Naval Submarine Medical Research Laboratory

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Impulse Peak Insertion Loss Testing of the Gentex® Corporation Enhanced Combat Helmet – Marine Corps

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14. ABSTRACT

The standard measure of attenuation provided by a headworn device (i.e., hearing protection device (HPD), helmet) in response to an impulsive noise is the impulse peak insertion loss (IPIL). This technical memorandum describes the IPIL testing conducted in accordance with the American National Standards Institute (ANSI) standard S12.42-2010 on the Gentex® Corporation Enhanced Combat Helmet – Marine Corps (ECH-M; Model A14493-3A1A6, Model A14493-3A0A6). Rather than testing at the nominal test levels specified by ANSI S12.42-2010 (i.e., 130, 150, and 170 decibel peak (dBP, re: 20 µPa)), all samples were tested at the nominal levels of 160 and 170 dBP, as these higher levels are more representative of military occupation impulse noise exposures. A total of five samples were fitted to an acoustic test fixture two times each for a total of 10 trials per test level. No samples were rejected. Results of the testing revealed mean IPIL values within 0.5 dB of each other at the 160 dBP and 170 dBP nominal levels.

15. SUBJECT TERMS

attenuation, impulse peak insertion loss, IPIL, blast, head worn device, hearing protection device, HPD, passive HPD, combat helmet

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CONTENTS

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. While not designed as an HPD, researchers at NSMRL were interested to know the amount of impulsive noise protection provided by the Enhanced Combat Helmet when worn. This technical memorandum therefore describes the IPIL testing conducted on the Gentex® Corporation Enhanced Combat Helmet – Marine Corps (ECH-M; Model: A14493-3A1A6, Model: A14493-3A0A6). 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". Rather than testing at the nominal test levels specified by ANSI S12.42-2010 (i.e., 130, 150, and 170 decibel peak (dBP, re: 20 μPa)), all samples were tested at the nominal levels of 160 and 170 dBP, as these higher levels are more representative of military occupation impulse noise exposures. A total of five samples were fitted to an acoustic test fixture two times each for a total of 10 trials per test level. No samples were rejected. As shown in Table 1, the results revealed negative overall mean IPIL values that were within 0.2 decibel (dB) of each other at the 160 dBP and 170 dBP nominal levels. The overall negative IPIL value was anticipated user, as the ECH-M is designed to provide ballistic and impact protection and not to serve as a HPD.

Table 1.
ECH-M mean (SD) IPIL value (in dB) for all test conditions.

160 dBP	170 dBP
-1.1 (0.3)	-1.3 (0.3)

Introduction

One of the helmets fielded to U.S. Marines is the Gentex® Corporation Enhanced Combat Helmet – Marine Corps (ECH-M; Gentex Corporation, Carbondale, PA). In operational environments, these helmets are often used without a hearing protection device (HPD), in concert with a single (e.g., earplug or earmuff) HPD, or with double (i.e., earplug with earmuff) HPDs. While the ECH-M alone is not a HPD, researchers at the Naval Submarine Medical Research Laboratory (NSMRL) were interested to determine the amount of impulse noise protection afforded to the Marine who would be wearing this helmet without any additional HPD.

The ECH-M is commercially available in small, medium, large, extra-large, and extra-extra-large. The ECH-M operator manual (Headquarters, Department of the Army, 2015) states that the ECH-M (and thereby the ECH-Army) provides ballistic protection via the shell configuration, while impact protection is provided via the shell geometry pad suspension system. The reduced shell edge cut in front of the eyes and at the ears "provides an unobstructed field of view and increased ambient hearing capabilities" (p. 0002-1) to the Service Member, thereby allowing for maximum sensory and situational awareness when donned.

The aim of the current work effort was to quantify the amount of impulsive noise protection provided by the ECH-M when used without an HPD (i.e., earplug, earmuff). This technical memorandum details the procedures followed to determine the impulse peak insertion loss (IPIL) value afforded to the wearer when the ECH-M is donned. In addition to reporting an overall device IPIL, ear-specific IPILs are reported for the tested nominal levels.

Methods

Facility

IPIL testing described herein was completed in NSMRL's1000 m^3 anechoic chamber in order to minimize any effects of sound reflections.

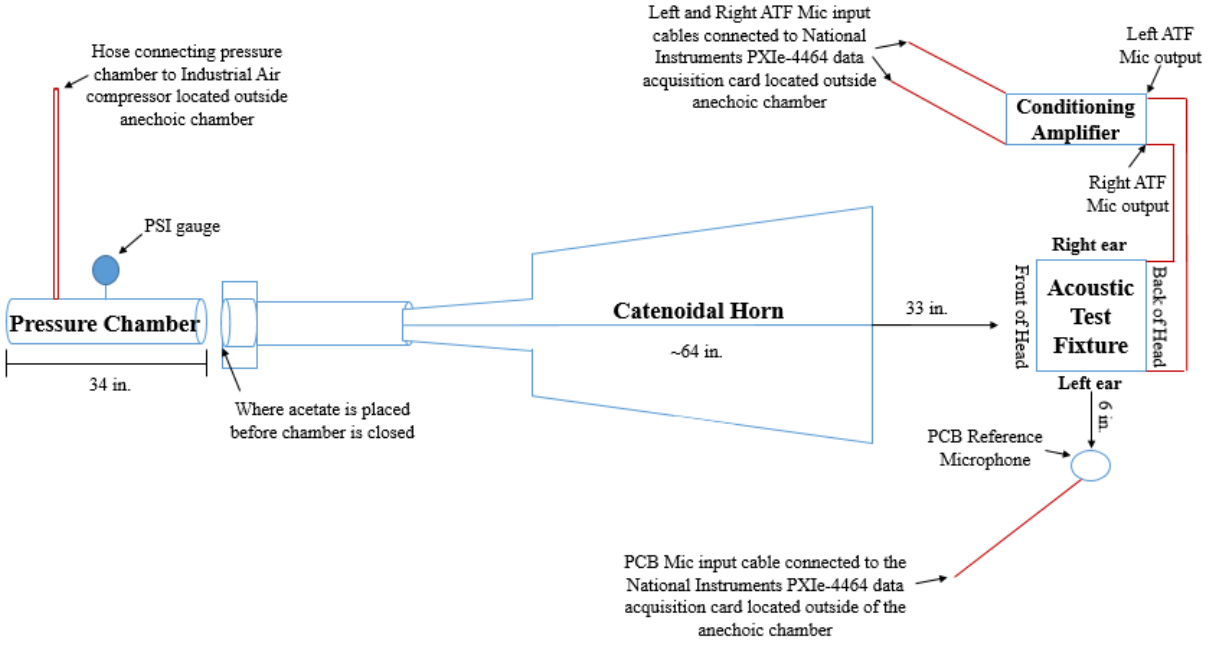
Equipment

Hardware. Acoustic impulses were generated by NSMRL's 4-inch shock tube (B/C Precision, Inc., Greendale, IN). The shock tube pressure chamber is approximately 34 inches (in.) long, with an inner diameter of 4.0 in. A 64-inch-long catenoidal tube horn consisting of four welded steel flat-projection sheets forming a square cross section was connected to the shock tube using a PVC 4.5 in. coupler. An industrial air compressor (ILA#1883054; Industrial Air Corporation, Memphis, TN) supplied pressurized air (900 kilopascal) to the shock tube. For each trial, a 7 in. by 7 in., acetate sheet (Grafix Plastic, Maple Heights, OH) was used as a membrane between the pressurized chamber and the catenoidal tube horn to enable pressurization of the air chamber. Each acetate sheet was 2 millimeters (mil.) thick.

The acoustic test fixture (ATF) used (GRAS 45CB-S2; GRAS Sound and Vibration, Twinsburg, OH) for all data acquisition was set up in accordance with (IAW) ANSI/ASA 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". The ATF was connected to a conditioning amplifier which also served as the power supply (GRAS Type 12AA; GRAS Sound and Vibration, Twinsburg, OH). A reference microphone (Type 378C20; PCB Piezotronics Inc., Depew, NY) was placed 6 in. from the ATF left pinna. The reference microphone, the left ATF microphone, and the right ATF microphone were calibrated each morning prior to data collection at 124 dB sound pressure level (SPL) using a 250 Hz tone. A diagram depicting the aerial view of the NSMRL 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 the 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 0.01 seconds, with a trigger level of 110 dB SPL. Each recording was 0.3 seconds in duration. Deviating from ANSI/ASA S12.42-2010, an electronic anti-aliasing filter (corner frequency of 93.0 kHz [3 dB down]) was applied to all waveforms by the data acquisition system during data collection instead of an analog filter.

The custom-written software program saved all recorded waveforms as files (.tdms), which were exported from the software for conversion into data files using an additional custom software programming script. The script compiled the reference PCB microphone, left ATF microphone, and right ATF microphone channels into a file (.mat) that saved variables for input to analysis script (MATLAB) similar to the script provided in Annex H of the ANSI/ASA S12.42-2010 standard. Minor alterations were made to the analysis script in order to accept 160 dBP and 170 dBP data (see Data Analysis below). The revised script processed and outputted all IPIL values reported herein, along with generating the closed-ear, open-ear, and free-field waveform plots (See Appendices A-F).

Product Samples. A total of five large (NSN: NSN 8470-01-592-6208) ECH-M helmet systems (Part Numbers: A14493-3A1A6, A14493-3A0A6) were used in this effort. The helmet systems were comprised of a shell, suspension system (i.e., seven geometric pads), and an H-Nape chinstrap retention system (NSN: 8470-01-599-3210). Each sample, consisting of one helmet system, was randomly assigned a number 1 through 5.

Figure 2.
Gentex® Corporation ECH-M helmet donned on the ATF.

Procedure

Each sampled helmet 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). No samples were rejected. To achieve an appropriate fit that would provide maximum attenuation, each helmet sample was expertly fitted to the ATF IAW instructions on the device packaging. The manufacturer fitting guidelines stated that all samples be inspected for any damage, blistering, loose material, or fraying prior to use. Once inspected, each helmet was 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 was stable on the ATF.

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

In place of the ANSI/ASA S12.42-2010 standardized calibration impulses at 130 and 150 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.

A Butterworth filter (6^{th} order, low-pass, corner frequency of 20 kHz [3 dB down]) was applied to all waveforms post-data collection by a programming software script (MATLAB, Natick, MA) post-processing.

Data Analysis

MATLAB (Natick, MA) was used to calculate IPIL values at the 160 and 170 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 zero Hz. The fit of the mean transfer function was tested by applying the mean transfer function for each ear to the free-field probe data gathered in the 160 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.

Results

As shown in Table 2, the overall mean IPIL values for the tested samples was -1.1 dB at 160 dBP and -1.3 dB at 170 dBP condition. The calculated IPIL values for all sample trials ranged between -0.8 to -1.8 dB at 160 dBP and -0.8 to -2.0 dB at 170 dBP. Also presented in Table 2 are the ear-specific means and standard deviations (SD) across all samples and trials, and the overall means and SD across all samples, trials, and ears. The waveforms for all trials with the ECH-M are provided in Appendices A to F.

Table 2.
Mean (SD) IPIL values (in dB) for Tested ECH-M Samples.

	160 dBP		170 dBP	
	Right	*Left*	*Right*	*Left*
HPD 1, Trial A	-1.0	-1.2	-1.2	-1.3
HPD 1, Trial B	-1.3	-0.9	-1.8	-1.2
HPD 2, Trial A	-1.6	-0.8	-1.9	-0.9
HPD 2, Trial B	-1.8	-0.7	-2.0	-0.8
HPD 3, Trial A	-1.1	-1.2	-1.2	-1.4
HPD 3, Trial B	-1.1	-1.2	-1.3	-1.4
HPD 4, Trial A	-1.1	-0.8	-1.4	-1.2
HPD 4, Trial B	-1.3	-1.0	-1.4	-1.2
HPD 5, Trial A	-1.6	-0.7	-1.8	-0.8
HPD 5, Trial B	-1.4	-0.8	-1.5	-0.9
Ear Specific Mean (SD)	-1.3 (0.3)	-0.9 (0.2)	-1.6 (0.3)	-1.1 (0.2)
Level Overall Mean (SD)	-1.1 (0.3)		-1.3 (0.3)	

Discussion

The current work effort evaluated the attenuation provided by the ECH-M to loud impulsive noises IAW ANSI S12.42-2010, which requires the impulse noise to be generated and directed to the front of the ATF at 0° elevation and 0° azimuth. Results revealed negative overall IPIL values within 0.2 dB of each other at the 160 and 170 dBP nominal levels. Since the stated design intent (Department of Army, 2015) of the ECH-M is to maximize visual and auditory awareness when donned, an overall negative IPIL value was anticipated.

Across ears, the individual trial mean IPIL values were found to vary as much as 1.0 dB at 160 dBP and 1.2 dB at 170 dBP. This may be due to a combination of inherent variance within the impulse system and test-retest variability. Additional work at NSMRL is underway to to assess the attenuation of an HPD (i.e., earmuff) worn in concert with the ECH-M, results are forthcoming (Kolias et al., 2021).

In the current effort, deviations were made from the ANSI/ASA S12.42-2010 standard governing impulse noise testing due to equipment and software limitations. First, rather than using an in-line analog external Bessel filter (6^{th} order, corner frequency 20.0 kHz [3 dB down]) to filter impulses during data acquisition, anti-alias filtering was accomplished by an analog filter and a digital filter. The analog filter was an anti-aliasing filter (corner frequency of 93.0 kHz [3 dB down]) applied to all waveforms by the National Instruments data acquisition hardware during data acquisition. The digital filter was a Butterworth filter (6^{th} order, low-pass, corner frequency of 20 kHz [3 dB down]) applied by the MATLAB post-processing script. This filter was used to mimic the effect of the ANSI/ASA S12.42-2010 standard required anti-aliasing Bessel filter.

Second, testing at the 130 dBP and 150 dBP nominal levels was omitted. The decision to exclude these test levels was the result of a prior analysis of impulse waveforms (unrelated to this report) generated at those levels with the NSMRL shock tube that resulted in signals without a shock front. In addition, impulse noise levels that are commonly observed in military occupational environments regularly exceed 150 dB resulting in test results at such levels of limited value for military application. At the measured levels described herein, all generated impulses had a shock front. Inclusion of the 160 dBP nominal level was beneficial, as data at 160 and 170 dBP provided a more representative indication of device performance at military- relevant impulse noise levels. It is important to note that these results do not guarantee similar ECH-M product performance across all users and environments. Product performance may be impacted by factors including variability in physical fit of the device (i.e., coverage of the ears) and if HPDs are used in conjunction.

A GRAS 45CB-S2 ATF was used due to the expectation of exposure of the ATF's ear simulators to unoccluded levels greater than 170 dBP. The use of the GRAS 45CB-S2 did not impact results as the signals from all tested conditions were well above the noise floor of NSMRL's blast system with the GRAS 45CB-S2, as shown in the Appendices A and C.

Conclusions

This report described the determination of the mean IPIL values provided by the ECH-M at 160 dBP and 170 dBP nominal levels. As shown in Table 3, test results revealed negative overall mean IPIL values within 0.2 dB of each other at the 160 and 170 dBP nominal levels. This suggests that rather than providing attenuation from an impulse noise emanating directly in front of the ATF at 0° elevation and 0° azimuth, the ECH-M channeled the noise toward the ears.

Table 3.
ECH-M mean (SD) IPIL value (in dB) for all test conditions.

