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DRAFT ADEON Project Dictionary (Terminology Standard) Version 2

Atlantic Deepwater Ecosystem Observatory Network (ADEON): An Integrated System for Long-Term Monitoring of Ecological and Human Factors on the Outer Continental Shelf

Contract: M16PC00003

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Contents

1 Abbreviations

Acoustical and non-acoustical abbreviations are listed in Table 1 and Table 2, respectively.

Table 1 – Acoustical abbreviations.

Abbreviation	**Meaning**
AAF	Anti-alias filter
ADC	analog to digital converter
AZFP	acoustic zooplankton fish profiler
Lrms	root-mean-square sound pressure level (synonym of sound pressure level – see also SPL)
Lpk	zero-to-peak sound pressure level (synonym of peak sound pressure level)
PL	propagation loss
ROC	receiver operating characteristic (curve)
SEL	sound exposure level
SELw	weighted sound exposure level
ESDL	sound exposure spectral density level
SL	source level
SPL	sound pressure level (synonym of root-mean-square sound pressure level – see also Lrms)
PSDL	mean-square sound pressure spectral density level
SWL	sound power level
TL	transmission loss

Table 2 – Non-acoustical abbreviations.

Abbreviation	**Meaning**
ADEON	Atlantic Deepwater Ecosystem Observatory Network
AIS	Automatic Identification System (for shipping)
AM	arithmetic mean
ANSI	American National Standards Institute
BIPM	International Bureau of Weights and Measures
BOEM	Bureau of Ocean Energy Management
cdf	cumulative probability distribution function
EC	European Commission
ESA	Endangered Species Act
EU	European Union
GES	(MSFD) Good Environmental Status
GM	geometric mean
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IQOE	International Quiet Ocean Experiment
ISO	International Organization for Standardization
ISQ	International System of Quantities
IWC	International Whaling Commission
JASCO	JASCO Applied Sciences

Abbreviation	Meaning
JIP	E&P Sound and Marine Life Joint Industry Programme
JIP UA-R	JIP reporting standard (Ainslie & de Jong, 2017)
JIP UA-T	JIP terminology standard (Ainslie et al., 2017b)
LSB	least significant bit
MMPA	Marine Mammal Protection Act
MS	(EU) Member State
MSFD	(EU) Marine Strategy Framework Directive
NA	not applicable
NMFS	NOAA National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OASIS	Ocean Acoustical Services and Instrumentation Systems, Inc.
OCS	outer continental shelf
ONR	Office of Naval Research
ONR-G	ONR Global
P.I.	Principal Investigator
rms	root-mean-square (square root of the mean-square value)
rss	root-sum-square (square root of the summed squared value)
SBU	Stony Brook University
SFA	Sustainable Fisheries Act
SI	International System of Units
SWFSC	NOAA Southwest Fisheries Science Center
TNO	Netherlands Organisation for Applied Scientific Research
TSG Noise	(EU expert group) Technical Sub-Group Noise
UNH	University of New Hampshire
UTC	Coordinated Universal Time

2 Introduction

2.1 ADEON project

The Atlantic Deepwater Ecosystem Observatory Network (ADEON) is a five-year study of the US Mid- and South Atlantic Outer Continental Shelf (OCS). The lead P.I. for this project is Dr. Jennifer Miksis-Olds, University of New Hampshire (UNH). Dr. Miksis-Olds leads a collaborative research team consisting of individuals from UNH, OASIS, TNO, JASCO, Stony Brook University, and NOAA.

This observatory network will generate multi-year measurements of the natural and human factors that describe the ecology and soundscape of the OCS. Multi-year observations of living marine resources and marine sound will assist Federal agencies, including BOEM, ONR, and NOAA, in complying with mandates in the Endangered Species Act (ESA), Marine Mammal Protection Act (MMPA), and Sustainable Fisheries Act (SFA).

2.2 Objectives

2.2.1 ADEON project objectives

The ADEON project objectives are to:

- Establish an ecosystem observation network that provides baseline monitoring and supports predictive modeling of the soundscape and its relationship to marine life and the environment of the Mid- and South Atlantic Planning Areas.
- Develop standardized measurement and processing methods and visualization metrics for comparing ADEON observations with data from other monitoring networks.
- Assess baseline soundscape and ecosystem conditions in support of predictive environmental modeling and trend analyses in the planning areas.
  - o How do soundscape and ecosystem components vary with water depth across the OCS?
  - o How do the soundscape and ecosystem components vary with latitude along the OCS?
  - o Where are the hot spots of human activity for consideration in ecosystem/habitat health impacts?
- Assess the spatial and temporal distribution of the soundscape and biological scatterers, including their expected variation and correlation with distance from the mooring locations.
  - o What are the environmental factors that define and constrain the horizontal range of appropriate extrapolation of observations measured at the stationary bottom lander sites?
- Develop and apply new methods for the effective visualization of five-dimensional (5D – time, latitude, longitude, frequency, and depth) soundscape data with interactive visual analysis tools that enable users to explore, analyze, and integrate ancillary ecosystem data streams with the 5D soundscape.
- Develop a robust data management system that archives and provides public access to multiple data streams to encourage future development of ecological models targeted at questions beyond the scope of this study.

2.2.2 *ADEON Standardization objectives*

The objectives of ADEON's Standardization task are to:

- Ensure compatibility within ADEON between soundscapes based on measurements and those based on models.
- Ensure compatibility between measurements made by different researchers or institutes within ADEON.
- Facilitate compatibility between ADEON soundscapes, whether based on measurement or model prediction, and soundscapes produced by a hypothetical future or parallel project within the US EEZ.
- Facilitate compatibility between metrics used to quantify ADEON soundscapes and those used to monitor ambient sound in the context of the EU's MSFD.

This report, the draft *Project Dictionary (Terminology Standard)*, completes the set of five (draft) Standardization reports, which together meet the above four objectives. The purpose of the Project Dictionary is to provide a common language for the other four documents.

2.3 What is a soundscape?

For airborne acoustics, in the context of human hearing, the term "soundscape" usually implies an element of perception of the sound. For example, entry 2.3 of ISO 12913-1:2014 defines this term as "acoustic environment as perceived or experienced and/or understood by a person or people, in context". However, the same term is used without this implication in contexts other than human hearing, both in air (Pijanowski et al., 2011; Farina and Pieretti, 2012; Gage and Axel, 2014) and in water (Fay, 2009; Dugan et al., 2013; Hastings and Širović, 2015). For this reason, the definition of "soundscape" according to the international underwater acoustical terminology standard ISO 18405 also excludes a perception element. Following ISO 18405, ADEON therefore defines the terms 'soundscape' and 'ambient sound' as shown in Figure 1 and Figure 2, respectively. The related terms "auditory scene" and "auditory stream" are in use to describe the perception of a soundscape by a listener (Hulse, 2002; Shamma et al., 2011).

> **3.1.1.3**
> **soundscape**
> <underwater acoustics> characterization of the *ambient sound* (3.1.1.2) in terms of its spatial, temporal and frequency attributes, and the types of sources contributing to the sound field

Figure 1 – Definition of "soundscape" from ISO 18405:2017.

3.1.1.2
ambient sound
sound (3.1.1.1) that would be present in the absence of a specified activity

Note 1 to entry: Ambient sound is location-specific and time-specific.

Note 2 to entry: In the absence of a specified activity, all sound is ambient sound.

Note 3 to entry: Ambient sound includes *ambient noise* (3.1.5.11).

Note 4 to entry: Examples of specified activity include the act of measuring the underwater sound and the radiation of sound by specified sound sources.

Note 5 to entry: Ambient sound can be anthropogenic (e.g. shipping) or natural (e.g. wind, biota).

Figure 2 – Definition of “ambient sound” from ISO 18405:2017.

2.4 Use of Standardized Terminology

The terminology standard ISO 18405:2017 ‘Underwater Acoustics – Terminology’ has international consensus and was developed specifically for underwater acoustics. The main alternative to ISO 18405 was ANSI S1.1-2013 ‘Acoustical Terminology’. ANSI S1.1 contains bioacoustical terminology for human hearing in air (for example, by default sound exposure level as defined by ANSI S1.1-2013 is A-weighted) and for biological contributions to sonar noise and reverberation. However, bioacoustical terminology relevant to aquatic animals and to underwater soundscapes is outside the scope of ANSI S1.1-2013, making ISO 18405 a natural choice for ADEON. ISO 18405 has been adopted by the ADEON project and is followed throughout this report.

