INTERNATIONAL STANDARD

ISO 18405

First edition
2017-04

Underwater acoustics — Terminology

Acoustique sous-marine — Terminologie

Reference number
ISO 18405:2017(E)

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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 ($F_{rp} = P^{1/2}$)	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.

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
$p_{0\text{-pk}}$
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, $\overline{p^2} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} p^2(t)\,\mathrm{d}t$, 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, $\overline{\delta^2} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} \delta^2(t)\,\mathrm{d}t$, 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, $\overline{u^2} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} u^2(t)\,\mathrm{d}t$, 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, $\overline{a^2} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a^2(t)\,\mathrm{d}t$, 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, $E_{p,T} = \int_{t_1}^{t_2} p^2(t)\,\mathrm{d}t$, 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 ($\mathrm{Pa^2\,s}$).

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, $E_{p,T} = \int_{-\infty}^{+\infty} {p_T}^2(t)\,\mathrm{d}t = \int_{-\infty}^{+\infty} \left|P(f)\right|^2 \mathrm{d}f = \int_{0}^{+\infty} E_f(f)\,\mathrm{d}f$, 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, $E_{\delta,T} = \int_{t_1}^{t_2} \delta^2(t)\mathrm{d}t$, 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, $E_{u,T} = \int_{t_1}^{t_2} u^2(t)\mathrm{d}t$, 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 [$(m/s)^2$ 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, $E_{a,T} = \int_{t_1}^{t_2} a^2(t)\mathrm{d}t$, 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 [$(m/s^2)^2$ 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.

Note 4 to entry: According to the continuous form of Parseval's theorem (also known as Plancherel's theorem), the *sound pressure spectrum* (3.1.2.2), $P(f)$, is related to the sound pressure $p(t)$ via the formula $\int_{-\infty}^{+\infty} \left|P\left(f\right)\right|^2 \mathrm{d}f = \int_{-\infty}^{+\infty} p^2\left(t\right)\mathrm{d}t$. Here, $|P(f)|^2$ is a function of both positive and negative frequencies and is known as a "double-sided" spectral density. By contrast, $E_f(f)$ is known as a "single-sided" spectral density because it is a function of non-negative frequencies only, and satisfies the formula $\int_0^{+\infty} E_f\left(f\right)\mathrm{d}f = \int_{-\infty}^{+\infty} p^2\left(t\right)\mathrm{d}t$. It follows from these formulae that for any positive non-zero frequency, $E_f(f) = 2|P(f)|^2$. For zero frequency, $E_f(0) = |P(0)|^2$.

Note 5 to entry: The integral over positive frequencies of the sound exposure spectral density is equal to the time-integrated squared sound pressure $\int_0^{+\infty} E_f\left(f\right)\mathrm{d}f = E_{p,T}$.

3.1.3.10
sound intensity
instantaneous sound intensity
I
product of the *sound pressure* (3.1.2.1), p, and the *sound particle velocity* (3.1.2.10), $\boldsymbol{u}$

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

Note 2 to entry: In formula form, $\boldsymbol{I}(t) = p(t)\,\boldsymbol{u}(t)$.

Note 3 to entry: Sound intensity is expressed in units of watt per metre squared (W/m^2).

Note 4 to entry: Sound intensity is a vector quantity. Spatial components of the sound intensity may be indicated by assigning subscripts to the symbol. For example, in Cartesian coordinates, $\boldsymbol{I} = (I_x, I_y, I_z)$. 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.

Note 5 to entry: Sound intensity is also known as the "Umov vector", "Poynting vector" or "Umov-Poynting vector".

Note 6 to entry: Sound pressure is a real scalar quantity and sound particle velocity is a real vector quantity. Sound intensity is therefore a real vector quantity.

Note 7 to entry: In the International System of Quantities (ISQ), sound pressure and sound particle velocity are instantaneous quantities. Their product, sound intensity, is therefore also an instantaneous quantity in the ISQ. The upper case symbol $\boldsymbol{I}$, without a subscript, is used to denote this instantaneous quantity to distinguish it from the time-averaged sound intensity, $\boldsymbol{I}_{\mathrm{av}}$.

Note 8 to entry: The term "sound intensity" is in widespread use as a synonym of "time-averaged sound intensity", $\boldsymbol{I}_{\mathrm{av}}$. This use is not compatible with the ISQ.

Note 9 to entry: This definition could become inapplicable in situations with a high mean fluid flow.

Note 10 to entry: This definition is in accordance with ISO 80000-8:2007, 8-17.1.

[SOURCE: ISO/TR 25417:2007, 2.12, modified]

3.1.3.11
time-averaged sound intensity
$\boldsymbol{I}_{\mathrm{av}}$
integral over a specified time interval of *sound intensity* (3.1.3.10), $\boldsymbol{I}$, divided by the duration of the time interval, for a specified frequency range

Note 1 to entry: In formula form, $\boldsymbol{I}_{\mathrm{av}} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} \boldsymbol{I}\left(t\right)\mathrm{d}t$, where t_1 and t_2 are the start and end times, respectively.

Note 2 to entry: Time-averaged sound intensity is expressed in units of watt per metre squared (W/m^2).

Note 3 to entry: Time-averaged sound intensity is a vector quantity. Spatial components of the time-averaged sound intensity may be indicated by assigning subscripts to the symbol. For example, in Cartesian coordinates, $\boldsymbol{I}_{\mathrm{av}} = (I_{\mathrm{av},x}, I_{\mathrm{av},y}, I_{\mathrm{av},z})$. 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.

Note 4 to entry: This definition is in accordance with ISO 80000-8:2007, 8.

[SOURCE: ISO/TR 25417:2007, 2.13, modified]

3.1.3.12
equivalent plane wave sound intensity
I_{eq}

mean-square sound pressure (3.1.3.1), $\overline{p^2}$, divided by the product of the density, ρ, and sound speed, c, of the undisturbed fluid

Note 1 to entry: In formula form, $I_{\mathrm{eq}} = \overline{p^2} / \rho c$.

Note 2 to entry: Equivalent plane wave sound intensity is expressed in units of watt per metre squared ($\mathrm{W/m^2}$).

Note 3 to entry: The averaging time and frequency band shall be specified.

Note 4 to entry: The equivalent plane wave sound intensity is a scalar quantity, equal to the component of *time-averaged sound intensity* (3.1.3.11) in the direction of propagation of a plane progressive sound wave having the specified mean-square sound pressure.

3.1.3.13
mean-square sound pressure spectral density
$\left(\overline{p^2}\right)_f$

distribution as a function of non-negative frequency of the *mean-square sound pressure* (3.1.3.1) per unit bandwidth of a sound having a continuous spectrum

Note 1 to entry: Mean-square sound pressure spectral density is expressed in units of pascal squared per hertz ($\mathrm{Pa^2/Hz}$).

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

Note 3 to entry: For operational purposes, mean-square sound pressure spectral density is estimated as the mean-square sound pressure in a finite frequency band divided by the frequency bandwidth. The averaging time and frequency band shall be specified.

Note 4 to entry: According to the continuous form of Parseval's theorem (also known as Plancherel's theorem), the *sound pressure spectrum* (3.1.2.2), $P(f)$, is related to the sound pressure, $p(t)$, via the formula $\int_{-\infty}^{+\infty} \left|P\left(f\right)\right|^2 \mathrm{d}f = \int_{-\infty}^{+\infty} p^2\left(t\right) \mathrm{d}t$. Here, $|P(f)|^2$ is a function of both positive and negative frequencies and is known as a "double-sided" spectral density. By contrast, $\left(\overline{p^2}\right)_f$ is known as a "single-sided" spectral density because it is a function of non-negative frequencies only and satisfies the formula $\int_0^{+\infty} \left(\overline{p^2}\right)_f \mathrm{d}f = \overline{p^2}$.

Note 5 to entry: As a consequence of the Wiener-Khinchin theorem, the mean-square sound pressure spectral density of a sound pressure signal is also equal to twice the Fourier transform (see ISO 80000-2) of the autocorrelation function of that signal.

Note 6 to entry: Mean-square sound pressure spectral density is one of several related quantities known generically as "power spectral density". The generic term is used with a descriptor (in this case, mean-square sound pressure) to indicate the type of power-like quantity whose spectral density is being described.

3.1.3.14
sound power
W
integral over a specified surface of the product of the *sound pressure* (3.1.2.1), *p*, and the component of the *sound particle velocity* (3.1.2.10) in the direction normal to that surface, u_n

Note 1 to entry: Sound power is a function of time, *t*, which may be indicated by means of an argument *t*, as in *W*(*t*).

Note 2 to entry: Sound power is expressed in watts (W).

Note 3 to entry: This definition could become inapplicable in situations with a high mean fluid flow.

