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Date: 22 January 2024

Origin: International

Latest date for receipt of comments: 16 March 2024

Project No. 2021/01936

Responsible committee: EH/1/7 Underwater acoustics

Interested committees:

Title: Draft BS ISO 7605 Underwater acoustics - measurement of underwater ambient sound.

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

DRAFT INTERNATIONAL STANDARD

ISO/DIS 7605

ISO/TC 43/SC 3

Secretariat: ANSI

Voting begins on:
2024-01-22

Voting terminates on:
2024-04-15

Underwater acoustics — measurement of underwater ambient sound

Acoustique sous-marine — mesure du son sous-marin

ICS: 17.140.01

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee [or Project Committee] ISO/TC 43, [Acoustics], Subcommittee SC 3, [Underwater acoustics].

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO 7605 standard describes a procedure for the measurement and analysis of underwater ambient sound. The development of this standard made use of resources previously developed by the UK National Physical Laboratory (Robinson et al. 2014), the US-funded project ADEON¹ and by the EU-funded Interreg programme JOMOPANS².

1) (University of New Hampshire online) Atlantic Deepwater Ecosystem Observatory Network (ADEON): An Integrated System for Long-Term Monitoring of Ecological and Human Factors on the Outer Continental Shelf (<https://adeon.unh.edu/standards>)

2) Joint Monitoring Programme for Ambient Noise North Sea (JOMOPANS) (<https://northsearegion.eu/jomopans>)

Underwater acoustics — measurement of underwater ambient sound

1 Scope

This document provides requirements and recommendations for a soundscape measurement study, involving measuring and reporting ambient sound in water, as characterized by sound pressure and selected quantities that can be derived from sound pressure. “Ambient sound” implies sound from any source except sources of self-noise.

The scope includes equipment performance, calibration and deployment, digital data acquisition and data processing. Data processing levels considered are raw digital acquisition data, sound pressure time series, sound pressure level time series and their statistics.

Data processing is the process of converting raw data into a form and context necessary to be interpreted by people and computers. Data processing is split into the following stages.

1. *Data collection*

Collecting data is the first step in data processing. Data is collected from available sources.

2. *Data preparation*

Data preparation is where collected data is checked to correct bad, redundant, incomplete, or incorrect data.

3. *Processing*

The prepared data is inputted to the computer or system to be processed as required.

4. *Data output*

The processed data is translated into in the form of graphs, videos, images, plain text, etc.

5. *Data storage*

The final stage of data processing is data storage where it is available for future use.

The scope excludes measurement of particle motion.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO IEC/80000, *Quantities and units*

ISO 18405, *Underwater acoustics — Terminology*

BIPM 2019, *9th (2019) edition*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in [external document reference xxx] and the following apply.

BIPM 2019

ISO/IEC 80000

ISO 18405

Terms that are used in this standard and defined by BIPM 2019 include second, minute, hour and day.

Terms that are used in this standard and defined by ISO 18405:2017 include decidecade, non-acoustic self-noise, sound, sound pressure, sound pressure level, weighted sound pressure and weighting function.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 Concepts and quantities: General

3.1.1

soundscape measurement study

activity that includes deployment, acquisition, processing and reporting of underwater ambient sound

3.1.2

soundscape measurement study report

report describing a soundscape measurement study

3.2 Concepts and quantities: Hardware

3.2.1 Concepts

3.2.1.1

hydrophone

electroacoustic transducer that produces electrical voltages in response to water borne pressure signals

Note 1 to entry: A hydrophone is designed to respond principally to underwater sound pressure.

Note 2 to entry: In general, a hydrophone may also produce a signal in response to non-acoustic pressure fluctuations (for example, those existing in a turbulent boundary layer during conditions of high water flow).

Note 3 to entry: Hydrophone types include reference hydrophones and measuring hydrophones. Measuring hydrophones are used in general measurements of sound fields, and reference hydrophones are principally used for calibration purposes (for example in comparison calibrations with measuring hydrophones).

Note 4 to entry: Hydrophones are principally used as listening devices, but in reciprocity calibration, a hydrophone is used as reciprocal transducer, not only acting as a hydrophone, but also as a projector (sound source [IEC 60565]).

Note 5 to entry: A compact, integrated *underwater acoustic measuring system* (3.2.1.6) is sometimes called a “digital hydrophone” from its superficial resemblance to a standalone analogue hydrophone.

Note 6 to entry: If a hydrophone is connected to a charge amplifier, the sensitivity of the hydrophone is sometimes described in terms of charge sensitivity, which is related to the voltage sensitivity of the hydrophone by its electrical capacitance.

