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Underwater acoustics — Terminology

Acoustique sous-marine — Terminologie

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Foreword

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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 on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 3, *Underwater acoustics*.

Introduction

0.1 Overview

Vocabulary is the most basic of subjects for standardization. Without an accepted standard for the definition of terminology, the production of scientific and engineering publications in a technical area, including the development of standards for measurement, processing or modelling in that area, becomes a laborious and time-consuming task that would ultimately result in the inefficient use of time and a high probability of misinterpretation.

Basic terminology of underwater acoustics is defined in 3.1, followed by levels in 3.2. These are followed by definitions of terms associated with sources of sound (3.3), propagation and scattering (3.4), underwater sound signals (3.5), and sonar equations (3.6). Finally, 3.7 defines basic bioacoustical terminology used in underwater acoustics.

0.2 Approach

The underlying philosophy followed in preparing this document is to define quantities independently of how they are measured.

0.3 Remark on exceptions to the ISO/IEC 80000 series

In this document, the ISO/IEC 80000 series is followed for the definitions of physical quantities, including the level of a power quantity and level of a field quantity. Two exceptions are made to this general rule, as follows.

- Inconsistencies between ISO 80000-1 and ISO 80000-3 make it necessary to choose between them (for example, the term “field quantity” used in ISO 80000-3 is deprecated by ISO 80000-1:2009, Annex C, which prefers the term “root-power quantity”). This document follows ISO 80000-3, which makes it incompatible with ISO 80000-1.

- The term “sound pressure level” is defined by ISO 80000-8 in a way that does not reflect conventional use of this term to mean the level of the mean-square sound pressure. This convention is reflected in ISO 80000-8 by the notes in the “Remarks” column alongside the definition. These remarks are inconsistent with the definition, making it necessary to choose between the definition and the remarks. This document follows the “Remarks”, which makes it incompatible with the ISO 80000-8 definition of “sound pressure level”.

0.4 Remark on levels and level differences, and their reference values

Levels used in underwater acoustics are defined in 3.2. In its most general form, a level L_Q of a quantity Q is defined in the International System of Quantities (see ISO 80000-3) as the logarithm of the ratio of the quantity Q to its reference value, Q_0. In formula form, this definition can be written as

$$L_Q = \log_r(Q/Q_0).$$

The nature of the quantity (Q), its reference value (Q_0) and the base of the logarithm (r) should all be specified. Reference values for use in underwater acoustics are specified by ISO 1683.

Two types of level are in widespread use in underwater acoustics, the level of a field quantity (see ISO 80000-3:2006, 3-21) and the level of a power quantity (see ISO 80000-3:2006, 3-22). In underwater acoustics, it is conventional to express both types of level in decibels (dB). When expressed in decibels, the level L_F of a field quantity F is

$$L_F = 20 \log_{10}(F/F_0) \text{ dB},$$

where F_0 is the reference value of the field quantity. Similarly, the level L_P of a power quantity P is

$$L_P = 10 \log_{10}(P/P_0) \text{ dB},$$

where P_0 is the reference value of the power quantity. This definition of L_P is a product of the three factors 10, $\log_{10}(P/P_0)$ and 1 dB. In words, this product is written in this document as “ten times the logarithm to the base 10 of the ratio P/P_0, in decibels”. For levels of both field and power quantities, the nature of the quantity (F or P) is implied by the name of the level, while the base of the logarithm is implied by the use of decibel as the unit. For all levels, the reference value is stated explicitly. The use by this document of the definitions of “level” and “decibel” from ISO 80000-3 results in inconsistencies between this document and ISO 80000-1 because of inconsistencies between ISO 80000-3 and ISO 80000-1:2009, Annex C.

Level differences [i.e. differences between levels of like quantities (see ANSI/ASA S1.1-2013, 10.44)] are also expressed in decibels. For example, if P_1 and P_2 are power quantities of the same kind, and $L_{P,1}$ and $L_{P,2}$ are their respective levels, the corresponding level difference is

$$\Delta L_P = L_{P,1} - L_{P,2} = 10 \log_{10}(P_1/P_0) \text{ dB} - 10 \log_{10}(P_2/P_0) \text{ dB} = 10 \log_{10}(P_1/P_2) \text{ dB}.$$

Similarly, for like field quantities F_1 and F_2, with respective levels, $L_{F,1}$ and $L_{F,2}$,

$$\Delta L_F = L_{F,1} - L_{F,2} = 20 \log_{10}(F_1/F_0) \text{ dB} - 20 \log_{10}(F_2/F_0) \text{ dB} = 20 \log_{10}(F_1/F_2) \text{ dB}.$$

Examples of level difference are transmission loss, array gain, and hearing threshold shift.

