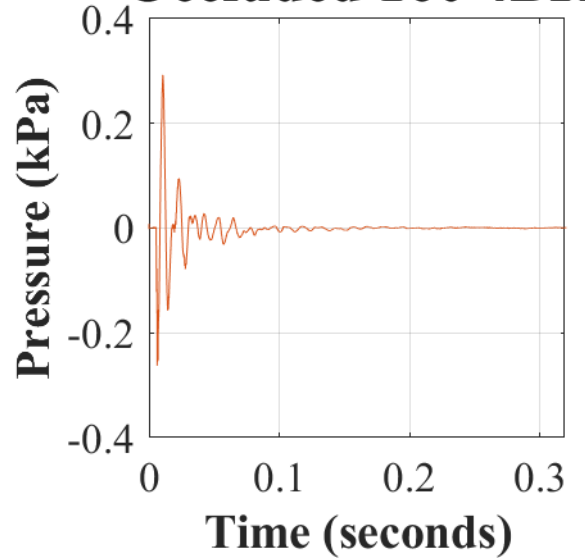
Occluded 160 4AR



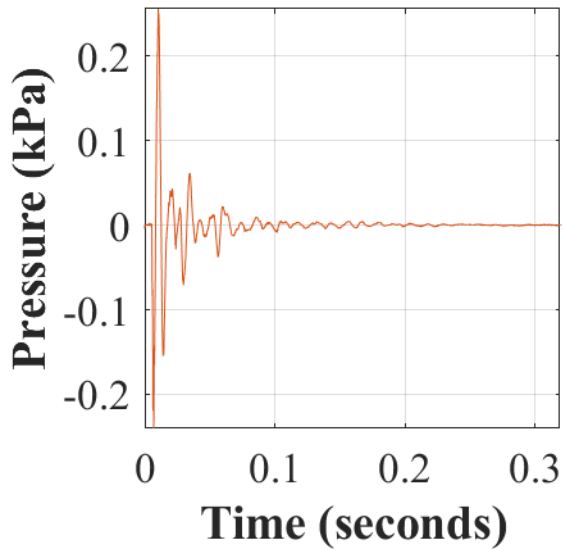
Occluded 160 4BL



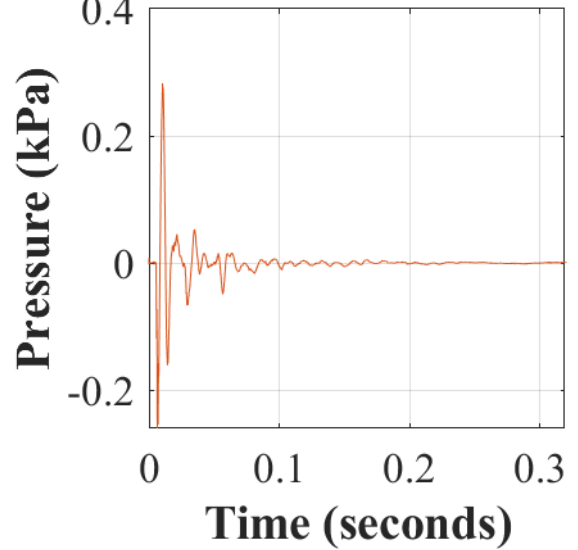
Occluded 160 4BR



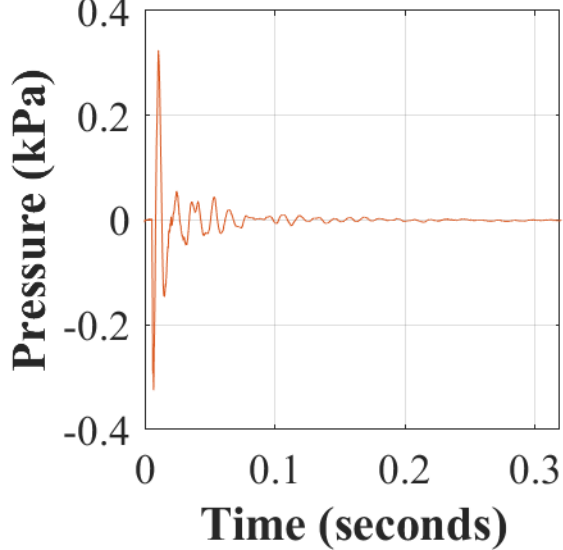
Occluded 160 5AL



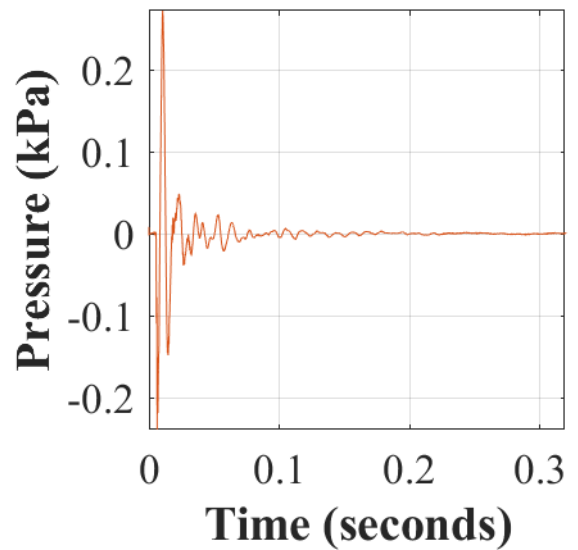
Occluded 160 5AR



Occluded 160 5BL

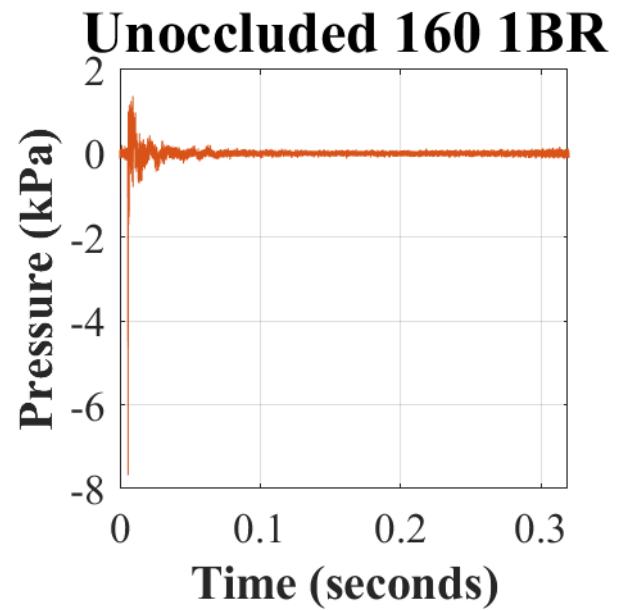
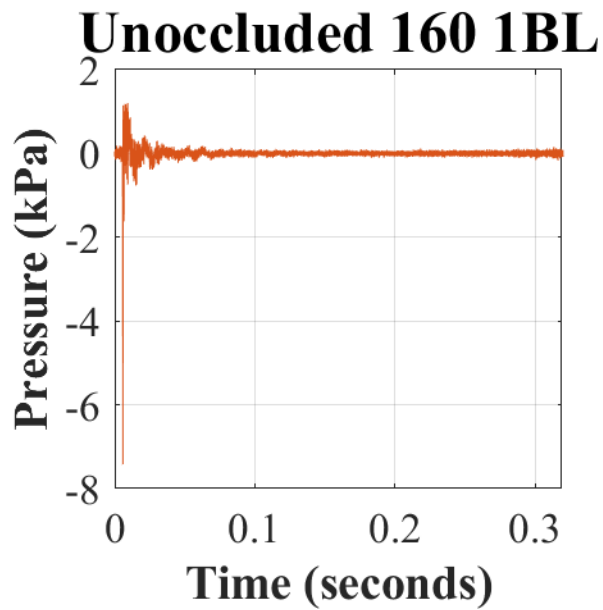
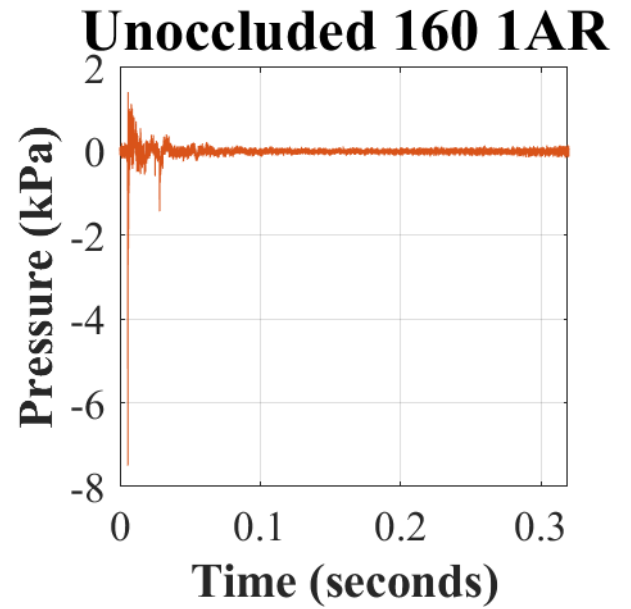
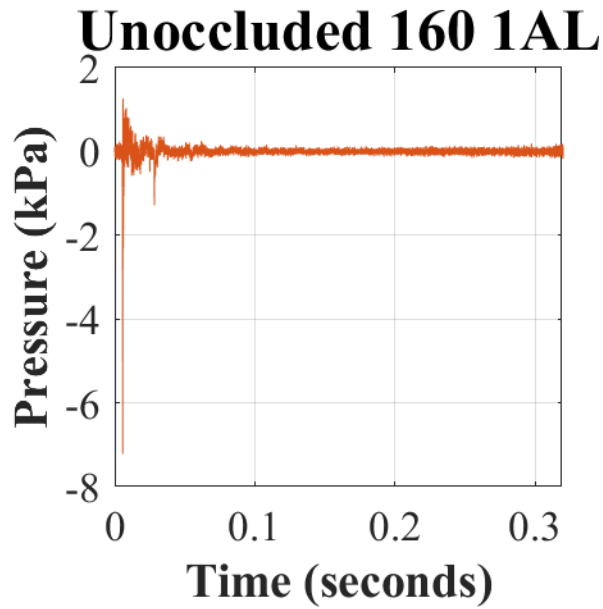