[SOURCE: IEC 60565-1]

3.2.1.2**pre-amplifier**

amplifier located immediately after the sensing element to increase the amplitude of the voltage (or current)

Note 1 to entry: A preamplifier often takes the form of a low-noise amplifier located as near as possible to the sensing element or another signal source. Other amplifiers may be placed later in the measurement chain.

Note 2 to entry: Adapted from IEC 60050-713-10-45 and ISO (18406:2017).

[SOURCE: Robinson and Wang (2021), Table 9]

3.2.1.3**aliasing**

false representation of spectral energy caused by mixing of spectral components above the Nyquist frequency with those spectral components below the Nyquist frequency

[SOURCE: ISO 18431-1]

3.2.1.4**anti-alias filter****AAF**

low-pass filter designed to avoid aliasing

Note 1 to entry: An anti-alias filter removes frequencies above the Nyquist frequency of the digital acquisition system.

[SOURCE: adapted from Robinson and Wang (2021), Table 9]

3.2.1.5**analogue-to-digital converter****ADC**

electronic component that converts an analogue input signal to a digital output signal

Note 1 to entry: The input signal is typically an analogue electric voltage, and the output is a digitized representation of the input sampled at finite time intervals. Adapted from ISO (18406:2017), IEC 60050-723-10-04.

[SOURCE: Robinson and Wang (2021), Table 9]

3.2.1.6**underwater acoustic measuring system****digital acquisition system, measuring system**

sequence of electronic components designed for data acquisition that may be considered together as whole, with a single overall performance

Note 1 to entry: An underwater acoustic acquisition system typically comprises a hydrophone, a pre-amplifier, an AAF, an ADC and some form of digital interface.

[SOURCE: Robinson and Wang (2021), Table 9]

3.2.1.7**ADC input**

analogue input signal to an ADC such as electric voltage

Note 1 to entry: Adapted from Ainslie et al. (2020).

[SOURCE: Robinson and Wang (2021), Table 9]

3.2.1.8

ADC output

digital representation of the ADC input sampled at finite time intervals

Note 1 to entry: An ADC output is suitable for storage in a digital storage medium or processing on a digital computer. Adapted from Ainslie et al. (2020).

[SOURCE: Robinson and Wang (2021), Table 9]

3.2.1.9

full-scale signal

signal whose value spans the entire range of input values representable by an ADC, from minimum unsaturated voltage to maximum unsaturated voltage, without clipping

Note 1 to entry: Compare IEEE (STD-1241-2010) (p 13): "A full-scale signal is one whose peak-to-peak amplitude spans the entire range of input values recordable by the analogue-to-digital converter under test."

Note 2 to entry: When a digital acquisition system displays nonlinear compression other than hard clipping, the full-scale amplitude corresponds to a signal that is 1 dB lower in amplitude than the amplitude which results in a measured 1 dB compression (reduction in gain).

[SOURCE: Ainslie et al. (2020)]

3.2.1.10

crosstalk

undesired energy appearing in a signal channel as a result of coupling from signals in other channels

Note 1 to entry: Typically caused by induction, conduction, radiative pick-up or non-linearity. Adapted from IEC 60050-722-15-03.

[SOURCE: Robinson and Wang (2021), Table 9]

3.2.1.11

autonomous underwater acoustic measuring system

digital autonomous acoustic recorder

underwater acoustic measuring system designed to operate without human intervention for sustained periods, with storage to record acoustic signals in a digital format

Note 1 to entry: Typically, these may be programmed to operate autonomously and sample over a range of duty cycles. Adapted from ISO (18406:2017).

[SOURCE: adapted from Robinson and Wang (2021), Table 9]

3.2.1.12

field calibration

method of using known inputs, possibly using physical stimuli (such as a known, calibrated and traceable acoustic source) or electrical input (charge or voltage signal injection) at the input (or other stage) of an underwater acoustic measuring system in order to ascertain that the system is, in fact, responding properly (i.e. within the system's stated uncertainty) to the known stimulus

[SOURCE: 17208-1:2016]

3.2.2 Hydrophone characteristics

3.2.2.1

free-field receive sensitivity

free-field voltage sensitivity

FFVS

$$M_f(f)$$

<of a hydrophone> quotient of the Fourier transform of the hydrophone open-circuit voltage signal to the Fourier transform of the acoustic pressure signal, for specified frequency and specified direction of plane wave sound incident on the position of the reference centre of the hydrophone in the undisturbed free-field if the hydrophone was removed

Note 1 to entry: In formula form, $M_f(f) = \frac{\int_{-\infty}^{+\infty} \exp(-2\pi i f t) v(t) dt}{\int_{-\infty}^{+\infty} \exp(-2\pi i f t) p(t) dt}$, where $v(t)$ is the hydrophone open-circuit voltage and $p(t)$ is the sound pressure.