[SOURCE: ISO 80000-8:2007, 8-16, modified]

3.1.3.15
time-averaged sound power
W_{av}
integral over a specified time interval of *sound power* (3.1.3.14), *W*, divided by the duration of the time interval, for a specified frequency range

Note 1 to entry: If the surface completely encloses a sound source, and in the absence of absorption, the time-averaged sound power is equal to the average rate per unit time at which sound energy is radiated from the source.

3.1.4 Logarithmic frequency intervals

3.1.4.1
one-third octave
one-third octave (base 2)
one third of an octave

Note 1 to entry: The frequency ratio corresponding to a one-third octave is $2^{1/3}$, or approximately 1,259 9.

Note 2 to entry: One-third octave (base 2) bands are defined in ISO 13261-1.

Note 3 to entry: From the definition 1 oct ≡ $\log_2(2) = 1$ (see ISO 80000-8:2007, 8-3.a), it follows that one one-third octave (base 2) (1/3 oct) is equal to 1/3, or approximately 0,333 33.

[SOURCE: DIN 13320]

3.1.4.2
one-third octave (base 10)
decidecade
ddec
one tenth of a decade

Note 1 to entry: The frequency ratio corresponding to a decidecade (1 ddec) is $10^{0,1}$, or approximately 1,258 9, which is smaller than a one-third octave (base 2) by approximately 0,08 %.

Note 2 to entry: The use of "one-third octave" to mean 1 ddec is permitted by IEC 61260-1 and ANSI/ASA S1.6-2016.

Note 3 to entry: From the definition 1 dec ≡ $\log_2(10)$ (see ISO 80000-8:2007, 8-3 b), it follows that one decidecade (0,1 dec) is equal to 0,1 $\log_2(10)$, or approximately 0,332 19.

Note 4 to entry: The symbol for one-third octave (base 10) is ddec. This symbol is not intended to be used as an abbreviation.

3.1.5 Other acoustical quantities

3.1.5.1
force impulse
$\boldsymbol{J_F}$
integral of a transient force, over a specified time interval or event, for a specified frequency range

Note 1 to entry: In formula form, $\boldsymbol{J_F} = \int_{-\infty}^{+\infty} \boldsymbol{F}(t)\mathrm{d}t$ or $\boldsymbol{J_F} = \int_{t_1}^{t_2} \boldsymbol{F}(t)\mathrm{d}t$, where $\boldsymbol{F}(t)$ is the force, and the integral is taken either over the entire time-history, or between specified limits (as in the second integral above).

Note 2 to entry: Force impulse is expressed in units of newton second (N s).

Note 3 to entry: Force impulse is a vector quantity. Spatial components of the force impulse may be indicated by assigning subscripts to the symbol. For example, in Cartesian coordinates, $\boldsymbol{J_F} = (J_{F,x}, J_{F,y}, J_{F,z})$. 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.

Note 4 to entry: The force impulse vector represents the total momentum transferred by the force during that time.

[SOURCE: Reference [35]]

3.1.5.2
pressure impulse
J_p
integral of a transient *sound pressure* (3.1.2.1), $p(t)$, over a specified time interval or event, for a specified frequency range

Note 1 to entry: In formula form, $J_p = \int_{-\infty}^{+\infty} p(t)\mathrm{d}t$ or $J_p = \int_{t_1}^{t_2} p(t)\mathrm{d}t$, where the integral is taken either over the entire time-history, or between specified limits (as in the second integral above).

Note 2 to entry: Pressure impulse is expressed in units of pascal second (Pa s).

Note 3 to entry: If the sound pressure is non-negative over the entire interval of integration, the pressure impulse is referred to as “positive-pressure impulse”.

Note 4 to entry: If the sound pressure is non-positive over the entire interval of integration, the magnitude of the pressure impulse is referred to as “negative-pressure impulse”.

Note 5 to entry: Pressure impulse is a scalar quantity.

Note 6 to entry: See also *force impulse* (3.1.5.1).

3.1.5.3
sound pressure variance
μ_2
variance of the *sound pressure* (3.1.2.1), $p(t)$, over a specified time interval, t_1 to t_2, for a specified frequency range

Note 1 to entry: In formula form, $\mu_2 = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} \left[p(t) - \bar{p}\right]^2 \mathrm{d}t$, where $\bar{p}$ is the mean sound pressure in the same time interval.

Note 2 to entry: Sound pressure variance is expressed in units of pascal squared (Pa^2).

Note 3 to entry: If the mean sound pressure is zero, the sound pressure variance is equal to the mean-square sound pressure.

3.1.5.4
sound pressure skewness

γ_1

skewness of the *sound pressure* (3.1.2.1), $p(t)$, over a specified time interval, t_1 to t_2, for a specified frequency range

Note 1 to entry: In formula form, $\gamma_1 = \frac{\mu_3}{\mu_2{}^{3/2}}$, where $\mu_3 = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \left[p(t) - \bar{p} \right]^3 \mathrm{d}t$ and μ_2 and $\bar{p}$ are the *sound pressure variance* (3.1.5.3) and mean sound pressure, respectively, in the same time interval.

3.1.5.5
sound pressure kurtosis

β

kurtosis of the *sound pressure*, $p(t)$, over a specified time interval, t_1 to t_2, for a specified frequency range

Note 1 to entry: In formula form, $\beta = \frac{\mu_4}{\mu_2{}^2}$, where $\mu_4 = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \left[p(t) - \bar{p} \right]^4 \mathrm{d}t$ and μ_2 and $\bar{p}$ are the *sound pressure variance* (3.1.5.3) and mean sound pressure, respectively, in the same time interval.

Note 2 to entry: See Reference [28].

3.1.5.6
characteristic acoustic impedance
characteristic specific acoustic impedance

Z_c

sound pressure (3.1.2.1) divided by the component of the *sound particle velocity* (3.1.2.10) in the direction of the wave propagation, at a point in a non-dissipative medium and for a plane progressive wave

Note 1 to entry: In a fluid of density, ρ, and speed of sound, c, the characteristic acoustic impedance is equal to the product, ρc.

Note 2 to entry: Characteristic acoustic impedance is expressed in units of pascal second per metre (Pa s/m).

[SOURCE: ISO 80000-8:2007, 8-19, modified]

3.1.5.7
specific acoustic impedance

z

Fourier transform of *sound pressure* (3.1.2.1), $P(f)$, divided by the Fourier transform of *sound particle velocity* (3.1.2.10) in a given direction, $U(f)$

Note 1 to entry: In formula form, $z(f) = P(f)/U(f) = P(f)\, U^*(f)/[U(f)\, U^*(f)]$.

Note 2 to entry: Specific acoustic impedance is expressed in units of pascal second per metre (Pa s/m).

Note 3 to entry: See IEC 60050 (IEV 801–25–13) and ISO 80000-2:2009, 2-18.1, Fourier transform.

Note 4 to entry: Specific acoustic impedance can also be defined as the complex sound pressure, $\tilde{p}(t)$, defined as the analytic representation of the sound pressure, divided by the complex sound particle velocity in a given direction, $\tilde{u}(t)$, defined as the analytic representation of the sound particle velocity. In formula form, $z = \tilde{p}(t) / \tilde{u}(t)$. For a harmonic wave of amplitude, F_0, angular frequency, ω, and wavenumber, k, i.e. $F(t) = F_0 \cos(kx - \omega t + f)$, where ϕ is a constant phase, the analytic representation of $F(t)$ is $\tilde{F}(t) = F_0 \exp(\mathrm{i}kx - \mathrm{i}\omega t + \mathrm{i}\phi)$.

Note 5 to entry: Specific acoustic impedance is a complex quantity whose magnitude equals the sound pressure amplitude divided by the amplitude of a given sound particle velocity component, and whose phase equals the sound pressure phase minus the phase of the given sound particle velocity component.

3.1.5.8
signal
specified time-varying electric current, voltage, *sound pressure* (3.1.2.1), *sound particle displacement* (3.1.2.9), or other field quantity of interest

3.1.5.9
noise
time-varying electric current, voltage, *sound pressure* (3.1.2.1), *sound particle displacement* (3.1.2.9), or other field quantity except the *signal* (3.1.5.8) or signals

3.1.5.10
acoustic self-noise
sound (3.1.1.1) at a receiver caused by the deployment, operation, or recovery of a specified receiver, and its associated platform

3.1.5.11
ambient noise
sound (3.1.1.1) except *acoustic self-noise* (3.1.5.10) and except sound associated with a specified *signal* (3.1.5.8)

Note 1 to entry: In the absence of a specified signal, ambient noise is all sound except acoustic self-noise.

Note 2 to entry: An example of a specified signal might be the echo from a sonar target.