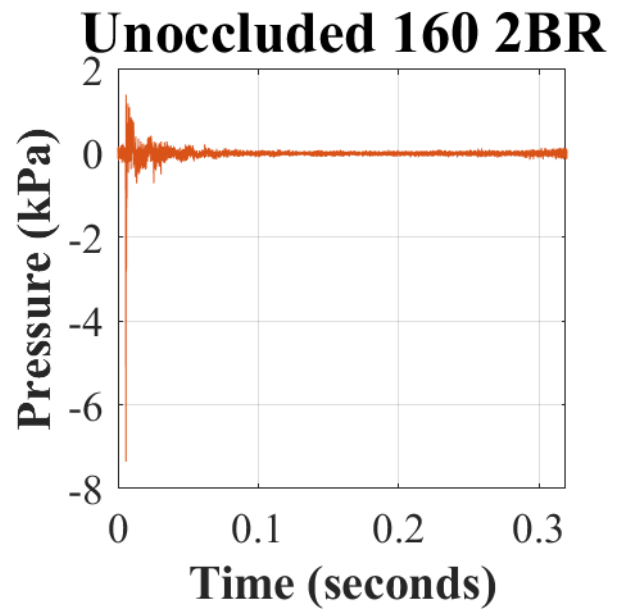
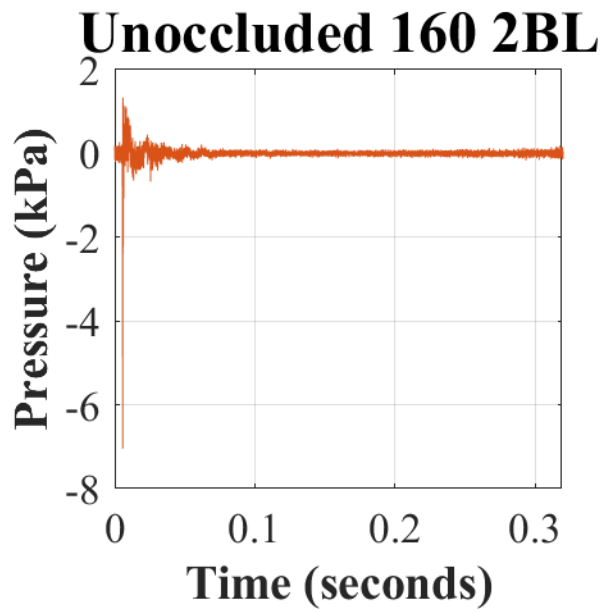
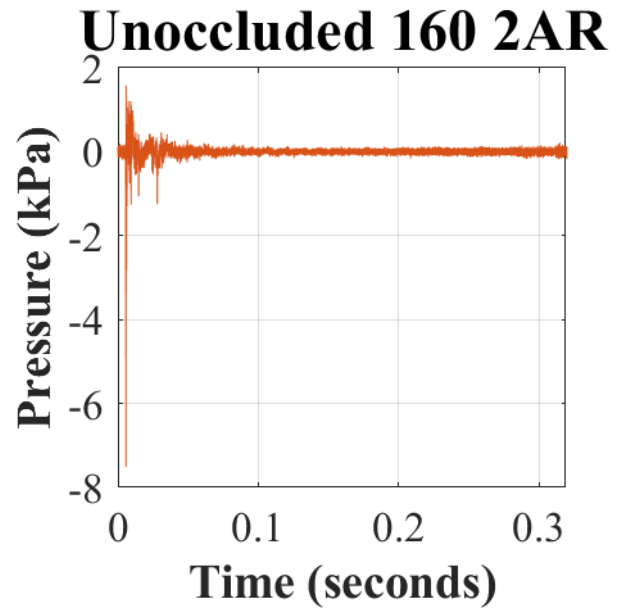
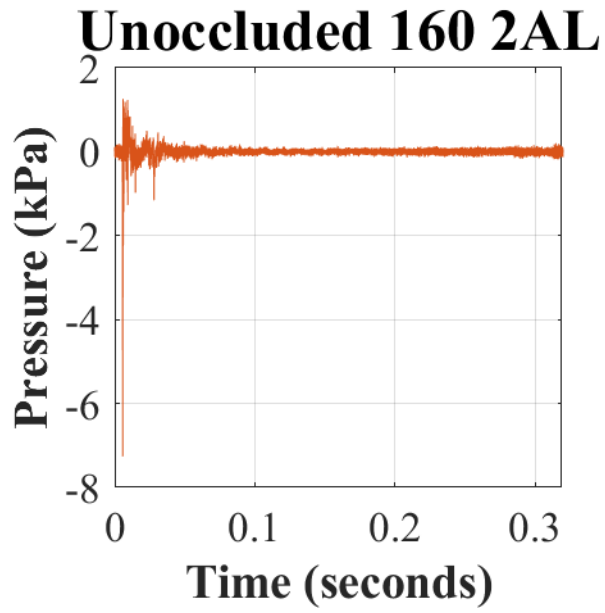
Occluded 160 5BR

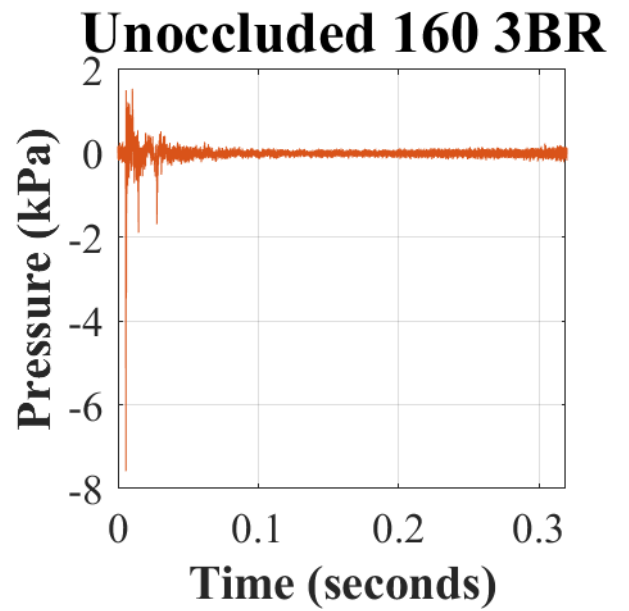
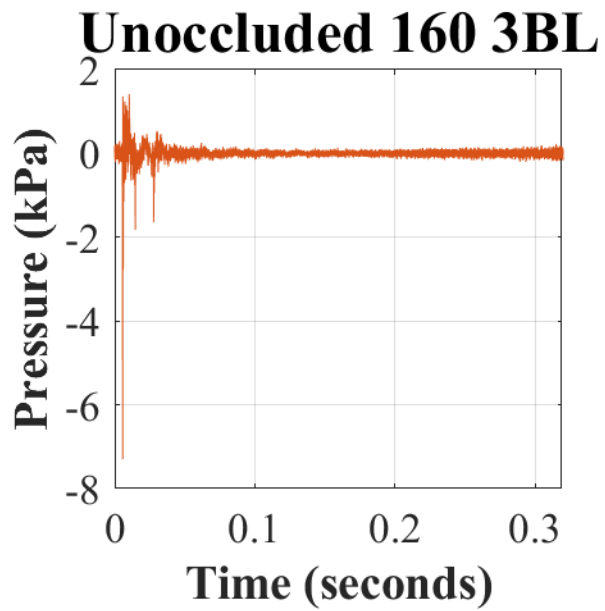
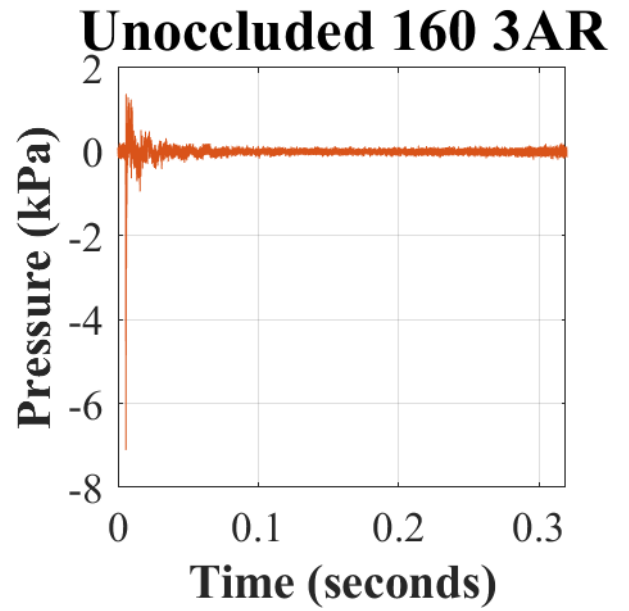
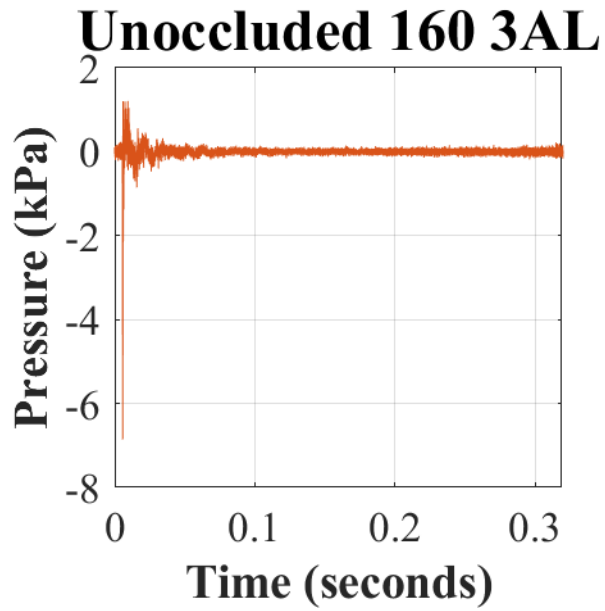


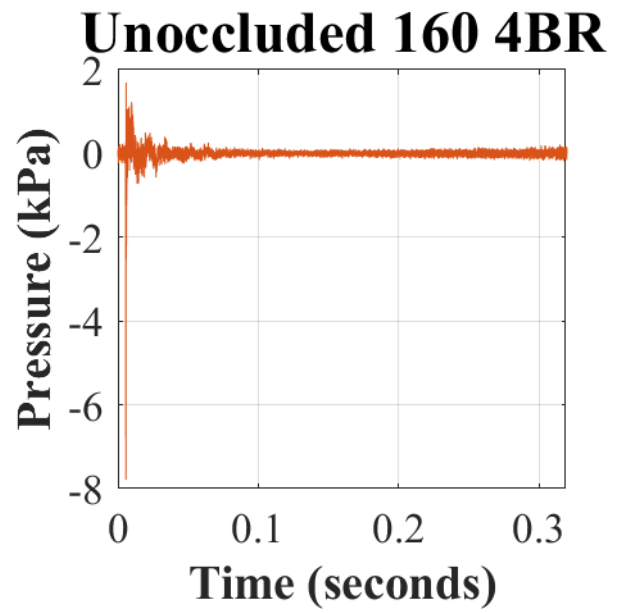
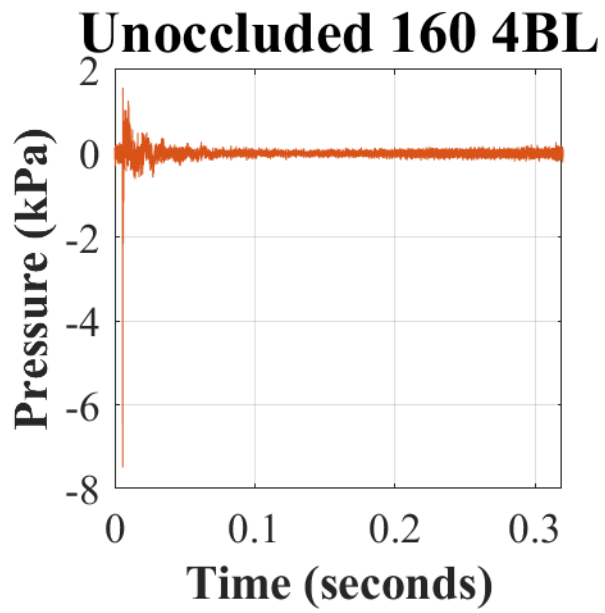
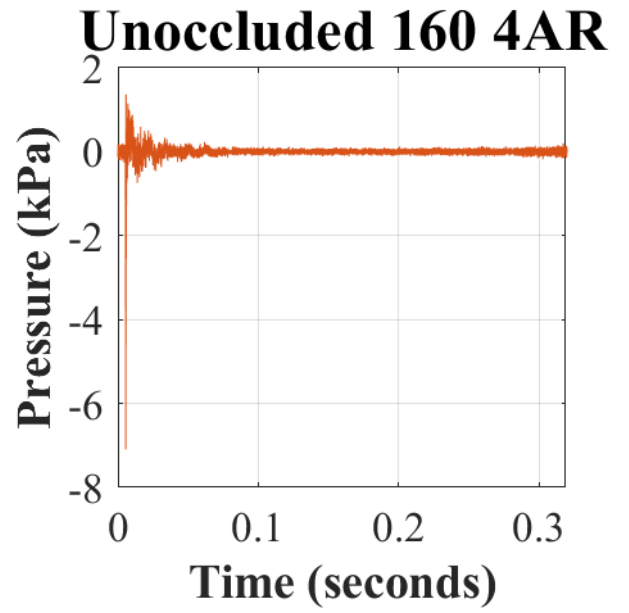
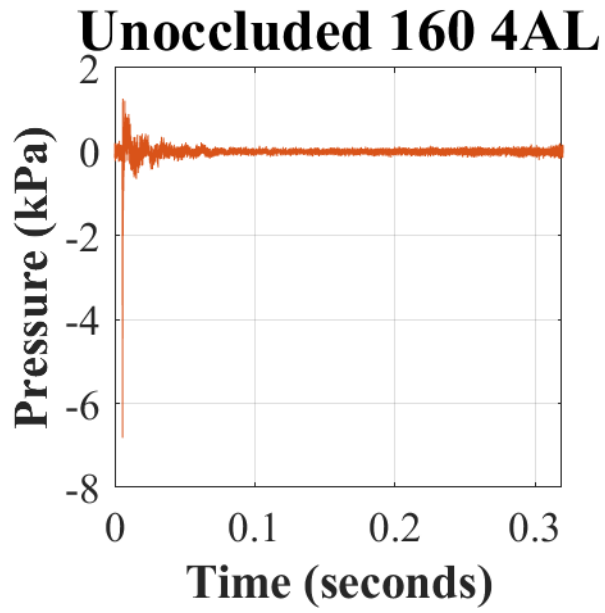
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the earmuff donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B)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