Note 2 to entry: Free-field receive sensitivity is expressed in volt per pascal (V Pa^{-1}).

Note 3 to entry: The hydrophone free-field receive sensitivity is a complex-valued parameter. The modulus of the free-field receive sensitivity of a hydrophone is expressed in units of volt per pascal, $\text{V}\cdot\text{Pa}^{-1}$. The phase angle is the argument of the sensitivity and represents the phase difference between the hydrophone electrical voltage and the sound pressure. The unit of phase angle is the radian.

Note 4 to entry: The term "response" is sometimes used instead of "sensitivity".

[SOURCE: IEC 60565-1]

3.2.2.2

equivalent bandwidth noise pressure

$$p_{N,eq}$$

quotient of the root-mean-square noise voltage at a specified central frequency in the relevant frequency band present at the electrical terminals of the hydrophone, in the absence of pressure fluctuations at the hydrophone input, and the modulus of its free-field receive sensitivity at a specified frequency

Note 1 to entry: Equivalent bandwidth noise pressure is expressed in pascals (Pa).

Note 2 to entry: Equivalent bandwidth noise pressure includes contributions from both acoustic and non-acoustic noise.

Note 3 to entry: Pressure fluctuations at the hydrophone input include thermal fluctuations.

Note 4 to entry: If the hydrophone contains an integral preamplifier, the output terminals considered are those at the output of the pre-amplifier and the sensitivity in question includes the pre-amplifier gain.

[SOURCE: adapted from ISO (18406:2017)]

3.2.2.3

non-acoustic self-noise voltage

self-noise voltage

$$v_{N,self}$$

voltage at a specified location in an acoustic receiver in the absence of sound pressure input at the hydrophone

Note 1 to entry: Self-noise voltage is expressed in volts (V).

Note 2 to entry: The measurement frequency band shall be specified.

[SOURCE: Ainslie et al. (2020)]

3.2.2.4

hydrophone non-acoustic self-noise voltage

non-acoustic self-noise voltage at the hydrophone output

Note 1 to entry: Hydrophone non-acoustic self-noise voltage is expressed in volts (V).

[SOURCE: Ainslie et al. (2020)]

3.2.2.5

hydrophone mean-square non-acoustic self-noise voltage spectral density self-noise voltage spectral density

quotient of mean-square hydrophone non-acoustic self-noise voltage in a specified frequency band and the width of the frequency band

Note 1 to entry: Hydrophone mean-square non-acoustic self-noise voltage spectral density is expressed in volt squared per hertz ($V^2 \text{ Hz}^{-1}$).

[SOURCE: Ainslie et al. (2020)]

3.2.3 Analogue acquisition system characteristics

3.2.3.1

electrical noise power

time-averaged product of noise current and noise voltage

Note 1 to entry: Electrical noise power is expressed in watts (W).

Note 2 to entry: In an electrical circuit of resistance, R , electrical noise power is given by mean-square noise voltage divided by R or mean-square noise current multiplied by R .

Note 3 to entry: The electrical noise power depends on the position in the processing chain at which it is determined.

Note 4 to entry: The position in the processing chain at which the noise is determined shall be specified.

Note 5 to entry: Compare IEEE (STD-1241-2010) ('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."

[SOURCE: modified Ainslie et al. (2020)]

3.2.3.2

electrical signal power

W_s

time-averaged product of signal current and signal voltage

Note 1 to entry: Electrical signal power is expressed in watts (W).

Note 2 to entry: In an electrical circuit of resistance, R , electrical signal power is given by mean-square signal voltage divided by R or mean-square signal current multiplied by R .

Note 3 to entry: The electrical signal power depends on the position in the processing chain at which it is determined.

Note 4 to entry: The position in the processing chain at which the signal is determined shall be specified.

[SOURCE: Ainslie et al. (2020)]

3.2.3.3**signal-to-noise power ratio** R_{SN}

signal-to-noise ratio

ratio of electrical signal power to electrical noise power

Note 1 to entry: The signal-to-noise power ratio depends on the position in the processing chain at which it is determined.

Note 2 to entry: The position in the processing chain at which the signal-to-noise power ratio is determined shall be specified.

[SOURCE: Ainslie et al. (2020)]

3.2.3.4**signal-plus-noise-to-noise power ratio****signal-plus-noise-to-noise ratio** $R_{\text{S+NN}}$

ratio of electrical signal-plus-noise power to electrical noise power

Note 1 to entry: The signal-plus-noise-to-noise power ratio depends on the position in the processing chain at which it is determined.