Every attempt has been made by the ADEON project to follow relevant international standards. Nevertheless where there is a project-specific need to depart from an international standard, this is achieved by giving the ADEON standard precedence over all others. For acoustical terminology, the following standards are followed, in order of decreasing precedence

- Project Dictionary (Terminology Standard) (this document)
- ISO 18405:2017 Underwater Acoustics – Terminology
- ISO 80000-8:2007 Quantities and Units – Acoustics
- ISO 80000-3:2006 Quantities and Units – Space and Time
- ISO 80000-1:2009 Quantities and Units – General

2.5 Purpose of this report

The purpose of this report is to provide terminology for the ADEON project.
The project’s focus on soundscapes means that the main focus of this report is on acoustical terminology relevant to soundscapes.

2.6 Report structure

The remainder of this report is structured as follows:

– Sec. 3: Mathematical symbols and conventions
– Sec. 4: General acoustical terminology

- Sec. 5: Acoustical terminology for soundscape description
- Sec. 6: Acoustical terminology for hardware
- Sec. 7: Levels and other logarithmic quantities usually expressed in decibels
- Sec. 8: Acoustical Terminology for soundscape data processing
- Sec. 9: Acoustical terminology for soundscape reporting
- Sec. 10 References
- Appendix A: Selected terminology from IEEE 1421 (informative)
- Appendix B: Non-acoustical terminology (normative)

3 Mathematical symbols and conventions

For mathematical symbols generally, ISO 80000-2 shall be followed. Functions and operations of particular relevance include logarithms and Fourier transforms.

3.1 Logarithms

Symbols for natural, base 2 and base 10 logarithms are listed in Table 3.

Table 3 – Standard symbols for logarithms (ISO 80000-2:2009).

type of logarithm	**Symbol**	**alternative symbol**	**notes**
base 2	$\log_2 x$	$\mathrm{lb}\, x$	
base e	$\log_\mathrm{e} x$	$\ln x$	also known as natural logarithm
base 10	$\log_{10} x$	$\lg x$	

3.2 Spectra (Fourier transform pairs)

As a general rule a lower case symbol is used for a time domain quantity such as sound pressure, $p(t)$, or source waveform, $s(t)$, with the upper case symbols $P(f)$ and $S(f)$ for the corresponding Fourier transforms (ISO 80000-2). Specifically, if $x(t)$ and $X(f)$ form a Fourier transform pair, they are related by

$$X(f) = \int_{-\infty}^{+\infty} x(t) \exp(-2\pi \mathrm{i} f t)\, \mathrm{d}t$$

$$x(t) = \int_{-\infty}^{+\infty} X(f) \exp(+2\pi \mathrm{i} f t)\, \mathrm{d}t.$$

4 General acoustical terminology

General acoustical terminology is defined in Table 4 (concepts), Table 5 (frequency bands) and Table 6 (basic sound field properties).

Table 4 – General acoustical terminology: concepts.

term	**Definition**
sound	alteration in pressure, stress or material displacement propagated via the action of elastic stresses in an elastic medium and that involves local compression and expansion of the medium, or the superposition of such propagated alterations **NOTES**: Source: ISO 18405, entry 3.1.1.1 If only acoustic pressure fluctuations are present (implying the absence of mean flow and turbulence), the total pressure at a location is the background hydrostatic pressure plus the sound pressure.
ambient sound	*sound* that would be present in the absence of a specified activity **NOTES**: see Figure 2 source: ISO 18405, entry 3.1.1.2
soundscape	<underwater acoustics> characterization of the *ambient sound* in terms of its spatial, temporal and frequency attributes, and the types of sources contributing to the sound field **NOTES**: see Figure 1 Source: ISO 18405, entry 3.1.1.3
material element	smallest element of the medium that represents the medium's mean density **NOTES**: Source: ISO 18405, entry 3.1.1.5
signal	specified time-varying electric current, voltage, *sound pressure*, *sound particle displacement*, or other field quantity of interest **NOTES**: Source: ISO 18405, entry 3.1.5.8
acoustic self-noise	*sound* at a receiver caused by the deployment, operation, or recovery of a specified receiver, and its associated platform **NOTES**: Source: ISO 18405, entry 3.1.5.10
ambient noise	*sound* except *acoustic self-noise* and except *sound* associated with a *specified signal*

term	Definition
	NOTES: Source: ISO 18405, entry 3.1.5.11
temporal observation window	interval of time within which a statistic of the sound pressure is calculated or estimated **NOTES**: Examples of statistic include rms sound pressure, peak sound pressure, and sound pressure kurtosis.
temporal analysis window	interval of time during which statistics are calculated over multiple temporal observation windows
spatial observation window	region of space within which the spatially averaged mean-square sound pressure is calculated or estimated, for a specified duration of the temporal observation window **NOTES**: The size of a spatial observation window is specified by means of an area (e.g., 1000 km^2) and a depth range (e.g., 50 m to 200 m).
spatial analysis window	region of space within which statistics are calculated over multiple spatial observation windows **NOTES**: The size of a spatial analysis window is specified by means of an area (e.g., 100 000 km^2) and a depth range (e.g., 50 m to 200 m).

Table 5 – General acoustical terminology: frequency bands.

term	Definition
octave **symbol**: oct	logarithmic frequency interval between frequencies f_1 and f_2 when f_2/f_1 = 2 **NOTES**: Based on ISO 80000-8:2007. The formal definition of this unit is “1 oct := lb 2 = 1”.
decade **symbol**: dec	logarithmic frequency interval between frequencies f_1 and f_2 when f_2/f_1 = 10 **NOTES**: Based on ISO 80000-8:2007. The formal definition of this unit is “1 dec := lb 10 = (lb 10) oct”. 1 dec ≈ 3.322 oct Standard decade bands adopted by ADEON are specified in Table 6 of Ainslie et al. (2017a).
one-third octave **synonym**: one-third octave (base 2)	one third of an octave **NOTES**:

term	Definition
symbol: oct	From ISO 18405, entry 3.1.4.1. One one-third octave is approximately equal to a decidecade: 1/3 oct ≈ 1.003 ddec
decidecade **synonym**: one-third octave (base 10) **symbol**: ddec	one tenth of a decade **NOTES**: From ISO 18405, entry 3.1.4.2. One decidecade is approximately equal to a one-third octave: 1 ddec ≈ 0.3322 oct. International standard decidecade bands adopted by ADEON are specified in Table 5 of Ainslie et al. (2017a).

Table 6 – General acoustical terminology: basic sound field properties.

term	Definition
sound pressure **symbol**: $p(t)$ **unit**: Pa	contribution to total pressure caused by the action of *sound* **NOTES**: Source: ISO 18405, entry 3.1.2.1
sound pressure spectrum **synonym**: complex sound pressure spectrum **symbol**: $P(f)$ **unit**: Pa/Hz	Fourier transform of the *sound pressure* **NOTES**: Source: ISO 18405, entry 3.1.2.2
sound particle displacement **symbol**: $\boldsymbol{\delta}(t)$ **unit**: m	displacement of a *material element* caused by the action of *sound* **NOTES**: Source: ISO 18405, entry 3.1.2.9
sound particle velocity **symbol**: $\boldsymbol{u}(t)$ **unit**: m/s	contribution to velocity of a *material element* caused by the action of *sound* **NOTES**: Source: ISO 18405, entry 3.1.2.10
sound particle acceleration **symbol**: $\boldsymbol{a}(t)$ **unit**: m/s^2	contribution to acceleration of a *material element* caused by the action of *sound* **NOTES**: Source: ISO 18405, entry 3.1.2.11

5 Acoustical terminology for soundscape description

Qualitative descriptions of concepts like “sound” and “soundscape” are needed (see Table 4) before the physical characteristics of these concepts (Table 7) and properties of sound sources (Table 8) can be quantified.

Table 7 – Sound field metrics (see Sec. 7 for definitions of logarithmic quantities such as levels and level differences).

preferred term	**Definition**
zero-to-peak sound pressure **synonym**: peak sound pressure; peak amplitude **symbol**: $p_{0-\mathrm{pk}}$; p_{pk} **unit**: Pa	greatest magnitude of the *sound pressure* during a specified time interval, for a specified frequency range **NOTES**: Source: ISO 18405, entry 3.1.2.3
mean-square sound pressure **symbol**: $\overline{p^2}$ **unit**: Pa^2	integral over a specified time interval of squared *sound pressure*, divided by the duration of the time interval, for a specified frequency range **NOTES**: Source: ISO 18405, entry 3.1.3.1
time-integrated squared sound pressure **synonym**: sound pressure exposure **symbol**: $E_{p,T}$ **unit**: Pa^2 s	<underwater acoustics> integral of the square of the *sound pressure*, p, over a specified time interval or event, for a specified frequency range **NOTES**: Source: ISO 18405, entry 3.1.3.5
sound pressure exposure spectral density **synonym**: sound exposure spectral density **symbol**: E_f **unit**: Pa^2 s/Hz	<underwater acoustics> distribution as a function of non-negative frequency of the time-integrated squared *sound pressure* per unit bandwidth of a sound having a continuous spectrum **NOTES**: Source: ISO 18405, entry 3.1.3.9
mean-square sound pressure spectral density **symbol**: $\left(\overline{p^2}\right)_f$ **unit**: Pa^2/Hz	distribution as a function of non-negative frequency of the *mean-square sound pressure* per unit bandwidth of a sound having a continuous spectrum **NOTES**: Source: ISO 18405, entry 3.1.3.13
average mean-square sound pressure **symbol**: $\langle\overline{p^2}\rangle$ **unit**: Pa^2	spatially averaged mean-square sound pressure, for a specified averaging time, specified frequency band, and specified averaging volume **NOTES**: The average mean-square sound pressure is needed for spatial statistics.