160 dBP	170 dBP
-1.1 (0.3)	-1.3 (0.3)

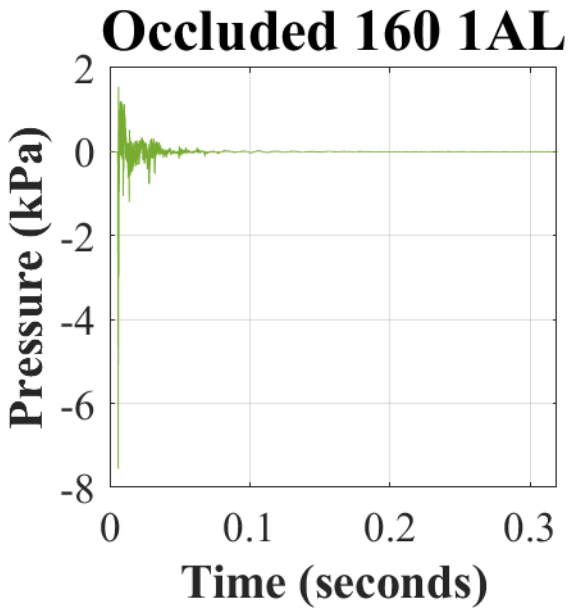
References

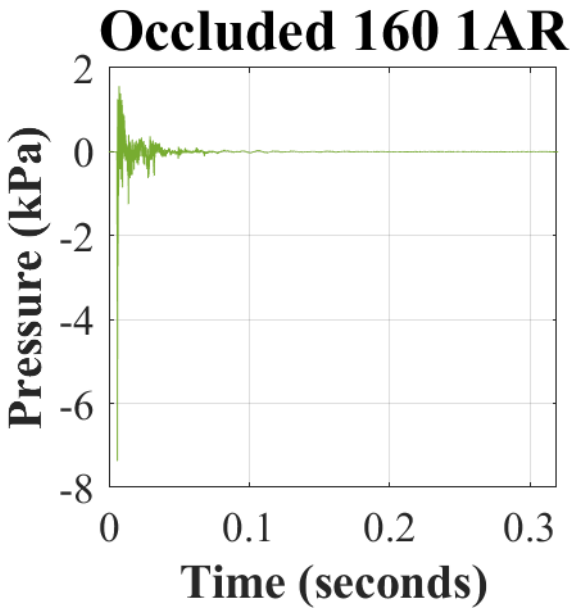
American National Standards Institute, Inc. (2010). *ANSI S12.42-2010: Methods for the Measurement of Insertion Loss of Hearing Protection Devices in Continuous or Impulsive Noise Using Microphone-in-Real-Ear or Acoustic Test Fixture Procedures.* Acoustical Society of America.

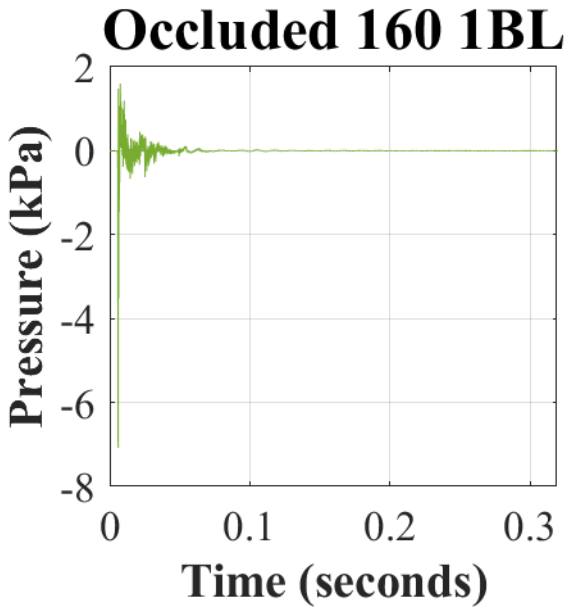
Headquarters, Department of the Army. (2015). *Army TM 10-8470-211-10, Marine Corps TM12030A: Technical Manual Operator Manual for Enhanced Combat Helmet- Army (ECH-A), Enhanced Combat Helmet- Marine Corps (ECH-M).* Department of the Army.

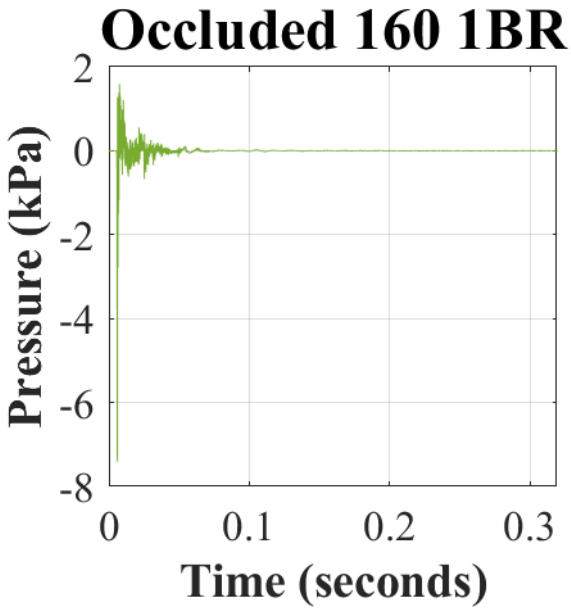
Kolias, A., Silvia, N., Schwaller, D., Karch, S.J., Federman, J. (2021). *Impulse Peak Insertion Loss Testing of the Gentex® Corporation Enhanced Combat Helmet – Marine Corps with the 3M™ PELTOR™ ComTac™ V Hearing Defender Headset.* Manuscript in Preparation.

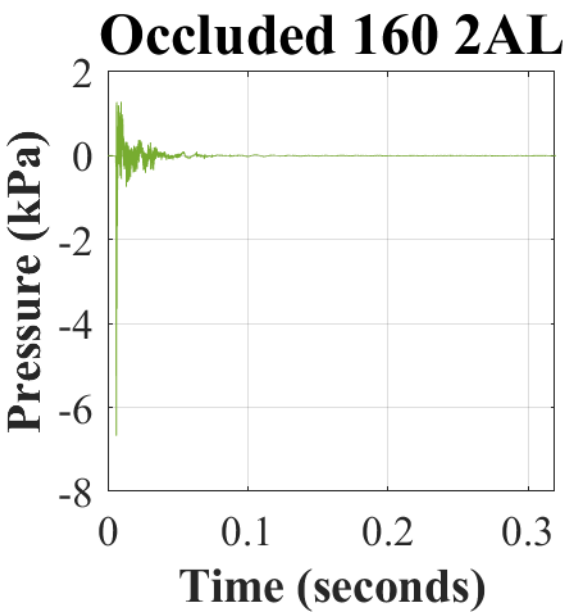
Appendix A. Recorded occluded (helmet donned) waveforms in response to 160 dBP with the ECH-M.







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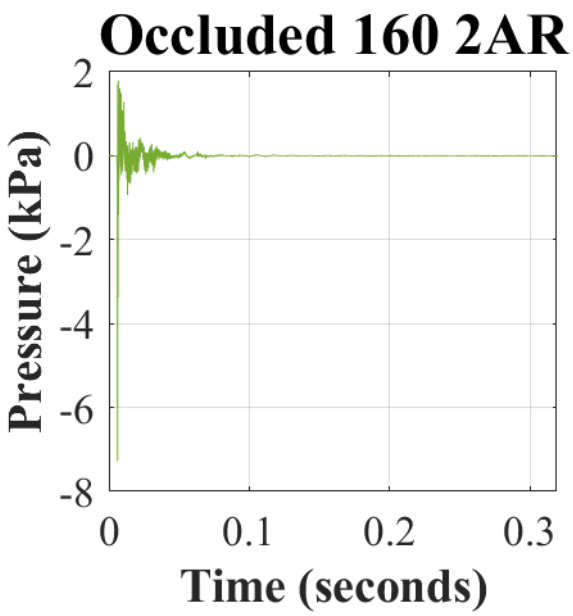
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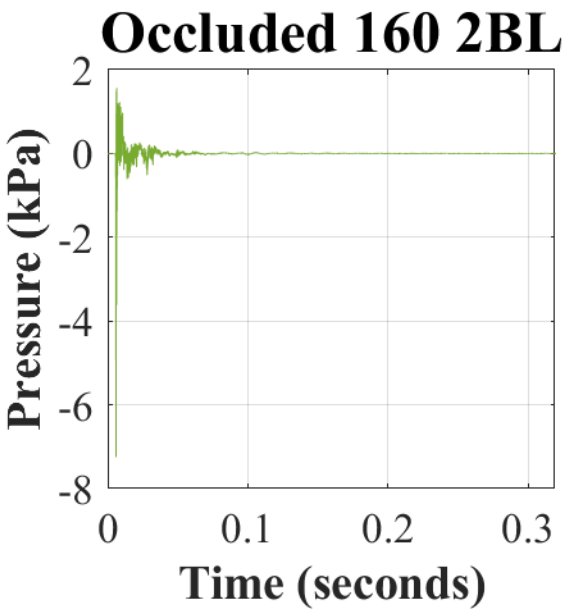
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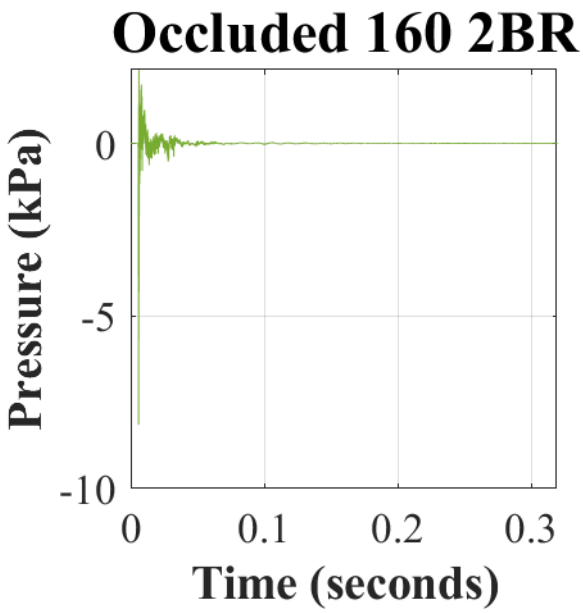
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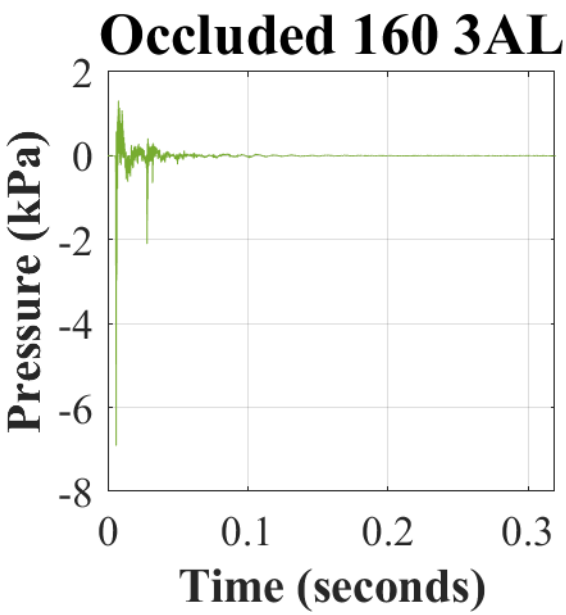
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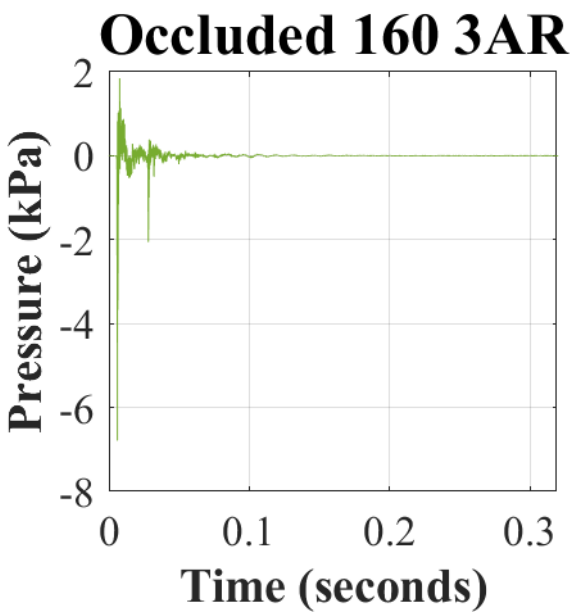
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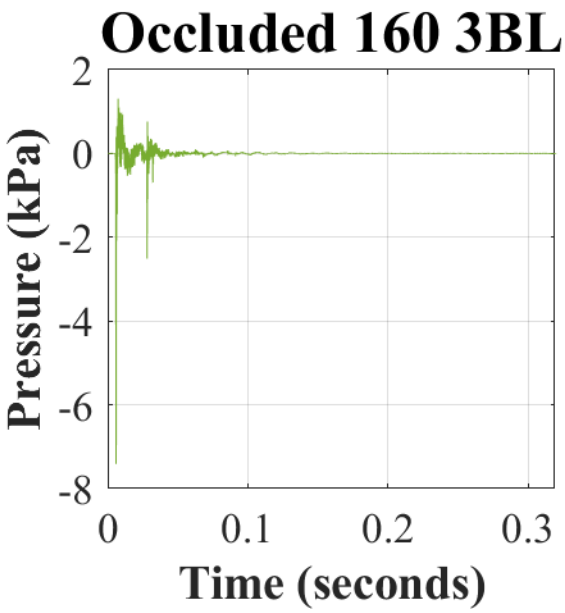
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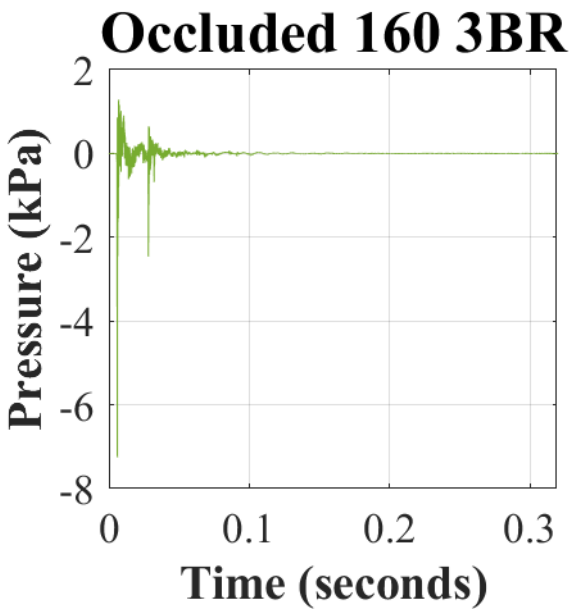
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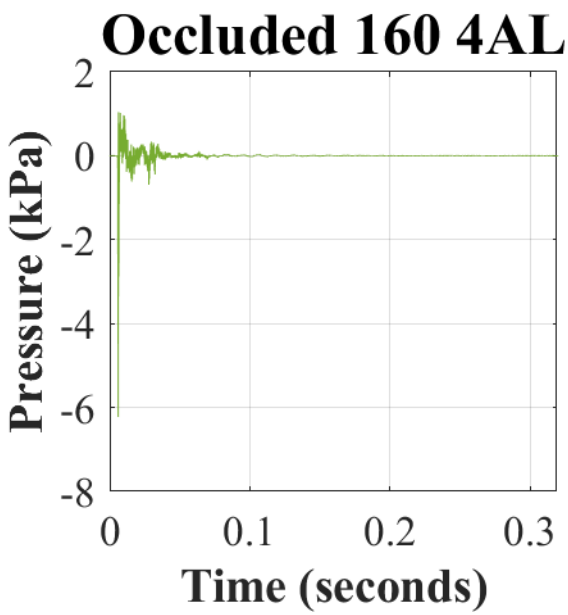
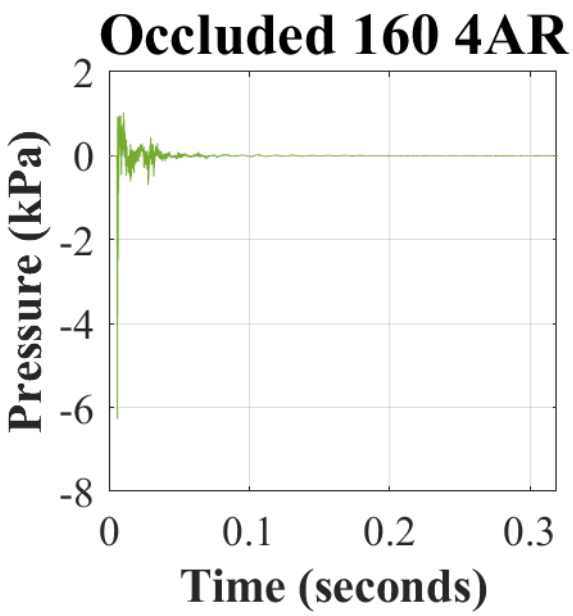
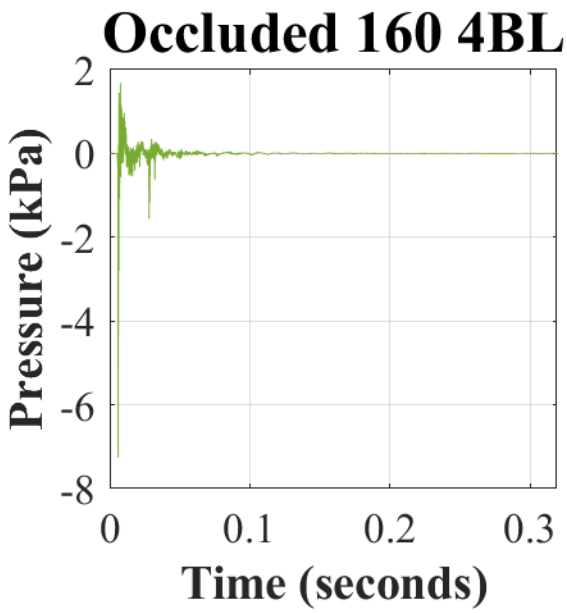
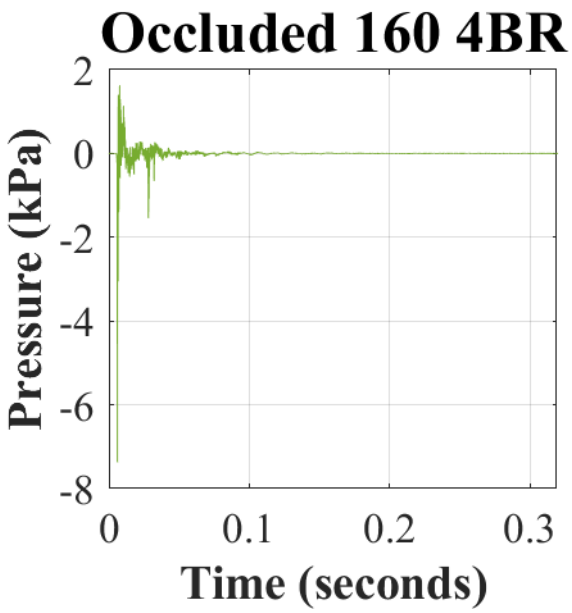
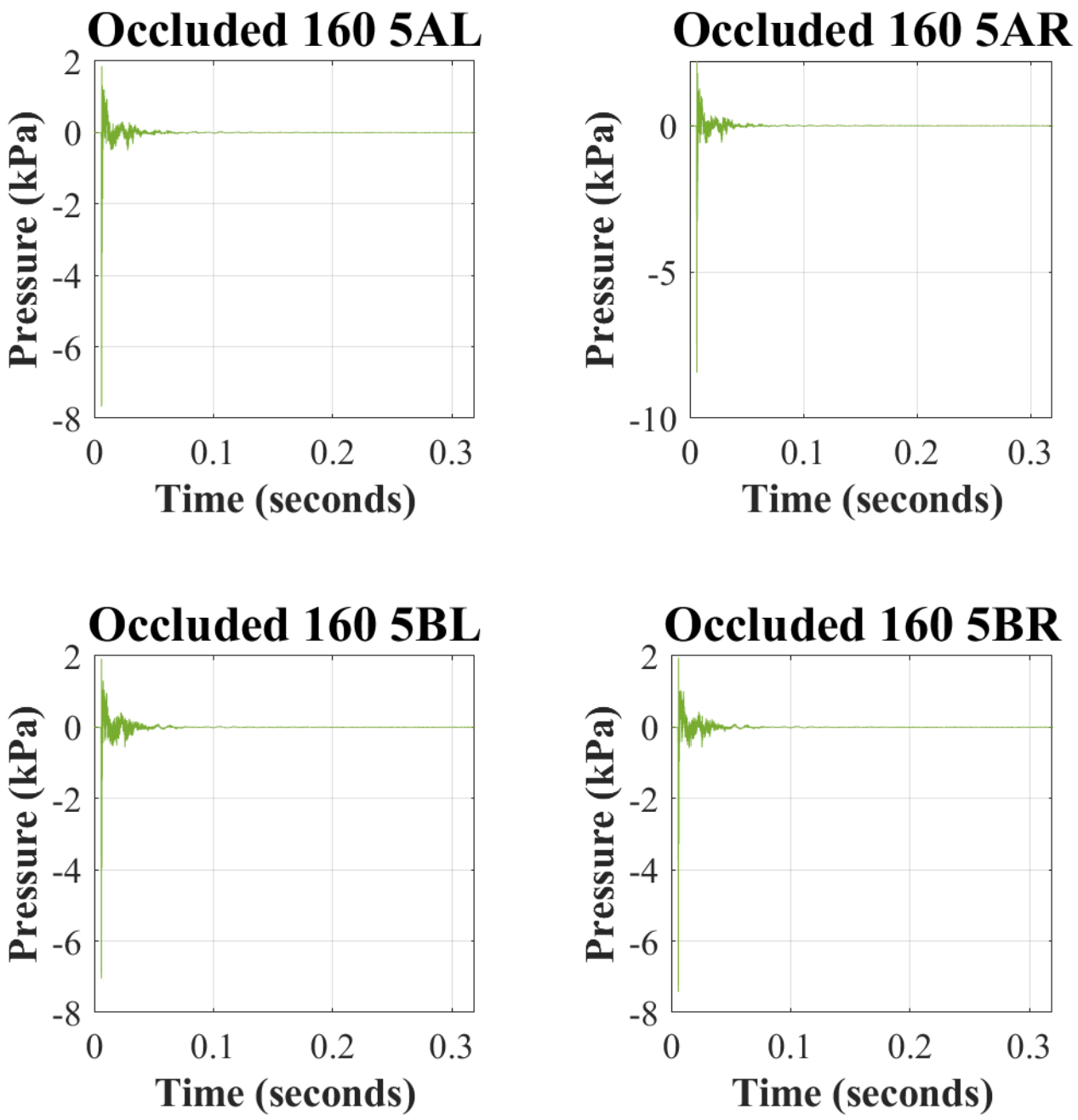
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)