Note 2 to entry: The position in the processing chain at which the signal-plus-noise-to-noise power ratio is determined shall be specified.

3.2.3.5**intermodulation distortion**

distortion resulting from the combination within the system of two independent input signals

Note 1 to entry: Adapted from IEC 60050-561-02-23 and IEC 60050-161-06-20 and : Ainslie et al. (2020).

Note 2 to entry: This occurs due to interaction in a system between the spectral components of the input signal or signals producing new output spectral components having frequencies equal to linear combinations of the inputs with integral coefficients of the frequencies of the input spectral components. Intermodulation can result from a single non-sinusoidal input signal or from several sinusoidal or non-sinusoidal input signals applied to the same or to different inputs. An input signal containing multiple tones may generate output distortion containing the sums and differences of the input tones.

[SOURCE: Robinson and Wang (2021), Table 12]

3.2.4 Sampling system characteristics**3.2.4.1****sampling rate****sampling frequency** f_s

number of samples of a signal taken per unit time

Note 1 to entry: Sampling frequency is expressed in hertz (Hz).

[SOURCE: IEC 60050-704-23-03]

3.2.4.2**Nyquist frequency** f_{Nyq}

maximum usable frequency available in data taken at a given sampling rate

Note 1 to entry: In formula form, $f_{\text{Nyq}} = f_s / 2$.

Note 2 to entry: Nyquist frequency is expressed in hertz (Hz).

Note 3 to entry: Except for the in-phase component of continuous signals, frequencies for analysis shall be lower than the Nyquist frequency.

Note 4 to entry: This standard imposes additional restrictions on the maximum useful frequency due to practical limitations in the realization of anti-aliasing filters.

[SOURCE: ISO 18431-1]

3.2.4.3

ADC input voltage

V_{ADC}

voltage at input to ADC

[SOURCE: Ainslie et al. (2020)]

3.2.4.4

integer ADC output

N_{ADC}

integer representation of ADC output, defined such that a unit change in integer ADC output corresponds to a change in the least significant bit from 0 to 1 or from 1 to 0

Note 1 to entry: The integer ADC output is equal to the product of ADC input voltage and ADC sensitivity to voltage.

Note 2 to entry: The integer ADC output is one of $2^{N_{\text{bit}}}$ consecutive integers, where N_{bit} is the bit depth.

Note 3 to entry: The integer ADC output is the ADC output when the ideal code bin width is equal to 1.

[SOURCE: Ainslie et al. (2020)]

3.2.4.5

bit depth

word size

N_{bit}

number of bits at ADC output used to represent one value of ADC input

[SOURCE: Ainslie et al. (2020)]

3.2.4.6

maximum integer ADC output

$N_{\text{ADC,max}}$

maximum possible value of the integer ADC output

[SOURCE: Ainslie et al. (2020)]

3.2.4.7

minimum integer ADC output

$N_{\text{ADC,min}}$

minimum possible value of the integer ADC output

Note 1 to entry: The integer ADC output can be positive or negative. If at least one value of the integer ADC output is negative, the minimum integer ADC output is also negative.

Note 2 to entry: The integer ADC output is one of $2^{N_{\text{bit}}}$ consecutive integers, where N_{bit} is the bit depth.

[SOURCE: Ainslie et al. (2020)]

3.2.4.8**full-scale ADC output** $N_{\text{ADC,FS}}$

one more than the difference between the maximum integer ADC output and the minimum integer ADC output

Note 1 to entry: The integer ADC output can be positive or negative. If the maximum integer ADC output is positive and the minimum integer ADC output is negative, then the full-scale ADC output is the sum of the maximum integer ADC output and the magnitude of the minimum integer ADC output

[SOURCE: adapted from Ainslie et al. (2020)]

3.2.4.9**ADC sensitivity to voltage** $M_{\text{ADC},v}$

quotient of root-mean-square integer ADC output ($N_{\text{ADC,rms}}$) and root-mean-square ADC input voltage ($v_{\text{ADC,rms}}$)

Note 1 to entry: In formula form, $M_{\text{ADC},v} = \frac{N_{\text{ADC,rms}}}{v_{\text{ADC,rms}}}$. The ADC sensitivity to voltage is equal to 2^N bit divided by the full-scale signal peak to peak voltage.

Note 2 to entry: ADC sensitivity to voltage is expressed in reciprocal volt (V^{-1}).

Note 3 to entry: Unless the ADC input voltage is equal to zero, the ADC sensitivity to voltage is also equal to the quotient of the integer ADC output and ADC input voltage.