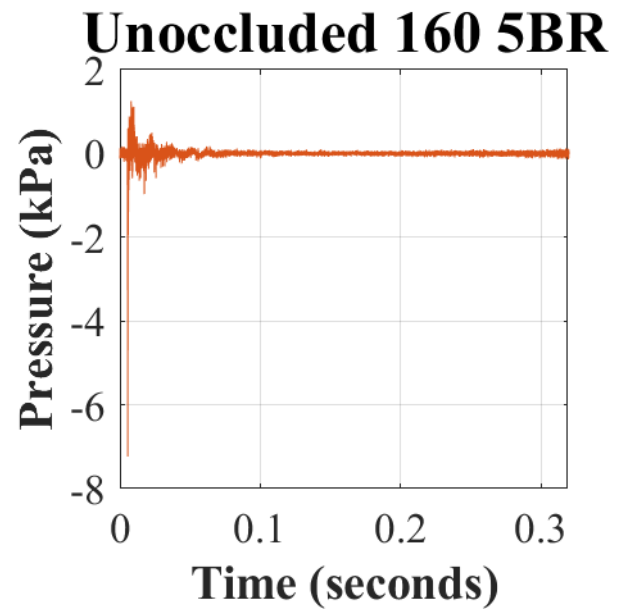
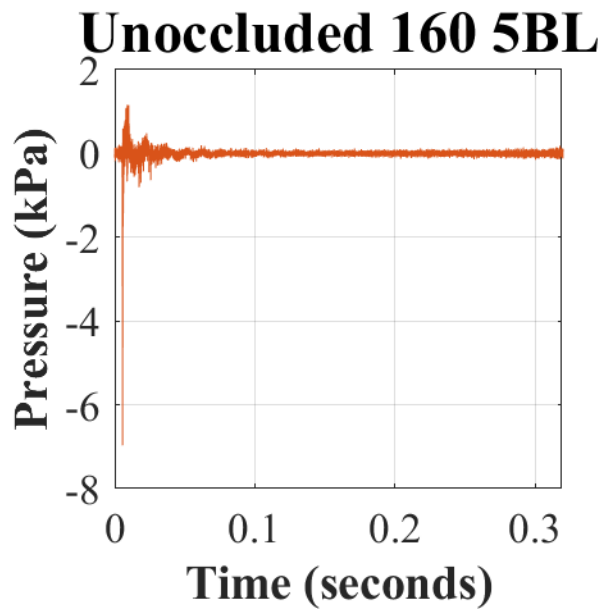
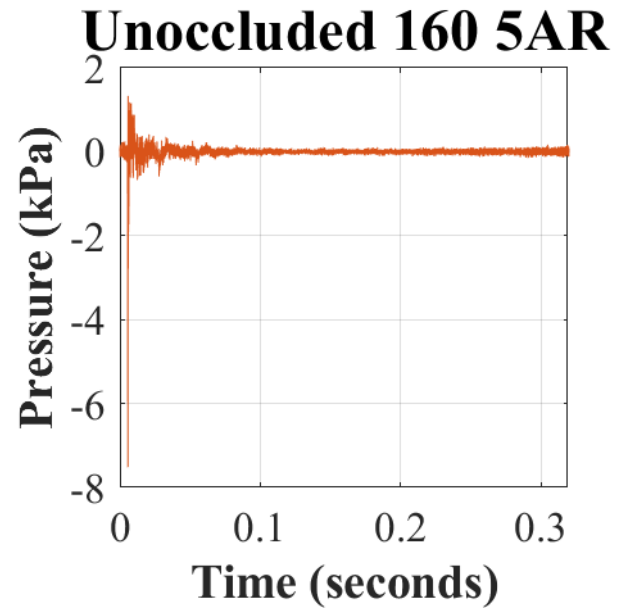
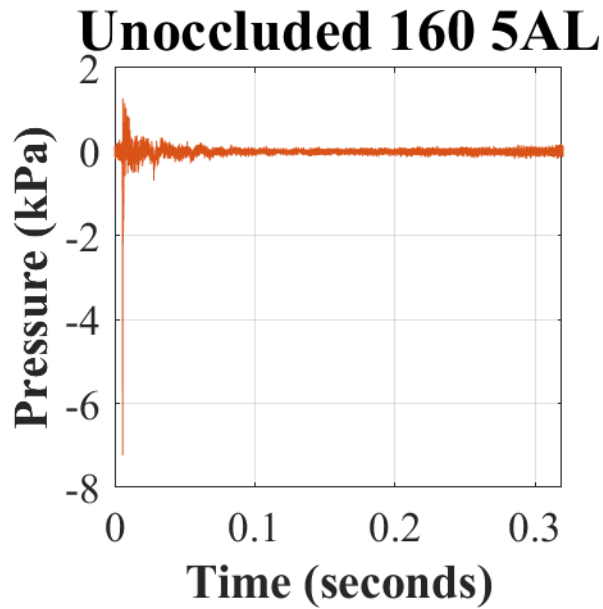
Appendix H. Estimated unoccluded (earmuff doffed) waveforms (in kilopascals (kPa)) over time (in seconds (s)) in response to 160 dBp with the ComTac™ III (MAX).







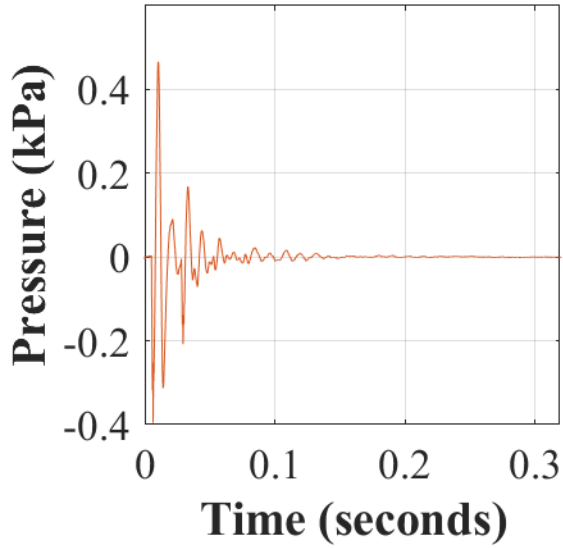




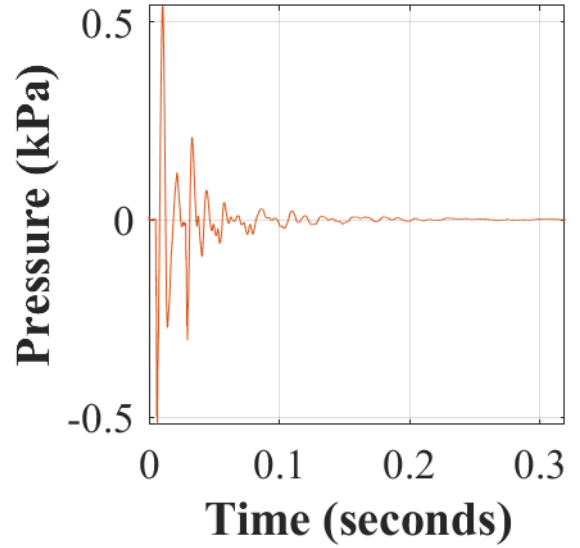
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the earmuff doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or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

Appendix I. Recorded occluded (earmuff donned) waveforms (in kilopascals (kPa)) over time (in seconds (s)) in response to 170 dBp with the ComTac™ III (MAX).