3.2 Levels used in underwater acoustics

3.2.1 Levels of acoustical power quantities

3.2.1.1
mean-square sound pressure level
root-mean-square sound pressure level
sound pressure level
SPL
$L_{p,\mathrm{rms}}$
L_p
DEPRECATED: mean-square SPL
ten times the logarithm to the base 10 of the ratio of the *mean-square sound pressure* (3.1.3.1) to the specified reference value, p_0^2, in decibels

Note 1 to entry: Mean-square sound pressure level is the level of the power quantity equal to the mean-square sound pressure, denoted $\overline{p^2}$. In formula form, $L_p = 10 \log_{10}(\overline{p^2}/p_0^2)$ dB.

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

Note 3 to entry: In underwater acoustics, the reference value of mean-square sound pressure, p_0^2, is 1 μPa^2. The reference value shall be specified.

Note 4 to entry: The averaging time and frequency range shall be specified.

Note 5 to entry: Mean-square sound pressure level can be written as the level of the field quantity root-mean-square sound pressure, i.e. $L_p = 20 \log_{10}(\sqrt{\overline{p^2}}/p_0)$ dB. The reference value of sound pressure is p_0 = 1 μPa.

Note 6 to entry: The abbreviation “mean-square SPL” is deprecated because in normal use of English this would mean “mean-square value of SPL”, the meaning of which differs from the intended one, “level of the mean-square sound pressure”.

Note 7 to entry: Weighted sound pressure level is defined in 3.7.

3.2.1.2
mean-square sound particle displacement level
root-mean-square sound particle displacement level
sound particle displacement level
SDL
$L_{\delta,\text{rms}}$
L_δ
ten times the logarithm to the base 10 of the ratio of the *mean-square sound particle displacement* (3.1.3.2) to the specified reference value, δ_0^2, in decibels

Note 1 to entry: Mean-square sound particle displacement level is the level of the power quantity equal to the mean-square magnitude of the sound particle displacement, denoted $\overline{\delta^2}$. In formula form, $L_\delta = 10 \log_{10}(\overline{\delta^2}/\delta_0^2)$ dB.

Note 2 to entry: Mean-square sound particle displacement level is expressed in decibels (dB).

Note 3 to entry: The reference value of mean-square sound particle displacement, δ_0^2, is 1 pm^2. The reference value shall be specified.

Note 4 to entry: The averaging time and frequency range shall be specified.

3.2.1.3
mean-square sound particle velocity level
root-mean-square sound particle velocity level
sound particle velocity level
SVL
$L_{u,\text{rms}}$
L_u
ten times the logarithm to the base 10 of the ratio of the *mean-square sound particle velocity* (3.1.3.3) to the specified reference value, u_0^2, in decibels

Note 1 to entry: Mean-square sound particle velocity level is the level of the power quantity equal to the mean-square magnitude of the sound particle velocity, denoted $\overline{u^2}$. In formula form, $L_u = 10 \log_{10}(\overline{u^2}/u_0^2)$ dB.

Note 2 to entry: Mean-square sound particle velocity level is expressed in decibels (dB).

Note 3 to entry: The reference value of mean-square sound particle velocity, u_0^2, is 1 (nm/s)^2. The reference value shall be specified.

Note 4 to entry: The averaging time and frequency range shall be specified.

[SOURCE: ANSI/ASA S1.1-2013, 3.23, modified]

3.2.1.4
mean-square sound particle acceleration level
root-mean-square sound particle acceleration level
sound particle acceleration level
SAL
L_a
ten times the logarithm to the base 10 of the ratio of the *mean-square sound particle acceleration* (3.1.3.4) to the specified reference value, a_0^2, in decibels

Note 1 to entry: Mean-square sound particle acceleration level is the level of the power quantity equal to the mean-square magnitude of the sound particle acceleration, denoted $\overline{a^2}$. In formula form, $L_a = 10 \log_{10}(\overline{a^2}/a_0^2)$ dB.

Note 2 to entry: Mean-square sound particle acceleration level is expressed in decibels (dB).

Note 3 to entry: The reference value of mean-square sound particle acceleration, a_0^2, is 1 μm^2/s^4. The reference value shall be specified.

Note 4 to entry: The averaging time and frequency range shall be specified.

3.2.1.5
time-integrated squared sound pressure level
sound exposure level
sound pressure exposure level
SEL
$L_{E,p}$
<underwater acoustics> ten times the logarithm to the base 10 of the ratio of the *time-integrated squared sound pressure* (3.1.3.5), E_p, to the specified reference value, $E_{p,0}$, in decibels

Note 1 to entry: Time-integrated squared sound pressure level is the level of the power quantity time-integrated squared sound pressure, denoted E_p. In formula form, $L_{E,p} = 10 \log_{10}(E_p/E_{p,0})$ dB.

Note 2 to entry: Time-integrated squared sound pressure level is expressed in decibels (dB).

Note 3 to entry: In underwater acoustics, the reference value of time-integrated squared sound pressure, $E_{p,0}$, is 1 μPa^2 s. The reference value shall be specified.

Note 4 to entry: The time duration and frequency range shall be specified.

Note 5 to entry: This definition is in accordance with ISO 80000-8:2007, 8.

Note 6 to entry: In air acoustics, the sound exposure level may be a weighted quantity (see ISO/TR 25417).

3.2.1.6
time-integrated squared sound particle displacement level
$L_{E,\delta}$
ten times the logarithm to the base 10 of the ratio of the *time-integrated squared sound particle displacement* (3.1.3.6), E_δ to the specified reference value, $E_{\delta,0}$, in decibels

Note 1 to entry: Time-integrated squared sound particle displacement level is the level of the power quantity time-integrated squared sound particle displacement, denoted E_δ. In formula form, $L_{E,\delta} = 10 \log_{10}(E_\delta/E_{\delta,0})$ dB.

Note 2 to entry: Time-integrated squared sound particle displacement level is expressed in decibels (dB).

Note 3 to entry: The reference value of time-integrated squared sound particle displacement, $E_{\delta,0}$, is 1 pm^2 s. The reference value shall be specified.

Note 4 to entry: The time duration and frequency range shall be specified.

3.2.1.7
time-integrated squared sound particle velocity level
$L_{E,u}$
ten times the logarithm to the base 10 of the ratio of the *time-integrated squared sound particle velocity* (3.1.3.7), E_u, to the specified reference value, $E_{u,0}$, in decibels

Note 1 to entry: Time-integrated squared sound particle velocity level is the level of the power quantity time-integrated squared sound particle velocity, denoted E_u. In formula form, $L_{E,u} = 10 \log_{10}(E_u / E_{u,0})$ dB.

Note 2 to entry: Time-integrated squared sound particle velocity level is expressed in decibels (dB).

Note 3 to entry: The reference value of time-integrated squared sound particle velocity, $E_{u,0}$, is 1 (nm/s)^2 s. The reference value shall be specified.

Note 4 to entry: The time duration and frequency range shall be specified.

3.2.1.8
time-integrated squared sound particle acceleration level
$L_{E,a}$
ten times the logarithm to the base 10 of the ratio of the *time-integrated squared sound particle acceleration* (3.1.3.8), E_a, to the specified reference value, $E_{a,0}$, in decibels

Note 1 to entry: Time-integrated squared sound particle acceleration level is the level of the power quantity time-integrated squared sound particle acceleration, denoted E_a. In formula form, $L_{E,a} = 10 \log_{10}(E_a / E_{a,0})$ dB.

Note 2 to entry: Time-integrated squared sound particle acceleration level is expressed in decibels (dB).

Note 3 to entry: The reference value of time-integrated squared sound particle acceleration, $E_{a,0}$, is 1 $(\mu m/s^2)^2$ s. The reference value shall be specified.

Note 4 to entry: The time duration and frequency range shall be specified.

3.2.1.9
sound exposure spectral density level
$L_{E,f}$
ten times the logarithm to the base 10 of the ratio of the *sound exposure spectral density* (3.1.3.9), E_f, to the specified reference value, $E_{f,0}$, in decibels

Note 1 to entry: Sound exposure spectral density level is the level of the power quantity sound exposure spectral density, denoted E_f. In formula form, $L_{E,f} = 10 \log_{10}(E_f / E_{f,0})$ dB.

Note 2 to entry: Sound exposure spectral density level is expressed in decibels (dB).

Note 3 to entry: In underwater acoustics, the reference value of sound exposure spectral density, $E_{f,0}$, is 1 μPa^2 s/Hz. The reference value shall be specified.

Note 4 to entry: If the operational form of the definition of sound exposure spectral density is used, the time duration and frequency range shall be specified.

3.2.1.10
mean-square sound pressure spectral density level
$L_{p,f}$
ten times the logarithm to the base 10 of the ratio of the *mean-square sound pressure spectral density* (3.1.3.13), $\left(\overline{p^2}\right)_f$, to the specified reference value, $\left(\overline{p^2}\right)_{f,0}$, in decibels

Note 1 to entry: Mean-square sound pressure spectral density level is the level of the power quantity mean-square sound pressure spectral density, denoted $\left(\overline{p^2}\right)_f$. In formula form, $L_{p,f} = 10\log_{10}\left[\left(\overline{p^2}\right)_f / \left(\overline{p^2}\right)_{f,0}\right]$ dB.