[SOURCE: Ainslie et al. (2020)]

3.2.4.10**maximum unsaturated voltage** v_{max}

maximum ADC input voltage for which the ADC sensitivity to voltage is independent of ADC input

Note 1 to entry: Maximum unsaturated voltage is expressed in volts (V).

Note 2 to entry: The maximum unsaturated voltage is the maximum ADC input voltage for which the ADC sensitivity to voltage is linear with input voltage.

[SOURCE: Ainslie et al. (2020)]

3.2.4.11**minimum unsaturated voltage** v_{min}

minimum ADC input voltage for which the ADC sensitivity to voltage is independent of ADC input

Note 1 to entry: Minimum unsaturated voltage is expressed in volts (V).

Note 2 to entry: The ADC input voltage can be positive or negative. If at least one value of the integer ADC input voltage is negative, the minimum unsaturated voltage is also negative.

[SOURCE: Ainslie et al. (2020)]

3.2.4.12

full-scale input range

full-scale range

full-scale voltage

FSR

difference between maximum unsaturated voltage and minimum unsaturated voltage

Note 1 to entry: Full-scale input range is expressed in volts (V).

Note 2 to entry: The ADC input voltage can be positive or negative. If the maximum unsaturated voltage is positive and the minimum unsaturated voltage is negative, then the full-scale input range is the sum of the maximum unsaturated voltage and the magnitude of the minimum unsaturated voltage.

Note 3 to entry: Compare IEEE (STD-1241-2010) ('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: $FSR = (2^N) \times (\text{ideal code width})$ in analog input units."

[SOURCE: Ainslie et al. (2020)]

3.2.4.13

ideal code bin width

ideal code width

ADC output step size

Q

full-scale input range divided by $N_{\text{ADC,FS}}$, where $N_{\text{ADC,FS}}$ is the full-scale ADC output

Note 1 to entry: The full-scale ADC output is equal to the total number of code bins plus one.

Note 2 to entry: Compare IEEE (STD-1241-2010) ('ideal code bin width', p14): "The ideal full-scale input range divided by the total number of code bins."

Note 3 to entry: Compare IEEE (STD-1241-2010) '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."

[SOURCE: adapted from Ainslie et al. (2020)]

3.2.4.14

pre-amplifier voltage gain

$G_{\text{PA},V}$

ratio of root-mean-square pre-amplifier output voltage to root-mean-square pre-amplifier input voltage

Note 1 to entry: The pre-amplifier voltage gain can vary with frequency.

Note 2 to entry: For a tonal signal, the pre-amplifier voltage is equal to the ratio of peak pre-amplifier output voltage to peak pre-amplifier input voltage.

[SOURCE: Ainslie et al. (2020)]

3.2.4.15

AAF voltage gain

$G_{\text{AAF},V}$

ratio of root-mean-square AAF output voltage to root-mean-square AAF input voltage

Note 1 to entry: The AAF voltage gain can vary with frequency.

[SOURCE: Ainslie et al. (2020)]

3.2.4.16 equivalent root-mean-square ADC noise voltage

$v_{N,eq}$

quotient of the root-mean-square integer ADC noise output and the ADC sensitivity to voltage

Note 1 to entry: In formula form, $v_{N,eq} = \frac{N_{ADC,rms}}{M_{ADC,V}}$.

Note 2 to entry: Equivalent root-mean-square ADC noise voltage is expressed in volts (V).

Note 3 to entry: Equivalent root-mean-square ADC noise voltage includes contributions from acoustic and non-acoustic noise.

[SOURCE: Ainslie et al. (2020)]

3.2.4.17 equivalent root-mean-square ADC self-noise voltage

$v_{N,eq,self}$

equivalent root-mean-square ADC noise voltage in the absence of ADC input

Note 1 to entry: Equivalent root-mean-square ADC self-noise voltage is expressed in volts (V).

[SOURCE: Ainslie et al. (2020)]

3.2.4.18 ADC electronic self-noise output

integer ADC output in the absence of ADC input

Note 1 to entry: An absence of ADC input can be achieved by short-circuiting the ADC input.

[SOURCE: Ainslie et al. (2020)]

3.2.5 Acquisition system characteristics

3.2.5.1 system sensitivity frequency response

M_{sys}

quotient of the root-mean-square output of the measuring system and the incident root-mean-square sound pressure that would be present at the position of the reference centre of the hydrophone in the undisturbed free field if the hydrophone was removed for specified frequency and specified direction of plane wave sound

Note 1 to entry: System sensitivity is expressed in reciprocal pascal (Pa^{-1}).

Note 2 to entry: The system sensitivity is defined here as a free-field sensitivity for an underwater acoustic measuring system designed to measure sound pressure signals in water. The response of the system will in general vary with acoustic frequency.