Differences between levels of power quantities of different kinds are encountered in 3.6 and 3.7 in connection with the response of underwater systems, and are also expressed in decibels. For example, if A and B are two power quantities, with A being a measure of the response signal (output) of a system and B a measure of the forcing signal (input), such that the system sensitivity is $S = A/B$, the sensitivity level of that system is

$$N_S = L_A - L_B = 10 \log_{10} (A/A_0) \text{ dB} - 10 \log_{10} (B/B_0) \text{ dB} = 10\log_{10}(S/S_0) \text{ dB}$$

where S_0, the reference value of the sensitivity, is equal to A_0/B_0.

An example of sensitivity level in underwater acoustics is target strength (reference value = 1 m^2). If this quantity were expressed instead as the difference between levels of field quantities, defined as the square root of the respective power quantities, the reference value would then become 1 m.

0.5 Remark on reference values of root-power quantities

For every real, positive power quantity, P, there exists a root-power quantity, F_{rp}, equal to the square root of P (see ISO 80000-1:2009), that is, $F_{\text{rp}} = P^{1/2}$. The level of this root-power quantity is

$$L_{F,\text{rp}} = 20 \log_{10}(F_{\text{rp}}/F_0) \text{ dB}.$$

This level is equal to L_P if the reference value F_0 is given by $F_0 = P_0^{1/2}$. Selected power quantities and their respective reference values are listed in columns 1 and 2 of Table 1. The corresponding root-power quantities and their respective reference values are listed in columns 3 and 4 of Table 1. A field quantity is “a quantity whose square is proportional to power when it acts on a linear system” (see ISO 80000-3), so all root-power quantities are also field quantities. For example, the level of mean-square sound pressure, with reference value 1 μPa^2, is equal to that of root-mean-square sound pressure, with reference value 1 µPa. These two reference values are therefore used interchangeably for sound pressure level.

Table 1 — Power quantities, their corresponding root-power quantities, and their reference values, based on Reference [21]

Power quantity (P)	Reference value (P_0)	Corresponding root-power quantity ($F_{\mathrm{rp}} = P^{1/2}$)	Reference value ($F_0 = P_0^{1/2}$)
Mean-square sound pressure	1 µPa^2	Root-mean-square sound pressure	1 µPa
Mean-square sound particle displacement	1 pm^2	Root-mean-square sound particle displacement	1 pm
Mean-square sound particle velocity	1 nm^2/s^2	Root-mean-square sound particle velocity	1 nm/s
Mean-square sound particle acceleration	1 µm^2/s^4	Root-mean-square sound particle acceleration	1 µm/s^2
Sound exposure	1 µPa^2 s	Root sound exposure	1 µPa s$^{1/2}$
Sound power	1 pW	Root sound power	1 pW$^{1/2}$
Sound energy	1 pJ	Root sound energy	1 pJ$^{1/2}$
Source factor	1 µPa^2 m^2	Root source factor	1 µPa m
Propagation factor	1 m^2	Root propagation factor	1 m

0.6 Remark on the usage of “acoustic” and “sound” in this document

This document recognizes the interchangeability of the words “acoustic” and “sound” when the word “sound” is used as part of a compound noun, and not otherwise.

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Underwater acoustics — Terminology

1 Scope

This document defines terms and expressions used in the field of underwater acoustics, including natural, biological and anthropogenic (i.e. man-made) sound. It includes the generation, propagation and reception of underwater sound and its scattering, including reflection, in the underwater environment including the seabed (or sea bottom), sea surface and biological organisms. It also includes all aspects of the effects of underwater sound on the underwater environment, humans and aquatic life. The properties of underwater acoustical systems are excluded.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1 General terms

3.1.1 General

3.1.1.1
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

Note 1 to entry: The medium in which the sound exists is often indicated by an appropriate adjective, e.g. airborne, water-borne, or structure-borne.