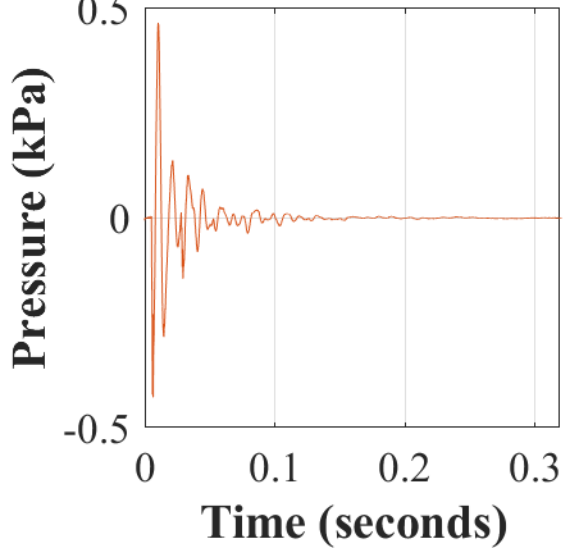
Occluded 170 1AL



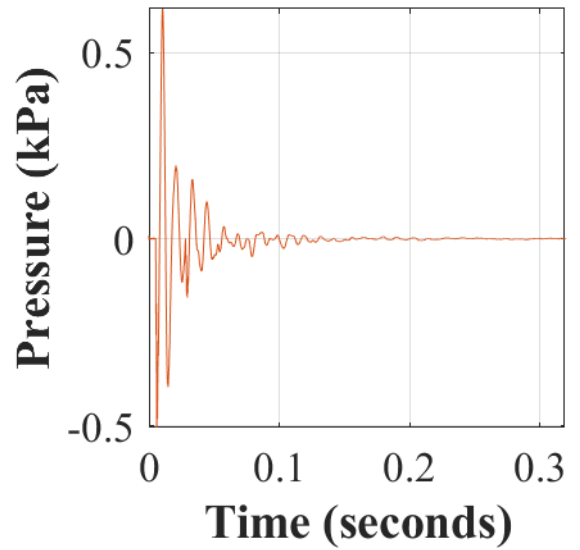
Occluded 170 1AR



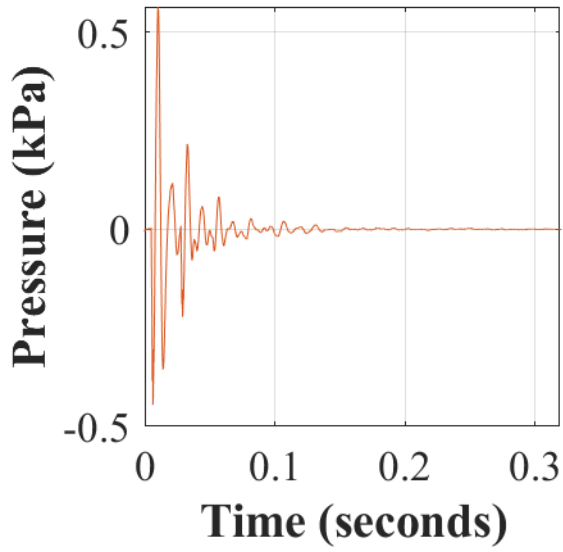
Occluded 170 1BL



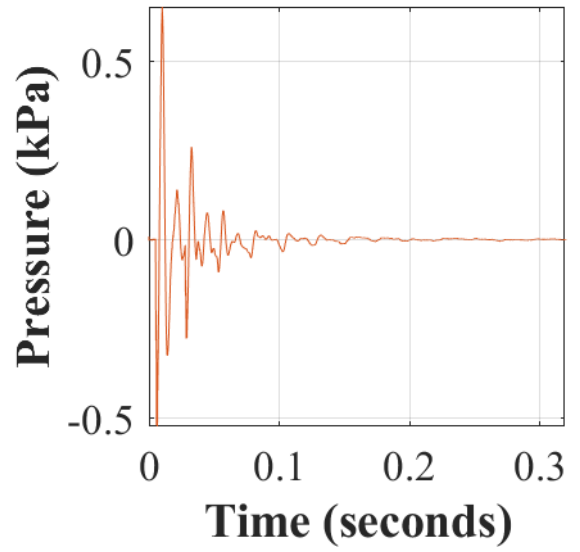
Occluded 170 1BR



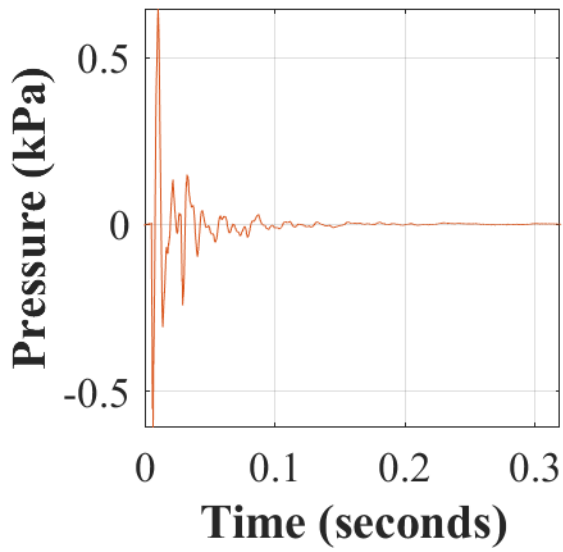
Occluded 170 2AL



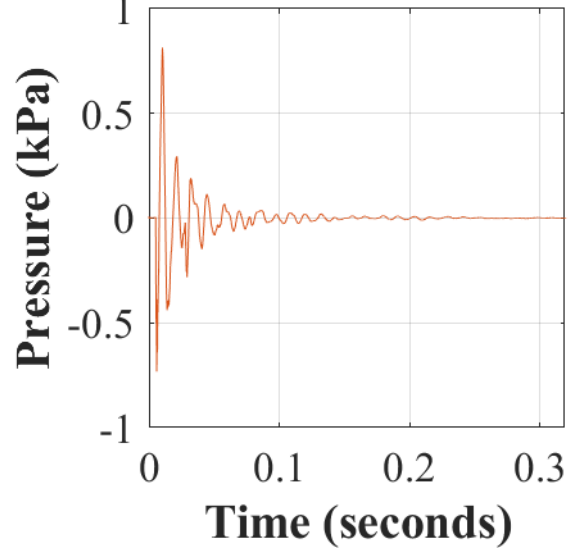
Occluded 170 2AR



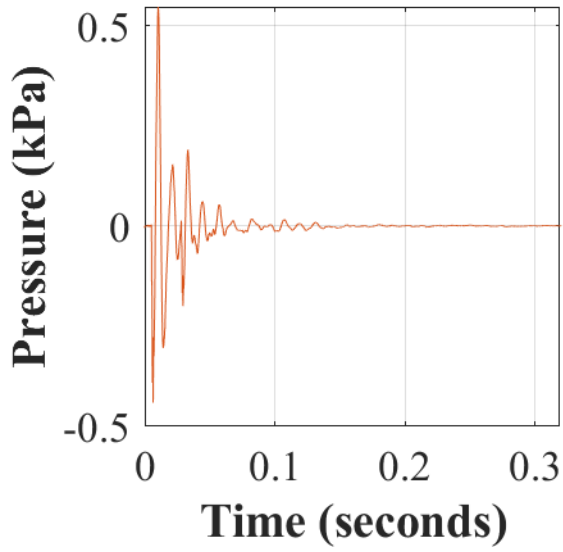
Occluded 170 2BL



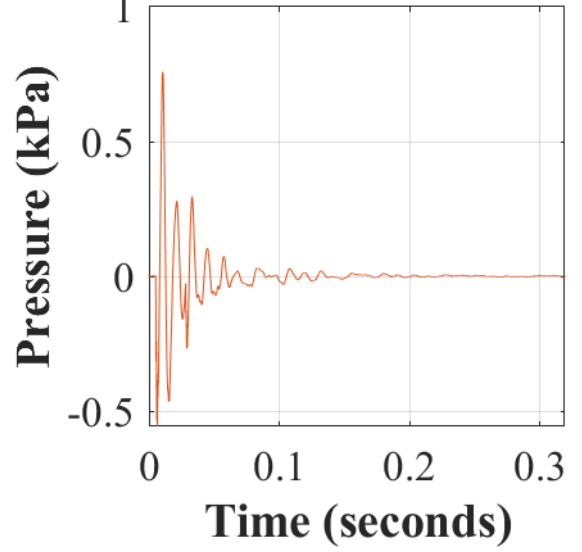
Occluded 170 2BR



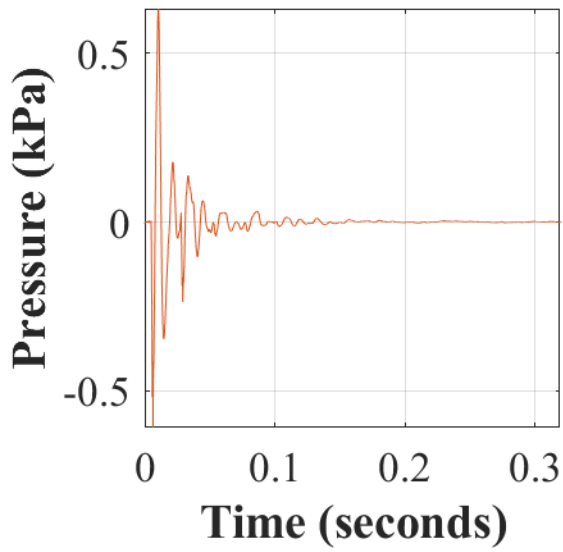
Occluded 170 3AL



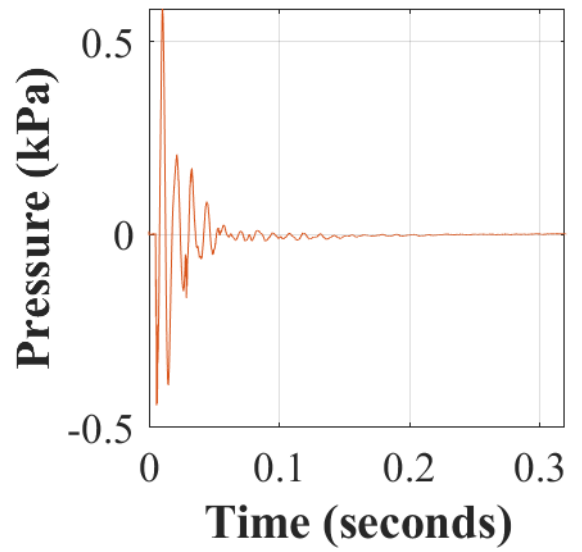
Occluded 170 3AR

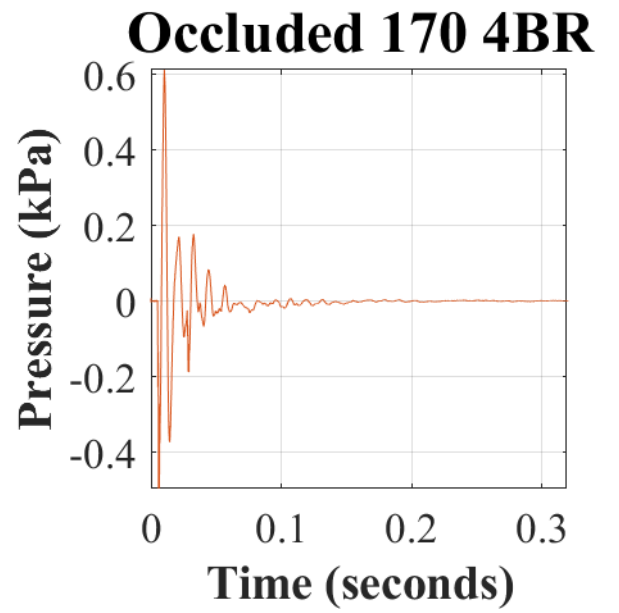
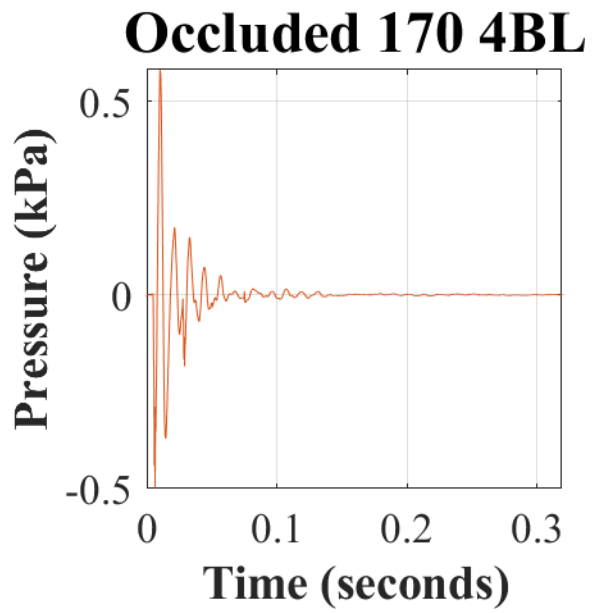
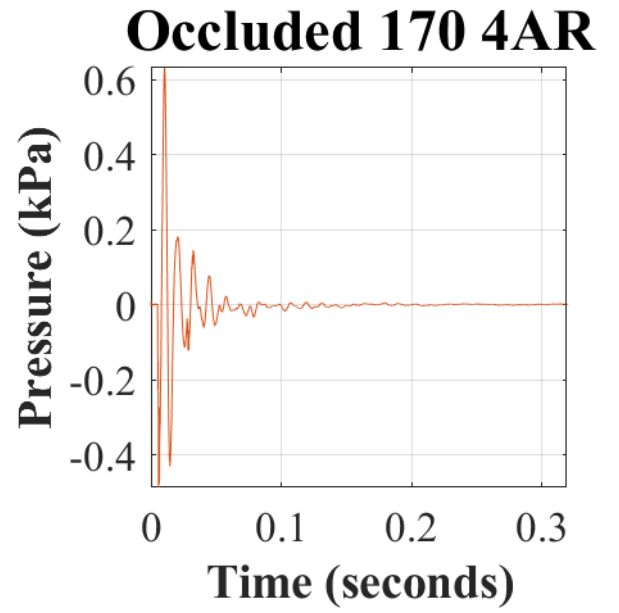
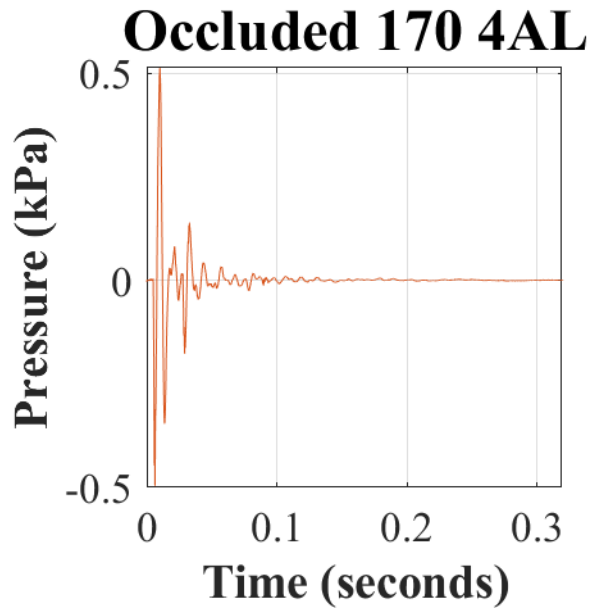