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


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

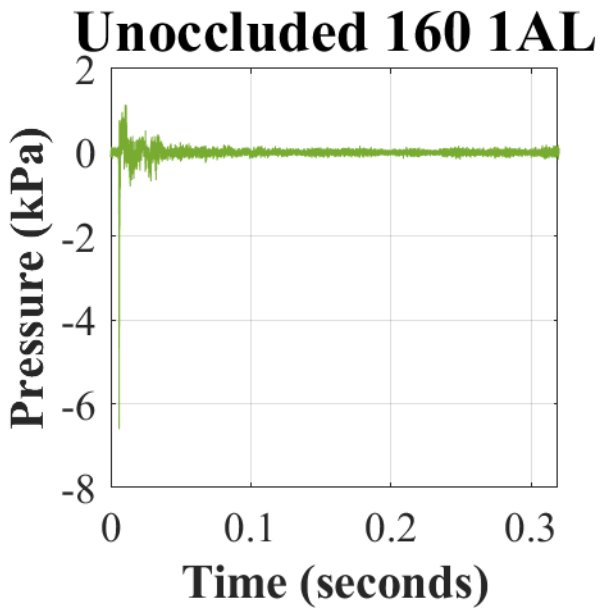

Occluded 160 4BL
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

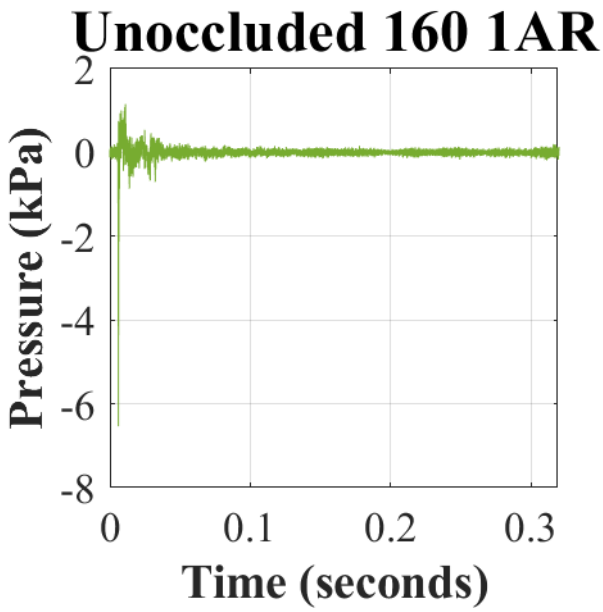

Occluded 160 4BR
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

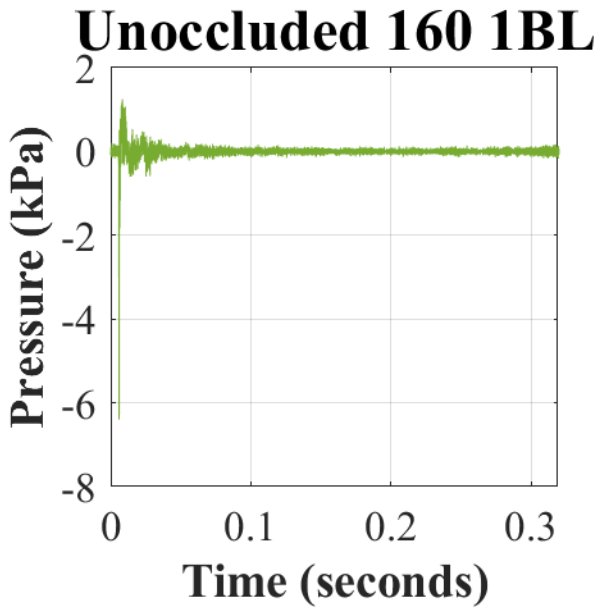


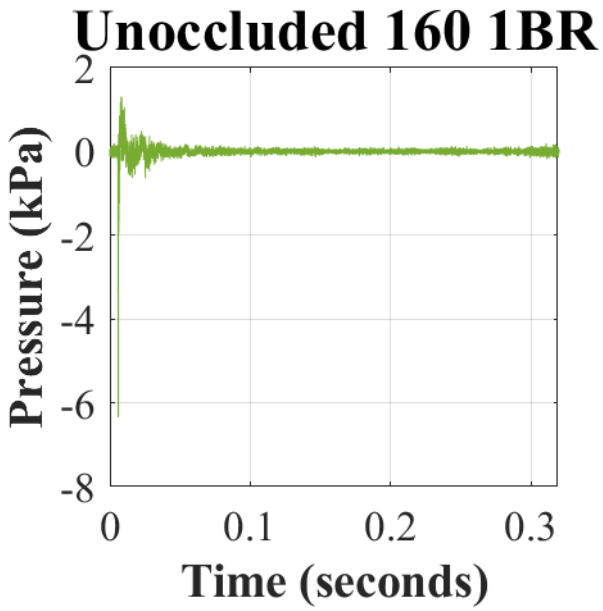
Note. The naming convention for all occluded waveforms is "Occluded LvL NnX", where 'Occluded' is the test condition (i.e., ATF has the helmet donned), 'LvL' is the nominal test level (i.e., 160 or 170 dBP), 'N' is the sample number (i.e., 1 to 5) of the device tested, 'n' is the trial (i.e., A or B) 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).

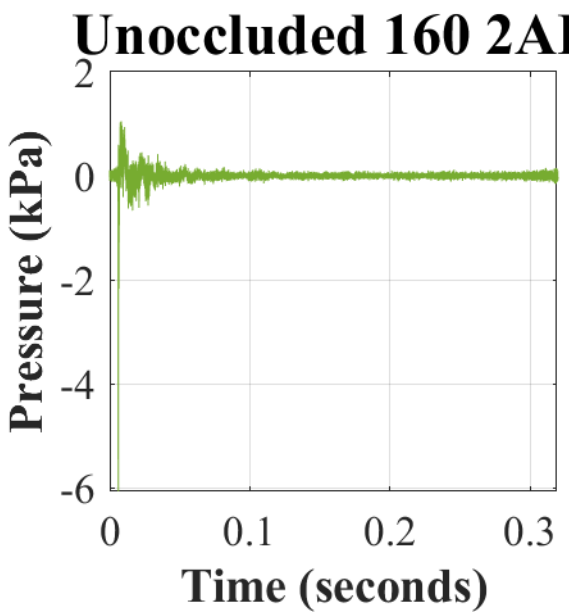
Appendix B. Estimated unoccluded (helmet doffed) waveforms in response to 160 dBP with the ECH-M.