preferred term	Definition
sound pressure kurtosis **symbol**: β **unit**: 1	kurtosis of the sound pressure, $p(t)$, over a specified time interval, t_1 to t_2, for a specified frequency range **NOTES**: Source: ISO 18405, entry 3.1.5.5

Table 8 – Source properties.

preferred term	Definition
source waveform **symbol**: s **unit**: Pa m	product of distance in a specified direction, r, from the *acoustic centre* of a sound source and the delayed *far-field sound pressure*, $p(t - t_0 + r/c)$, for a specified time origin, t_0, if placed in a hypothetical infinite uniform lossless medium of the same density and sound speed, c, as the actual medium at the location of the source, with identical motion of all acoustically active surfaces as the actual source in the actual medium, where t is time **NOTES**: Based on ISO 18405, entry 3.3.1.4. Modifications to ISO 18405 are shown in blue text.
source spectrum **symbol**: S **unit**: Pa m/Hz	Fourier transform of the *source waveform* **NOTES**: Source: ISO 18405, entry 3.3.1.8
source factor **symbol**: F_S; $F_{S,mp}$ **unit**: Pa² m²	product of the square of the distance from the *acoustic centre* of a sound source, in a specified direction, r^2 , and *mean-square sound pressure* in the acoustic far field at that distance, $\overline{p^2}$, of a sound source, if placed in a hypothetical infinite uniform lossless medium of the same density and sound speed as the real medium at the location of the source, with identical motion of all acoustically active surfaces as the true source in the true medium **NOTES**: Based on ISO 18405, entry 3.3.1.6. Modifications to ISO 18405 are shown in blue text.
source factor spectral density **symbol**: $F_{S,f}$; $F_{S,f,mp}$ **unit**: Pa² m²/Hz	ratio of source factor in a specified frequency band to the width of that frequency band
surface-affected source waveform **symbol**: s' **unit**: Pa m	product of distance in a specified direction, r, from the *acoustic centre* of a sound source and its sea surface-reflected image and the delayed *far-field sound pressure*, $p(t - t_0 + r/c)$, for a specified time origin, t_0, if placed in a hypothetical semi-infinite uniform lossless medium of the same density and sound speed, c, as the actual medium at the location of the source, with identical motion of all acoustically active surfaces as the actual source in the actual medium, where t is time **NOTES**:

preferred term	Definition
	Source: ISO 18405, entry 3.3.1.7
surface-affected source spectrum **symbol**: S' **unit**: Pa m/Hz	Fourier transform of the *surface-affected source waveform* **NOTES**: Source: ISO 18405, entry 3.3.1.9
surface-affected source factor **symbol**: $F_{\mathrm{S,dp}}$ **unit**: Pa² m²	product of the square of the distance from the *acoustic centre* of a sound source and its sea surface-reflected image, in a specified direction, r^2, and *mean-square sound pressure* in the *acoustic far field* at that distance, $\overline{p^2}$, of a sound source, if placed in a hypothetical semi-infinite uniform lossless medium of the same density and sound speed as the real medium at the location of the source, with identical motion of all acoustically active surfaces as the true source in the true medium **NOTES**: needed for the specification of wind source level
surface-affected source factor spectral density **symbol**: $F_{\mathrm{S},f,\mathrm{dp}}$ **unit**: Pa² m²/Hz	ratio of surface-affected source factor in a specified frequency band to the width of that frequency band
areic source factor spectral density **symbol**: $F_{\mathrm{S},f,a}$; $F_{\mathrm{S},f,a,\mathrm{mp}}$ **unit**: $\mathrm{Pa^2 m^2 Hz^{-1}/m^2}$	ratio of source factor spectral density from a specified region of the surface to the area of that specified region **NOTES**: An alternative way of writing the unit is $\mathrm{Pa^2\ Hz^{-1}}$. However, the full form $\mathrm{Pa^2 m^2 Hz^{-1}/m^2}$ is preferred to avoid the risk of confusion with the unit for mean-square sound pressure spectral density.
areic surface-affected source factor spectral density **symbol**: $F_{\mathrm{S},f,a,\mathrm{dp}}$ **unit**: $\mathrm{Pa^2 m^2 Hz^{-1}/m^2}$	ratio of surface-affected source factor spectral density from a specified region of the surface, evaluated in the vertical direction, to the area of that specified region **NOTES**: An alternative way of writing the unit is $\mathrm{Pa^2\ Hz^{-1}}$. However, the full form $\mathrm{Pa^2 m^2 Hz^{-1}/m^2}$ is preferred to avoid the risk of confusion with the unit for mean-square sound pressure spectral density.

6 Acoustical terminology for hardware

This section describes the terminology needed for the ADEON hardware specification (Martin et al., 2017). The description includes a list of concepts (Table 9), followed by a sequence of tables listing the terminology used for characterizing the properties of a hydrophone (Table 10), a pre-amplifier and an anti-alias filter (AAF) (Table 11), a passive acoustic recorder system (comprising one hydrophone, one pre-amplifier, one AAF, and one analog to digital converter (ADC); Table 12), and the terminology related to active acoustic echo sounders (Table 13).

Table 9. Acoustical terminology for ADEON hardware specification: Concepts.

Term	Definition
hydrophone	transducer designed to convert underwater sound to electricity **NOTES**: hydrophone input = system input
hydrophone input **synonym**: system input	pressure fluctuation in the water at the sensitive face of the hydrophone
hydrophone output	variable capacitance voltage that changes in response to the hydrophone input
pre-amplifier	electronic component that increases the amplitude of an electric current or voltage
anti-alias filter (AAF)	low-pass filter that avoids undersampling of an analog signal during digitization by removing frequencies above the Nyquist frequency of the analog-to-digital converter
analog-to-digital converter (ADC)	electronic component that samples an analog electric current or voltage into a digitized representation of that electric current or voltage **NOTES**: Compare IEEE 1241: “A device that converts a continuous time signal into a discrete-time discrete-amplitude signal.”
system	sequence of electronic components comprising (in this order) a hydrophone, a pre-amplifier, an AAF, and an ADC **NOTES**: System processing starts with the hydrophone converting pressure fluctuations into electrical ones. “System input” is therefore synonymous with “hydrophone input”. System processing ends with the ADC converting voltage fluctuations into digital counts. “System output” is therefore synonymous with “ADC output”.
ADC input	generic term referring to an analog representation of the ADC input such as current or voltage

Term	Definition
ADC output **synonym**: system output	generic term referring to a digital representation of the ADC input, suitable for storage in a digital storage medium or processing on a digital computer
ping	single transmission from the sonar projectors in an echo sounder **NOTES**: A ping can be transmitted at multiple frequencies for capable instruments.
burst	sequence of pings closely spaced in time over which the measured backscattering can be averaged to increase signal to noise ratio
acoustic zooplankton fish profiler	remotely deployed echo sounder designed to provide information about the distribution with depth of fish and zooplankton
crosstalk	undesired energy appearing in a signal as a result of coupling from other signals **NOTES**: Compare IEEE 1241: “Undesired energy appearing in a signal as a result of coupling from other signals.”

Table 10. Acoustical terminology for ADEON hardware specification: Quantities used to characterize a hydrophone.