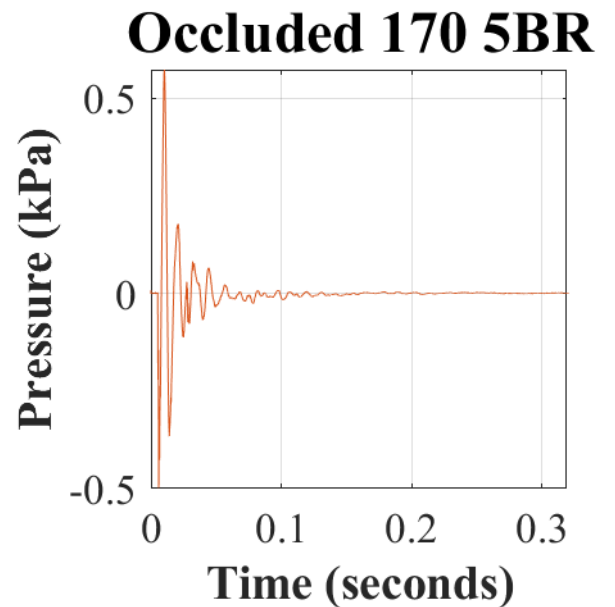
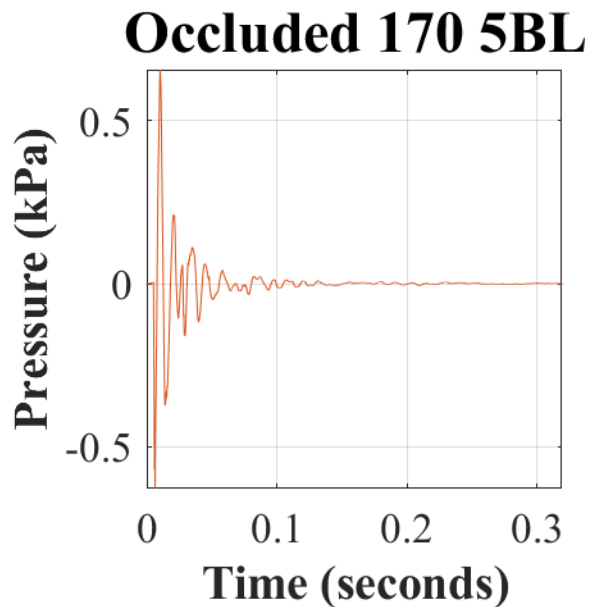
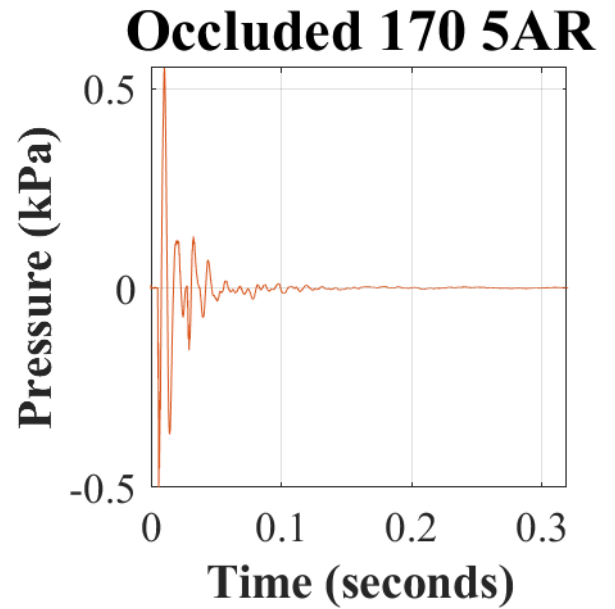
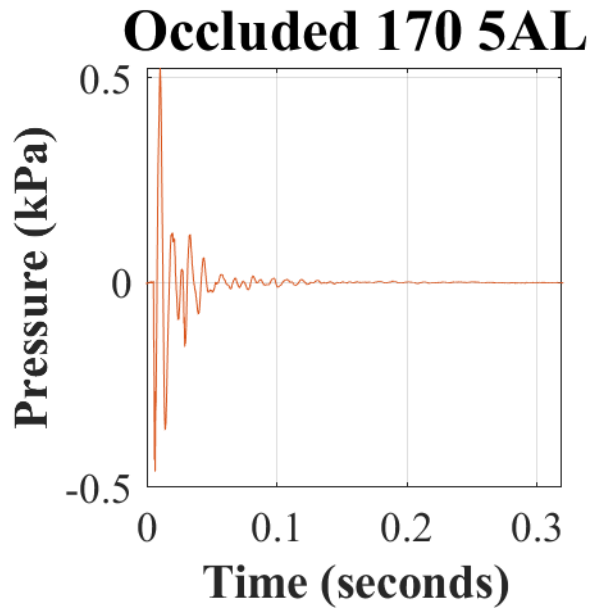
Occluded 170 3BL



Occluded 170 3BR

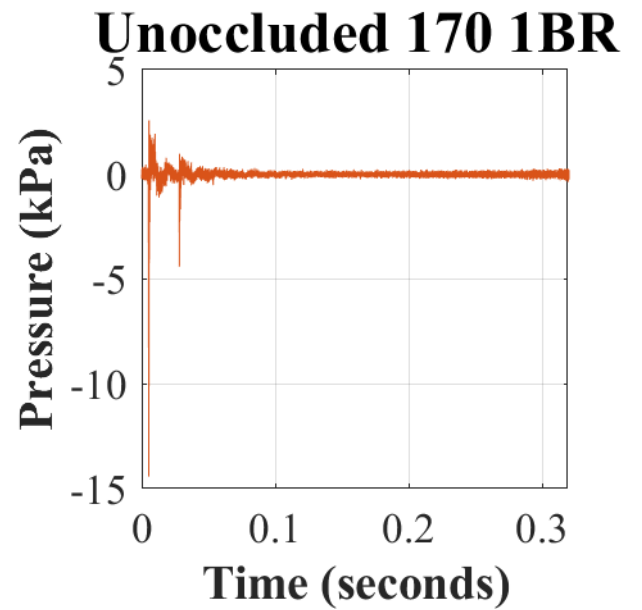
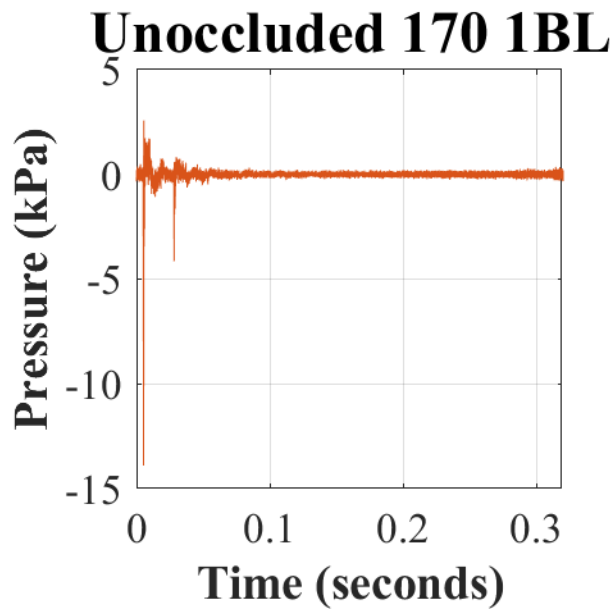
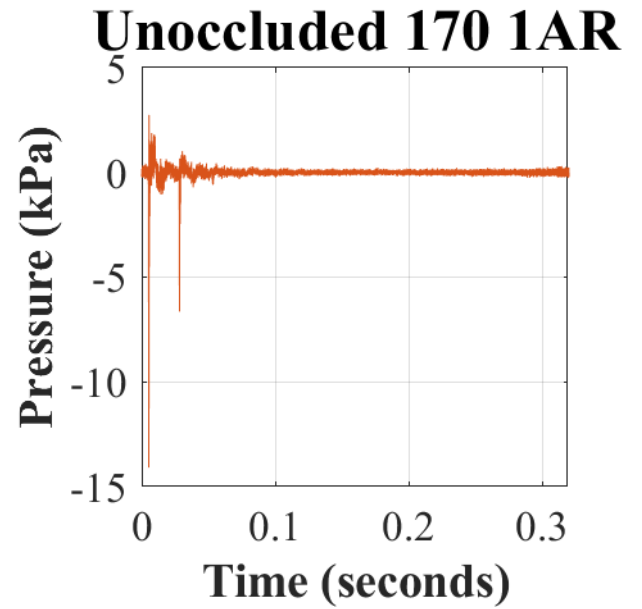
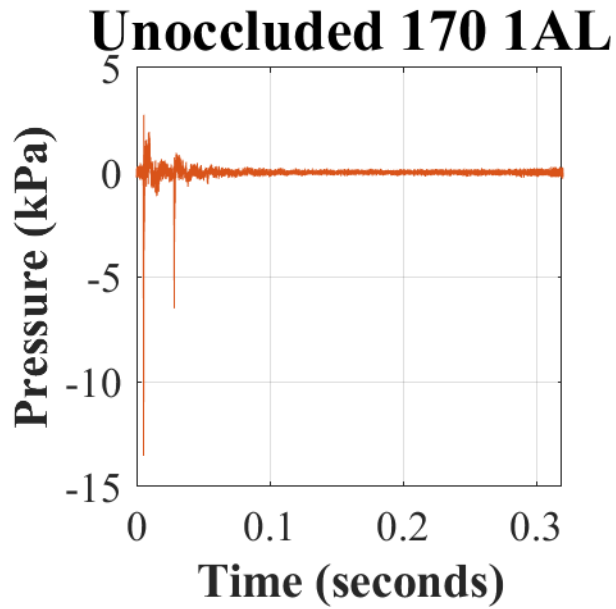


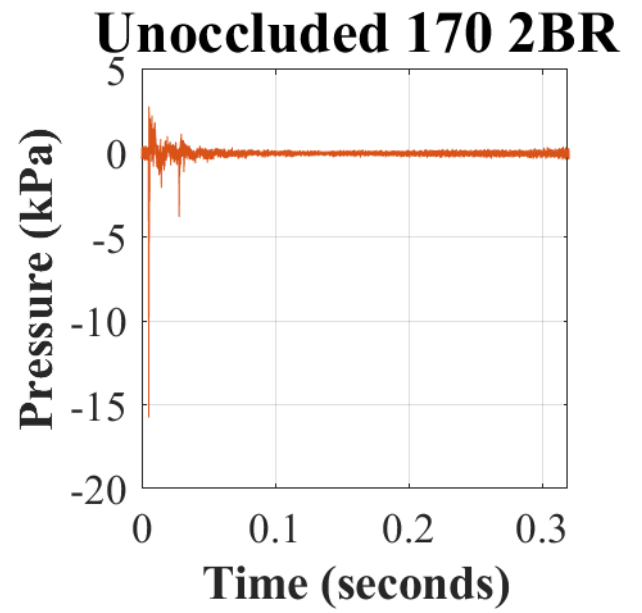
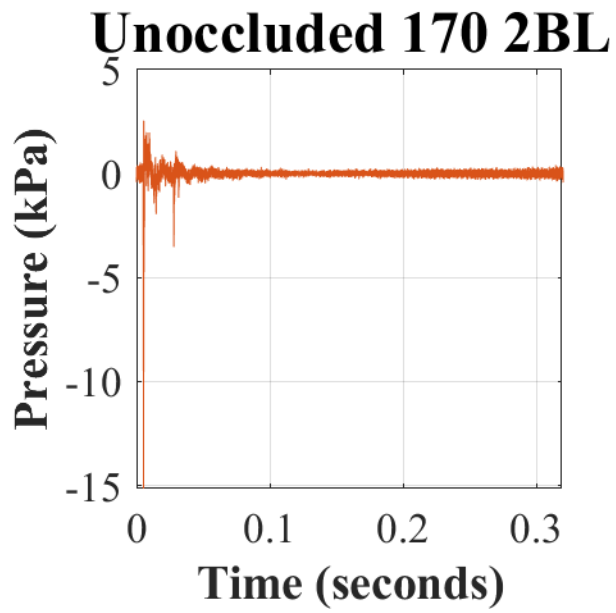
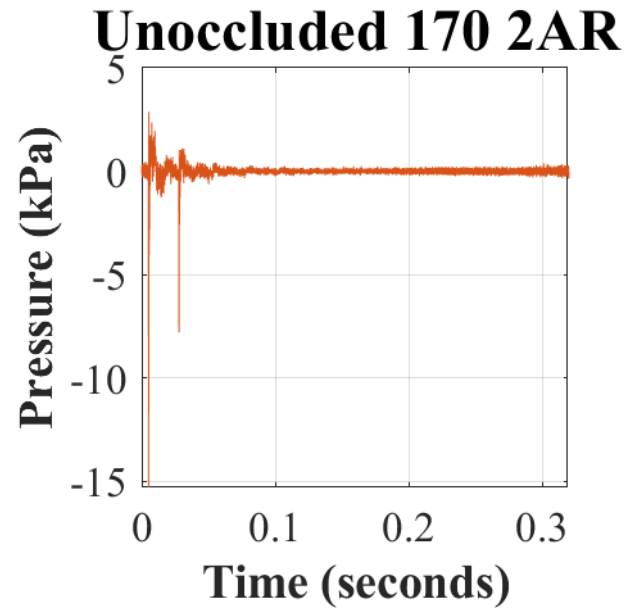
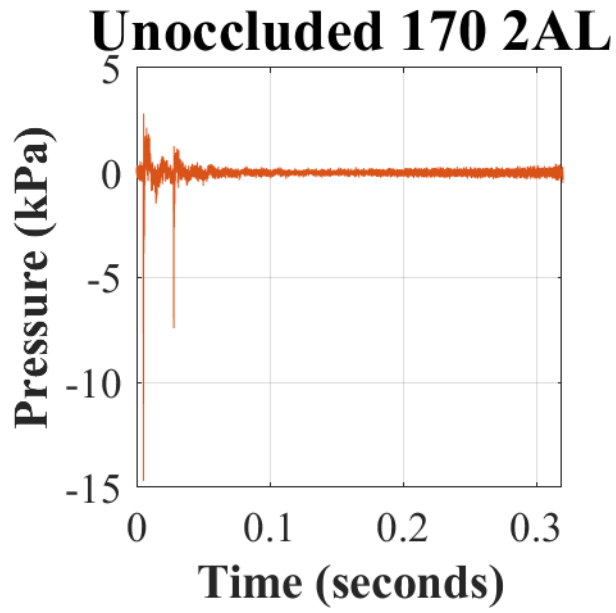