Note 2 to entry: Mean-square sound pressure spectral density level is expressed in decibels (dB).

Note 3 to entry: In underwater acoustics, the reference value of mean-square sound pressure spectral density, $\left(\overline{p^2}\right)_{f,0}$, is 1 μPa^2/Hz. The reference value shall be specified.

Note 4 to entry: If the operational form of the definition of mean-square sound pressure spectral density is used, the averaging time and frequency range shall be specified.

3.2.2 Levels of acoustical field quantities

3.2.2.1
zero-to-peak sound pressure level
peak sound pressure level
$L_{p,0\text{-pk}}$
$L_{p,\text{pk}}$
DEPRECATED: peak SPL
twenty times the logarithm to the base 10 of the ratio of the *zero-to-peak sound pressure* (3.1.2.3), p_{pk}, to the specified reference value, p_0, in decibels

Note 1 to entry: Zero-to-peak sound pressure level is the level of the field quantity zero-to-peak sound pressure, denoted p_{pk}. In formula form, $L_{p,\text{pk}} = 20 \log_{10}(p_{\text{pk}}/p_0)$ dB.

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

Note 3 to entry: In underwater acoustics, the reference value of zero-to-peak sound pressure, p_0, is 1 μPa. The reference value shall be specified.

Note 4 to entry: The time interval and frequency range shall be specified.

Note 5 to entry: The abbreviation "peak SPL" is deprecated because in normal use of English, this would mean "peak value of SPL", the meaning of which differs from the intended one, "level of the peak sound pressure".

[SOURCE: ISO/TR 25417:2007, 2.5, modified]

3.2.2.2
peak compressional sound pressure level
$L_{p,\text{pk,c}}$
twenty times the logarithm to the base 10 of the ratio of the *peak compressional sound pressure*, $p_{\text{pk,c}}$, to the specified reference value, p_0, in decibels

Note 1 to entry: Peak compressional sound pressure level is the level of the field quantity *peak compressional sound pressure*, denoted $p_{\text{pk,c}}$. In formula form, $L_{p,\text{pk,c}} = 20 \log_{10}(p_{\text{pk,c}}/p_0)$ dB.

Note 2 to entry: Peak compressional sound pressure level is expressed in decibels (dB).

Note 3 to entry: In underwater acoustics, the reference value of peak compressional sound pressure, p_0, is 1 µPa. The reference value shall be specified.

Note 4 to entry: The time interval and frequency range shall be specified.

3.2.2.3
peak rarefactional sound pressure level
$L_{p,\text{pk,r}}$
twenty times the logarithm to the base 10 of the ratio of the *peak rarefactional sound pressure*, $p_{\text{pk,r}}$, to the specified reference value, p_0, in decibels

Note 1 to entry: Peak rarefactional sound pressure level is the level of the field quantity peak rarefactional sound pressure, denoted $p_{\text{pk,r}}$. In formula form, $L_{p,\text{pk,r}} = 20 \log_{10}(p_{\text{pk,r}}/p_0)$ dB.

Note 2 to entry: Peak rarefactional sound pressure level is expressed in decibels (dB).

Note 3 to entry: In underwater acoustics, the reference value of peak rarefactional sound pressure, p_0, is 1 µPa. The reference value shall be specified.

Note 4 to entry: The time interval and frequency range shall be specified.

3.3 Terms for properties of underwater sound sources

3.3.1 Source waveforms and factors

3.3.1.1
acoustic far field
spatial region in a uniform medium where the direct-path field amplitude, compensated for absorption loss, varies inversely with range

Note 1 to entry: In the acoustic far field, sound pressure and sound particle velocity are substantially in phase.

Note 2 to entry: Common engineering practice is to identify the distance from the source that is equal to or exceeds π times the square of the largest dimension of the source divided by the acoustic wavelength as the far field region.

Note 3 to entry: The ranges are all taken along a given direct path between the source and the receiver.

Note 4 to entry: The inverse dependence on range does not imply that the source radiates equally in all directions.

Note 5 to entry: See Reference [30].

3.3.1.2
far-field sound pressure
sound pressure (3.1.2.1) in the *acoustic far field* (3.3.1.1) of a sound source

3.3.1.3
acoustic centre
point from which outgoing wavefronts appear to diverge in the *acoustic far field* (3.3.1.1), under free-field conditions

Note 1 to entry: The position of the acoustic centre generally depends on frequency.

Note 2 to entry: Directional sources have a different acoustic centre, in general, for each spherical harmonic component of the radiation field (monopole, dipole, etc.). An alternative definition involves assigning each radiation direction two acoustic centres, one for amplitude and one for phase.

[SOURCE: Reference [35]]

3.3.1.4
source waveform
s
product of distance in a specified direction, r, from the *acoustic centre* (3.3.1.3) of a sound source and the delayed *far-field sound pressure* (3.3.1.2), $p(t - t_0 + r/c)$, 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

Note 1 to entry: Source waveform is a function of time, which may be indicated by means of an argument t, as in $s(t)$, where s is source waveform and t is time.

Note 2 to entry: In formula form, $s(t - t_0) = r\, p(t - t_0 + r/c)$. Substitution of $t_0 = r/c$ in this formula and rearranging for p results in the more familiar expression $p(t) = s(t - r/c)/r$.

Note 3 to entry: Source waveform is expressed in units of pascal metre (Pa m).

Note 4 to entry: Evaluating the far-field sound pressure at the delayed time, $t - t_0 + r/c$, ensures that the source waveform is independent of the precise distance, r, in the acoustic far-field.

Note 5 to entry: The hypothetical medium is unbounded in all directions.

Note 6 to entry: For a directional sound source such as a sonar projector, the direction is that of the principal axis unless stated otherwise.

Note 7 to entry: The numerical value of the source waveform, when expressed in units of pascal metre, is equal to the sound pressure that would exist at a distance of 1 m from a hypothetical point monopole source, when expressed in pascals, if placed in the same hypothetical infinite uniform lossless medium for which the source waveform is defined, and if the source waveform of the hypothetical point source is equal to that of the true source waveform in the specified direction. For this reason, it is common to use this hypothetical sound pressure as an alternative metric to the source waveform. This alternative metric is typically cited in units of “micropascal at one metre”, often abbreviated “µPa @ 1 m”. As a pressure, the correct unit for this alternative metric is the pascal (Pa) or micropascal (µPa). The properties of the hypothetical point monopole source depend on the specified direction.

3.3.1.5
sound exposure source factor
energy source factor
$F_{S,E}$
product of the square of the distance from the *acoustic centre* (3.3.1.3) of a source, in a specified direction, r^2, and *time-integrated squared sound pressure* (3.1.3.5) in the *acoustic far field* (3.3.1.1) at that distance, $E_p(r)$, 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

Note 1 to entry: In formula form, $F_{S,E} = r^2\, E_p(r)$.

Note 2 to entry: Energy source factor is expressed in units of pascal squared metre squared second (Pa^2 m^2 s).

Note 3 to entry: The frequency range shall be specified.

Note 4 to entry: The value of the energy source factor is independent of the distance, *r*.

Note 5 to entry: Energy source factor is a property of a transient sound source.

Note 6 to entry: The integration time for the exposure is the entire duration of the received pulse.

Note 7 to entry: The use of "energy" in the name of this term implies a quantity proportional to the time-integrated squared sound pressure.

Note 8 to entry: The hypothetical medium is unbounded in all directions.

Note 9 to entry: For a directional sound source such as a sonar projector, the direction is that of the principal axis unless stated otherwise.

Note 10 to entry: The distance can be specified from points in the source other than the acoustic centre without changing the value of the energy source factor.

Note 11 to entry: The numerical value of the energy source factor, when expressed in units of pascal squared metre squared second, is equal to the time-integrated squared sound pressure that would exist at a distance of 1 m from a hypothetical point monopole source, when expressed in units of pascal squared, if placed in the same hypothetical infinite uniform lossless medium for which the energy source factor is defined, and if the energy source factor of the hypothetical point source is equal to that of the true energy source factor in the specified direction. For this reason, it is common to use this hypothetical time-integrated squared sound pressure as an alternative metric to the energy source factor. This alternative metric is typically cited in units of "micropascal squared second at one metre", often abbreviated "μPa^2 s @ 1 m". As a time-integrated squared pressure, the correct unit for this alternative metric is the pascal squared second (Pa^2 s) or micropascal squared second (μPa^2 s). The properties of the hypothetical point monopole source depend on the specified direction.

Note 12 to entry: The real medium around the source is assumed to be locally uniform in the sense that the *characteristic acoustic impedance* (3.1.5.6) of this medium is independent of position around the source.