Preferred term	Definition
free-field voltage sensitivity **synonym**: voltage sensitivity **symbol**: $M_{\mathrm{hp},V}$ **unit**: $\mathrm{V\ Pa^{-1}}$	ratio of the rms open-circuit output voltage to the rms spatially-averaged sound pressure in the undisturbed plane-progressive free field **NOTES**: Free-field voltage sensitivity is a property of a voltage hydrophone, for a specified frequency band and a specified direction of sound incidence. Adapted from IEV 801-25-53
free-field current sensitivity **synonym**: current sensitivity **symbol**: $M_{\mathrm{hp},I}$ **unit**: $\mathrm{A^{-1}}$	ratio of the rms short-circuit output current to the rms spatially-averaged sound pressure in the undisturbed plane-progressive free field **NOTES**: Free-field current sensitivity is a property of a current hydrophone, for a specified frequency band and a specified direction of sound incidence. Adapted from IEV 801-25-56
equivalent rms hydrophone noise sound pressure **symbol**: $p_{\mathrm{N,eq}}$ **unit**: Pa	ratio of the rms open-circuit output voltage to the free-field voltage sensitivity **NOTES**: Adapted from ISO 18405 (3.6.1.15)
hydrophone non-acoustic self-noise voltage **synonym**: self-noise voltage **unit**: V	open-circuit output voltage in the absence of sound pressure at the hydrophone input
hydrophone mean-square non-acoustic self-noise voltage spectral density **synonym**: self-noise voltage spectral density **unit**: V^2/Hz	ratio of mean-square hydrophone non-acoustic self-noise voltage in a specified frequency band to the width of the frequency band
equivalent hydrophone mean-square non-acoustic self-noise sound pressure spectral density **synonym**: hydrophone self-noise sound pressure spectral density **unit**: Pa^2/Hz	ratio of hydrophone mean-square non-acoustic self-noise voltage spectral density to the squared free-field voltage sensitivity
hydrophone self-noise spectral density	mean-square self-noise voltage spectral density at the hydrophone output divided by the squared free-field open-circuit hydrophone voltage sensitivity

Table 11. Acoustical terminology for ADEON hardware specification: Quantities used to characterize a digital sampling system, including pre-amplifier and anti-alias filter (AAF).

Preferred term	Definition
integer ADC output **symbol**: N **unit**: 1	integer representation of ADC output, defined such that a unit change in integer ADC output corresponds to a change in the lowest significant bit from 0 to 1 or from 1 to 0 **NOTES**: The integer ADC output is equal to the product of ADC sensitivity to voltage and ADC input voltage.
maximum integer ADC output **symbol**: N_{max} **unit**: 1	largest possible value of the integer ADC output
minimum integer ADC output **symbol**: N_{min} **unit**: 1	smallest possible value of the integer ADC output
full-scale ADC output **symbol**: N_{FS} **unit**: 1	difference between maximum integer ADC output and minimum integer ADC output
bit depth **synonym**: word size **symbol**: N_{bit} **unit**: bit	amount of digital memory available at ADC output to digitize one value of ADC input
ADC sensitivity to voltage **symbol**: $M_{\mathrm{ADC},V}$ **unit**: V^{-1}	ratio of rms integer ADC output to rms ADC input voltage
ADC voltage conversion factor **symbol**: μ_V **unit**: V	reciprocal of ADC sensitivity to voltage
maximum unsaturated voltage **symbol**: v_{max} **unit**: V	maximum ADC input voltage for which the ADC sensitivity to voltage is independent of ADC input
minimum unsaturated voltage **symbol**: v_{min} **unit**: V	minimum ADC input voltage for which the ADC sensitivity to voltage is independent of ADC input

Preferred term	Definition
full-scale input range **synonym**: full-scale voltage **abbreviation**: full-scale range; FSR	difference between maximum unsaturated voltage and minimum unsaturated voltage **NOTES**: Compare IEEE 1241 (‘full-scale range’, p13): “The difference between the most positive and most negative analog inputs of a converter’s operating range. For an N-bit converter, FSR is given by: FSR = (2^N)x(ideal code width) in analog input units.”
ideal code bin width **synonym**: least significant bit; ADC output step size **abbreviation**: ideal code width **symbol**: Q	full-scale input range divided by $2^{N_{\mathrm{FS}}+1}$, where N_{FS} is the full-scale ADC output **NOTES**: Compare IEEE 1241 (‘ideal code bin width’, p14): “The ideal full-scale input range divided by the total number of code bins.” ‘least significant bit’, p14: “With reference to analog-to-digital converter input signal amplitude, an LSB [least significant bit] is synonymous with one ideal code bin width.”
equivalent mean-square ADC self-noise voltage **abbreviation**: ADC self-noise voltage **symbol**: $V_{\mathrm{N,eq}}^2$ **unit**: V	ratio of mean-square integer ADC output to the squared ADC sensitivity to voltage
pre-amplifier voltage gain **symbol**: $G_{\mathrm{pA},V}$ **unit**: 1	ratio of rms pre-amplifier output voltage to rms pre-amplifier input voltage
AAF voltage gain **symbol**: $G_{\mathrm{AAF},V}$ **unit**: 1	ratio of rms AAF output voltage to rms AAF input voltage
full-scale signal **abbreviation**: FSR	signal whose peak-to-peak value spans the entire range of input values recordable by an ADC, from minimum unsaturated voltage to maximum unsaturated voltage **NOTES**: Compare IEEE 1241 (p13): “A full-scale signal is one whose peak-to-peak amplitude spans the entire range of input values recordable by the analog-to-digital converter under test.”

Preferred term	**Definition**
non-acoustic self-noise	fluctuations in voltage in an acoustic receiver in the absence of sound pressure input **NOTES**: Based on ISO 18405. Note 1 to entry: In a digital receiver system, the voltage might be converted to a digital representation of the original voltage. In this situation, the word “voltage” in this definition is to be interpreted as “voltage that would have been generated in an equivalent analogue receiver system”. EXAMPLE Electrical noise.
signal-to-noise-and-distortion ratio **abbreviation**: SINAD	square root of the signal to noise power ratio at the ADC output **NOTES**: Compare IEEE 1241 (p16): “For a pure sine-wave input of specified amplitude and frequency, the ratio of the root-mean-square (rms) amplitude of the analog-to-digital converter output signal to the rms amplitude of the output noise, where noise is defined as above to include not only random errors but also nonlinear distortion and the effects of sampling time errors.”

Table 12. Acoustical terminology for ADEON hardware specification: Quantities used to characterize the passive data recorder acquisition system.

Preferred term	Definition
total system sensitivity **symbol**: M_{tot} **unit**: Pa^{-1}	ratio of rms integer ADC output to the rms spatially-averaged sound pressure in the undisturbed plane-progressive free field **NOTES**: For a voltage hydrophone, the total system sensitivity is related to the hydrophone and ADC sensitivities according to $M_{\mathrm{tot}} = M_{\mathrm{hp},V} G_{\mathrm{pA},V} G_{\mathrm{AAF},V} M_{\mathrm{ADC},V}$.
system non-acoustic self-noise output **synonym**: system self-noise output; ADC self-noise output **unit**: 1	system output in the absence of sound pressure at the hydrophone input
system mean-square non-acoustic self-noise output spectral density **synonym**: system self-noise output spectral density; ADC self-noise output spectral density **unit**: 1/Hz	ratio of mean-square ADC non-acoustic self-noise output in a specified frequency band to the width of the frequency band
equivalent system mean-square non-acoustic self-noise sound pressure spectral density **synonym**: system self-noise sound pressure spectral density	ratio of system mean-square non-acoustic self-noise output spectral density to the squared total system sensitivity
noise power **unit**: W	time-averaged product of noise current and noise voltage **NOTES**: In an electrical circuit of resistance R, noise power is given by mean-square noise voltage divided by R or mean-square noise current multiplied by R. The noise power depends on the position in the processing chain at which it is determined. The position in the processing chain at which the noise is determined shall be specified. Compare IEEE 1241 ('noise (total)', p15): "Any deviation between the output signal (converted to input units) and the input signal except deviations caused by linear time-invariant system response (gain and phase shift), or a dc level shift. For example, noise includes the effects of random errors (random noise), fixed pattern errors, nonlinearities (e.g., harmonic or intermodulation distortion), and aperture uncertainty. See also: random noise."

Preferred term	Definition
signal power **symbol**: W_{S} **unit**: W	time-averaged product of signal current and signal voltage **NOTES**: In an electrical circuit of resistance R, signal power is given by mean-square signal voltage divided by R or mean-square signal current multiplied by R. The signal power depends on the position in the processing chain at which it is determined. The position in the processing chain at which the signal is determined shall be specified.
signal to noise power ratio **synonym**: signal to noise ratio **symbol**: R_{SN} **unit**: 1	ratio of signal power to noise power **NOTES**: The signal to noise power ratio depends on the position in the processing chain at which it is determined. The position in the processing chain at which the signal to noise power ratio is determined shall be specified.
intermodulation distortion **Abbreviation**: IMD	If the input signal contains multiple tones, the generated distortion is not only the integer harmonics of the tones, but also the sums and differences to the tones. This distortion is created due to nonlinearities in the system. It is referred to as intermodulation distortion (IMD). **NOTES**: When testing for IMD, apply a test signal of two tones each with a level 12 dB below full scale. The magnitude of the IMD signals are found at the sum and differences of the two tones and their harmonics. The THD level of the signal source should be at least 10 dB below the THD of the device under test.
system self-noise spectral density	mean-square self-noise voltage spectral density at the system output divided by the squared system voltage sensitivity

Table 13. Terminology related to the operation and configuration of active acoustic echo sounders: quantities.