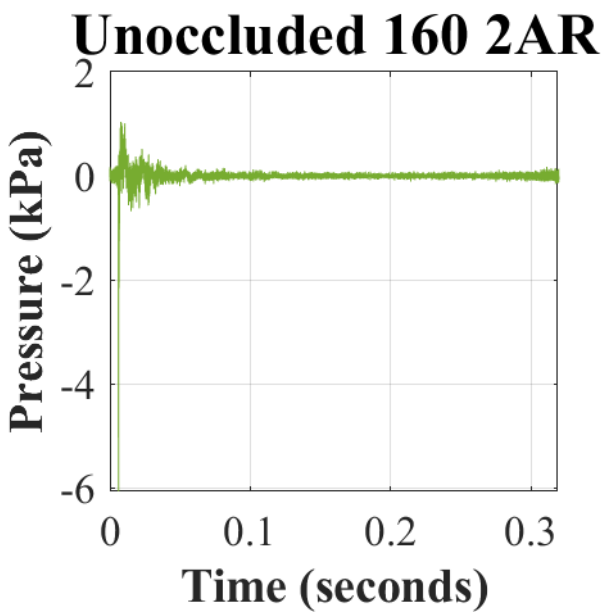


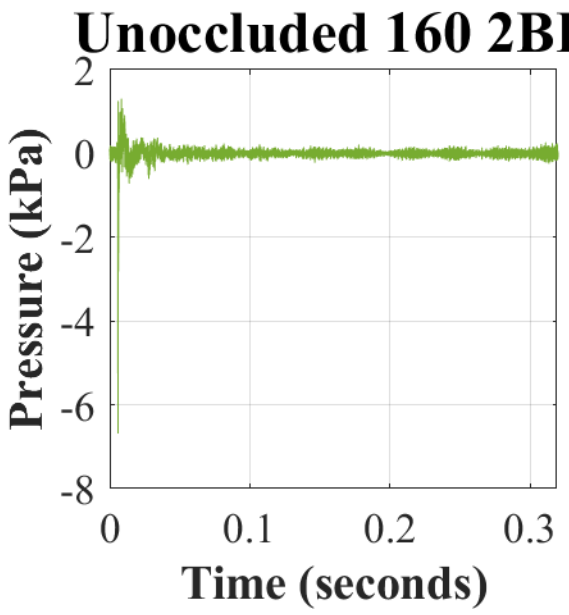


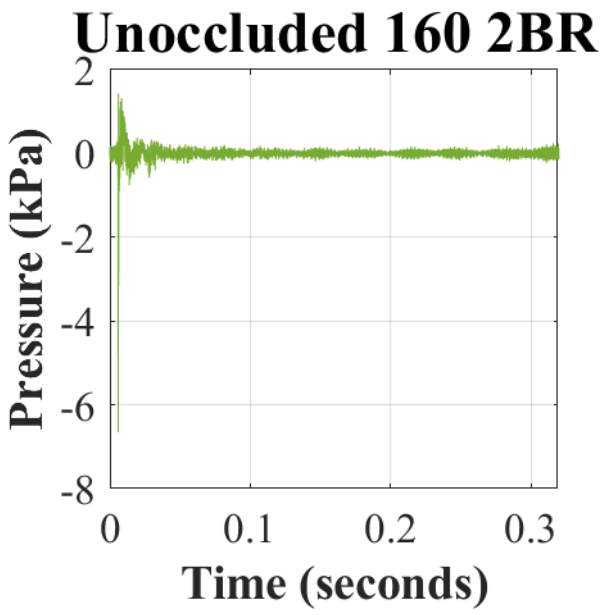


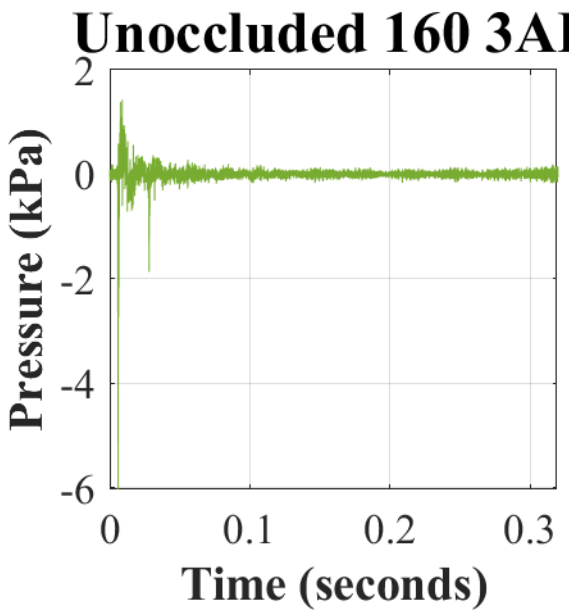


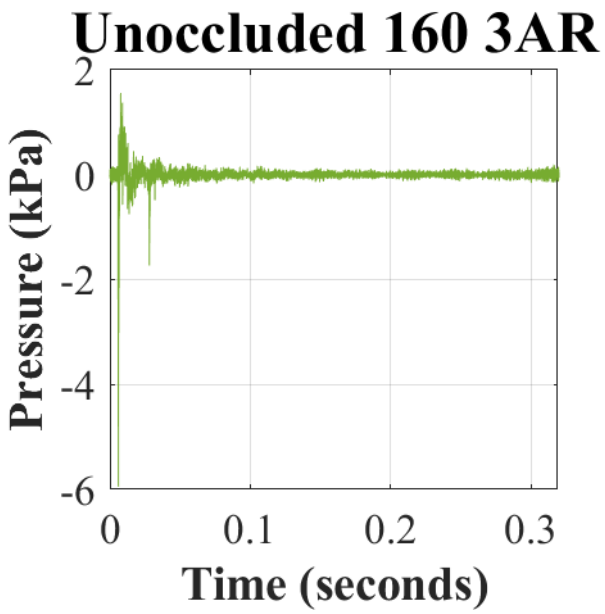

Unoccluded 160 2AL
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

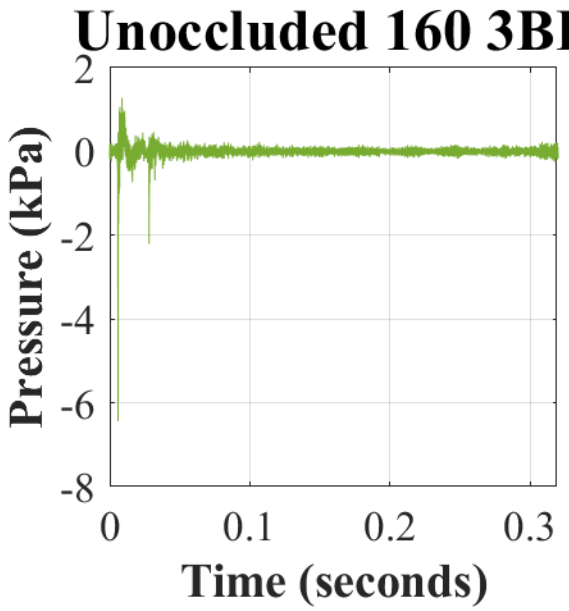

Unoccluded 160 2AR
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

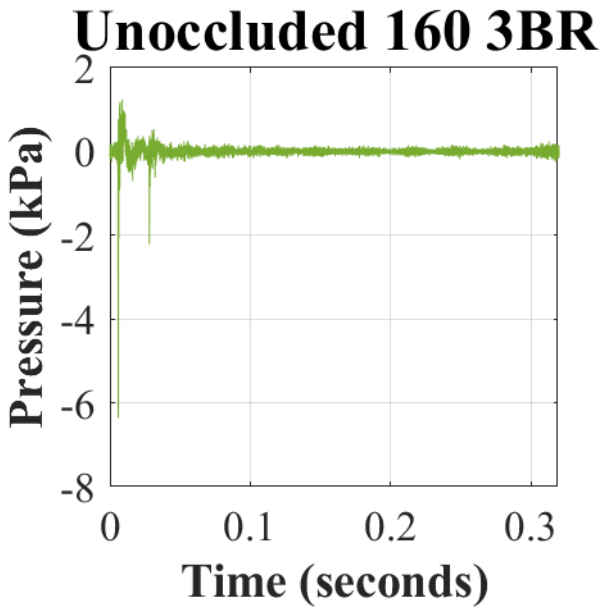

Unoccluded 160 2BL
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

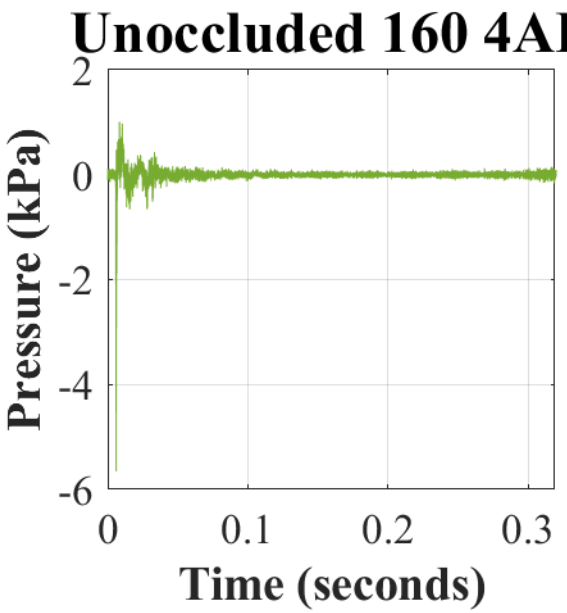

Unoccluded 160 2BR
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

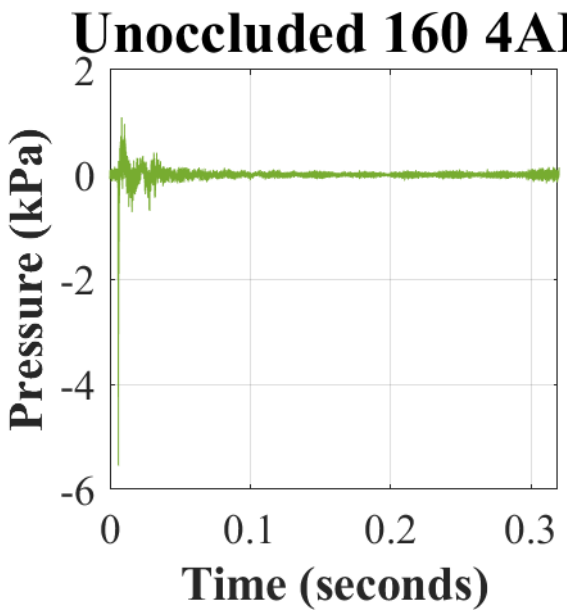

Unoccluded 160 3AL
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

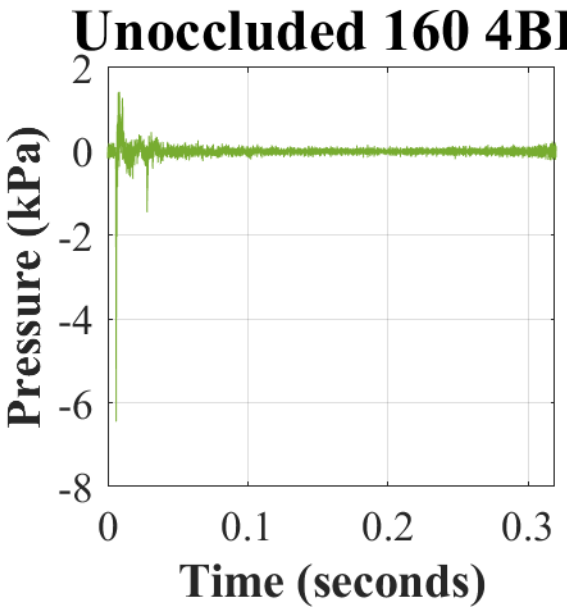

Unoccluded 160 3AR
Pressure (kPa)
2
0
-2
-4
-6
0
0.1
0.2
0.3
Time (seconds)

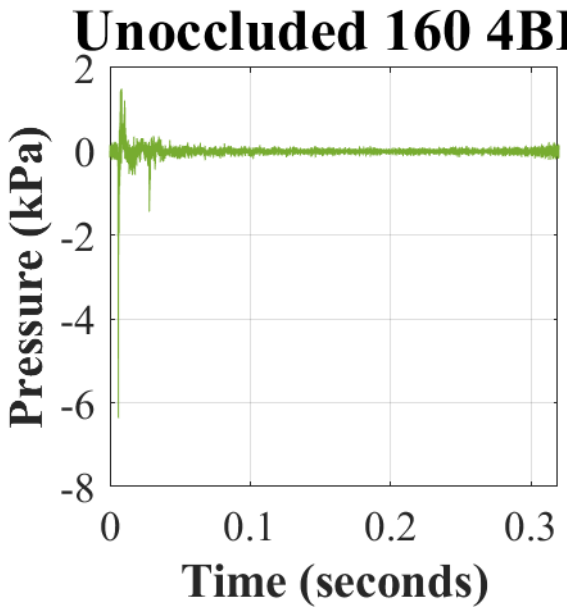

Unoccluded 160 3BL
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

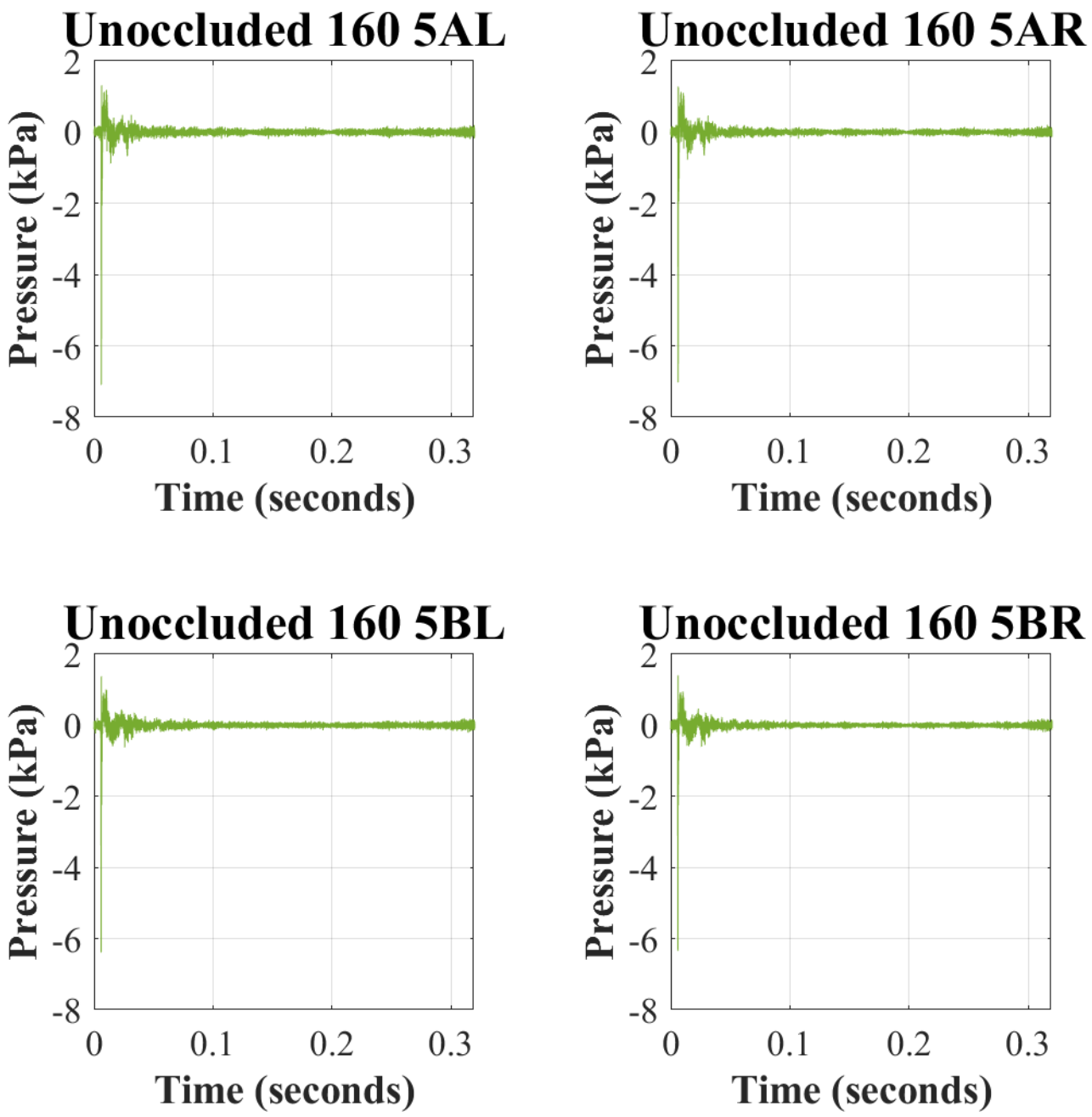

Unoccluded 160 3BR
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)


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


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

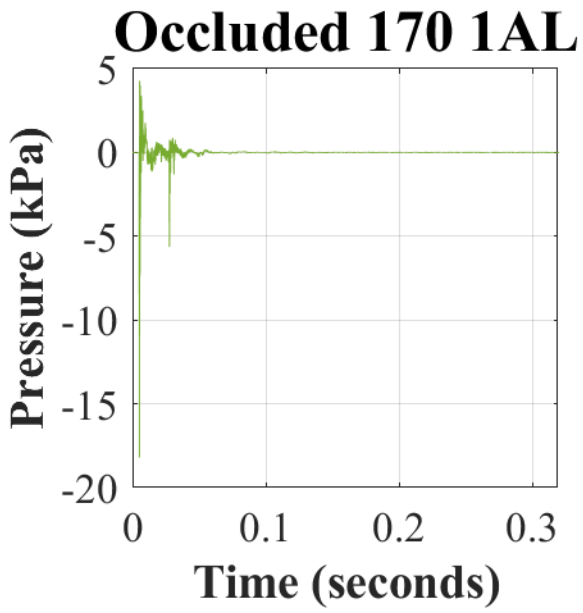

Unoccluded 160 4BL
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

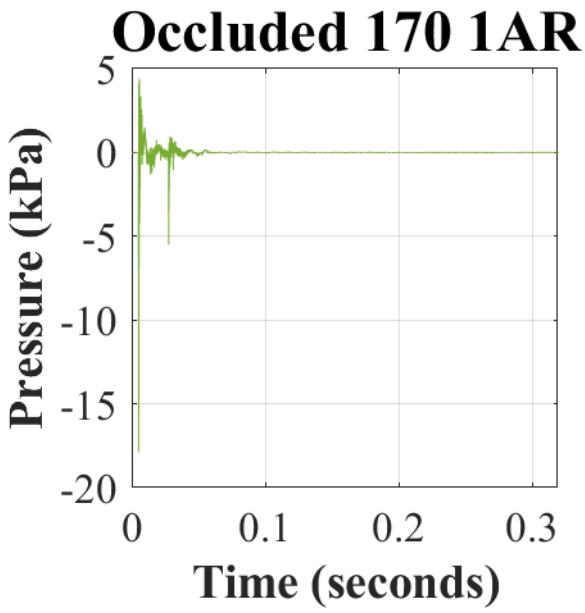

Unoccluded 160 4BR
Pressure (kPa)
2
0
-2
-4
-6
-8
0
0.1
0.2
0.3
Time (seconds)

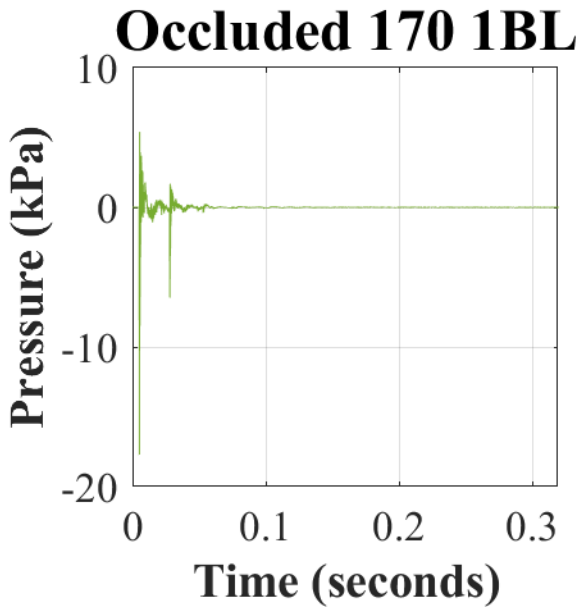


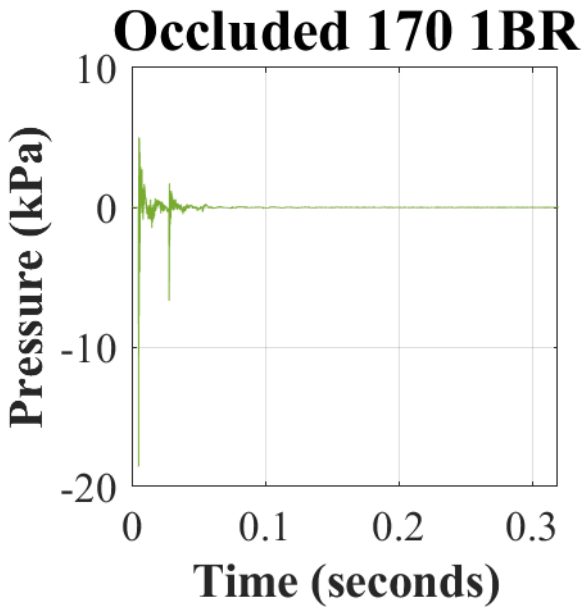
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the helmet doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or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

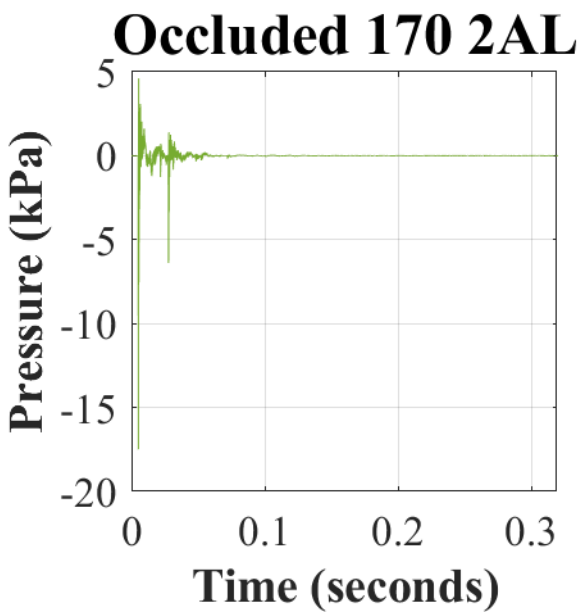
Appendix C. Recorded occluded (helmet donned) waveforms in response to 170 dBP with the ECH-M.