3.3.1.6
source factor
F_S
product of the square of the distance from the *acoustic centre* (3.3.1.3) of a source, in a specified direction, r^2, and *mean-square sound pressure* (3.1.3.1) in the *acoustic far field* (3.3.1.1) 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

Note 1 to entry: In formula form, $F_S = r^2\ \overline{p^2}\ (r)$.

Note 2 to entry: Source factor is expressed in units of pascal squared metre squared (Pa^2 m^2).

Note 3 to entry: The time interval and frequency range shall be specified.

Note 4 to entry: The value of the source factor is independent of the distance, *r*.

Note 5 to entry: Source factor is a property of a statistically stationary sound source.

Note 6 to entry: The hypothetical medium is unbounded in all directions.

Note 7 to entry: The distance can be specified from points in the source other than the acoustic centre without changing the value of the source factor.

Note 8 to entry: For a directional sound source such as a sonar projector, the direction is that of the principal axis unless stated otherwise.

Note 9 to entry: The numerical value of the square root of the source factor, when expressed in units of pascal metre, is equal to the root-mean-square sound pressure that would exist at a distance of 1 m from a hypothetical point monopole source, when expressed in pascals, if placed in the same hypothetical infinite uniform lossless medium for which the source factor is defined, and if the source factor of the hypothetical point source is equal to that of the true source factor in the specified direction. For this reason, it is common to use this hypothetical root-mean-square sound pressure as an alternative metric to the source factor. This alternative metric is typically cited in units of "micropascal at one metre", often abbreviated "μPa @ 1 m". As a pressure, the correct unit for this alternative metric is the pascal (Pa) or micropascal (μPa). The properties of the hypothetical point monopole source depend on the specified direction.

Note 10 to entry: The real medium around the source is assumed to be locally uniform in the sense that the *characteristic acoustic impedance* (3.1.5.6) of this medium is independent of position around the source.

3.3.1.7
surface-affected source waveform
far-field signature
s'
product of distance in a specified direction, r, from the *acoustic centre* (3.3.1.3) of a sound source and its sea surface-reflected image and the delayed *far-field sound pressure* (3.3.1.2), $p(t - t_0 + r/c)$, 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

Note 1 to entry: Surface-affected source waveform is a function of time, which may be indicated by means of an argument t, as in $s'(t)$, where s' is surface-affected source waveform and t is time.

Note 2 to entry: In formula form, $s'(t - t_0) = r\,p(t - t_0 + r/c)$. Substitution of $t_0 = r/c$ in this formula and rearranging for p results in the more familiar expression $p(t) = s'(t - r/c)/r$.

Note 3 to entry: Surface-affected source waveform is expressed in units of pascal metre (Pa m).

Note 4 to entry: Evaluating the far-field sound pressure at the delayed time, $t - t_0 + r/c$, ensures that the surface-affected source waveform is independent of the precise distance, r, in the *acoustic far field* (3.3.1.1).

Note 5 to entry: The acoustic centre is a point on or close to the sea surface.

Note 6 to entry: The surface-affected source waveform is a function of elevation angle. It can also be a function of azimuth angle.

Note 7 to entry: The presence of the sea surface means that the acoustic far field is the sum of two contributions: a direct path and a surface-reflected path. The contribution from the surface-reflected path, sometimes referred to as a "ghost" is usually assumed to undergo a π phase shift at the sea surface.

Note 8 to entry: The presence of the sea surface can influence the behaviour of the source.

Note 9 to entry: The concept of surface-affected source waveform is valid for low frequency sound, such that perfect specular reflection occurs at the sea surface reflection. A typical criterion might be for the product of acoustic wave number and root-mean-square surface wave height to be much less than unity.

Note 10 to entry: The origins of time and range should be clearly stated.

Note 11 to entry: The synonym "far-field signature" is most commonly used to characterize sound sources used for reflection seismology.

3.3.1.8
source spectrum
S
Fourier transform of the *source waveform* (3.3.1.4)

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

Note 2 to entry: In formula form, $S(f) = \int_{-\infty}^{+\infty} \exp(-2\pi \mathrm{i} f t)\; s(t)\,\mathrm{d}t$. If $S(f)$ is known, $s(t)$ can be calculated using the inverse Fourier transform $s(t) = \int_{-\infty}^{+\infty} \exp(+2\pi \mathrm{i} f t)\; S(f)\,\mathrm{d}f$. See ISO 80000-2.

Note 3 to entry: The source spectrum is expressed in units of pascal metre per hertz (Pa m/Hz).

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

Note 5 to entry: The numerical value of the source spectrum, when expressed in units of pascal metre per hertz, is equal to the *sound pressure spectrum* (3.1.2.2) that would exist at a distance of 1 m from a hypothetical point monopole source, when expressed in pascals, if placed in the same hypothetical infinite uniform lossless medium for which the source spectrum is defined, and if the source spectrum of the hypothetical point source is equal to that of the true source spectrum in the specified direction. For this reason, it is common to use this hypothetical sound pressure spectrum as an alternative metric to the source spectrum. This alternative metric is typically cited in units of "micropascal per hertz at one metre", often abbreviated "μPa/Hz @ 1 m". As a pressure spectrum, the correct unit for this alternative metric is the pascal per hertz (Pa/Hz) or micropascal per hertz (μPa/Hz). The properties of the hypothetical point monopole source depend on the specified direction.

Note 6 to entry: Source spectrum is used in reflection seismology.

3.3.1.9
surface-affected source spectrum
S′
Fourier transform of the *surface-affected source waveform* (3.3.1.7)

Note 1 to entry: Surface-affected source spectrum is a function of frequency, which may be indicated by means of an argument *f*, as in $S'(f)$, where S' is surface-affected source spectrum and *f* is frequency.

Note 2 to entry: In formula form, $S'(f) = \int_{-\infty}^{+\infty} \exp(-2\pi \mathrm{i} f t)\; s'(t)\,\mathrm{d}t$. If $S'(f)$ is known, $s'(t)$ can be calculated using the inverse Fourier transform $s'(t) = \int_{-\infty}^{+\infty} \exp(+2\pi \mathrm{i} f t)\; S'(f)\,\mathrm{d}f$. See ISO 80000-2.

Note 3 to entry: The surface-affected source spectrum is expressed in units of pascal metre per hertz (Pa m/Hz).

Note 4 to entry: The surface-affected source spectrum depends on elevation angle. It can also depend on azimuth angle.

Note 5 to entry: The concept of surface-affected source spectrum is valid for low frequency sound, such that perfect specular reflection occurs at the sea surface reflection. A typical criterion might be for the product of acoustic wave number and root-mean-square surface wave height to be much less than unity.

Note 6 to entry: In general, $S'(f)$ is a complex function of frequency.

3.3.2 Source levels

3.3.2.1
source level
SL
L_S
ten times the logarithm to the base 10 of the ratio of the *source factor* (3.3.1.6), F_S, to the specified reference value, $F_{S,0}$, in decibels

Note 1 to entry: Source level is the level of the power quantity source factor, denoted F_S. In formula form, $L_S = 10\log_{10}(F_S/F_{S,0})$ dB, where $F_{S,0} = 1\ \mu\text{Pa}^2\ \text{m}^2$.

Note 2 to entry: Source level is expressed in decibels (dB).

Note 3 to entry: The source level in a specified direction is equal to the *mean-square sound pressure level* (3.2.1.1) at a distance of 1 m from a hypothetical point source, placed in the (hypothetical) infinite uniform lossless medium used to define the source factor, and with the same source factor for the specified direction as the true source. This equality has led to the widespread practice of citing source level with a reference value of "1 µPa @ 1 m". According to this document, the reference value for source level is $F_{S,0}$ = 1 µPa^2 m^2. The reference value shall be specified.

Note 4 to entry: The time interval and frequency range shall be specified.

Note 5 to entry: Source level can be written as the level of the field quantity root source factor, i.e.

$L_S = 20 \log_{10}(\sqrt{F_S} \,/\, \sqrt{F_{S,0}}\,)$ dB. The reference value of root source factor is 1 µPa m.

Note 6 to entry: Source level is a property of a statistically stationary sound source.

Note 7 to entry: For a directional sound source such as a sonar projector, the direction is that of the principal axis unless stated otherwise.

Note 8 to entry: The source level can be determined by adding *propagation loss* (3.4.1.4) to the measured mean-square sound pressure level.

Note 9 to entry: Source level is a property of an underwater sound source that is determined by the motion of its moving surfaces. If sound is scattered from an otherwise passive underwater object, the "motion" referred to in the definition of source factor refers to the motion relative to that of the incident field, i.e. relative to the sound particle motion that would have existed in the absence of the scattering object. In the context of the *active sonar equation* (3.6.2.11), the definition of "source level" applies to objects that scatter sound in this way. For a plane wave incident on the object from direction θ_i, whose mean-square sound pressure level is L_p, the source level in the direction θ_s is given by $L_S(\theta_s) = L_p(\theta_i) + N_{TS}(\theta_i, \theta_s)$, where N_{TS} is the *target strength* (3.6.2.8) of the object.