Quantity	Definitions
number of pings per burst **unit**: 1	number of individual pings in each burst
burst Interval **unit**: s	difference between the start times of two consecutive bursts **NOTES**: The burst interval can be equal to the ping period. See Lemon et al. (2012).
pulse duration **synonym**: pulse length **unit**: s	duration of the transmitted acoustic excitation pulse **NOTES**: usually expressed in milliseconds (ms)
digitization rate **unit**: Hz	rate at which echo sounder samples are processed by the ADC when digitizing the returned acoustic signal
ping period **unit**: s	difference between the start times of two consecutive pings **NOTES**: See Lemon et al. (2012).
bin size **unit**: m	vertical dimension of the smallest insonified volume an echo sounder can resolve
maximum range **unit**: m	distance, rounded to the nearest bin size that the echo sounder listens for returns **NOTES**: Acoustic returns from objects further away than the maximum range are not recorded by the instrument.
lockout range **unit**: m	distance, rounded to the nearest bin size after the pulse is transmitted that over which an AZFP will ignore echoes **NOTES**: The lockout range is selectable by the user. The selected value can be between 0 and the maximum range – 1 m.

7 Levels and other logarithmic quantities usually expressed in decibels

7.1 Level of a power quantity

In general, a level is a logarithm of a ratio of two like quantities. A widely used level in acoustics is the level of a power quantity (ISO 80000-3:2006; IEC 60027-3:2002). A power quantity is one that is proportional to power. The level of a power quantity, P, is the logarithm of that power quantity to a reference value of the same quantity, P_0 , defined such that

$$L_P = 10 \log_{10} \frac{P}{P_0} \text{ dB}.$$

When expressing the value of a level of a power quantity in decibels, the reference value, P_0, shall be specified. Some common examples, with standard reference values, are listed in Table 14.

Table 14 – Examples of level of a power quantity, and associated reference values for sound in water (ISO 1683:2015; ISO 18405:2017). For comparison, the final column lists corresponding reference values for sound in air (ISO 1683).

level, L_P	**power quantity, P**	**reference value (sound in water), P_0**	**reference value (sound in air), P_0**
sound exposure level (SEL)	sound exposure	$1\ \mu\text{Pa}^2\ \text{s}$	$400\ \mu\text{Pa}^2\ \text{s}$
mean-square sound pressure spectral density level (PSDL)	mean-square sound pressure spectral density	$1\ \mu\text{Pa}^2/\text{Hz}$	$400\ \mu\text{Pa}^2/\text{Hz}$
sound power level (SWL)	sound power	$1\ \text{pW}$	$1\ \text{pW}$
sound pressure level (Lrms or SPL)	mean-square sound pressure	$1\ \mu\text{Pa}^2$	$400\ \mu\text{Pa}^2$
source level (SL)	source factor	$1\ \mu\text{Pa}^2\ \text{m}^2$	NA

7.2 Level of a field quantity

Also widely used in acoustics is the level of a field quantity (ISO 80000-3:2006; IEC 60027-3:2002). A field quantity is one whose square is proportional to power. The level of a field quantity, F, is the logarithm of that field quantity to a reference value of the same quantity, F_0 , defined such that

$$L_F = 20 \log_{10} \frac{F}{F_0} \text{ dB}.$$

When expressing the value of a level of a field quantity in decibels, the reference value, F_0, shall be specified. Some examples, with standard reference values, are listed in Table 15. The levels (of the listed field quantities) defined in Table 15 have identical values to the levels of the corresponding power quantities listed in Table 14. The reason for providing both definitions is to clarify that the choice between P_0 (say 1 μPa^2/Hz) and F_0 (1 μPa/Hz$^{1/2}$) for the reference quantity makes no difference to the value of the level. The level of a power quantity is identical to the level of the corresponding field quantity, defined as the square root of the power quantity (also known as a 'root-power quantity' (ISO 80000-1:2009; Ainslie 2015)).

Table 15 – Examples of level of a field quantity, and associated reference values for sound in water (ISO 1683:2015; ISO 18405:2017). For comparison, the final column lists corresponding reference values for sound in air (ISO 1683).

level, L_F	**field quantity, F**	**reference value (sound in water), F_0**	**reference value (sound in air), F_0**
sound exposure level (SEL)	root-sound exposure	$1\ \mu\text{Pa s}^{\frac{1}{2}}$	$20\ \mu\text{Pa s}^{\frac{1}{2}}$
mean-square sound pressure spectral density level (PSDL)	square root of the mean-square sound pressure spectral density	$1\ \mu\text{Pa/Hz}^{\frac{1}{2}}$	$20\ \mu\text{Pa/Hz}^{\frac{1}{2}}$
sound power level (SWL)	root-sound power	$1\ \text{pW}^{\frac{1}{2}}$	$1\ \text{pW}^{\frac{1}{2}}$
sound pressure level (Lrms or SPL)	root-mean-square sound pressure	$1\ \mu\text{Pa}$	$20\ \mu\text{Pa}$
source level (SL)	root-source factor	$1\ \mu\text{Pa m}$	NA

7.3 Definitions of levels and other logarithmic quantities usually expressed in decibels

Table 16 to Table 19 define levels and other logarithmic quantities usually expressed in decibels.

Table 16 – Levels and other logarithmic quantities usually expressed in decibels: sound field metrics.

quantity	**definition**
mean-square sound pressure level **synonym**: root-mean-square sound pressure level; sound pressure level **abbreviation**: SPL; Lrms **deprecated**: rms SPL; root-mean-square SPL; mean-square SPL **symbol**: L_p; $L_{p,\text{rms}}$	level of the *mean-square sound pressure* In equation form $$L_{p,\text{rms}} = 10\lg\frac{p_\text{rms}^2}{p_0^2}\ \text{dB}$$ reference value: $$p_0^2 = 1\ \mu\text{Pa}^2$$ $$p_0 = 1\ \mu\text{Pa}$$ **NOTES**: based on ISO 18405, entry 3.2.1.1 SPL is also equal to the level of the field quantity *root-mean-square sound pressure*.
time-integrated squared sound pressure level **synonym**: sound exposure level; sound pressure exposure level **abbreviation**: SEL **symbol**: $L_{E,p}$ **reference value**: 1 μPa^2 s	level of the *time-integrated squared sound pressure* In equation form $$L_{E,p} = 10\lg\frac{E}{E_0}\ \text{dB}$$ reference value: $$E_0 = 1\ \mu\text{Pa}^2\text{s}$$ $$E_0^{1/2} = 1\ \mu\text{Pa s}^{1/2}$$ **NOTES**: based on ISO 18405, entry 3.2.1.5

quantity	definition
sound exposure spectral density level **abbreviation**: ESDL **symbol**: $L_{E,f}$ **reference value**: 1 μPa² s/Hz	level of the *sound exposure spectral density* In equation form $$L_{E,f} = 10\lg\frac{E_f}{E_{f,0}}\ \mathrm{dB}$$ reference value: $$E_{f,0} = 1\ \mu\mathrm{Pa}^2\mathrm{s/Hz}$$ $$E_{f,0}^{1/2} = 1\ \mu\mathrm{Pa\ s}^{\frac{1}{2}}/\mathrm{Hz}^{1/2}$$ **NOTES**: based on ISO 18405, entry 3.2.1.9
mean-square sound pressure spectral density level **abbreviation**: PSDL **symbol**: $L_{p,f}$ **reference value**: 1 μPa²/Hz	level of the *mean-square sound pressure spectral density* In equation form $$L_{p,f} = 10\lg\frac{\left(\overline{p^2}\right)_f}{\left(\overline{p^2}\right)_{f,0}}\ \mathrm{dB}$$ reference value: $$\left(\overline{p^2}\right)_{f,0} = 1\ \mu\mathrm{Pa}^2/\mathrm{Hz}$$ $$\sqrt{\left(\overline{p^2}\right)_{f,0}} = 1\ \mu\mathrm{Pa/Hz}^{1/2}$$ **NOTES**: based on ISO 18405, entry 3.2.1.10
zero-to-peak sound pressure level **synonym**: peak sound pressure level **abbreviation**: Lpk **deprecated**: peak SPL **symbol**: $L_{p,0-\mathrm{pk}}$; $L_{p,\mathrm{pk}}$	level of the *zero-to-peak sound pressure* In equation form $$L_{p,0-\mathrm{pk}} = 10\lg\frac{p_{0-\mathrm{pk}}^2}{p_0^2}\ \mathrm{dB}$$ reference value: $$p_0^2 = 1\ \mu\mathrm{Pa}^2$$ $$p_0 = 1\ \mu\mathrm{Pa}$$ **NOTES**: based on ISO 18405, entry 3.2.2.1

Table 17 – Levels and other logarithmic quantities usually expressed in decibels: source metrics.