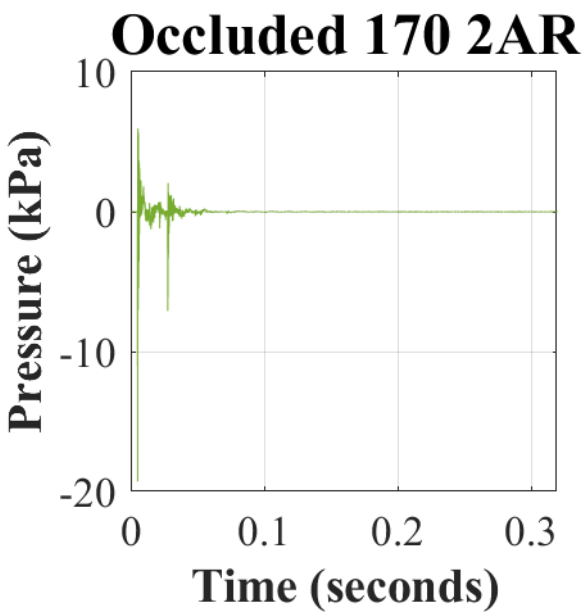


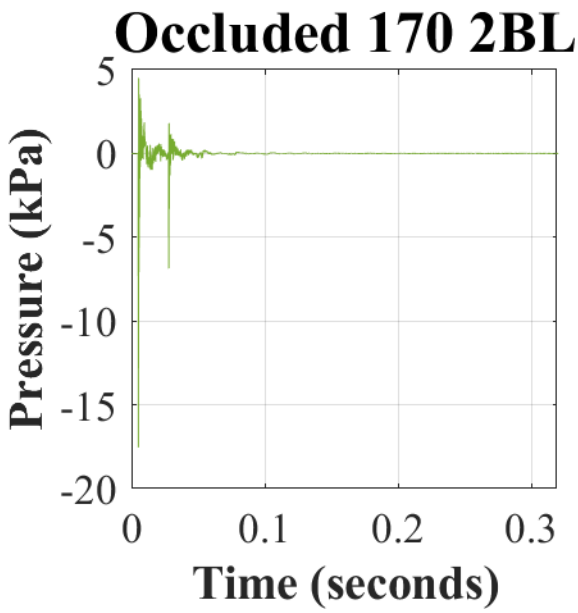


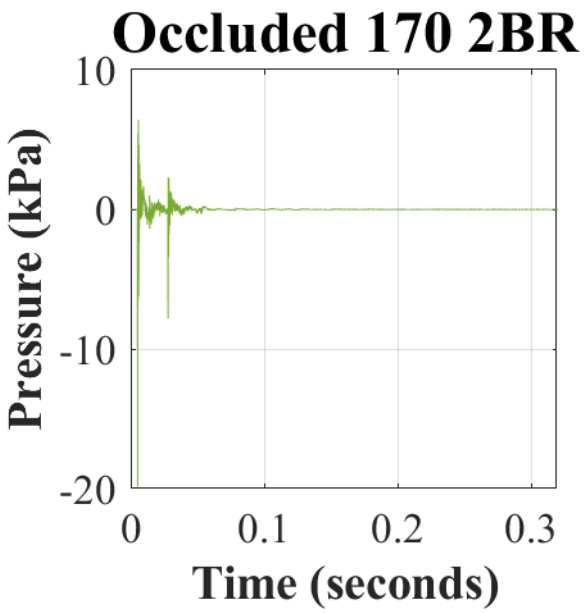


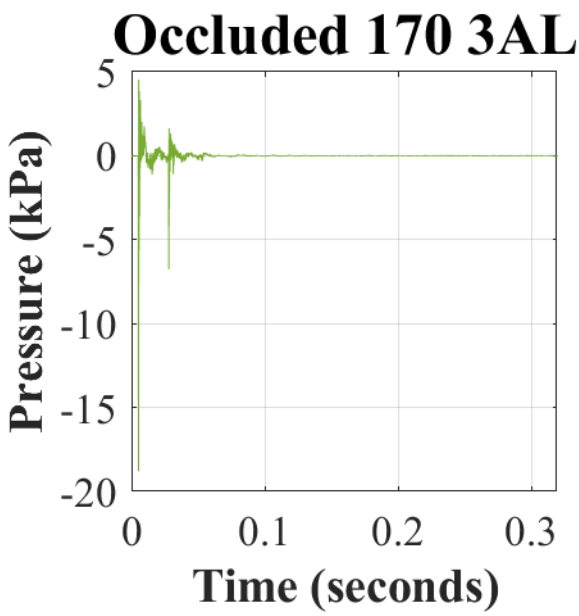


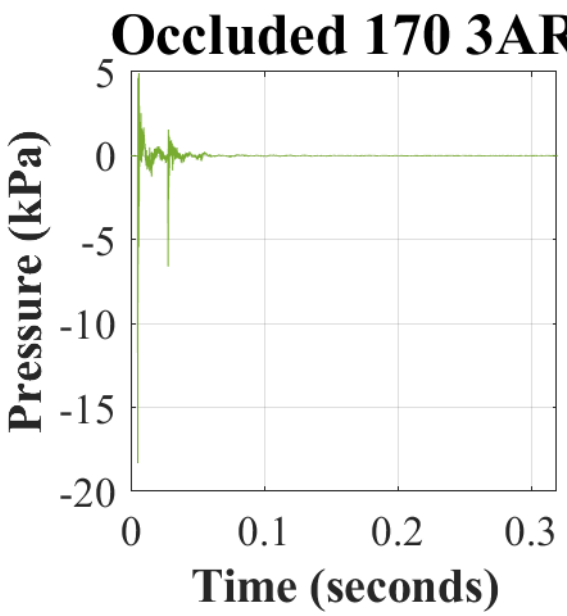

Occluded 170 2AL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

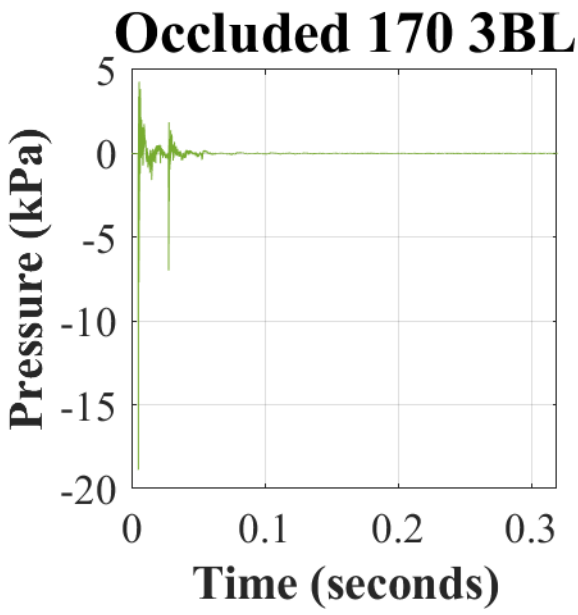

Occluded 170 2AR
Pressure (kPa)
10
0
-10
-20
0
0.1
0.2
0.3
Time (seconds)

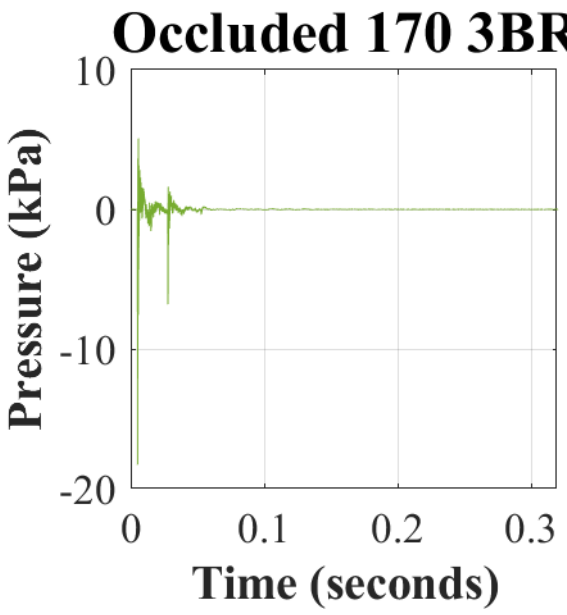

Occluded 170 2BL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

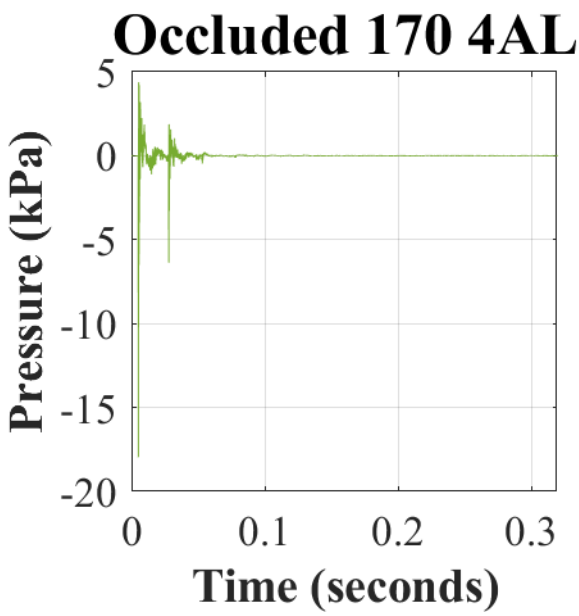

Occluded 170 2BR
Pressure (kPa)
10
0
-10
-20
0
0.1
0.2
0.3
Time (seconds)