Note 2 to entry: In the remainder of this document, the medium is assumed to be a compressible fluid.

Note 3 to entry: A sound wave is a realization of sound.

Note 4 to entry: The word “sound” may also be used as part of a compound noun, in which case, it is a synonym of “acoustic”. For example, “acoustic pressure” and “acoustic power”’ are synonyms of *sound pressure* (3.1.2.1) and *sound power* (3.1.3.14).

[SOURCE: Reference [23] and Reference [35]]

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).

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

3.1.1.4
reverberation

sound (3.1.1.1) resulting from cumulative scattering of sound by an aggregation, or ensemble, of scatterers

Note 1 to entry: Reverberation commonly arises from scatterers in a volume or on a surface.

3.1.1.5
material element
sound particle

smallest element of the medium that represents the medium's mean density

Note 1 to entry: The characteristic length scale of this element is of the order of several times the mean free molecular path (see Reference [22]).

3.1.2 Acoustical field quantities

3.1.2.1
sound pressure

p

contribution to total pressure caused by the action of *sound* (3.1.1.1)

Note 1 to entry: Sound pressure is a function of time, which may be indicated by means of an argument t, as in $p(t)$, where p is sound pressure and t is time.

Note 2 to entry: Sound pressure is expressed in pascals (Pa).

Note 3 to entry: The term "sound pressure" is sometimes used as a synonym of "root-mean-square sound pressure". This use is deprecated.

Note 4 to entry: The term "sound pressure" is defined by IEC 60050 as the root-mean-square value of $p(t)$. While this IEC definition is not compatible with the present (ISO) definition, users of ISO standards might nevertheless encounter the IEC definition, for example, in hydrophone calibration standards developed by the IEC.

Note 5 to entry: Weighted sound pressure is defined in 3.7.1.1.

[SOURCE: ISO 80000-8:2007, 8-9.1 and 8-9.2, modified]

3.1.2.2
sound pressure spectrum

P

Fourier transform of the *sound pressure* (3.1.2.1)

Note 1 to entry: Sound pressure spectrum is a function of frequency, which may be indicated by means of an argument f, as in $P(f)$, where P is sound pressure spectrum and f is frequency.

Note 2 to entry: In formula form, $P\left(f\right)=\int_{-\infty}^{+\infty}\exp\left(-2\pi\mathrm{i}\,f\,t\right)\,p(t)\,\mathrm{d}t$, where $p(t)$ is the sound pressure as a function of time, t. If $P(f)$ is known, $p(t)$ can be calculated using the inverse Fourier transform $p\left(t\right)=\int_{-\infty}^{+\infty}\exp\left(+2\pi\mathrm{i}\,f\,t\right)$ $P(f)\,\mathrm{d}f$. See ISO 80000-2:2009.

Note 3 to entry: Sound pressure spectrum is expressed in units of pascal per hertz (Pa/Hz).

Note 4 to entry: In general, $P(f)$ is a complex function of frequency.

Note 5 to entry: The definition of sound pressure spectrum applies to a single-event or transient sound pressure signal, in which case, for the purpose of the integral over time in the formula for $P(f)$, the sound pressure $p(t)$ is set to zero at all times before the signal starts and after it ends. It can also be applied to a finite segment of a continuous sound pressure signal, in which case, the start and end times of the segment shall be specified.

3.1.2.3

zero-to-peak sound pressure
peak sound pressure

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

p_{pk}

greatest magnitude of the *sound pressure* (3.1.2.1) during a specified time interval, for a specified frequency range

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

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

[SOURCE: ISO/TR 25417:2007, 2.4, modified]

3.1.2.4

compressional pressure

p_{c}

sound pressure (3.1.2.1), $p(t)$, when $p(t) > 0$, where t is time

Note 1 to entry: Compressional pressure is expressed in pascals (Pa).

Note 2 to entry: For shock waves, compressional pressure may be referred to as “blast overpressure”. See Reference [33].

3.1.2.5

peak compressional pressure

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

greatest *compressional pressure* (3.1.2.4) during a specified time interval, for a specified frequency range

Note 1 to entry: Peak compressional pressure is expressed in pascals (Pa).