quantity	definition
source level **synonym**: source factor level; monopole source level **abbreviation**: SL **symbol**: L_S; $L_\mathrm{S,mp}$	level of the *source factor* In equation form $$L_\mathrm{S,mp} = 10\lg\frac{F_\mathrm{S,mp}}{F_\mathrm{S,mp,0}}\ \mathrm{dB}$$ reference value: $$F_\mathrm{S,mp,0} = 1\ \mu\mathrm{Pa}^2\mathrm{m}^2$$ $$F_\mathrm{S,mp,0}^{1/2} = 1\ \mu\mathrm{Pa\ m}$$ **NOTES**: based on ISO 18405, entry 3.3.2.1
source factor spectral density level	level of the source factor spectral density In equation form

quantity	definition
synonym: monopole source spectral density level **abbreviation**: source spectral density level; monopole source spectrum level (MSSL) **symbol**: $L_{\mathrm{S},f}$; $L_{\mathrm{S},f,\mathrm{mp}}$	$$L_{\mathrm{S},f,\mathrm{mp}} = 10\lg\frac{F_{\mathrm{S},a,f,\mathrm{mp}}}{F_{\mathrm{S},a,f,\mathrm{mp},0}}\ \mathrm{dB}$$ reference value: $$F_{\mathrm{S},a,f,\mathrm{mp},0} = 1\ \mu\mathrm{Pa}^2\mathrm{m}^2/\mathrm{Hz}$$ $$F^{1/2}_{\mathrm{S},a,f,\mathrm{mp},0} = 1\ \mu\mathrm{Pa\ m}/\mathrm{Hz}^{1/2}$$ **NOTES**: Source factor spectral density is a power quantity. This level is needed for correct interpretation of the source level associated with ships (Wales and Heitmeyer, 2002).
areic surface-affected source factor spectral density level **synonym**: areic dipole source spectral density level **abbreviation**: areic surface-affected source spectral density level; areic dipole source spectrum level **symbol**: $L_{\mathrm{S},a,f,\mathrm{dp}}$	level of the areic surface-affected source factor spectral density In equation form $$L_{\mathrm{S},a,f,\mathrm{dp}} = 10\lg\frac{F_{\mathrm{S},a,f,\mathrm{dp}}}{F_{\mathrm{S},a,f,\mathrm{dp},0}}\ \mathrm{dB}$$ reference value: $$F_{\mathrm{S},a,f,\mathrm{dp},0} = 1\ \mu\mathrm{Pa}^2\mathrm{m}^2/(\mathrm{m}^2\mathrm{Hz})$$ $$F^{1/2}_{\mathrm{S},a,f,\mathrm{dp},0} = 1\ \mu\mathrm{Pa\ m}/\left(\mathrm{m\ Hz}^{1/2}\right)$$ **NOTES**: Areic surface-affected source factor spectral density is a power quantity. This level is needed for correct interpretation of the source level associated with wind (Kuperman and Ferla, 1985).

Table 18 – Levels and other logarithmic quantities usually expressed in decibels: propagation and scattering metrics.

quantity	definition
transmission loss **abbreviation**: TL **symbol**: N_{TL}	reduction in a specified level between two specified points x_1, x_2 that are within an underwater acoustic field In equation form, if the specified level is sound pressure level $$\Delta L_{\mathrm{TL}} = L_{p,\mathrm{rms}}(\boldsymbol{x}_1) - L_{p,\mathrm{rms}}(\boldsymbol{x}_2)$$ or equivalently, using the definition of sound pressure level $L_{p,\mathrm{rms}}$ $$N_{\mathrm{TL}}(\boldsymbol{x}) = 10\lg\frac{p^2_{\mathrm{rms}}(\boldsymbol{x}_1)}{p^2_{\mathrm{rms}}(\boldsymbol{x}_2)}\ \mathrm{dB}.$$ **NOTES**: Source: ISO 18405, entry 3.4.1.3 Transmission loss is the difference between two like levels and therefore has no reference value. Compare 'propagation loss'.
propagation loss **abbreviation**: PL	the quantity $$N_{\mathrm{PL}}(\boldsymbol{x}) = 10\lg\frac{F(\boldsymbol{x})^{-1}}{F_0^{-1}}\ \mathrm{dB},$$

quantity	**definition**
symbol: N_{PL}	where $F(\boldsymbol{x})$ is the propagation factor (ISO, 2017; 3.3.1.6), defined as the ratio of mean-square sound pressure (p_{rms}^2) to source factor (S), such that $$F(\boldsymbol{x}) = \frac{p_{\mathrm{rms}}^2(\boldsymbol{x})}{S},$$ and therefore $$F(\boldsymbol{x})^{-1} = \frac{S}{p_{\mathrm{rms}}^2(\boldsymbol{x})}.$$ reference value: $$F_0^{-1} = 1\ \mathrm{m}^2$$ $$F_0^{-1/2} = 1\ \mathrm{m}$$ **NOTES**: The formal definition of 'propagation loss' according to ISO 18405 (entry 3.4.1.4) is: "difference between *source level* (3.3.2.1) in a specified direction, L_{S}, and *mean-square sound pressure level* (3.2.1.1), $L_p(x)$, at a specified position, x". In equation form $$N_{\mathrm{PL}}(\boldsymbol{x}) = L_{\mathrm{S}} - L_{p,\mathrm{rms}}(\boldsymbol{x}),$$ or equivalently, using the definitions of source level L_{S} and sound pressure level $L_{p,\mathrm{rms}}$ $$N_{\mathrm{PL}}(\boldsymbol{x}) = 10\,\lg\frac{S/p_{\mathrm{rms}}^2(\boldsymbol{x})}{S_0/p_0^2}\ \mathrm{dB}.$$ This equation is equivalent to our definition of 'propagation loss' as the level of the reciprocal propagation factor, and explains the origin of $F_0^{-1} = S_0/p_0^2 = 1\ \mathrm{m}^2$ as the reference value for propagation loss. Compare 'transmission loss'.
volume backscattering strength **abbreviation**: VBS **symbol**: $S_{\mathrm{v,B}}$ **reference value**: 1 $\mathrm{m}^{-1}\ \mathrm{sr}^{-1}$	*volume scattering strength* evaluated in the backscattering direction

Table 19. Levels and other logarithmic quantities usually expressed in decibels: receiver metrics.

quantity	**definition**
voltage sensitivity level **symbol**: $L_{M,V}$	the quantity $$L_{M,V} = 10 \lg \frac{M_{\mathrm{hp},V}^2}{M_{V,0}^2} \text{ dB},$$ where $M_{\mathrm{hp},V}$ is the free-field voltage sensitivity reference value: $$M_{V,0}^2 = 1\ V^2/\mu\mathrm{Pa}^2$$ $$M_{V,0} = 1\ V/\mu\mathrm{Pa}$$
signal to noise level difference **abbreviation**: SNR **symbol**: ΔL_{SN}	the quantity $$\Delta L_{\mathrm{SN}} = 10 \lg R_{\mathrm{SN}} \text{ dB},$$ where R_{SN} is the signal to noise power ratio reference value: NA
hydrophone spectral noise floor level **symbol**: $L_{M,V,\mathrm{hp}}$	level of the hydrophone self-noise spectral density In equation form $$L_{M,V,\mathrm{hp}} = 10 \lg \frac{\left(p_{\mathrm{N,eq}}^2\right)_f}{p_0^2/f_0} \text{ dB},$$ where $\left(p_{\mathrm{N,eq}}^2\right)_f$ is the hydrophone self-noise spectral density reference value: $$p_0^2/f_0 = 1\ \mu\mathrm{Pa}^2/\mathrm{Hz}$$ $$p_0/f_0^{\frac{1}{2}} = 1\ \mu\mathrm{Pa}/\mathrm{Hz}^{\frac{1}{2}}$$
system spectral noise floor level **synonym**: recorder spectral noise floor level **symbol**: $L_{M,V,\mathrm{sys}}$	level of the system self-noise spectral density In equation form $$L_{M,V,\mathrm{sys}} = 10 \lg \frac{\left(p_{\mathrm{N,eq}}^2\right)_f}{p_0^2/f_0} \text{ dB},$$ where $\left(p_{\mathrm{N,eq}}^2\right)_f$ is the system self-noise spectral density reference value: $$p_0^2/f_0 = 1\ \mu\mathrm{Pa}^2/\mathrm{Hz}$$ $$p_0/f_0^{\frac{1}{2}} = 1\ \mu\mathrm{Pa}/\mathrm{Hz}^{\frac{1}{2}}$$
dynamic range **abbreviation**: DR **symbol**: ΔL_{DR}	the quantity $$\Delta L_{\mathrm{DR}} = 10 \lg \frac{\overline{V_{\mathrm{FS}}^2}}{V_{\mathrm{N.eq}}^2} \text{ dB},$$ where $\overline{V_{\mathrm{FS}}^2}$ is the mean-square voltage of a sinusoidal full-scale signal and $V_{\mathrm{N.eq}}^2$ is the equivalent mean-square ADC self-noise voltage reference value: NA

quantity	**definition**
total harmonic distortion **abbreviation**: THD	the quantity $$\Delta L_{\mathrm{DR}} = 10\,\mathrm{lg}\frac{V_2^2 + V_3^2 \ldots + V_{n+1}^2}{V_1^2}\ \mathrm{dB},$$ where V_1 is the rms voltage of a sinusoidal full-scale signal and $V_2 \ldots V_{n+1}$ are the mean-square ADC self-noise voltage of the first n harmonics **NOTES**: See Sec. 3.4.4.7 of Martin et al. (2017) Compare IEEE 1241 (p17): “For a pure sine-wave input of specified amplitude and frequency, the root-sum-of-squares (rss) of all the harmonic distortion components including their aliases in the spectral output of the analog-to-digital converter. Unless otherwise specified, THD is estimated by the rss of the second through the tenth harmonics, inclusive. THD is often expressed as a decibel ratio with respect to the root-mean-square amplitude of the output component at the input frequency.”