3.3.2.2
sound exposure source level
energy source level
ESL
$L_{S,E}$
ten times the logarithm to the base 10 of the ratio of the *sound exposure source factor* (3.3.1.5), $F_{S,E}$ to the specified reference value, $F_{S,E,0}$, in decibels

Note 1 to entry: Sound exposure source level is the level of the power quantity sound exposure source factor, denoted, $F_{S,E}$. In formula form, $L_{S,E} = 10 \log_{10}(F_{S,E}/F_{S,E,0})$ dB, where $F_{S,E,0}$ = 1 µPa^2 m^2 s.

Note 2 to entry: Sound exposure source level is expressed in decibels (dB).

Note 3 to entry: The sound exposure source level in a specified direction is equal to the *time-integrated squared sound pressure level* (3.2.1.5) at a distance of 1 m from a hypothetical point source, placed in the (hypothetical) infinite uniform lossless medium used to define the sound exposure source factor, and with the same sound exposure source factor for the specified direction as the true source. This equality has led to the widespread practice of citing source level with a reference value of "1 µPa^2 s @ 1 m". According to this document, the reference value for source level is $F_{S,E,0}$ = 1 µPa^2 m^2 s. The reference value shall be specified.

Note 4 to entry: The frequency range shall be specified.

Note 5 to entry: Sound exposure source level is a property of a transient sound source.

Note 6 to entry: The integration time for the exposure is the entire duration of the received pulse.

Note 7 to entry: For a directional sound source such as a sonar projector, the direction is that of the principal axis unless stated otherwise.

Note 8 to entry: The sound exposure source level can be determined by adding *sound exposure propagation loss* (3.4.1.5) to the measured time-integrated squared sound pressure level.

Note 9 to entry: The use of "energy" in the name of this term implies the level of a quantity proportional to the *time-integrated squared sound pressure* (3.1.3.5).

3.4 Terms related to propagation and scattering of underwater sound

3.4.1 Propagation

3.4.1.1
propagation factor
F_P
mean-square sound pressure (3.1.3.1) divided by the *source factor* (3.3.1.6) in a specified direction

Note 1 to entry: Propagation factor is expressed in units of reciprocal metre squared (m^{-2}).

Note 2 to entry: Propagation factor is equal to $10^{-N_{PL}/(10\text{ dB})}$ m^{-2}, where N_{PL} is the *propagation loss* (3.4.1.4).

Note 3 to entry: The time interval and frequency range shall be specified.

Note 4 to entry: Propagation factor applies to a statistically stationary sound source.

3.4.1.2
sound exposure propagation factor
energy propagation factor
F_E
time-integrated squared sound pressure (3.1.3.5) divided by the *sound exposure source factor* (3.3.1.5) in a specified direction

Note 1 to entry: Sound exposure propagation factor is expressed in units of reciprocal metre squared (m^{-2}).

Note 2 to entry: Sound exposure propagation factor is equal to $10^{-N_{PL,E}/(10\text{ dB})}$ m^{-2}, where $N_{PL,E}$ is the *sound exposure propagation loss* (3.4.1.5).

Note 3 to entry: The frequency range shall be specified.

Note 4 to entry: The integration time for the exposure is the entire duration of the received pulse.

Note 5 to entry: Sound exposure propagation factor applies to a transient source.

Note 6 to entry: The use of "energy" in the name of this term implies a ratio of two quantities proportional to the time-integrated squared sound pressure.

3.4.1.3
transmission loss
TL
ΔL_{TL}
reduction in a specified level between two specified points $\boldsymbol{x}_1$, $\boldsymbol{x}_2$ that are within an underwater acoustic field

Note 1 to entry: In formula form, $\Delta L_{TL} = L(\boldsymbol{x}_1) - L(\boldsymbol{x}_2)$, where $L(\boldsymbol{x})$ is the specified level at position $\boldsymbol{x}$. By convention, $\boldsymbol{x}_1$ is chosen to be closer to the source of sound than $\boldsymbol{x}_2$, such that transmission loss is usually a positive quantity.

Note 2 to entry: Transmission loss is expressed in decibels (dB).

Note 3 to entry: The averaging time and frequency range shall be specified.

Note 4 to entry: Examples of levels that might be specified include *mean-square sound pressure level* (3.2.1.1) and sound intensity level.

Note 5 to entry: The characteristic concerned (such as mean-square sound pressure level) shall be clearly identified because in all transmission systems more than one characteristic is propagated.

Note 6 to entry: The term "transmission loss" is sometimes used as a synonym of *propagation loss* (3.4.1.4). This use is deprecated.

[SOURCE: ANSI/ASA S1.1-2013, 5.35, modified]

3.4.1.4
propagation loss
PL
N_{PL}
difference between *source level* (3.3.2.1) in a specified direction, L_S, and *mean-square sound pressure level* (3.2.1.1), $L_p(\boldsymbol{x})$, at a specified position, $\boldsymbol{x}$

Note 1 to entry: In formula form, $N_{PL}(\boldsymbol{x}) = L_S - L_p(\boldsymbol{x})$.

Note 2 to entry: Propagation loss is expressed in decibels (dB).

Note 3 to entry: The reference value for propagation loss is 1 m^2. The reference value shall be specified.

Note 4 to entry: The averaging time and frequency range shall be specified.

Note 5 to entry: Propagation loss applies to a statistically stationary sound source.

Note 6 to entry: Propagation loss is equal to $10\log_{10}[F_P^{-1}/(1\ \mathrm{m}^2)]$ dB, where F_P is the *propagation factor* (3.4.1.1).

Note 7 to entry: The term "propagation loss" is sometimes used as a synonym of *transmission loss* (3.4.1.3). This use is deprecated.

3.4.1.5
sound exposure propagation loss
energy propagation loss
EPL
$N_{PL,E}$
difference between *sound exposure source level* (3.3.2.2) in a specified direction, $L_{S,E}$, and *time-integrated squared sound pressure level* (3.2.1.5), $L_{E,p}(\boldsymbol{x})$, at a specified position, $\boldsymbol{x}$

Note 1 to entry: In formula form, $N_{PL,E}(\boldsymbol{x}) = L_{S,E} - L_{E,p}(\boldsymbol{x})$.

Note 2 to entry: Sound exposure propagation loss is expressed in decibels (dB).

Note 3 to entry: The reference value for energy propagation loss, $S_{E,0}/E_0$, is 1 m^2. Here $S_{E,0}$ is the reference value of *sound exposure source factor* (3.3.1.5) and E_0 is the reference value of time-integrated squared sound pressure. The reference value of energy propagation loss shall be specified.

Note 4 to entry: The frequency range shall be specified.

Note 5 to entry: The integration time for the exposure is the entire duration of the received pulse.

Note 6 to entry: Sound exposure propagation loss applies to a transient sound source.

Note 7 to entry: Sound exposure propagation loss is equal to $10\log_{10}(F_E^{-1}/1\ \mathrm{m}^2)$ dB, where F_E is the *sound exposure propagation factor* (3.4.1.2).

3.4.2 Scattering

3.4.2.1
differential scattering cross section
σ_Ω
quotient of the ensemble-average of the free-field *time-averaged sound power* (3.1.3.15) radiated per unit solid angle in a specified direction in the far field of the scattered field by the magnitude of the *time-averaged sound intensity* (3.1.3.11) of the incident field, for an incident plane wave and specified continuous incident signal

Note 1 to entry: Differential scattering cross section is expressed in units of metre squared per steradian (m^2/sr).

Note 2 to entry: Differential scattering cross section is equal to the squared magnitude of the form function.

Note 3 to entry: Differential scattering cross section is a bistatic quantity depending on the incident (θ_i) and scattering (θ_s) elevation angles and the incident (ϕ_i) and scattering (ϕ_s) horizontal azimuthal angles. This angle-dependence may be indicated by means of its arguments, as in σ_Ω (θ_i, ϕ_i; θ_s, ϕ_s).

Note 4 to entry: A related term, known as the "backscattering cross section", is defined by some authors as $\sigma_{\Omega,0}$ (see Reference [25]) and by others as $4\pi\sigma_{\Omega,0}$ (see Reference [36]), where the zero subscript indicates evaluation in the backscattering direction such that $\sigma_{\Omega,0}(\theta_i, \phi_i) = \sigma_\Omega(\theta_i, \phi_i; \theta_i, \phi_i)$. The pertinent American national standard [ANSI (2013)] defines backscattering cross section as $4\pi\sigma_{\Omega,0}$.