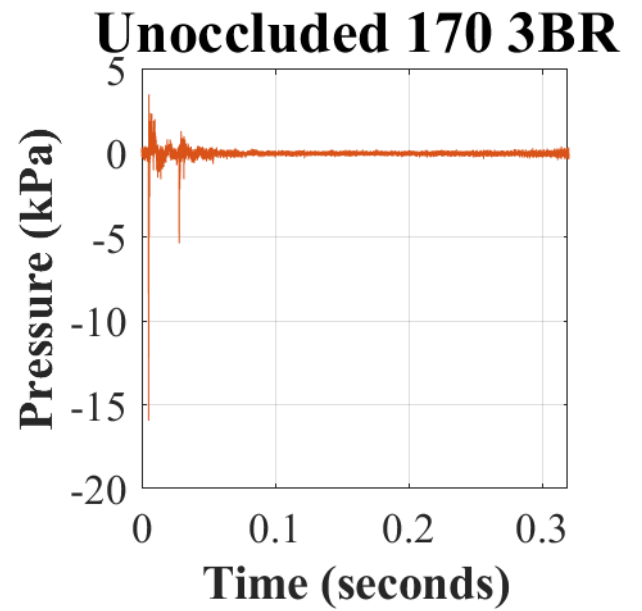
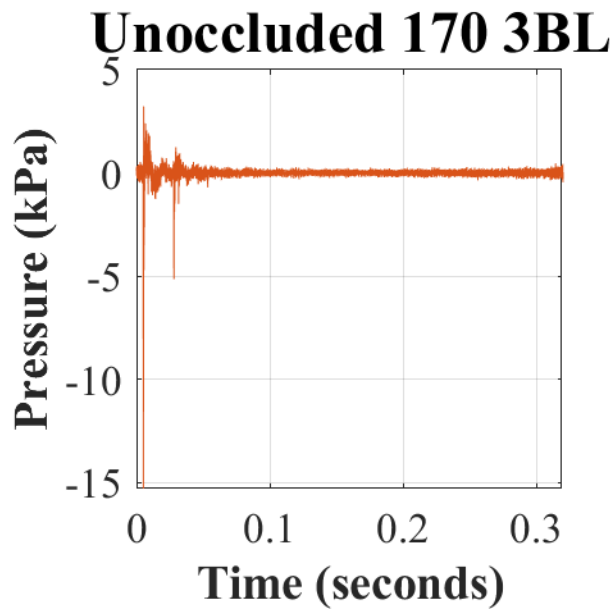
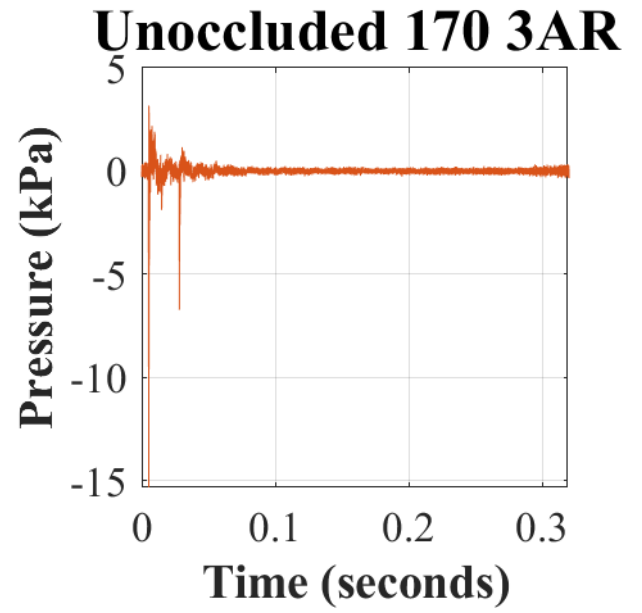
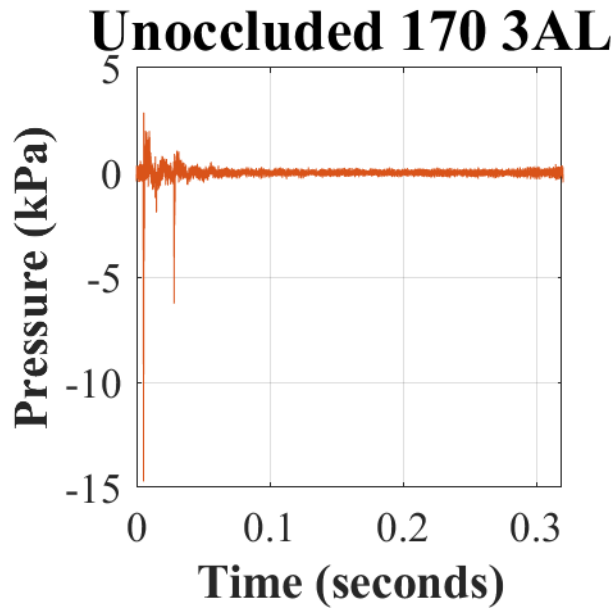


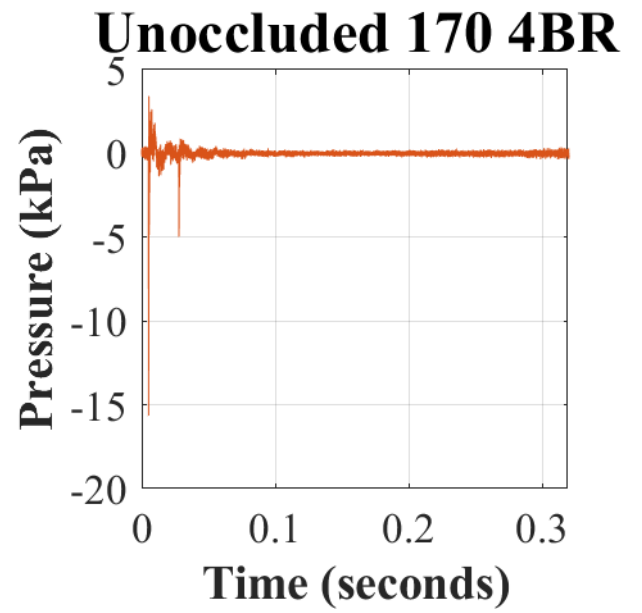
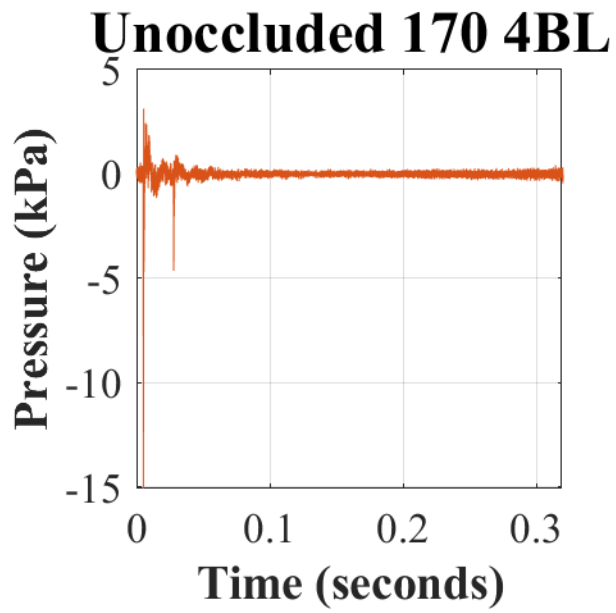
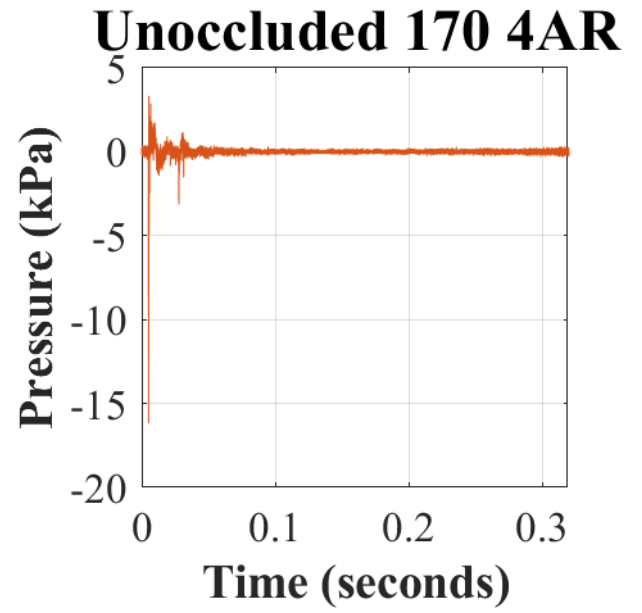
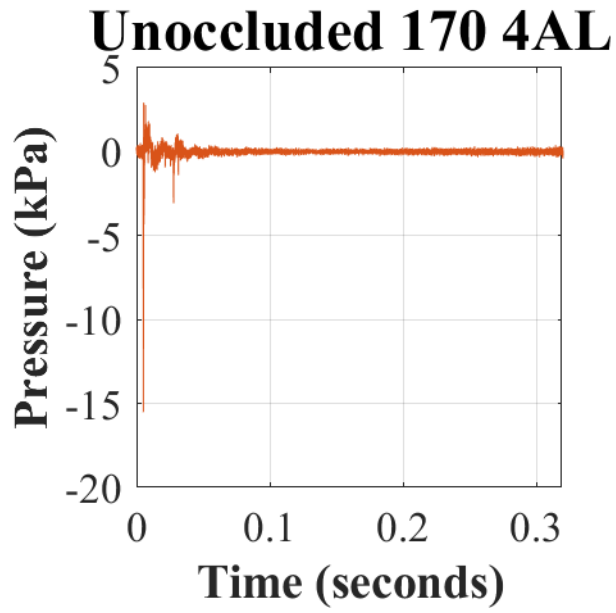
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Occluded’ is the test condition (i.e., ATF has the earmuff donned), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or B)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

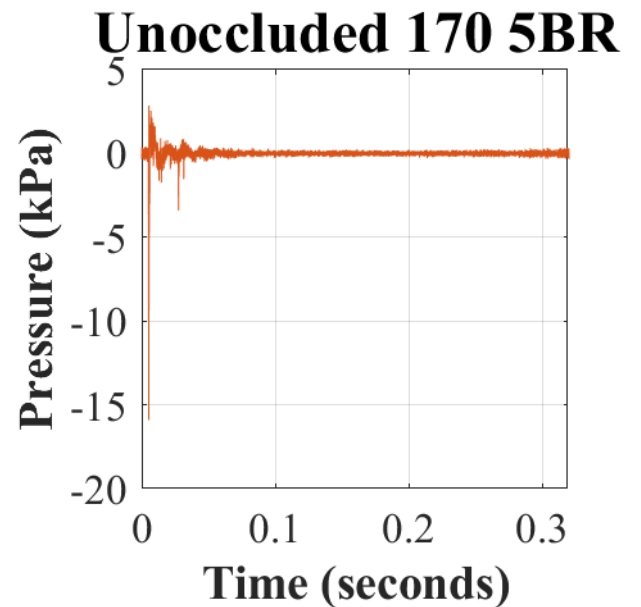
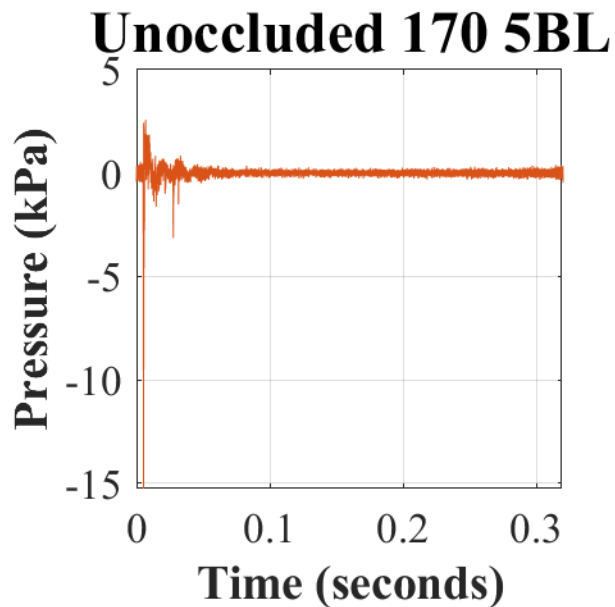
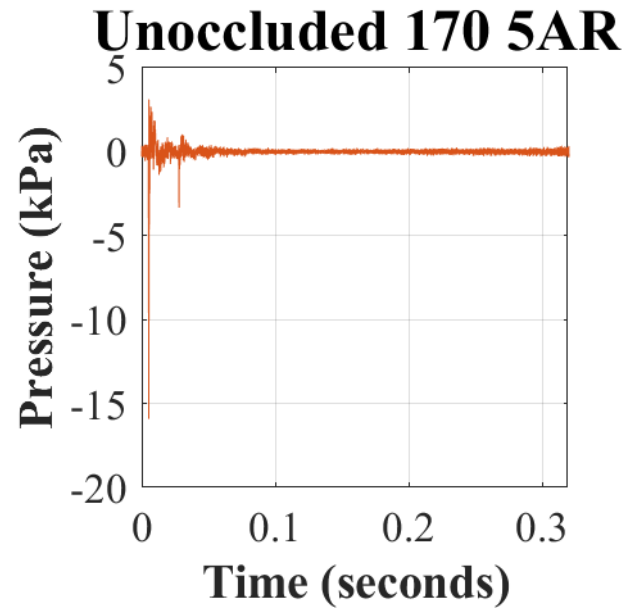
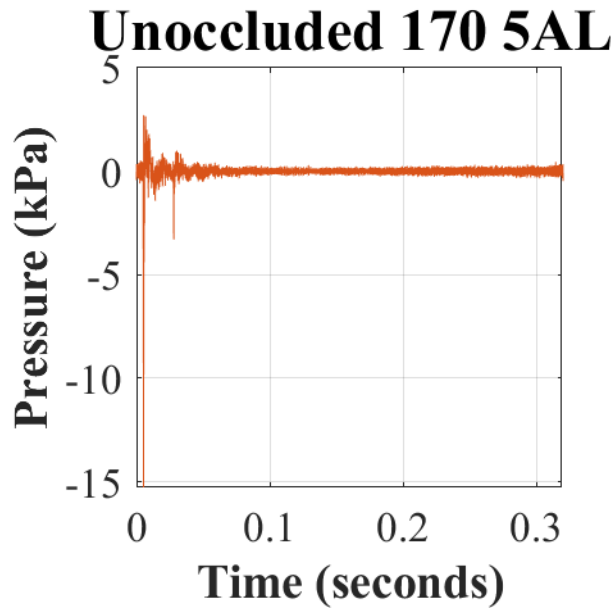
Appendix J. Estimated unoccluded (earmuff doffed) waveforms (in kilopascals (kPa)) over time (in seconds (s)) in response to 170 dBp with the ComTac™ III (MAX).