8 Acoustical Terminology for soundscape data processing

Terminology for soundscape data processing is defined in Table 20, Table 21 and Table 22.

Table 20 – Soundscape terminology: concepts.

Term	Definition
echolocation click	forward projected signal of short duration whose primary function is echo ranging, target detection or discrimination **NOTES**: Echolocation clicks are projected through the melon of toothed whales. Source: ISO 18405, entry 3.7.3.3
high frequency marine mammal click	echolocation click of center frequency exceeding 8 kHz and duration less than 1000 µs
raw data	calibrated sound pressure time series **NOTES**: The raw data are input to the click detection algorithm.
shipping tonal	sound generated by a sea-going vessel with a bandwidth less than 1 Hz, and duration greater than 20 s
shipping band	frequency band between 40 Hz and 315 Hz
rms time series	time series of root-mean-square voltage computed from the raw data over a specified temporal analysis window
spectrogram detection window	region in a spectrogram identified as a potential signal of interest, and is therefore tagged as worthy of further processing for classification purposes

Table 21 – Soundscape terminology: processing windows and statistical measures.

preferred term	Definition
N percent temporal exceedance level **symbol**: $L_{t,N\%}$	*mean-square sound pressure level* that is exceeded for N % of the time in a specified analysis window **NOTES**: Based on entry 3.1.3 of ISO 1996-1:2003. The frequency band, the location, and the duration of the temporal observation window shall be specified.

preferred term	Definition
Nth temporal level percentile	value of *mean-square sound pressure level* below which N % of observations fall, in a specified analysis window **NOTES**: Based on ISO 11064-4: “value of a variable below which a certain percentage of observations fall”. The frequency band, the location, and the duration of the temporal observation window shall be specified.
N percent spatial exceedance level **symbol**: $L_{x,N\%}$	*mean-square sound pressure level* that is exceeded for N % of the space in a specified analysis spatial observation window **NOTES**: The frequency band, the duration of the temporal observation window, and the volume, shape and location of the spatial observation window shall be specified.
Nth spatial level percentile	value of *mean-square sound pressure level* below which N % of observations fall, in a specified analysis spatial observation window **NOTES**: The frequency band, the duration of the temporal observation window, and the volume, shape and location of the spatial observation window shall be specified.

Table 22 – Soundscape terminology: source identification.

Term	Definition
minimum spectrogram window frequency	minimum frequency of a spectrogram detection window **NOTES**: see Table 5 of Heaney et al. (2017)
maximum instantaneous bandwidth	maximum bandwidth in one time bin of a spectrogram detection window that is permitted for a detection **NOTES**: see Table 5 of Heaney et al. (2017)
centroid frequency	weighted average frequency of a signal, where the frequency weighting function is the power spectral density of the signal **NOTES**: source: Quan and Harris (1997)

Term	Definition
spectrogram window sweep rate	centroid frequency of the last time bin in a spectrogram detection window, minus the centroid frequency of the first time bin in that window, divided by the duration of the window **NOTES**: see Table 5 of Heaney et al. (2017)

9 Acoustical terminology for soundscape reporting

9.1 Reporting quantities (general)

Reporting shall follow the JIP reporting standard Ainslie and de Jong (2017), henceforth abbreviated “JIP UA-R”. UA-R follows the International System of Quantities (ISQ) (ISO, 2009), with appropriate exceptions from IEEE 260.1-2014 (IEEE, 2014).
In the ISQ a quantity Q is written

$$Q = xU,$$

where U is the unit in which the quantity is expressed and x is a dimensionless number equal to Q/U (the numerical value of Q when expressed in the unit U). The value of Q may be reported either in the form

$$Q = xU,$$

or (dividing both sides by U)

$$\frac{Q}{U} = x.$$

9.2 Reporting levels and other quantities usually reported in decibels

Levels (L), sensitivity levels (N) and level differences (ΔL) are reported in decibels. Three alternative styles are described below. One of these three styles shall be chosen and followed consistently in any one document.

9.2.1 *Style 1 (IEC standard, A)*

Style 1 follows IEC 60027-3 (IEC, 2002). According to IEC (2002), the level L of a power quantity P may be reported in the form

$$L_{P/P_0} = x \text{ dB},$$

where P_0 is the reference value. For example if the sound exposure level relative to E_0 is 140 dB ($x = 140$), this is written

$$L_{E/E_0} = 140 \text{ dB}.$$

In this equation the unit is the decibel (dB) and the reference value is P_0.
Sensitivity level (symbol N)

$$N_{S/S_0} = y \text{ dB},$$

where S_0 is the reference value. For example if the hydrophone sensitivity level relative to M_0 is -110 dB ($y = -110$), this is written

$$N_{M/M_0} = -110 \text{ dB}.$$

Level difference ΔL

$$\Delta L_{P_1/P_2} = z \text{ dB}.$$

There is no reference value because P_1 and P_2 are quantities of the same kind (their dimensions and units cancel). For example if the pre-amplifier gain ($G_{\text{pA},V}$), is equal to 10 V/V, the corresponding sensitivity level is 20 dB ($z = 20$), which is written

$$\Delta L_G = 20 \text{ dB}.$$

In Style 1, no suffix, subscript or qualifier of any kind follows the unit symbol ‘dB’.

9.2.2 *Style 2 (UA-R)*

UA-R permits an alternative style (Style 2), of the form

$$L_E = 140 \text{ dB re } E_0$$
$$N_M = -110 \text{ dB re } M_0$$
$$\Delta L_G = 20 \text{ dB}.$$

In Style 2, no suffix, subscript or qualifier follows the unit symbol 'dB' except a qualifier of the form '$\mathrm{re}\ P_0$' in the case of a level or a sensitivity level.

9.2.3 Style 3 (IEC standard, B)

IEC, 2002 permits an alternative style (Style 3), of the form

$$L_E(\mathrm{re}\ E_0) = 140\ \mathrm{dB}$$
$$N_M(\mathrm{re}\ M_0) = -110\ \mathrm{dB}$$
$$\Delta L_G = 20\ \mathrm{dB}.$$

In Style 3, no suffix, subscript or qualifier of any kind follows the unit symbol 'dB'.

9.3 Summary

Styles 1 and 2 are summarized in Table 23.

Table 23 – Summary table: Sensitivity level and system gain vs frequency: $E_0 = 1\ \mu\mathrm{Pa}^2\mathrm{s}$; $M_0 = 1\ \mathrm{V}/\mu\mathrm{Pa}$.

What	**Style 1 (IEC, A)**	**Style 2 (UA-R)**	**Style 3 (IEC, B)**
Level (L)	$L_{E/(1\ \mu\mathrm{Pa}^2\mathrm{s})} = 140\ \mathrm{dB}$	$L_E = 140\ \mathrm{dB\ re}\ 1\ \mu\mathrm{Pa}^2\mathrm{s}$	$L_E(\mathrm{re}\ 1\ \mu\mathrm{Pa}^2\mathrm{s}) = 140\ \mathrm{dB}$
Sensitivity level (N)	$N_{M/(1\ \mathrm{V}\ \mu\mathrm{Pa}^{-1})} = -110\ \mathrm{dB}$	$N_M = -110\ \mathrm{dB\ re}\ 1\ \mathrm{V}\ \mu\mathrm{Pa}^{-1}$	$N_M(\mathrm{re}\ 1\ \mathrm{V}\ \mu\mathrm{Pa}^{-1}) = -110\ \mathrm{dB}$
Level difference (ΔL)	$\Delta L_G = 20\ \mathrm{dB}$	$\Delta L_G = 20\ \mathrm{dB}$	$\Delta L_G = 20\ \mathrm{dB}$

No subscripts shall be used with the unit symbol (dB, not $\mathrm{dB_{rms}}$).
No suffixes shall be used following the unit symbol dB except (with Style 2 only) of the form "$\mathrm{re}\ P_0$", where P_0 represents the international standard reference value of the power quantity.