Note 2 to entry: A peak compressional pressure can only arise from a positive sound pressure.

Note 3 to entry: For shock waves, peak compressional pressure may be referred to as “peak blast overpressure”.

3.1.2.6

rarefactional pressure

p_{r}

magnitude of *sound pressure* (3.1.2.1), $|p(t)|$, when $p(t) < 0$, where p is sound pressure and t is time

Note 1 to entry: Rarefactional pressure is expressed in pascals (Pa).

3.1.2.7

peak rarefactional pressure

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

greatest *rarefactional pressure* (3.1.2.6) during a specified time interval, for a specified frequency range

Note 1 to entry: Peak rarefactional pressure is expressed in pascals (Pa).

Note 2 to entry: A peak rarefactional pressure can only arise from a negative sound pressure.

Note 3 to entry: Peak rarefactional pressure is always positive.

3.1.2.8
peak-to-peak sound pressure

$p_{\text{pk-pk}}$

sum of the *peak compressional pressure* (3.1.2.5) and the *peak rarefactional pressure* (3.1.2.7) during a specified time interval, for a specified frequency range

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

Note 2 to entry: The start and end times used to determine the time interval for the peak compressional pressure shall be the same as those used to determine the time interval for the peak rarefactional pressure.

3.1.2.9
sound particle displacement

$\boldsymbol{\delta}$

displacement of a *material element* (3.1.1.5) caused by the action of *sound* (3.1.1.1)

Note 1 to entry: Sound particle displacement is a function of time, t, which may be indicated by means of an argument t, as in $\boldsymbol{\delta}(t)$.

Note 2 to entry: Sound particle displacement is expressed in metres (m).

Note 3 to entry: Sound particle displacement is a vector quantity. Spatial components of the sound particle displacement may be indicated by assigning subscripts to the symbol. For example, in Cartesian coordinates, $\boldsymbol{\delta} = (\delta_x, \delta_y, \delta_z)$. By convention in underwater acoustics, the z axis is usually chosen to point vertically down from the sea surface, with x and y axes in the horizontal plane.

[SOURCE: ISO 80000-8:2007, 8-10, modified]

3.1.2.10
sound particle velocity

$\boldsymbol{u}$

contribution to velocity of a *material element* (3.1.1.5) caused by the action of *sound* (3.1.1.1)

Note 1 to entry: Sound particle velocity is a function of time, t, which may be indicated by means of an argument t, as in $\boldsymbol{u}(t)$.

Note 2 to entry: For small-amplitude sound waves in an otherwise stationary medium, the sound particle velocity and *sound particle displacement* (3.1.2.9) are related by

$$\boldsymbol{u} = \frac{\partial \boldsymbol{\delta}}{\partial t}$$

where $\boldsymbol{\delta}(t)$ is the sound particle displacement at time, t, and the partial derivative is evaluated at a fixed position. The formula above is an approximation, with relative error of order $|\boldsymbol{u}/c|$, where c is the speed of sound in the medium.

Note 3 to entry: Sound particle velocity is expressed in units of metre per second (m/s).

Note 4 to entry: Sound particle velocity is a vector quantity. Spatial components of the sound particle velocity may be indicated by assigning subscripts to the symbol. For example, in Cartesian coordinates, $\boldsymbol{u} = (u_x, u_y, u_z)$. By convention in underwater acoustics, the z axis is usually chosen to point vertically down from the sea surface, with x and y axes in the horizontal plane.

[SOURCE: ISO 80000-8:2007, 8-11, modified]

3.1.2.11
sound particle acceleration

$\boldsymbol{a}$

contribution to acceleration of a *material element* (3.1.1.5) caused by the action of *sound* (3.1.1.1)

Note 1 to entry: Sound particle acceleration is a function of time, t, which may be indicated by means of an argument t, as in $\boldsymbol{a}(t)$.

Note 2 to entry: For small-amplitude sound waves in an otherwise stationary medium, the sound particle acceleration and *sound particle velocity* (3.1.2.10) are related by

$$\boldsymbol{a} = \frac{\partial \boldsymbol{u}}{\partial t}$$

where $\boldsymbol{u}(t)$ is the sound particle velocity at time, t, and the partial derivative is evaluated at a fixed position. The formula above is an approximation, with relative error of order $|\boldsymbol{u}/c|$, where c is the speed of sound in the medium.