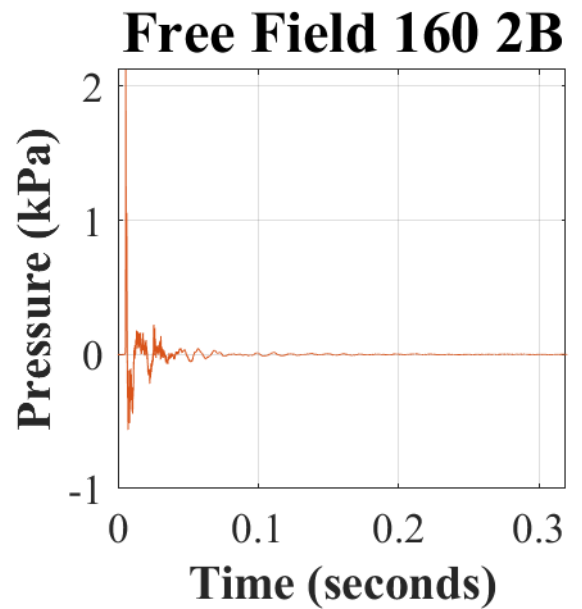
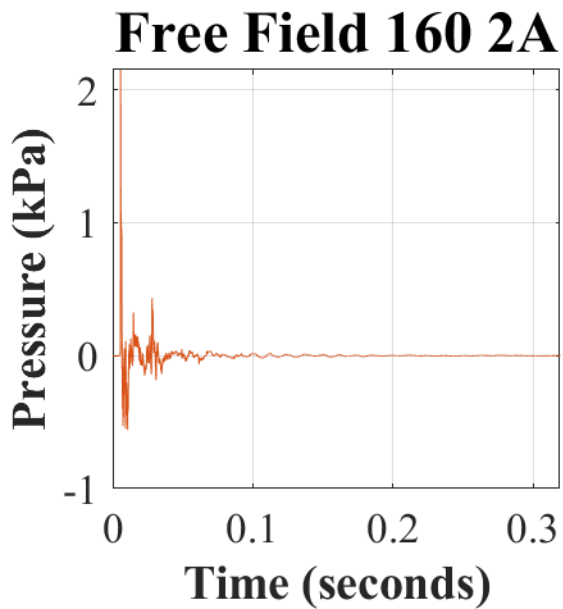
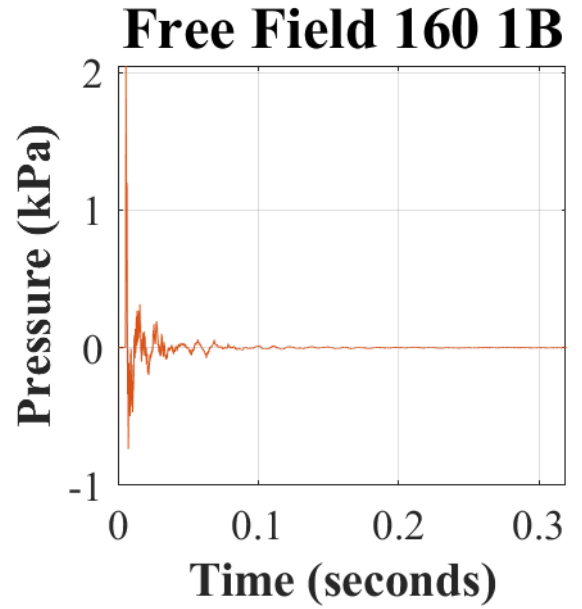
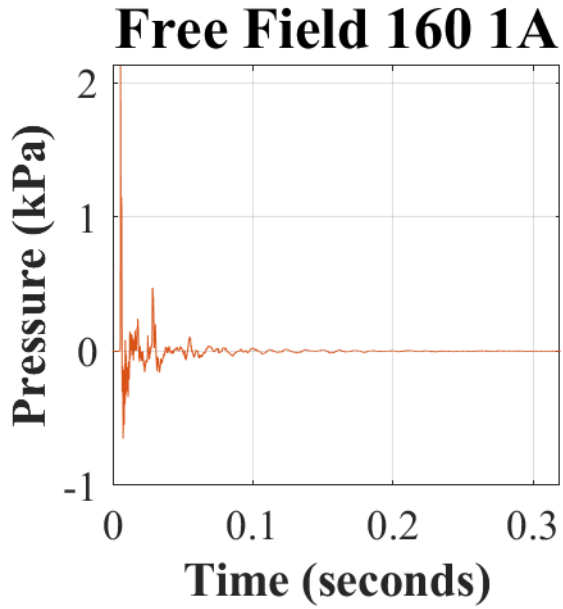




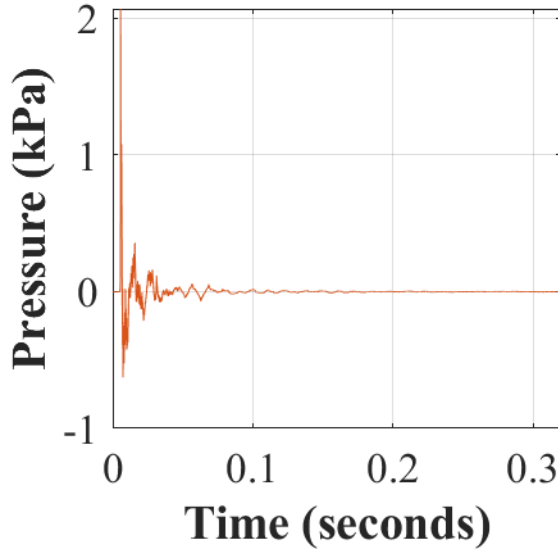


Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the earmuff doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBp), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or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

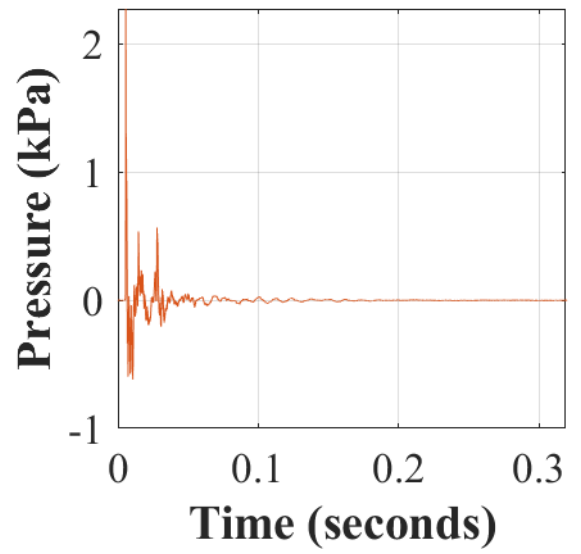
Appendix J. Recorded waveform (in kilopascals (kPa)) over time (in seconds (s)) of the impulse measured with the free-field probe at 160 dBp and the ComTac™ III (MAX) donned.



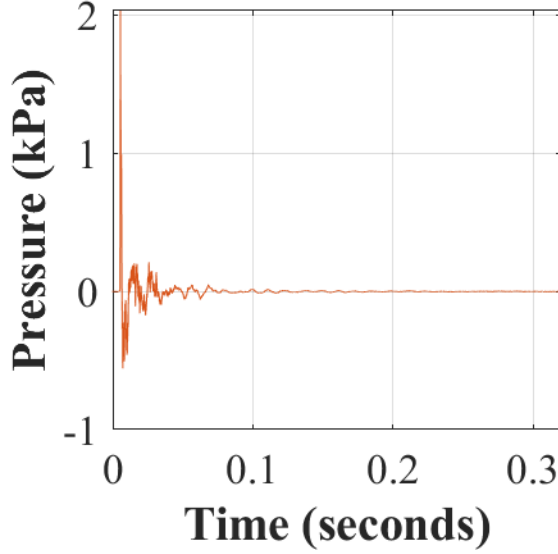
Free Field 160 3A



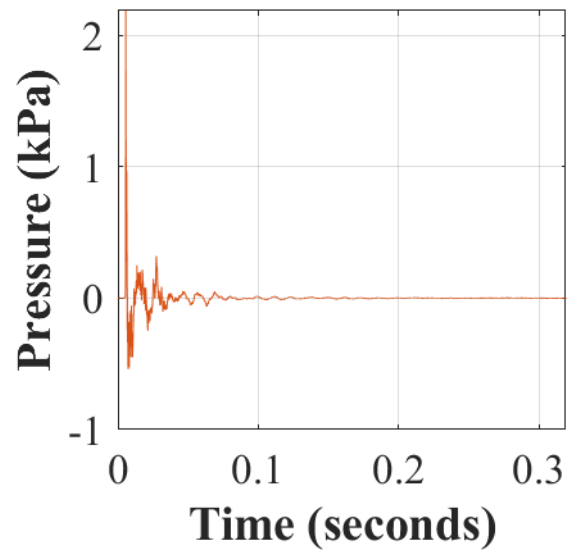
Free Field 160 3B

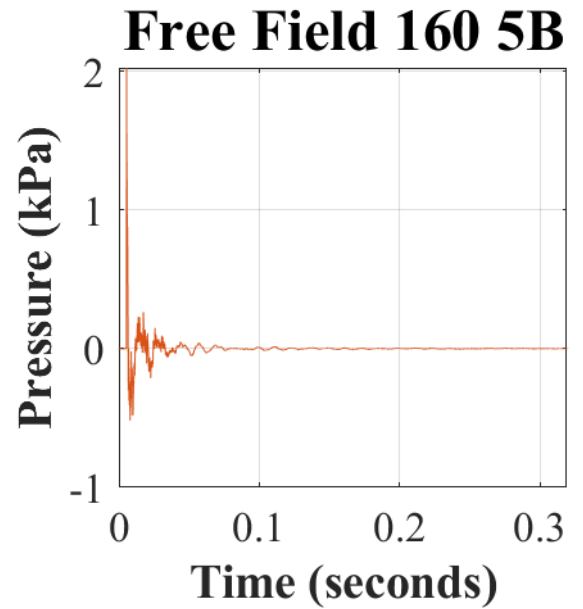
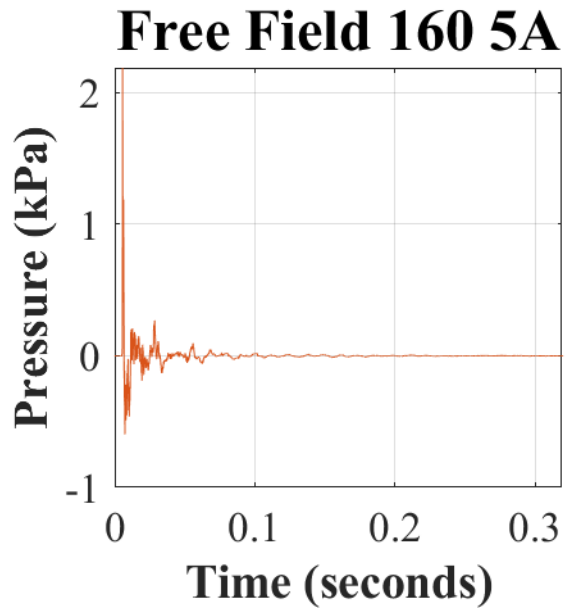