3.4.2.2
total scattering cross section
σ_t
differential scattering cross section (3.4.2.1), σ_Ω, of an object, integrated over all solid angles with respect to the scattering direction

Note 1 to entry: In formula form, $\sigma_t(\theta_i, \phi_i) = \oint_{4\pi} \sigma_\Omega\left(\theta_i, \phi_i; \theta_s, \phi_s\right) d\Omega_s$, where θ_i and θ_s are incident and scattering elevation angles, and ϕ_i and ϕ_s the incident and scattering horizontal azimuthal angles, respectively. The integral is over all scattered solid angle elements $d\Omega_s$.

Note 2 to entry: Total scattering cross section is expressed in units of metre squared (m^2).

Note 3 to entry: Total scattering cross section depends on the incident elevation (θ_i) and horizontal azimuthal (ϕ_i) angles. This angle-dependence may be indicated by means of its arguments, as in $\sigma_t(\theta_i, \phi_i)$.

[SOURCE: ANSI/ASA S1.1-2013, 5.49, modified]

3.4.2.3
absorption cross section
σ_a
quotient of the ensemble-average of the free-field time-averaged rate at which sound energy is converted to heat by the *time-averaged sound intensity* (3.1.3.11) of the incident field, for an incident plane wave

Note 1 to entry: Absorption cross section is expressed in units of metre squared (m^2).

3.4.2.4
extinction cross section
σ_e
quotient of the mean rate of work done on a scatterer by the magnitude of the *time-averaged sound intensity* (3.1.3.11) of the incident field, for an incident plane wave

Note 1 to entry: Extinction cross section is expressed in units of metre squared (m^2).

Note 2 to entry: The extinction cross section is equal to the sum of the *total scattering cross section* (3.4.2.2) and the *absorption cross section* (3.4.2.3), i.e. $\sigma_e = \sigma_t + \sigma_a$.

3.4.2.5
volume differential scattering cross section per unit volume
σ_v
quotient of the ensemble-average of the free-field *time-averaged sound power* (3.1.3.15) radiated per unit solid angle in a specified direction in the far field of the scattered field per unit volume of water by the *time-averaged sound intensity* (3.1.3.11) of the incident field, for an incident plane wave

Note 1 to entry: Volume differential scattering cross section per unit volume is expressed in units of reciprocal metre reciprocal steradian (m^{-1} sr^{-1}).

Note 2 to entry: Volume differential scattering cross section per unit volume is a bistatic quantity depending on the incident (θ_i) and scattering (θ_s) elevation angles and the incident (ϕ_i) and scattering (ϕ_s) horizontal azimuthal angles. This angle-dependence may be indicated by means of its arguments, as in σ_v (θ_i, ϕ_i; θ_s, ϕ_s).

3.4.2.6
sea surface differential scattering cross section per unit area
σ_s
ratio of the ensemble-average of the free-field *time-averaged sound power* (3.1.3.15) radiated per unit solid angle in a specified direction in the far field of the scattered field per unit area of sea surface to the *time-averaged sound intensity* (3.1.3.11) of the incident field, for an incident plane wave

Note 1 to entry: Sea surface differential scattering cross section per unit area is expressed in units of reciprocal steradian (sr^{-1}).

Note 2 to entry: Both the incident and scattered fields are understood to be in the water.

Note 3 to entry: Sea surface differential scattering cross section per unit area is a bistatic quantity depending on the incident (θ_i) and scattering (θ_s) elevation angles and the incident (ϕ_i) and scattering (ϕ_s) horizontal azimuthal angles. This angle-dependence may be indicated by means of its arguments, as in σ_s (θ_i, ϕ_i; θ_s, ϕ_s).

3.4.2.7
sea bottom differential scattering cross section per unit area
σ_b
ratio of the ensemble-average of the free-field *time-averaged sound power* (3.1.3.15) radiated per unit solid angle in a specified direction in the far field of the scattered field per unit area of sea bottom to the *time-averaged sound intensity* (3.1.3.11) of the incident field, for an incident plane wave

Note 1 to entry: Sea bottom differential scattering cross section per unit area is expressed in units of reciprocal steradian (sr^{-1}).

Note 2 to entry: Both the incident and scattered fields are understood to be in the water.

Note 3 to entry: Sea bottom differential scattering cross section per unit area is a bistatic quantity depending on the incident (θ_i) and scattering (θ_s) elevation angles and the incident (ϕ_i) and scattering (ϕ_s) horizontal azimuthal angles. This angle-dependence may be indicated by means of its arguments, as in σ_b (θ_i, ϕ_i; θ_s, ϕ_s).

3.4.2.8
volume scattering strength
S_V
ten times the logarithm to the base 10 of the ratio of the *volume differential scattering cross section per unit volume* (3.4.2.5) to the reference value, $\sigma_{v,0}$, in decibels

Note 1 to entry: In formula form, $S_V = 10\log_{10}\frac{\sigma_v}{\sigma_{v,0}}\,\mathrm{dB}$.

Note 2 to entry: Volume scattering strength is expressed in decibels (dB).

Note 3 to entry: The reference value of volume differential scattering cross section per unit volume is $\sigma_{v,0} = 1\,\mathrm{m}^{-1}\,\mathrm{sr}^{-1}$. The reference value shall be specified.

Note 4 to entry: Volume scattering strength is a bistatic quantity depending on the incident (θ_i) and scattering (θ_s) elevation angles and the incident (ϕ_i) and scattering (ϕ_s) horizontal azimuthal angles. This angle-dependence may be indicated by means of its arguments, as in S_V (θ_i, ϕ_i; θ_s, ϕ_s).

3.4.2.9
sea surface scattering strength
S_S
ten times the logarithm to the base 10 of the ratio of the *sea surface differential scattering cross section per unit area* (3.4.2.6) to the reference value, $\sigma_{s,0}$, in decibels

Note 1 to entry: In formula form, $S_s = 10\log_{10}\frac{\sigma_s}{\sigma_{s,0}}\,\mathrm{dB}$.

Note 2 to entry: Sea surface scattering strength is expressed in decibels (dB).

Note 3 to entry: The reference value of sea surface differential scattering cross section per unit area is $\sigma_{\mathrm{s},0} = 1\ \mathrm{sr}^{-1}$. The reference value shall be specified.

Note 4 to entry: Sea surface scattering strength is a bistatic quantity depending on the incident (θ_{i}) and scattering (θ_{s}) elevation angles and the incident (ϕ_{i}) and scattering (ϕ_{s}) horizontal azimuthal angles. This angle-dependence may be indicated by means of its arguments, as in S_s (θ_{i}, ϕ_{i}; θ_{s}, ϕ_{s}).

3.4.2.10
sea bottom scattering strength
S_{b}
ten times the logarithm to the base 10 of the ratio of the *sea bottom differential scattering cross section per unit area* (3.4.2.7) to the reference value, $\sigma_{\mathrm{b},0}$, in decibels

Note 1 to entry: In formula form, $S_{\mathrm{b}} = 10\log_{10}\dfrac{\sigma_{\mathrm{b}}}{\sigma_{\mathrm{b},0}}\ \mathrm{dB}$.

Note 2 to entry: Sea bottom scattering strength is expressed in decibels (dB).

Note 3 to entry: The reference value of sea bottom differential scattering cross section per unit area is $\sigma_{\mathrm{b},0} = 1\ \mathrm{sr}^{-1}$. The reference value shall be specified.

Note 4 to entry: Sea bottom scattering strength is a bistatic quantity depending on the incident (θ_{i}) and scattering (θ_{s}) elevation angles and the incident (ϕ_{i}) and scattering (ϕ_{s}) horizontal azimuthal angles. This angle-dependence may be indicated by means of its arguments, as in S_b (θ_{i}, ϕ_{i}; θ_{s}, ϕ_{s}).

3.5 Terms for properties of underwater sound signals

3.5.1 Sound signals

3.5.1.1
analytic signal
q
complex quantity whose real part is equal to the *signal* (3.1.5.8), $p(t)$, and whose imaginary part is equal to the Hilbert transform of $p(t)$

Note 1 to entry: Analytic signal is a function of time, which may be indicated by means of an argument t, as in $q(t)$, where q is analytic signal and t is time.

Note 2 to entry: In formula form, the analytic signal, $q(t)$, of a signal, $p(t)$, is given by $q(t) = p(t) + \mathrm{i}\, h(t)$, where $h(t)$ is the Hilbert transform of $p(t)$.

Note 3 to entry: If the signal, $p(t)$, is *sound pressure* (3.1.2.1), the analytic signal is expressed in pascals (Pa).

3.5.1.2
complex envelope
μ
product of the *analytic signal* (3.5.1.1), $q(t)$, and the exponential function of the product of the constant $-2\pi\mathrm{i}$, a constant frequency, f_0, and the time, t

Note 1 to entry: Complex envelope is a function of time, which may be indicated by means of an argument t, as in $\mu(t)$, where μ is complex envelope and t is time.

Note 2 to entry: In formula form, $\mu(t) = q(t)\exp(-2\pi\mathrm{i}f_0 t)$.