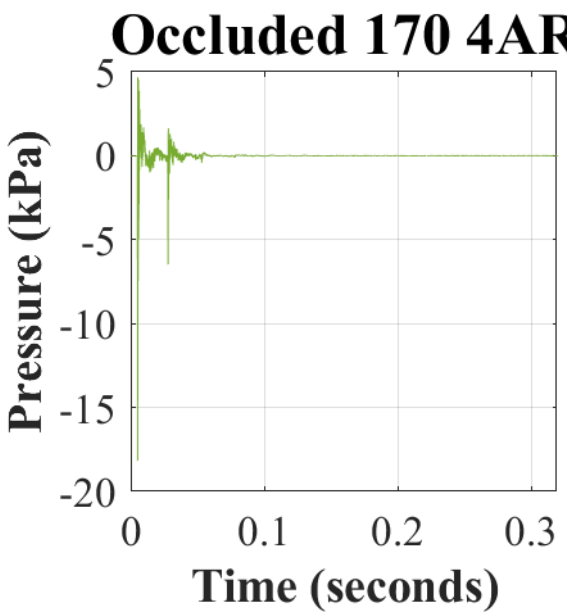

Occluded 170 3AL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

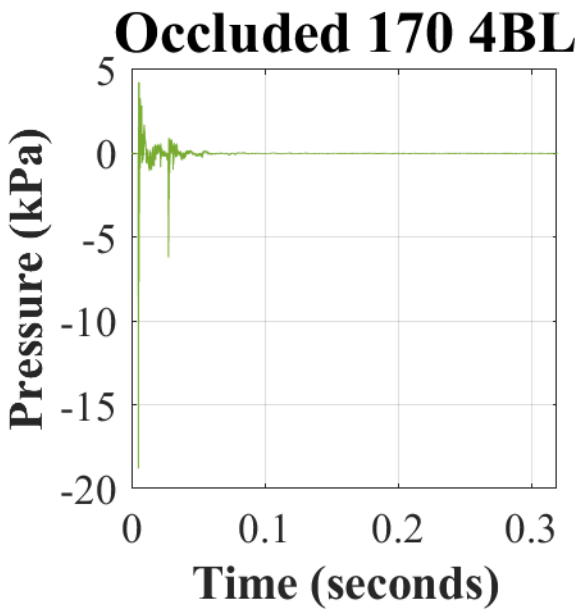

Occluded 170 3AR
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

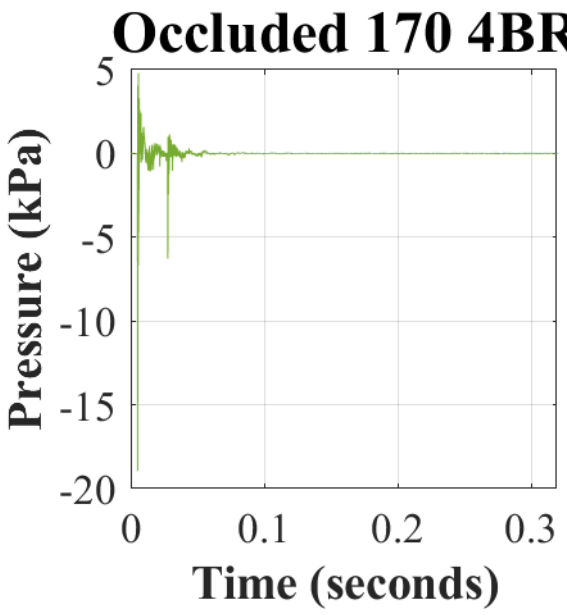

Occluded 170 3BL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

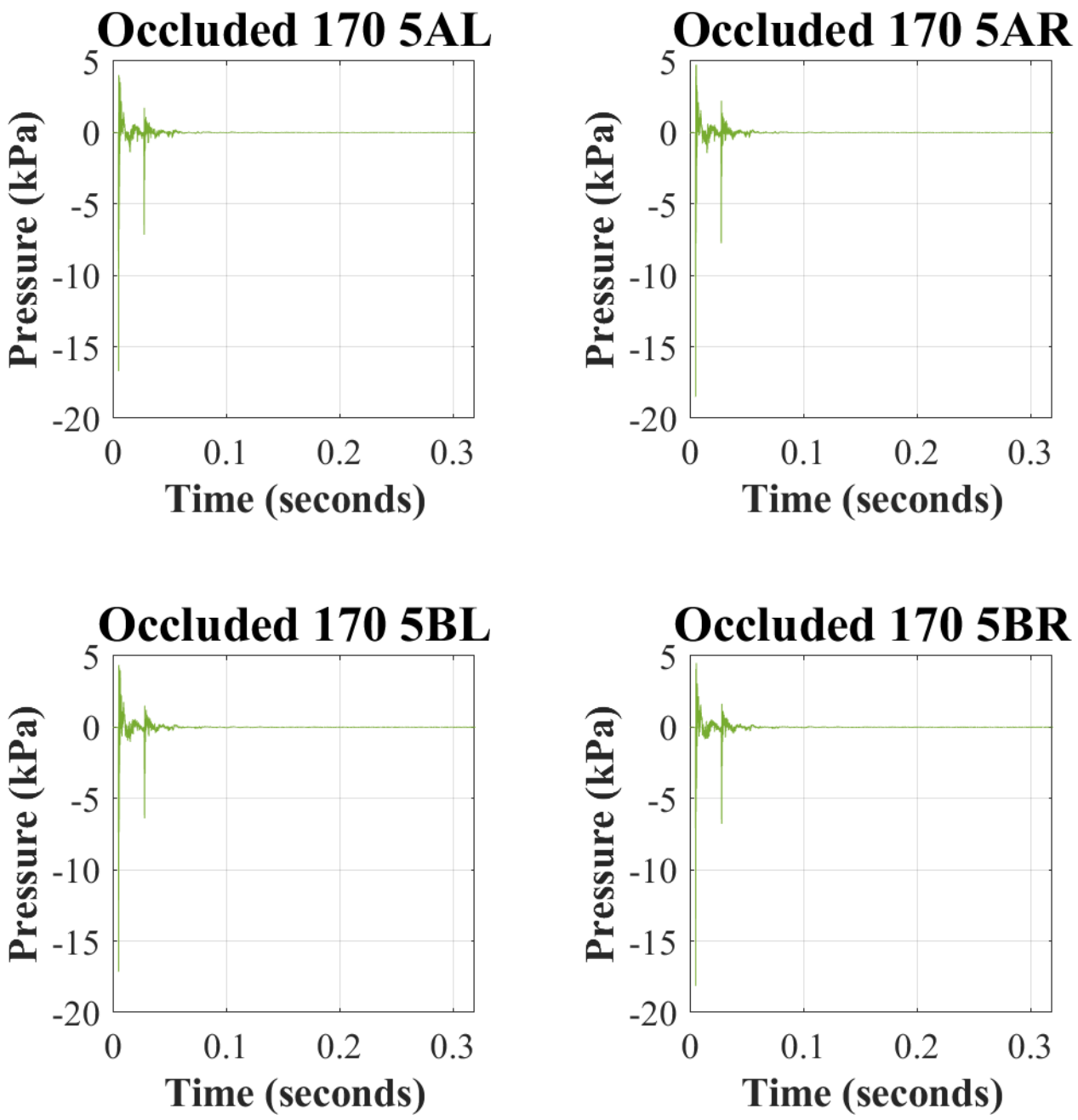

Occluded 170 3BR
Pressure (kPa)
10
0
-10
-20
0
0.1
0.2
0.3
Time (seconds)


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


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

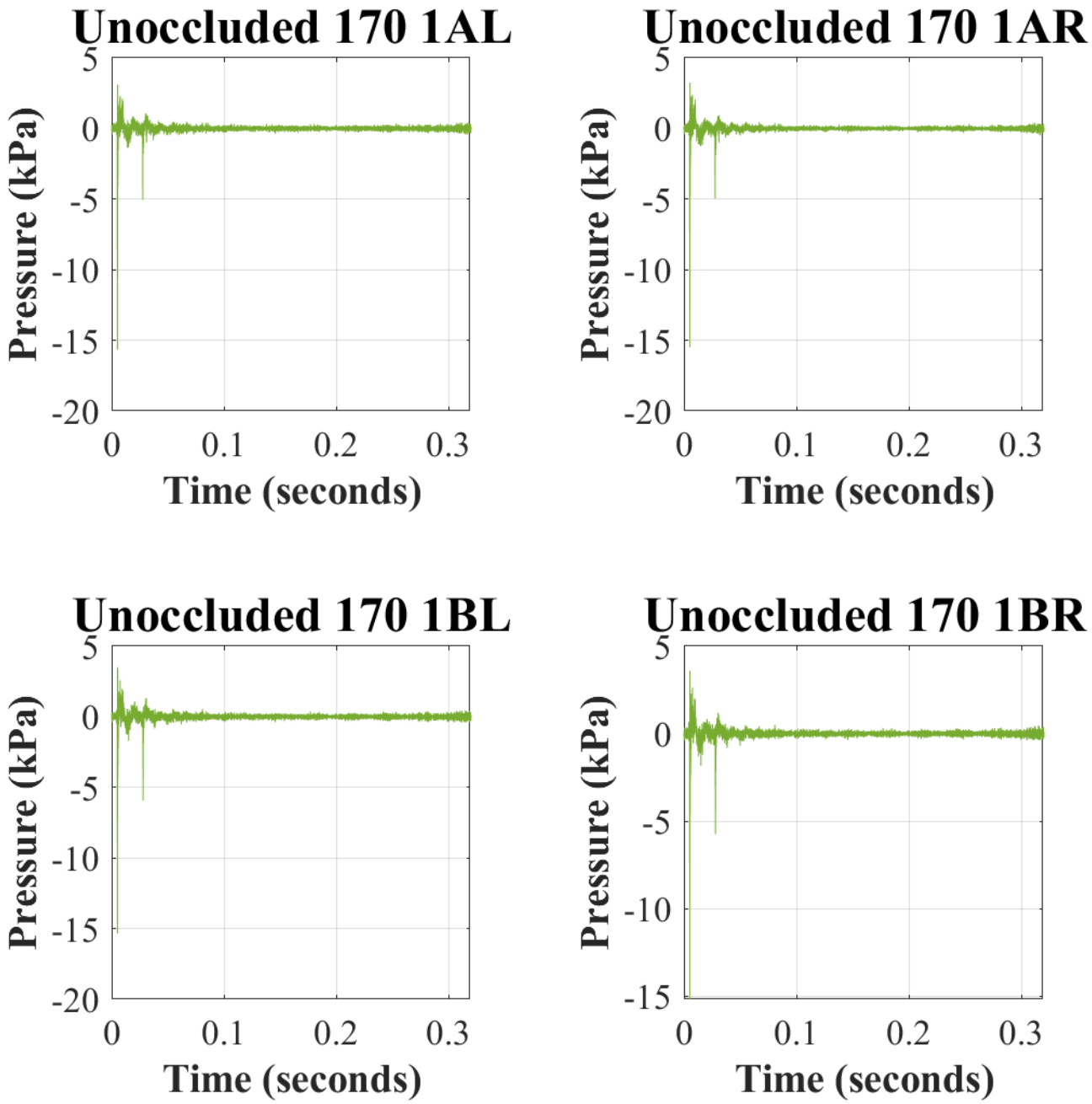

Occluded 170 4BL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

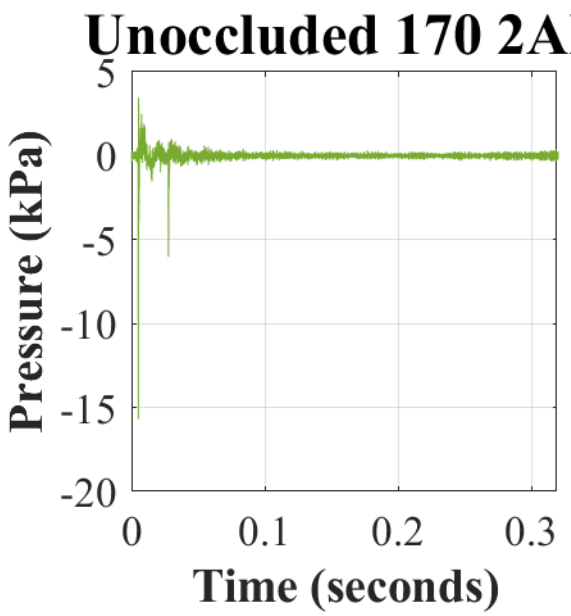

Occluded 170 4BR
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

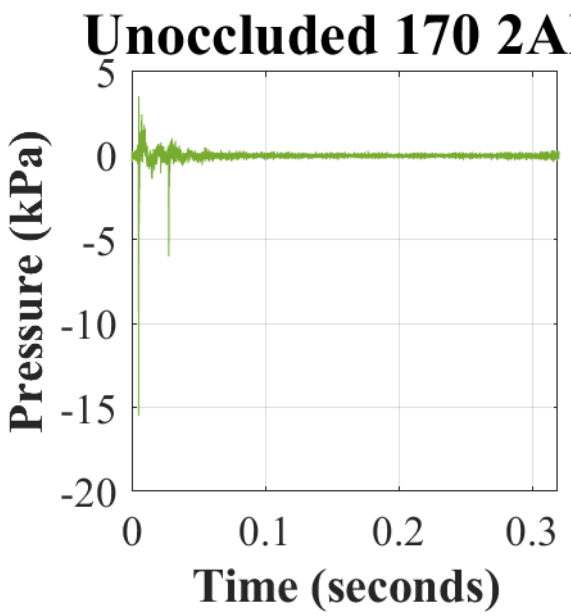


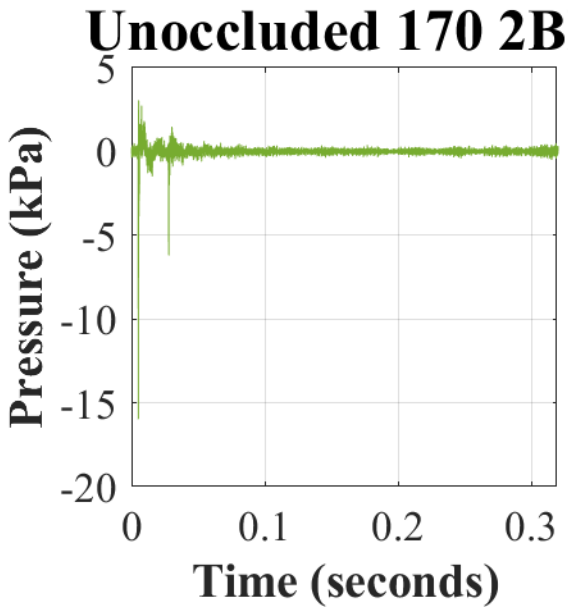
Note. The naming convention for all occluded waveforms is "Occluded LvL NnX", where 'Occluded' is the test condition (i.e., ATF has the helmet donned), 'LvL' is the nominal test level (i.e., 160 or 170 dBP), 'N' is the sample number (i.e., 1 to 5) of the device tested, 'n' is the trial (i.e., A or B) 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).

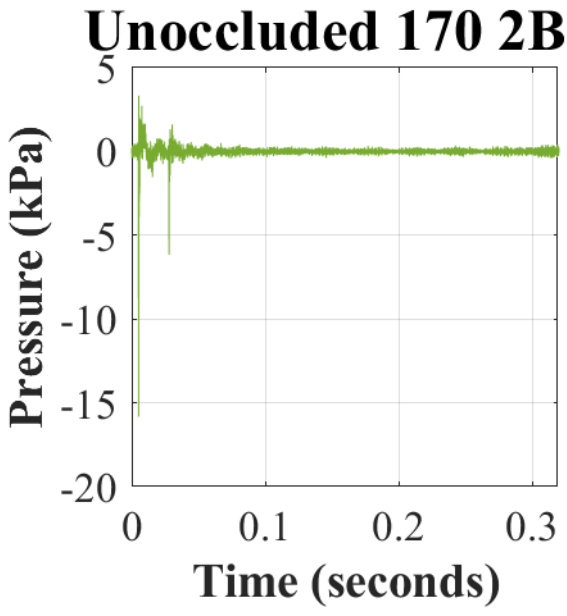
Appendix D. Estimated unoccluded (helmet doffed) waveforms in response to 170 dBP with the ECH-M.