Note 3 to entry: Sound particle acceleration is expressed in units of metre per second squared (m/s^2).

Note 4 to entry: Sound particle acceleration is a vector quantity. Spatial components of the sound particle acceleration may be indicated by assigning subscripts to the symbol. For example, in Cartesian coordinates, $\boldsymbol{a} = (a_x, a_y, a_z)$. By convention in underwater acoustics, the z axis is usually chosen to point vertically down from the sea surface, with x and y axes in the horizontal plane.

[SOURCE: ISO 80000-8:2007, 8-12, modified]

3.1.3 Acoustical power quantities

3.1.3.1

mean-square sound pressure

$\overline{p^2}$

integral over a specified time interval of squared *sound pressure* (3.1.2.1), divided by the duration of the time interval, for a specified frequency range

Note 1 to entry: In formula form, $\overline{p^2} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} p^2\left(t\right)\mathrm{d}t$, where $p(t)$ is the sound pressure, and t_1 and t_2 are the start and end times, respectively. For a transient sound, the start and end times are sometimes chosen to correspond to the start and end of the *percentage energy signal duration* (3.5.1.5).

Note 2 to entry: Mean-square sound pressure is expressed in units of pascal squared (Pa^2).

Note 3 to entry: The square root of the mean-square sound pressure is a field quantity known as the root-mean-square sound pressure. This field quantity may be denoted p_{rms}.

3.1.3.2

mean-square sound particle displacement

$\overline{\delta^2}$

integral over a specified time interval of squared magnitude of the *sound particle displacement* (3.1.2.9), divided by the duration of the time interval, for a specified frequency range

Note 1 to entry: In formula form, $\overline{\delta^2} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} \delta^2\left(t\right)\mathrm{d}t$, where $\delta(t)$ is the magnitude of the sound particle displacement, and t_1 and t_2 are the start and end times, respectively.

Note 2 to entry: Mean-square sound particle displacement is expressed in units of metre squared (m^2).

Note 3 to entry: The square root of the mean-square sound displacement is a field quantity known as the root-mean-square sound displacement. This field quantity may be denoted δ_{rms}.

3.1.3.3
mean-square sound particle velocity

$\overline{u^2}$

integral over a specified time interval of squared magnitude of the *sound particle velocity* (3.1.2.10), divided by the duration of the time interval, for a specified frequency range

Note 1 to entry: In formula form, $\overline{u^2} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} u^2\left(t\right)\mathrm{d}t$, where $u(t)$ is the magnitude of the sound particle velocity, and t_1 and t_2 are the start and end times, respectively.

Note 2 to entry: Mean-square sound particle velocity is expressed in units of (metre per second) squared [$(\mathrm{m/s})^2$].

Note 3 to entry: The square root of the mean-square sound velocity is a field quantity known as the root-mean-square sound velocity. This field quantity may be denoted u_{rms}.

3.1.3.4
mean-square sound particle acceleration

$\overline{a^2}$

integral over a specified time interval of squared magnitude of the *sound particle acceleration* (3.1.2.11), divided by the duration of the time interval, for a specified frequency range

Note 1 to entry: In formula form, $\overline{a^2} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a^2\left(t\right)\mathrm{d}t$, where $a(t)$ is the magnitude of the sound particle acceleration, and t_1 and t_2 are the start and end times, respectively.

Note 2 to entry: Mean-square sound particle acceleration is expressed in units of (metre per second squared) squared [$(\mathrm{m/s}^2)^2$].

Note 3 to entry: The square root of the mean-square sound acceleration is a field quantity known as the root-mean-square sound acceleration. This field quantity may be denoted a_{rms}.

3.1.3.5
time-integrated squared sound pressure
sound pressure exposure
sound exposure

$E_{p,T}$

<underwater acoustics> integral of the square of the *sound pressure* (3.1.2.1), p, over a specified time interval or event, for a specified frequency range

Note 1 to entry: In formula form, $E_{p,T} = \int_{t_1}^{t_2} p^2\left(t\right)\mathrm{d}t$, where t_1 and t_2 are the start and end times of the time interval or event, respectively, and $T = t_2 - t_1$ is the duration of the signal.