Note 3 to entry: The analogue system sensitivity is described in terms of the electrical voltage developed per pascal of acoustic pressure and is stated in units of V/Pa. The sensitivity level re 1 V/ μPa is expressed in decibels. For digital systems, the calibration of the ADC is typically incorporated into the overall sensitivity of the whole system, which is the number of digital counts per unit change in sound pressure (unit Pa^{-1}).

Note 4 to entry: If the hydrophone is physically attached to the body of an acoustic recorder (rather than deployed on an extension cable), diffraction and scattering of sound by the recorder body may affect the free-field sensitivity at kilohertz frequencies, causing enhanced directivity compared to the response of the free hydrophone.

Note 5 to entry: In general, the measuring system may introduce a phase delay into the measured signal. This may be accounted for by representing the system sensitivity as a complex valued quantity, the modulus of which represents the magnitude-only response (and is described by the definition above) and the phase of which describes the phase response of the system.

Note 6 to entry: In general, the system sensitivity varies with acoustic frequency, but deconvolution can be difficult or impractical working with time domain. $M_{\text{sys}0}$ is the measured sensitivity at a frequency above the hydrophone's low-frequency cutoff, but where the wavelength of sound is much longer than the physical dimensions of the system and/or calibration apparatus.

[SOURCE: ISO (18406:2017)]

3.2.5.2

nominal system sensitivity

$M_{\text{sys}0}$

system sensitivity at a nominal frequency

Note 1 to entry: Nominal system sensitivity is expressed in reciprocal pascal (Pa^{-1}).

3.2.5.3

system weighting function

$W_{\text{sys}}(f)$

ratio of system sensitivity to nominal system sensitivity

3.2.5.4

calibration scale factor

reciprocal of nominal system sensitivity

Note 1 to entry: Calibration scale factor is expressed in pascals (Pa).

3.2.5.5

system sensitivity frequency response

system weighting function

$M_{\text{sys}}(f)$

frequency dependent system sensitivity

Note 1 to entry: System sensitivity frequency response is expressed in reciprocal pascal (Pa^{-1}).

Note 2 to entry: The system weighting function maps frequency to sensitivity. The sensitivity values may need to be interpolated between frequencies from provided calibration data.

3.2.5.6

system frequency band

usable frequency band of the underwater acoustic measuring system

Note 1 to entry: The lowest usable frequency of the measuring system often depends on a high-pass filter built into the hydrophone preamplifier to reduce non-acoustic flow and movement noise. The highest usable frequency is generally dependent on anti-aliasing filters and the Nyquist frequency. The Nyquist frequency depends on the sampling rate.

3.2.5.7

system non-acoustic self-noise output

system digital output in the absence of sound pressure at the hydrophone input

Note 1 to entry: Adapted from : Ainslie et al. (2020).

[SOURCE: Robinson and Wang (2021), Table 12]

3.2.5.8**system mean-square non-acoustic self-noise output spectral density****system self-noise output spectral density****ADC self-noise output spectral density**

distribution as a function of non-negative frequency of the mean-square ADC non-acoustic self-noise output per unit bandwidth of a sound having a continuous spectrum

Note 1 to entry: System mean-square non-acoustic self-noise output spectral density is expressed in reciprocal hertz (Hz^{-1}).

[SOURCE: Ainslie et al. (2020)]

3.2.5.9**input-referred system non-acoustic self-noise sound pressure spectral density****system self-noise sound pressure spectral density****system spectral self-noise**

quotient of system mean-square non-acoustic self-noise output spectral density and the squared system sensitivity

Note 1 to entry: Input-referred system non-acoustic self-noise sound pressure spectral density is expressed in pascal squared per hertz ($\text{Pa}^2 \text{Hz}^{-1}$).

[SOURCE: Ainslie et al. (2020)]

3.2.5.10**system-weighted sound pressure**

p_{sysw}

weighted sound pressure when the linear filter is the underwater acoustic measuring system

Note 1 to entry: System-weighted sound pressure is expressed in pascals (Pa).

Note 2 to entry: See ISO (18405:2017), entry 3.7.1.1.

Note 3 to entry: The measuring system might include a hydrophone, a pre-amplifier and an ADC (including anti-alias filter).

Note 4 to entry: The measuring system shall be specified.

Note 5 to entry: A filter is a process that removes from a signal some component or feature.

Note 6 to entry: The linear filter might be chosen to characterize a specified frequency-dependent transfer function of a mechanical or electrical system.