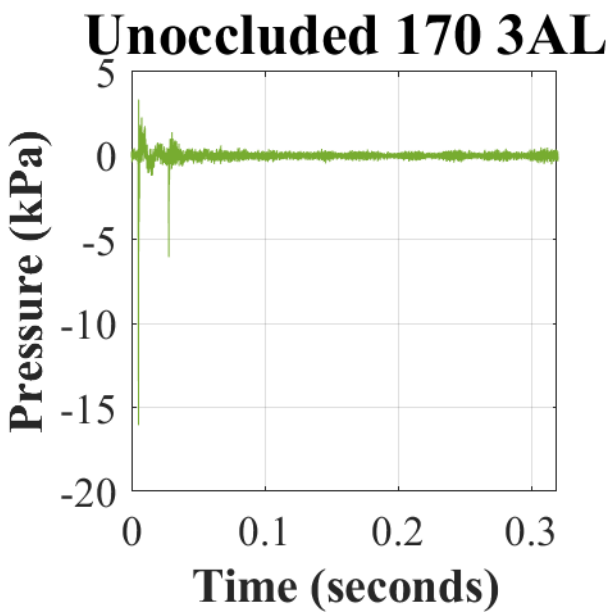


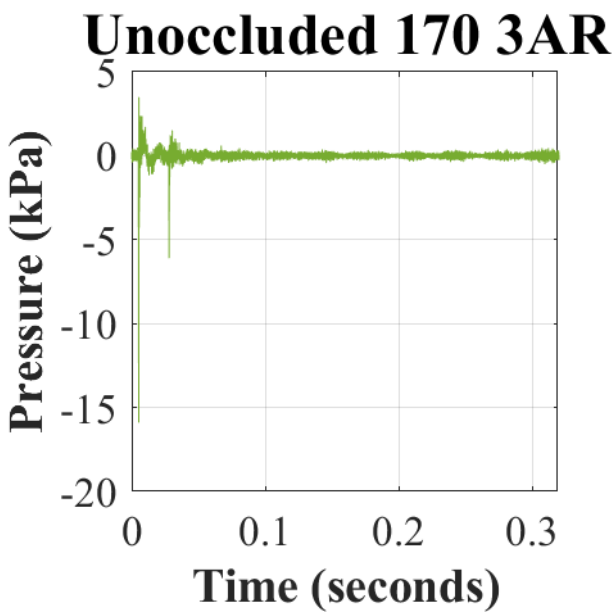

Unoccluded 170 2AL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

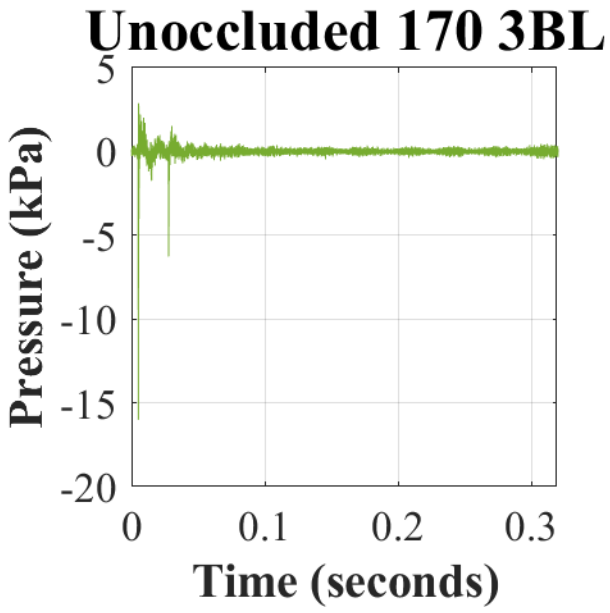

Unoccluded 170 2AR
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

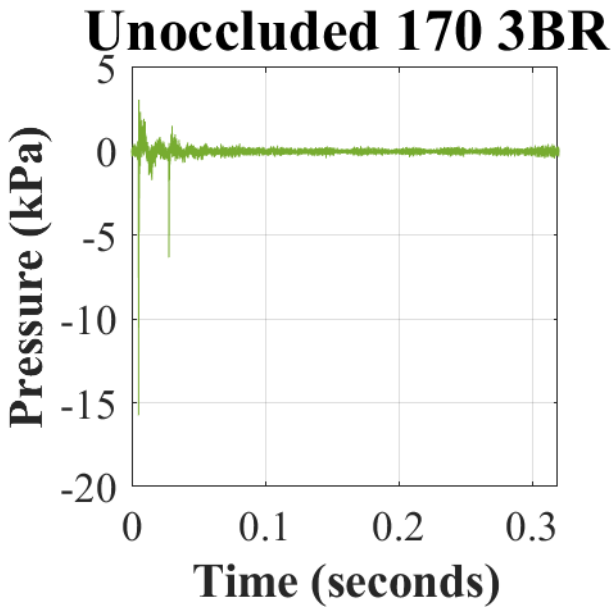

Unoccluded 170 2BL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

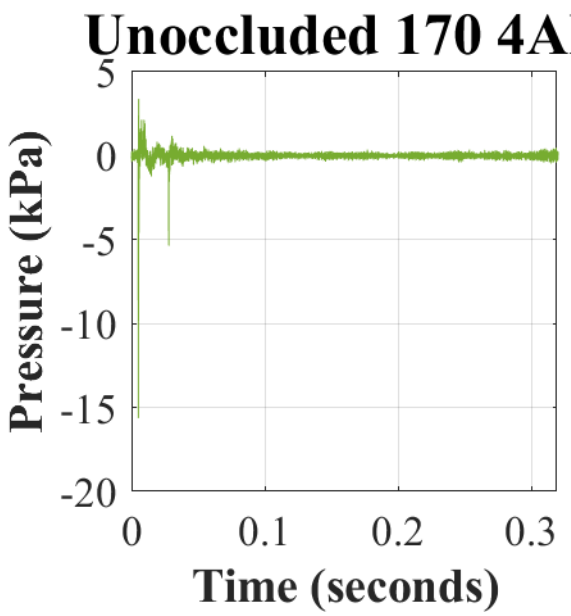

Unoccluded 170 2BR
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

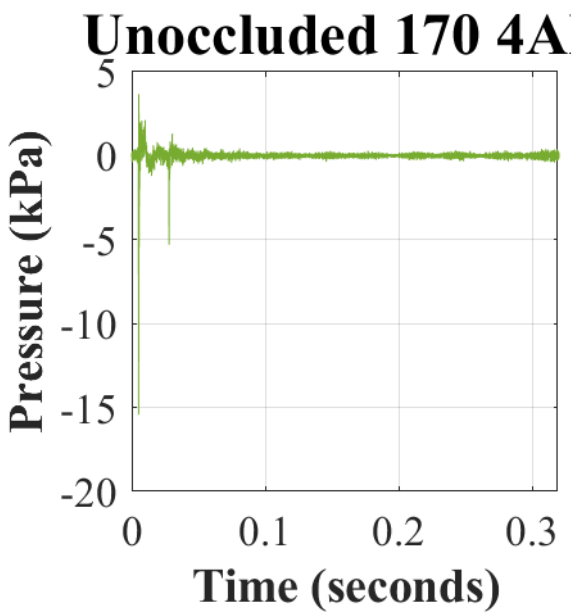

Unoccluded 170 3AL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

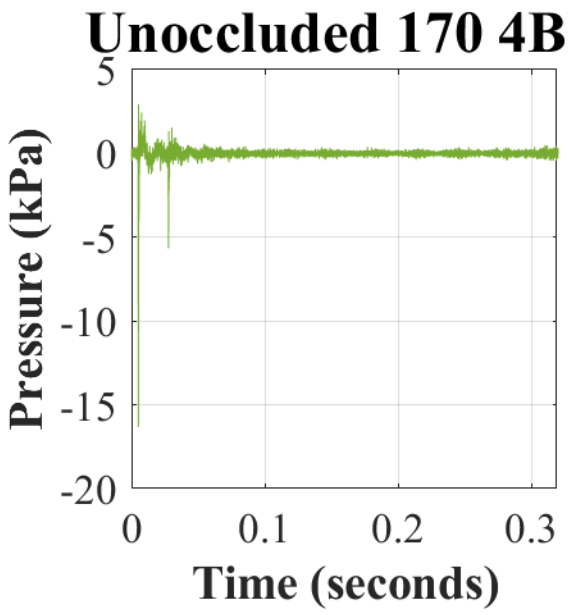

Unoccluded 170 3AR
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

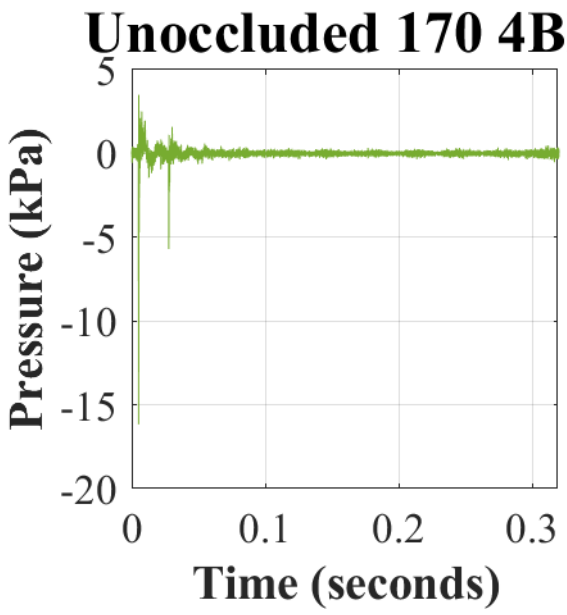

Unoccluded 170 3BL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

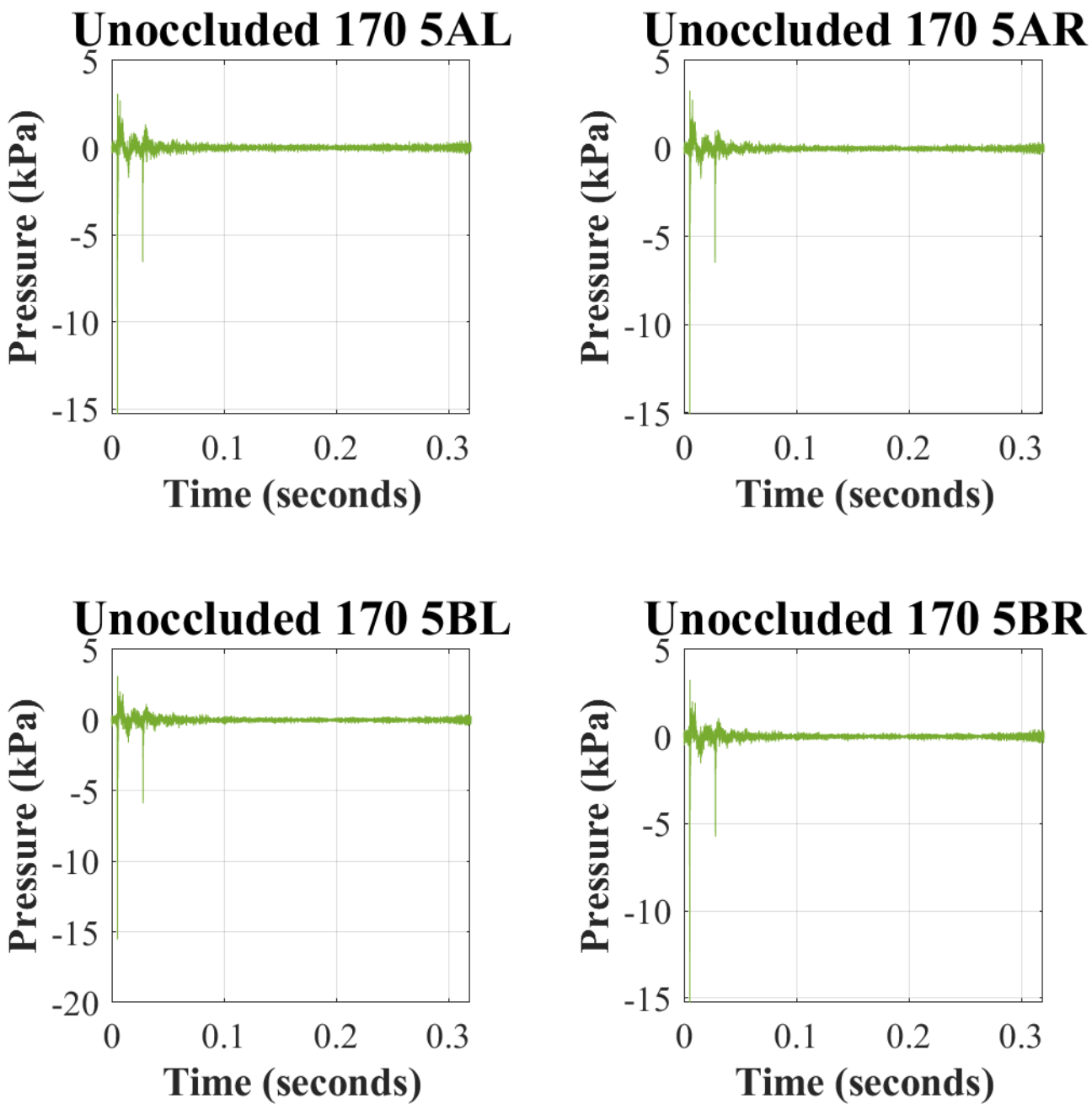

Unoccluded 170 3BR
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)


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


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

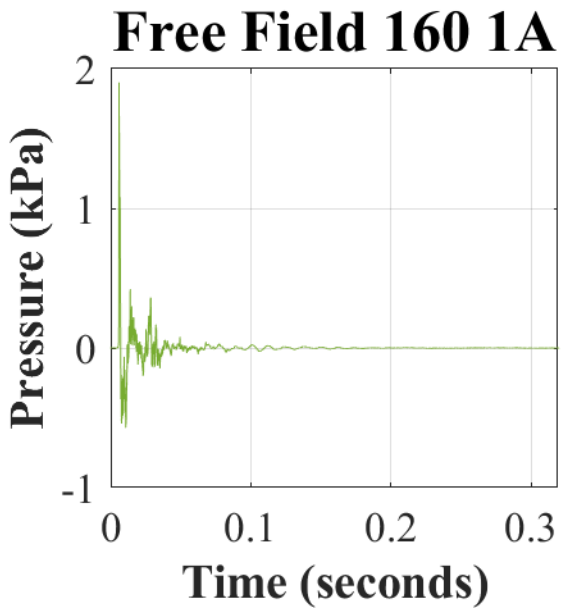

Unoccluded 170 4BL
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

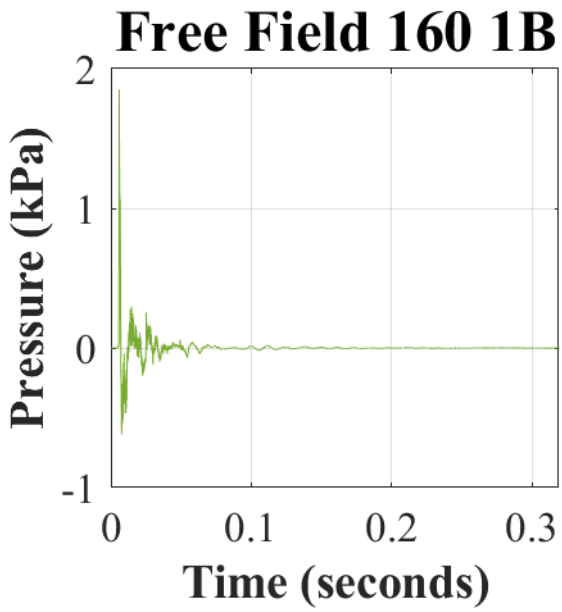

Unoccluded 170 4BR
Pressure (kPa)
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
Time (seconds)

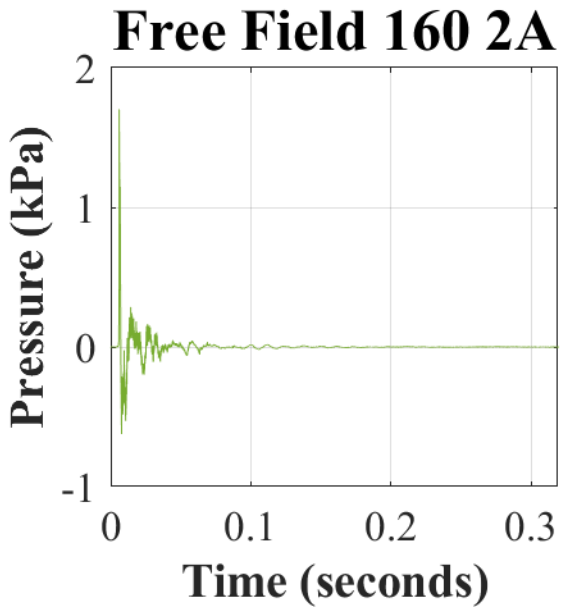


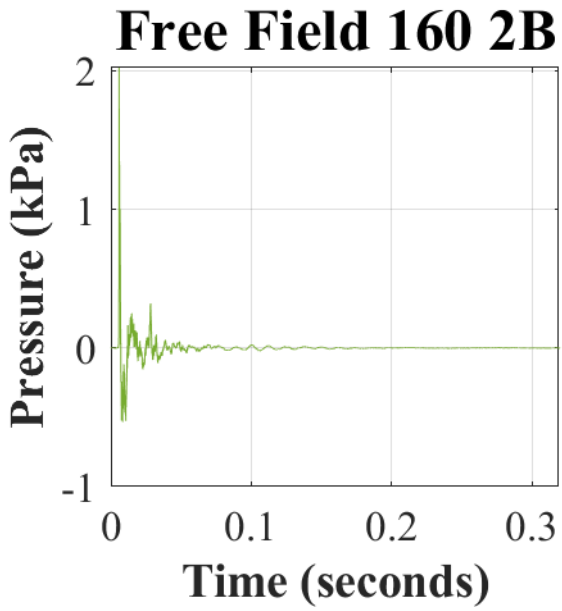
Note. The naming convention for all occluded waveforms is “Occluded LvL NnX”, where ‘Unoccluded’ is the test condition (i.e., ATF has the helmet doffed), ‘LvL’ is the nominal test level (i.e., 160 or 170 dBP), ‘N’ is the sample number (i.e., 1 to 5) of the device tested, ‘n’ is the trial (i.e., A or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

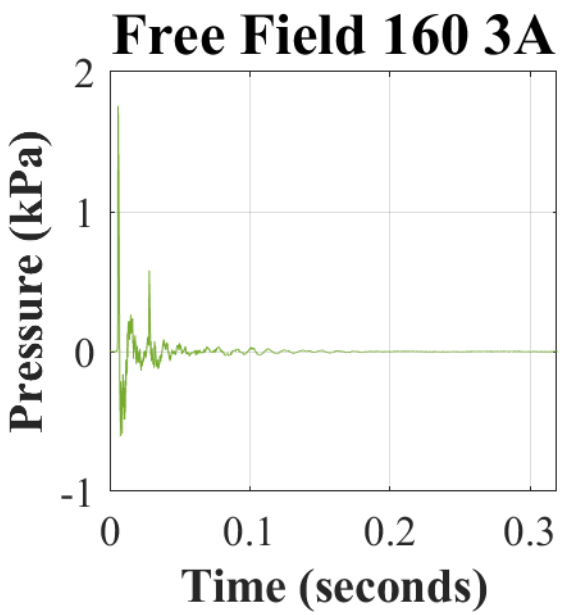
Appendix E. Recorded waveform of the impulse measured with the free-field probe at 160 dBP and the ECH-M donned.