Note 2 to entry: Time-integrated squared sound pressure is expressed in units of pascal squared second (Pa^2 s).

Note 3 to entry: According to the continuous form of Parseval's theorem (also known as Plancherel's theorem), the time-integrated squared sound pressure can be written as the frequency-integrated *sound exposure spectral density* (3.1.3.9). In formula form, $E_{p,T} = \int_{-\infty}^{+\infty} {p_T}^2\left(t\right)\mathrm{d}t = \int_{-\infty}^{+\infty}\left|P\left(f\right)\right|^2 \mathrm{d}f = \int_{0}^{+\infty} E_f\left(f\right)\mathrm{d}f$, where $p_T(t)$ is equal to $p(t)$ for $t_1 < t < t_2$ and is otherwise zero, $P(f)$ is the Fourier transform (see ISO 80000-2) of $p_T(t)$ and E_f is the sound exposure spectral density of the pressure time series $p_T(t)$.

Note 4 to entry: In the far field the time-integrated squared sound pressure is equal to the product of the *characteristic acoustic impedance* (3.1.5.6) of the medium and the magnitude of the time-integrated *sound intensity* (3.1.3.10). In the near field this equality does not hold in general.

Note 5 to entry: See also *weighted time-integrated squared sound pressure* (3.7.1.2).

3.1.3.6

time-integrated squared sound particle displacement

$E_{\delta,T}$

integral of the square of the magnitude of the *sound particle displacement* (3.1.2.9), δ, over a specified time interval or event, for a specified frequency range

Note 1 to entry: In formula form, $E_{\delta,T} = \int_{t_1}^{t_2} \delta^2\left(t\right)\mathrm{d}t$, where t_1 and t_2 are the start and end times of the time interval or event, respectively, and $T = t_2 - t_1$ is the duration of the signal.

Note 2 to entry: Time-integrated squared sound particle displacement is expressed in units of metre squared second (m^2 s).

3.1.3.7

time-integrated squared sound particle velocity

$E_{u,T}$

integral of the square of the magnitude of the *sound particle velocity* (3.1.2.10), u, over a specified time interval or event, for a specified frequency range

Note 1 to entry: In formula form, $E_{u,T} = \int_{t_1}^{t_2} u^2\left(t\right)\mathrm{d}t$, where t_1 and t_2 are the start and end times of the time interval or event, respectively, and $T = t_2 - t_1$ is the duration of the signal.

Note 2 to entry: Time-integrated squared sound particle velocity is expressed in units of (metre per second) squared second [$(\mathrm{m/s})^2$ s].

3.1.3.8

time-integrated squared sound particle acceleration

$E_{a,T}$

integral of the square of the magnitude of the *sound particle acceleration* (3.1.2.11), a, over a specified time interval or event, for a specified frequency range

Note 1 to entry: In formula form, $E_{a,T} = \int_{t_1}^{t_2} a^2\left(t\right)\mathrm{d}t$, where t_1 and t_2 are the start and end times of the time interval or event, respectively, and $T = t_2 - t_1$ is the duration of the signal.

Note 2 to entry: Time-integrated squared sound particle acceleration is expressed in units of (metre per second squared) squared second [$(\mathrm{m/s}^2)^2$ s].

3.1.3.9

sound exposure spectral density

sound pressure exposure spectral density

E_f

<underwater acoustics> distribution as a function of non-negative frequency of the *time-integrated squared sound pressure* (3.1.3.5) per unit bandwidth of a sound having a continuous spectrum

Note 1 to entry: Sound exposure spectral density is expressed in units of pascal squared second per hertz (Pa^2 s/Hz).

Note 2 to entry: In its idealized form, sound exposure spectral density is evaluated as the limit, as the bandwidth tends to zero, of the time-integrated squared sound pressure in a finite frequency band divided by the frequency bandwidth.

Note 3 to entry: For operational purposes, sound exposure spectral density is estimated as the time-integrated squared sound pressure in a finite frequency band divided by the frequency bandwidth. The result is equal to the mean value of the sound exposure spectral density, averaged across the band. The time duration and frequency band shall be specified.