[SOURCE: Ainslie et al. (2020)]

3.2.5.11**zero-to-peak system-weighted sound pressure****peak system-weighted sound pressure**

$p_{\text{sysw},0-\text{pk}}$

$p_{\text{sysw},\text{pk}}$

greatest magnitude of the system-weighted sound pressure during a specified time interval, for a specified frequency range

Note 1 to entry: Zero-to-peak system-weighted sound pressure is expressed in pascals (Pa).

Note 2 to entry: A zero-to-peak system-weighted sound pressure can arise from a positive or negative system-weighted sound pressure.

[SOURCE: based on ISO 18405.]

3.2.6 Levels and other logarithmic quantities

3.2.6.1

system maximum recording level

$L_{\max}$

maximum sound pressure level that the measuring system can measure with a specified amount of distortion.

Note 1 to entry: System maximum recording level is expressed in decibels (dB).

Note 2 to entry: The system maximum recording level depends on the *full-scale signal* (3.2.1.9), the full-scale *ADC output* (3.2.4.8) and the *full-scale input range* (3.2.4.12).

Note 3 to entry: The reference value of sound pressure is 1 µPa.

Note 4 to entry: Generally 1 dB of distortion is the maximum acceptable, so that $L_{\max}$ occurs at the maximum unsaturated voltage input (see 3.2.4.10).

3.2.6.2

free-field receive sensitivity level

L_M

twenty times the logarithm to the base 10 of the ratio of the modulus of the free-field receive sensitivity M_f to a reference value of sensitivity, M_0 , in decibels

$$L_M = 20 \log_{10} \frac{|M_f|}{M_0} \text{ dB}$$

Note 1 to entry: Free-field receive sensitivity level is expressed in decibels (dB).

Note 2 to entry: The reference value of free-field receive sensitivity, M_0 , is 1 V·µPa⁻¹.

Note 3 to entry: Free-field receive sensitivity level is a property of a hydrophone.

[SOURCE: IEC 60565-1]

3.2.6.3

hydrophone spectral noise floor level

$L_{N,eq,f, hp}$

level of the hydrophone self-noise spectral density

Note 1 to entry: In formula form, $L_{N,eq,f, hp} = 10 \log_{10} \frac{(p_{N,eq}^2)_f}{p_0^2 / f_0} \text{ dB}$, where $(p_{N,eq}^2)_f$ is the hydrophone self-noise spectral density.

Note 2 to entry: Hydrophone spectral noise floor level is expressed in decibels (dB).

Note 3 to entry: The reference value of hydrophone self-noise spectral density is $p_0^2 / f_0 = 1 \mu\text{Pa}^2 / \text{Hz}$.

[SOURCE: Ainslie et al. (2020)]

3.2.6.4**system spectral noise floor level
recorder spectral noise floor level** $L_{N,eq,f,sys}$

level of the system self-noise spectral density

Note 1 to entry: In formula form, $L_{N,eq,f,sys} = 10 \lg \frac{(p_{N,eq}^2)_f}{p_0^2 / f_0}$ dB, where $(p_{N,eq}^2)_f$ is the system self-noise spectral density.

Note 2 to entry: System spectral noise floor level is expressed in decibels (dB).

Note 3 to entry: The reference value of system self-noise spectral density is $p_0^2 / f_0 = 1 \mu\text{Pa}^2 / \text{Hz}$.

[SOURCE: Ainslie et al. (2020)]

3.2.6.5**ADC dynamic range** $\Delta L_{DR,ADC}$

quantity given by $\Delta L_{DR,ADC} = 10 \lg \frac{\overline{v_{FS}^2}}{v_{N,eq,self}^2}$ dB, where $\overline{v_{FS}^2}$ is the mean-square voltage of a sinusoidal

full-scale signal and $v_{N,eq,self}$ is the equivalent root-mean-square ADC self-noise voltage

Note 1 to entry: ADC dynamic range is expressed in decibels (dB).

[SOURCE: Ainslie et al. (2020)]

3.2.6.6**system dynamic range** $\Delta L_{DR,sys}$

quantity given by $\Delta L_{DR,sys} = 10 \lg \frac{\overline{v_{FS}^2}}{v_{N,eq,self}^2 + v_{N,self}^2}$ dB, where $\overline{v_{FS}^2}$ is the mean-square voltage of a

sinusoidal full-scale signal, $v_{N,eq,self}$ is the equivalent root-mean-square ADC self-noise voltage and $v_{N,self}$ is the non-acoustic self-noise voltage at the ADC input

Note 1 to entry: System dynamic range is expressed in decibels (dB).

Note 2 to entry: The measurement frequency band shall be specified.