9.4 Reporting quantities in a table

The same three styles may be used in tables.

9.4.1 Style 1 (IEC standard, A)

In Style 1, quantities (including but not limited to levels) shall be tabulated in the form illustrated by Table 24 (example showing SEL vs distance) and Table 25 (example showing sensitivity level and pre-amplifier gain vs frequency).

Table 24 – Example 1 (Style 1): Sound exposure level vs distance.

x/m	$L_{E/(1\ \mu\mathrm{Pa}^2\mathrm{s})}$/ dB
10	160
100	140
1000	120

Table 25 – Example 2 (Style 1): Sensitivity level and pre-amplifier gain vs frequency.

f/kHz	$N_{M/(1\ \mathrm{V}\ \mu\mathrm{Pa}^{-1})}$/ dB	ΔL_G/ dB
10	-115	24
100	-110	20
1000	-112	28

9.4.2 *Style 2 (UA-R)*

In Style 2, levels shall be tabulated in the form illustrated by Table 26 (example showing SEL vs distance) and Table 27 (example showing sensitivity level and pre-amplifier gain vs frequency).

Table 26 – Example 1 (Style 2): Sound exposure level vs distance.

x	L_E
10 m	$160\ \mathrm{dB\ re\ 1\ \mu Pa^2 s}$
100 m	$140\ \mathrm{dB\ re\ 1\ \mu Pa^2 s}$
1000 m	$120\ \mathrm{dB\ re\ 1\ \mu Pa^2 s}$

Table 27 – Example 2 (Style 2): Sensitivity level and pre-amplifier gain vs frequency.

f	N_M	ΔL_G
10 kHz	$-115\ \mathrm{dB\ re\ 1\ V\ \mu Pa^{-1}}$	24 dB
100 kHz	$-110\ \mathrm{dB\ re\ 1\ V\ \mu Pa^{-1}}$	20 dB
1000 kHz	$-112\ \mathrm{dB\ re\ 1\ V\ \mu Pa^{-1}}$	28 dB

9.4.3 *Style 3 (IEC standard, B)*

In Style 3, levels shall be tabulated in the form illustrated by Table 28 (example showing SEL vs distance) and Table 29 (example showing sensitivity level and pre-amplifier gain vs frequency).

Table 28 – Example 1 (Style 3): Sound exposure level vs distance.

x	L_E (re 1 $\mathrm{\mu Pa^2 s}$)
10 m	160 dB
100 m	140 dB
1000 m	120 dB

Table 29 – Example 2 (Style 3): Sensitivity level and pre-amplifier gain vs frequency.

f	N_M (re 1 $\mathrm{V\ \mu Pa^{-1}}$)	ΔL_G
10 kHz	-115 dB	24 dB
100 kHz	-110 dB	20 dB
1000 kHz	-112 dB	28 dB

9.5 Deprecation of $\mathrm{dB_x}$, dB X and dBX

Subscripts of the form $\mathrm{dB_X}$ (e.g., $\mathrm{dB_{rms}}$, $\mathrm{dB_{peak}}$, $\mathrm{dB_{SPL}}$, $\mathrm{dB_{SEL}}$, $\mathrm{dB_M}$, $\mathrm{dB_{ht}}$) are deprecated.
Suffixes of the form dB X (e.g., “dB rms”, “dB peak”, “dB SPL”, “dB SEL”, “dB M”, “dB ht”) are deprecated.
Suffixes of the form dBX (e.g., “dBrms”, “dBpeak”, “dBSPL”, “dBSEL”, “dBM”, “dBht”, “dBFS”, “dBc”) are deprecated.

9.6 Use of abbreviations in equations

With the exception of “SNR” as an abbreviation of “signal to noise level difference”, symbols (not abbreviations) shall be used to represent quantities and units in equations.

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A Selected terminology from IEEE 1421 (informative)

Selected terminology for digital parameters from IEEE 1421 is presented in Table 30.

Table 30 – Selected terminology from IEEE 1421

term	IEEE 1421 definition
analog-to-digital converter (ADC)	A device that converts a continuous signal into a discrete-time discrete-amplitude signal.
effective number of bits (ENOB)	A measure of the signal-to-noise-and-distortion ratio used to compare actual analog-to-digital converter (ADC) performance to an ideal ADC.
full-scale range (FSR)	The difference between the most positive and most negative analog inputs of a converter's operating range. For an *N*-bit converter, FSR is given by: $$\text{FSR} = (2^N)(\text{ideal code width})$$ in analog input units.
full-scale signal	A full-scale signal is one whose peak-to-peak amplitude spans the entire range of input values recordable by the analog-to-digital converter under test.
least significant bit (LSB)	With reference to analog-to-digital converter input signal amplitude, an LSB is synonymous with one ideal code bin width.
noise (total)	Any deviation between the outputs signal (converted to input units) and the input signal except deviations caused by linear time-invariant system response (gain and phase shift), or a dc level shift. For example, noise includes the effects of random errors (random noise), fixed pattern errors, nonlinearities (e.g., harmonic or intermodulation distortion), and aperture uncertainty. *See also*: **random noise**.
random noise	A non-deterministic fluctuation in the output of an analog-to-digital converter, described by its frequency spectrum and its amplitude statistical properties. *See also*: **noise**.
signal-to-noise-and-distortion ratio (SINAD)	For a pure sine-wave input of specified amplitude and frequency, the ratio of the root-mean-square (rms) amplitude of the analog-to-digital converter output signal to the rms amplitude of the output noise, where noise is defined as above to include not only random errors but also nonlinear distortion and the effects of sampling time errors.
signal-to-noise ratio (SNR)	For a pure sine-wave input of specified amplitude and frequency, the ratio of the root-mean-square (rms) amplitude of the analog-to-digital converter output signal to the rms amplitude of the output noise, this does not include the harmonic distortion components that are used for the estimate of THD. Note: This was called signal-to-non-harmonic ratio (SNHR) in the previous version of this standard.
spurious-free dynamic range (SFDR)	For a pure sine-wave input of specified amplitude and frequency, the ratio of the amplitude of the analog-to-digital converter's output averaged spectral component at the input frequency, f_i, to the amplitude of the largest harmonic or spurious spectral component observed over the full Nyquist band, $\max\{\, \lvert X(f_h)\rvert \; or \; \lvert X(f_s)\rvert \}$: $$\text{SFDR(dB)} = 20\log_{10}\left(\frac{\lvert X_{\text{avm}}(f_i)\rvert}{\max\limits_{f_s, f_h}\{\lvert X_{\text{avm}}(f_h)\rvert \text{ or } \lvert X_{\text{avm}}(f_s)\rvert\}}\right)$$ where X_{avm} is the averaged spectrum of the ADC output f_i is the input signal frequency f_h and f_s are the frequencies of the set of harmonic and spurious spectral components

term	IEEE 1421 definition
total harmonic distortion (THD)	For a pure sine-wave input of specified amplitude and frequency, the root-sum-of-squares (rss) of all the harmonic distortion components including their aliases in the spectral output of the analog-to-digital converter. Unless otherwise specified, THD is estimated by the rss of the second through the tenth harmonics, inclusive. THD is often expressed as a decibel ratio with respect to the root-mean-square amplitude of the output component at the input frequency.

B Non-acoustical terminology (normative)

In general the International System of Quantities (ISQ), as described in ISO/IEC 80000, shall be followed. If by exception a need arises to use a unit outside the ISQ, IEEE Std 260.1 (e.g., for a conversion from liters to cubic inches to characterize the volume of an airgun array) shall be followed. For non-acoustical terminology, the following standards are followed, in order of decreasing precedence

- non-acoustical ADEON terminology (this appendix)
- the JIP terminology standard Ainslie et al. (2017b), henceforth abbreviated UA-T
- ISO/IEC 80000 Quantities and Units
- The International System of Units (SI): 8th edition (BIPM, 2014)

Units of distance, speed and angle are listed in (Table 31). Units of data storage are listed in Table 32.

Table 31 – Units of distance, speed and angle (from ISO 80000-3:2006).

name of unit		**definition**
nautical mile	nmi	1852 m
knot	kn	1 nmi/h
degree (angle)	°	(2π/360) rad
minute (angle)	′	(1/60)°
second (angle)	″	(1/60)′

Table 32 – Units of data storage (IEC 80000-13:2008).

name of unit	**Symbol**	**definition**	**notes**
kilobyte	kB	1000 B	not 1024 B
megabyte	MB	1000 kB	not 1024 kB
gigabyte	GB	1000 MB	not 1024 MB
terabyte	TB	1000 GB	not 1024 GB
petabyte	PB	1000 TB	not 1024 TB
exabyte	EB	1000 PB	not 1024 PB
zettabyte	ZB	1000 EB	not 1024 EB
yottabyte	YB	1000 ZB	not 1024 ZB