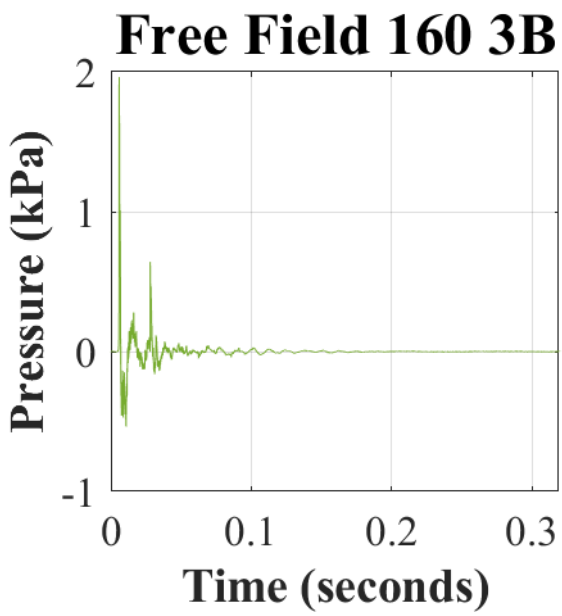


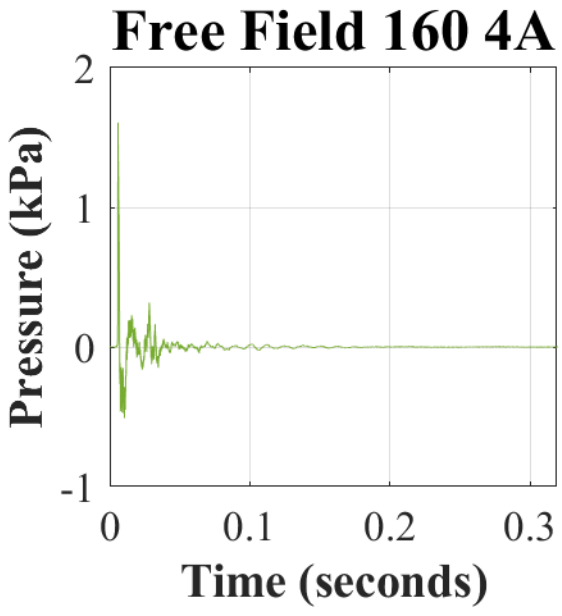


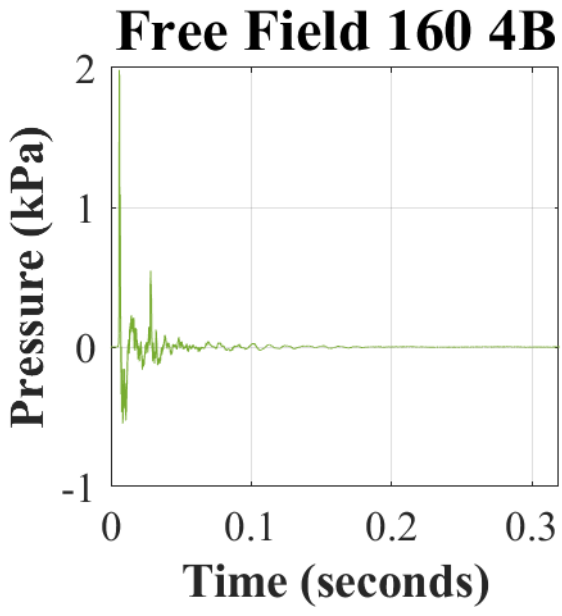


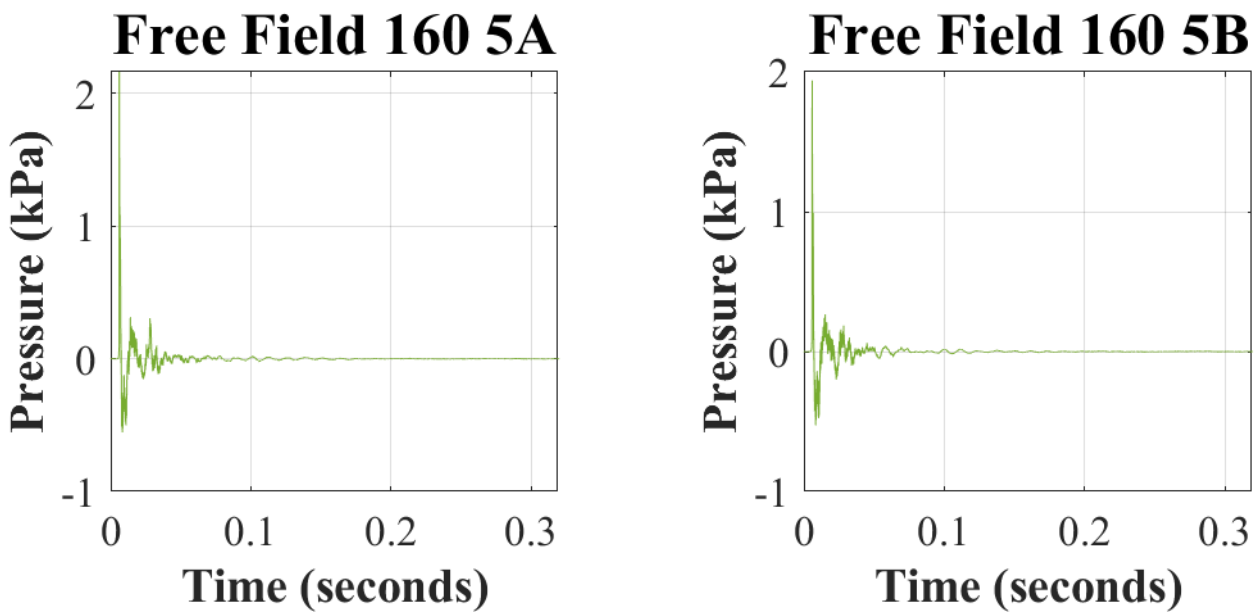



Free Field 160 3A
Pressure (kPa)
Time (seconds)
2
1
0
-1
0
0.1
0.2
0.3


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

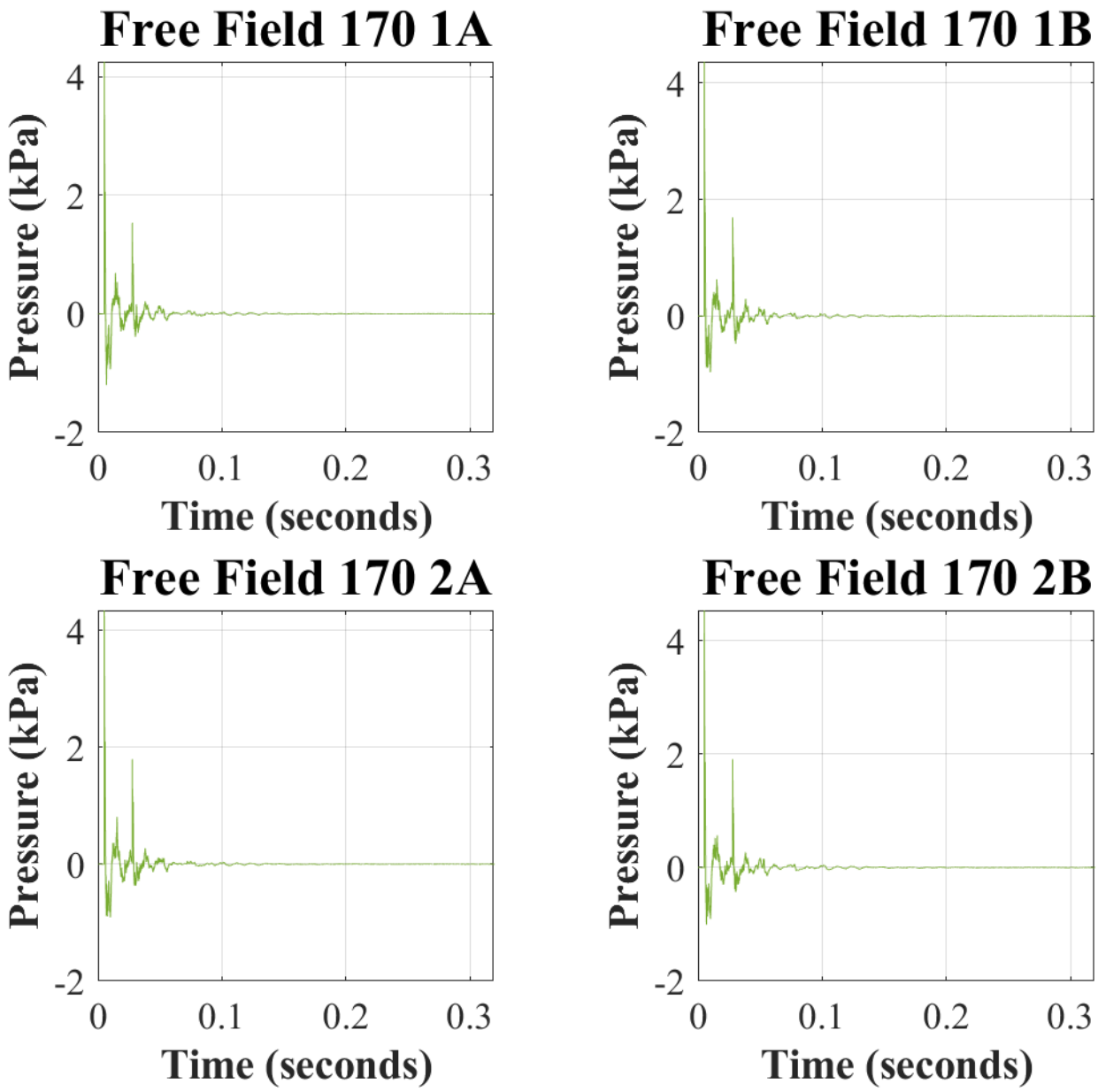

Free Field 160 4A
Pressure (kPa)
Time (seconds)
2
1
0
-1
0
0.1
0.2
0.3

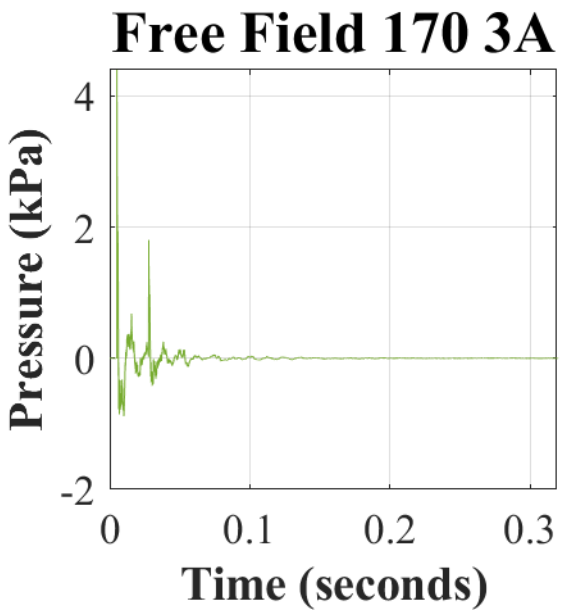

Free Field 160 4B
Pressure (kPa)
Time (seconds)
2
1
0
-1
0
0.1
0.2
0.3

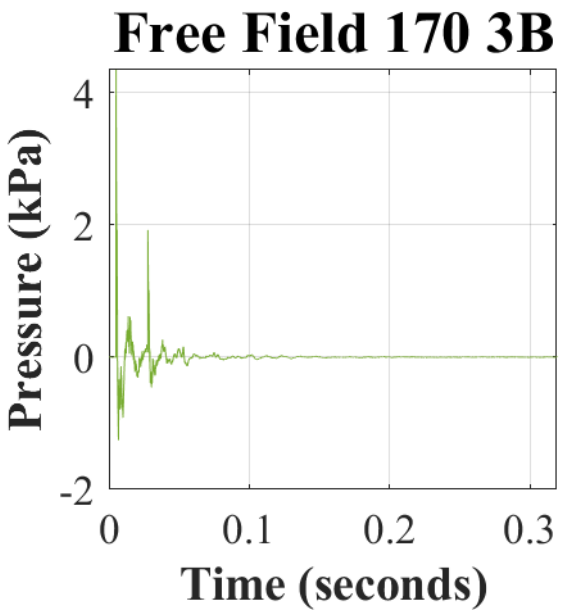


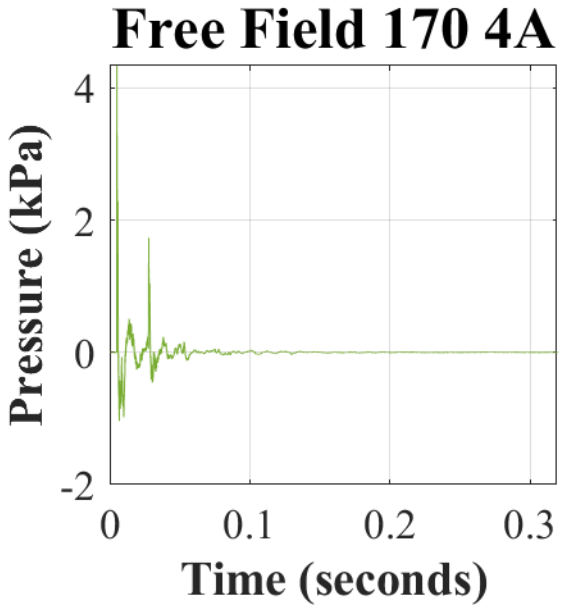
Note. The naming convention for all free-field waveforms is “Free Field LvL Nn”, where ‘Free Field’ indicates that the recording was obtained using the PCB reference microphone, ‘LvL’ is the nominal test level (170 dBP), ‘N’ is the device sample number (1 to 5), and ‘n’ is the device trial (i.e., A or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

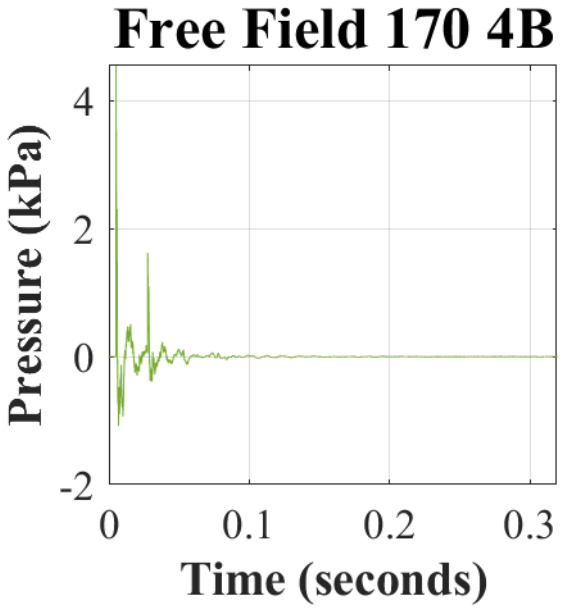
Appendix F. Recorded waveform of the impulse measured with the free-field probe at 170 dBP and the ECH-M donned.

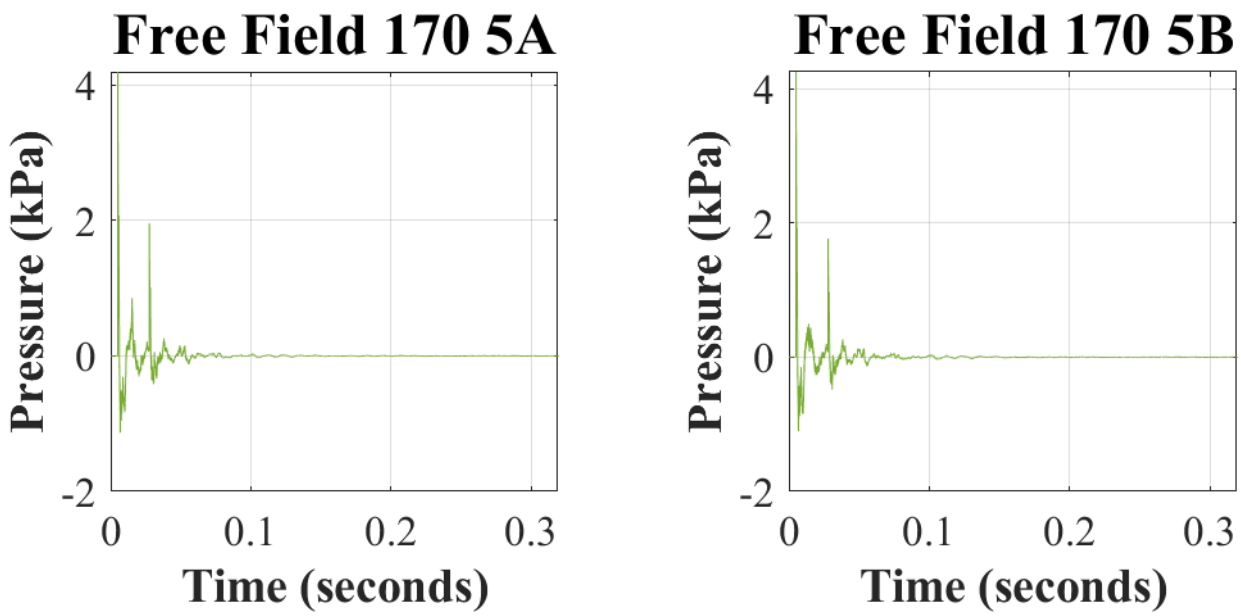



Free Field 170 3A
Pressure (kPa)
4
2
0
-2
0
0.1
0.2
0.3
Time (seconds)


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


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


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



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