[SOURCE: Ainslie et al. (2020)]

3.2.6.7**total harmonic distortion****THD**

quantity given by

$$\Delta L_{THD} = 10 \lg \frac{v_2^2 + v_3^2 + \dots + v_{n+1}^2}{v_1^2} \text{ dB},$$

where v_1 is the root-mean-square voltage of a sinusoidal full-scale signal and $v_2 \dots v_{n+1}$ are the root-mean-square ADC voltage of the first n harmonics

Note 1 to entry: Total harmonic distortion is expressed in decibels (dB).

Note 2 to entry: Compare IEEE (STD-1241-2010) (p 17): “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.”

[SOURCE: Ainslie et al. (2020)]

3.2.6.8 system-weighted sound pressure level

$L_{p,\text{sysw}}$

level of the mean-square system-weighted sound pressure

Note 1 to entry: In formula form, $L_{p,\text{sysw}} = 10 \lg \frac{\overline{p_{\text{sysw}}^2}}{p_0^2}$ dB, where $\overline{p_{\text{sysw}}^2}$ is the mean-square system-weighted sound pressure.

Note 2 to entry: System-weighted sound pressure level is expressed in decibels (dB).

Note 3 to entry: The reference value of mean-square system-weighted sound pressure is $p_0^2 / f_0 = 1 \mu\text{Pa}^2 / \text{Hz}$.

[SOURCE: Ainslie et al. (2020)]

3.2.6.9 signal-to-noise level difference

ΔL_{SN}

quantity given by

$$\Delta L_{\text{SN}} = 10 \lg R_{\text{SN}} \text{ dB},$$

where R_{SN} is the signal-to-noise power ratio

Note 1 to entry: Signal-to-noise level difference is expressed in decibels (dB).

3.2.6.10 signal-plus-noise-to-noise level difference

$\Delta L_{\text{S+NN}}$

quantity ΔL_{SN} in the formula

$$\Delta L_{\text{SN}} = 10 \lg R_{\text{S+NN}} \text{ dB},$$

where $R_{\text{S+NN}}$ is the signal-to-noise power ratio

Note 1 to entry: Signal-plus-noise-to-noise level difference is expressed in decibels (dB).

3.2.6.11 equivalent bandwidth noise pressure level

$L_{\text{N,eq}}$

quantity $L_{\text{N,eq}}$ given by

$$L_{\text{N,eq}} = 10 \lg \frac{p_{\text{N,eq}}^2}{p_0^2} \text{ dB},$$

where $p_{\text{N,eq}}$ is the equivalent bandwidth noise pressure and p_0 is the reference sound pressure

Note 1 to entry: Equivalent bandwidth noise pressure level is expressed in decibels (dB).

Note 2 to entry: The reference sound pressure, p_0 , is 1 μPa .

3.3 Concepts and quantities: Data processing

3.3.1

temporal observation window

TOW

interval of time within which a statistic of the sound field is calculated or estimated

Note 1 to entry: Examples of statistic include root-mean-square sound pressure, peak sound pressure and sound pressure kurtosis. An example is root-mean-square sound pressure calculated using a temporal observation window of 1 min.

Note 2 to entry: The duration of the temporal observation window may be denoted t_{OW} .

[SOURCE: Ainslie et al. (2020)]

3.3.2

temporal analysis window

TAW

interval of time during which statistics are calculated over multiple temporal observation windows

Note 1 to entry: An example is a 24 h distribution of root-mean-square sound pressure calculated using a temporal observation window of 1 min. In this example, the temporal analysis window is 24 h and the temporal observation window is 1 min.

Note 2 to entry: The duration of the temporal analysis window may be denoted t_{AW} .

[SOURCE: Ainslie et al. (2020)]

3.3.3

Discrete Fourier transform terms

3.3.3.1

Fourier series representation

representation of a periodic discrete time signal $x(n)$ having period N of the form:

$$x(n) = \sum_{m=0}^{N-1} c_m e^{\frac{i2\pi nm}{N}}$$

where c_m are complex coefficients that define the amplitude and phase for each of the N complex exponential in the summand

Note 1 to entry: this form is restricted to periodic signals and to periodic approximations of aperiodic signals.

3.3.3.2

discrete Fourier transform

discrete transform in time and frequency, based on the discrete Fourier series, used to obtain a spectral estimation of N uniformly time-spaced samples of a signal observed over a finite duration

$$X(m) = \frac{1}{N} \sum_{n=0}^{N-1} x(n) e^{\frac{-i2\pi nm}{N}}$$

where $X(m)$ is equal to c_m in the Fourier series representation of $x(n)$ (3.3.3.1) abbreviation: DFT

Note 1 to entry: the FFT is a computationally efficient way to calculate this sum, although commercial packages differ on how the sum is scaled.

Note 2 to entry: Further information on the discrete Fourier transform is provided in Informative Annex B