Free Field 160 4A



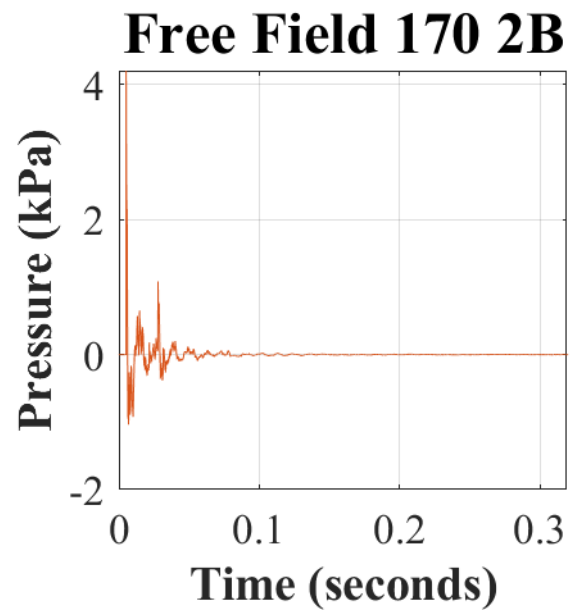
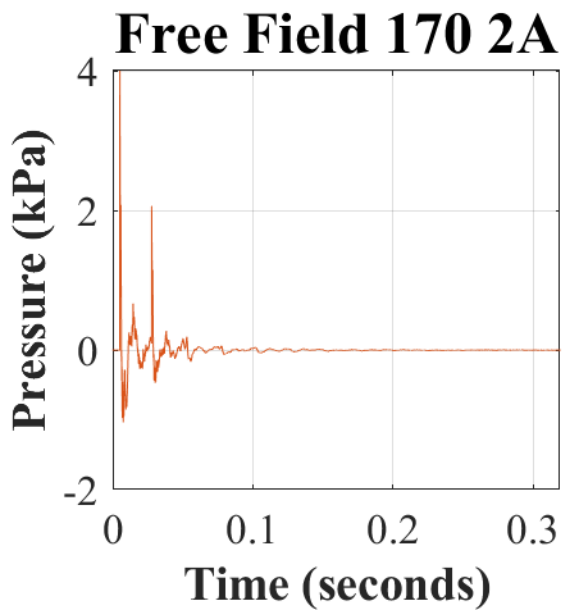
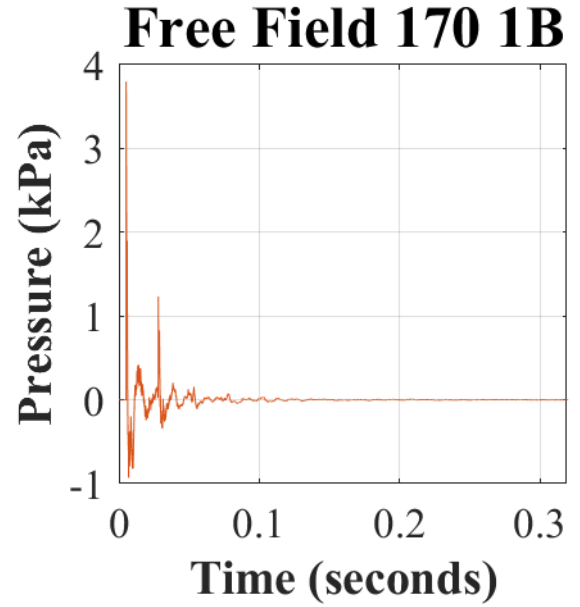
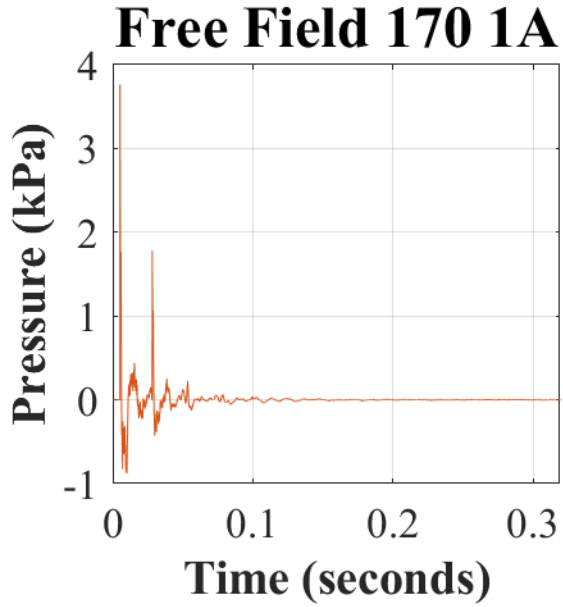
Free Field 160 4B

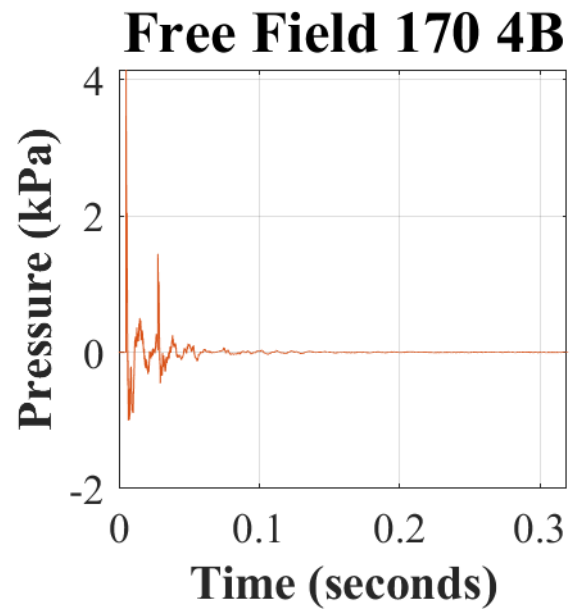
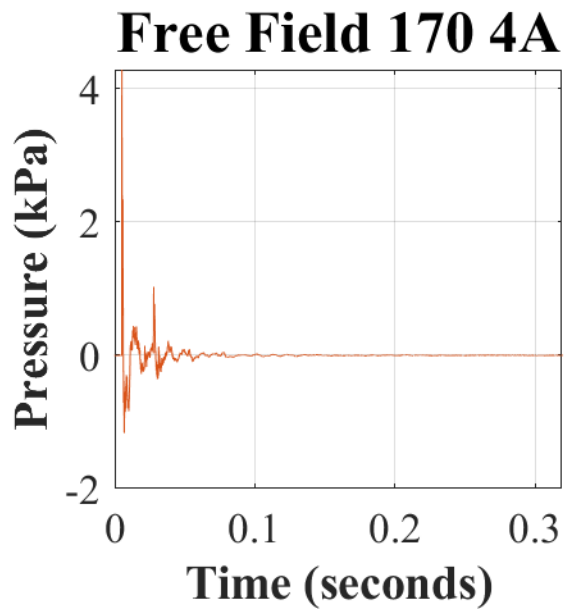
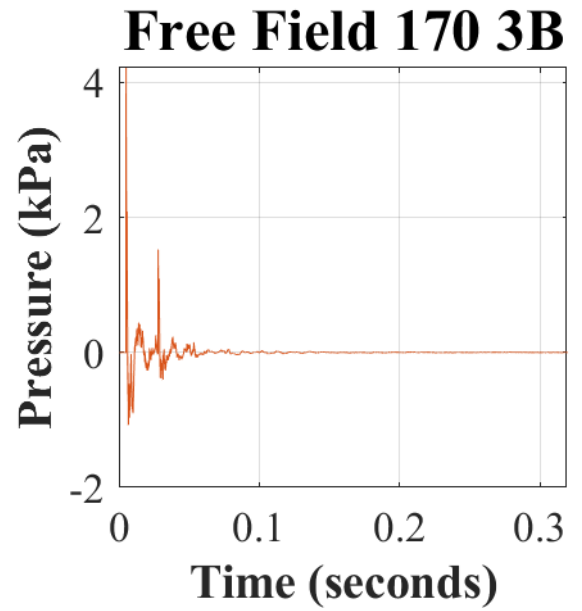
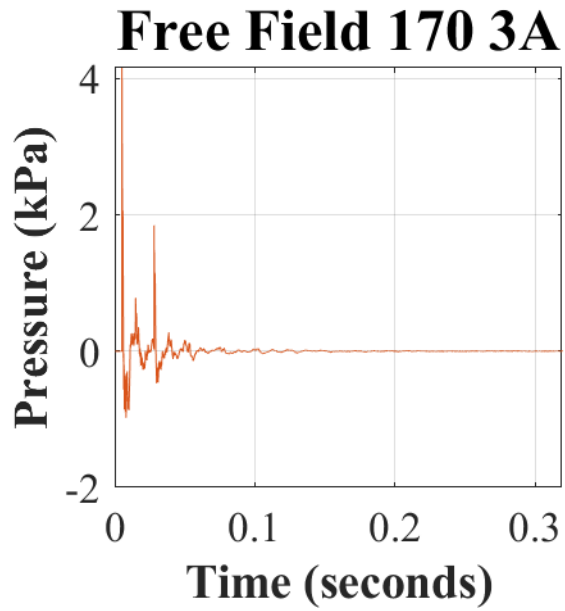


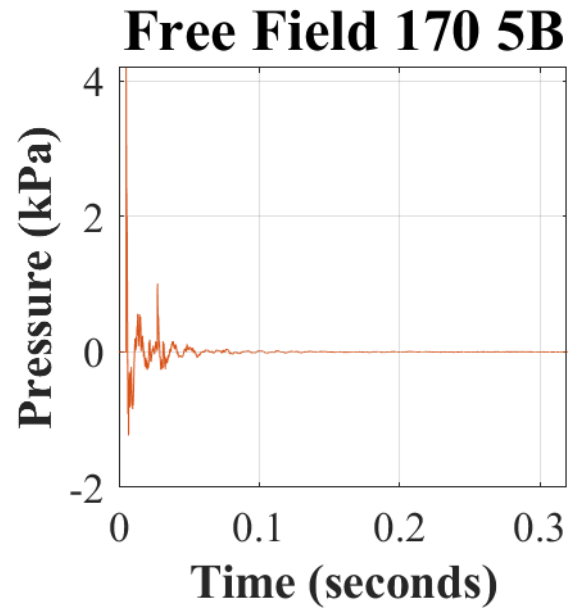
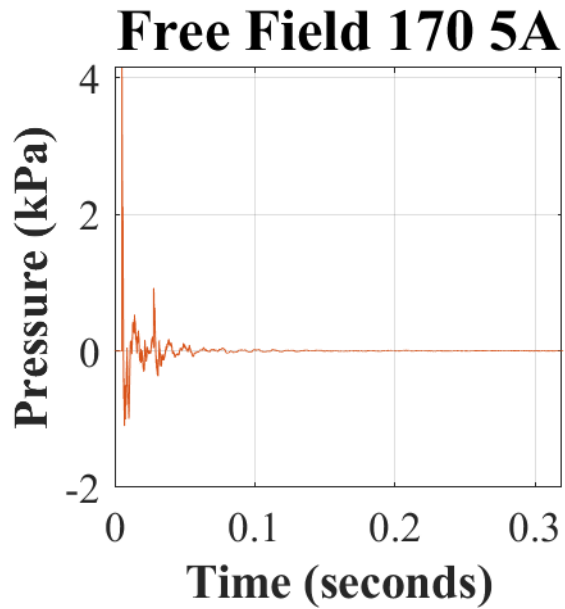


Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (170 dB), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

Appendix L. 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™ III (MAX) donned.







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