Note 3 to entry: If $q(t)$ is the analytic signal of the *sound pressure* (3.1.2.1), the complex envelope is expressed in pascals (Pa).

Note 4 to entry: For a narrowband signal, the quantity f_0 is typically the centre frequency of that signal.

3.5.1.3
effective signal duration
τ_{eff}
square of the integral with respect to time of $|\mu(t)|^2$ divided by the integral with respect to time of $|\mu(t)|^4$, where $\mu(t)$ is the *complex envelope* (3.5.1.2) of the *sound pressure* (3.1.2.1)

Note 1 to entry: In formula form, $\tau_{\mathrm{eff}} = \frac{\left[\int_{-\infty}^{+\infty} |\mu(t)|^2 \, \mathrm{d}t\right]^2}{\int_{-\infty}^{+\infty} |\mu(t)|^4 \, \mathrm{d}t}$.

Note 2 to entry: Effective signal duration is expressed in seconds (s).

Note 3 to entry: Effective signal duration is a property of a transient signal.

Note 4 to entry: The magnitude of the complex envelope is equal to the magnitude of the *analytic signal* (3.5.1.1).

[SOURCE: Reference [24]]

3.5.1.4
threshold exceedance signal duration
$\tau_{y\ \mathrm{dB}}$
time during which the *mean-square sound pressure level* (3.2.1.1) (SPL) exceeds a specified threshold y decibels below the maximum SPL, for a specified averaging time

Note 1 to entry: Threshold exceedance signal duration is expressed in seconds (s).

Note 2 to entry: If there is more than one threshold crossing in each direction, threshold exceedance signal duration is made unambiguous by choosing the time interval between the first crossing with increasing SPL and the last one with decreasing SPL.

Note 3 to entry: Threshold exceedance signal duration is a property of a transient signal.

[SOURCE: Reference [32], modified]

3.5.1.5
percentage energy signal duration
$\tau_{x\ \%}$
time during which a specified percentage x of *time-integrated squared sound pressure* (3.1.3.5) occurs, starting at $(50 - x/2)$ % and ending at $(50 + x/2)$ % of total energy

Note 1 to entry: Percentage energy signal duration is expressed in seconds (s).

Note 2 to entry: Percentage energy signal duration is a property of a transient signal.

[SOURCE: Reference [32], modified]

3.5.1.6
effective signal bandwidth
ν_{eff}
square of the integral with respect to frequency of $|M(f)|^2$ divided by the integral with respect to frequency of $|M(f)|^4$, where $M(f)$ is the Fourier transform of the *complex envelope* (3.5.1.2), $\mu(t)$, corresponding to a time-dependent field quantity, $p(t)$

Note 1 to entry: In formula form, $\nu_{\mathrm{eff}} = \frac{\left[\int_{-\infty}^{+\infty} |M(f)|^2 \, \mathrm{d}f\right]^2}{\int_{-\infty}^{+\infty} |M(f)|^4 \, \mathrm{d}f}$, where $M(f)$ is the Fourier transform (see ISO 80000-2) of the complex envelope, $\mu(t)$.

Note 2 to entry: Effective signal bandwidth is expressed in hertz (Hz).

[SOURCE: Reference [24]]

3.6 Terms related to sonar equations

3.6.1 General

3.6.1.1
sonar signal sound pressure
sound pressure (3.1.2.1) at a specified position caused by the presence of a target

Note 1 to entry: The specified position is usually a hydrophone, which might form part of a sonar receiving array.

3.6.1.2
sonar signal voltage
voltage at a sonar receiver, for a specified frequency band, caused by the *sonar signal sound pressure* (3.6.1.1)

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".

3.6.1.3
target echo
sound (3.1.1.1) at a sonar receiver originating from an active sonar transmission, and subsequently re-radiated by a target

Note 1 to entry: For active sonar, the target echo is a synonym of *sonar signal sound pressure* (3.6.1.1).

3.6.1.4
sonar reverberation
<active sonar> *sound* (3.1.1.1) at a sonar receiver originating from an active sonar transmission except a *target echo* (3.6.1.3)

Note 1 to entry: Sonar reverberation is caused by, for example, the cumulative scattering by myriad inhomogeneities in the environment.

3.6.1.5
background noise
acoustic noise
combination of *ambient noise* (3.1.5.11), *acoustic self-noise* (3.1.5.10) and, where applicable, *sonar reverberation* (3.6.1.4)

Note 1 to entry: The concept of *background noise* (3.6.1.5) is used in measurement systems.

Note 2 to entry: If the measurement system includes an active transmitter (e.g. active sonar or airgun array), background noise is the combination of ambient noise, acoustic self-noise and sonar reverberation.

Note 3 to entry: If the measurement system does not include an active transmitter (e.g. passive sonar or hearing studies), background noise is the combination of ambient noise and acoustic self-noise.

3.6.1.6
non-acoustic self-noise
fluctuations in voltage at a sonar receiver output in the absence of sound pressure input

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.

3.6.1.7
self-noise
fluctuations in voltage caused by the combination of *acoustic self-noise* (3.1.5.10) and *non-acoustic self-noise* (3.6.1.6)

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 Flow noise.

3.6.1.8
sonar noise voltage
voltage at a sonar receiver, for a specified frequency band, caused by the combination of *background noise* (3.6.1.5) and *non-acoustic self-noise* (3.6.1.6)

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”.

3.6.1.9
sonar signal-to-noise ratio
SNR
R_{SN}
ratio of mean-square *sonar signal voltage* (3.6.1.2) to mean-square *sonar noise voltage* (3.6.1.8) at a specified point in the receiver processing chain

Note 1 to entry: Points in the processing chain that may be specified include, but are not limited to, the inputs to and outputs from a beamformer.

Note 2 to entry: The frequency band for the sonar noise voltage shall be the same as for the sonar signal voltage.

Note 3 to entry: The relationship between the sonar signal-to-noise ratio and related terms is summarized in Figure 1.

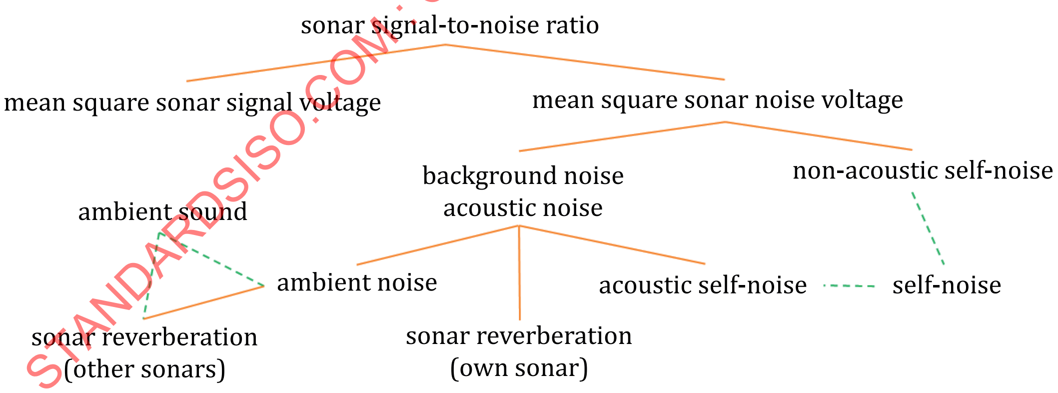

Figure 1 — The relationship between the sonar signal-to-noise ratio and related terms[1)]

3.6.1.10
probability of detection
p_{d}
probability of making a *signal* (3.1.5.8) present decision when one (and only one) signal is present, for a single observation

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3.6.1.11
probability of false alarm
p_{fa}
probability of making a *signal* (3.1.5.8) present decision when no signal is present, for a single observation

3.6.1.12
noise detector output
output of a detector when the sonar signal is absent from the input

3.6.1.13
signal plus noise detector output
output of a detector when the sonar signal is present in the input

3.6.1.14
detection index
d
ratio of the squared difference between mean *signal plus noise detector output* (3.6.1.13) and mean *noise detector output* (3.6.1.12) to the variance of the noise detector output, for a specified detector

Note 1 to entry: See also *detectability index* (3.7.2.14).

[SOURCE: Reference [39], p382]

3.6.1.15
equivalent mean-square sonar noise sound pressure
$p_{N,eq}^2$
mean-square *sonar noise voltage* (3.6.1.8), V_N^2, at the hydrophone output divided by the squared free-field open-circuit hydrophone voltage sensitivity, M_p^2

Note 1 to entry: In formula form, $p_{N,eq}^2 = V_N^2/M_p^2$.

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

Note 3 to entry: The frequency band for the *sonar noise voltage* (3.6.1.8) shall be specified.

Note 4 to entry: Free-field open-circuit hydrophone voltage sensitivity is defined by IEC 60500.

3.6.2 Sonar equations and sonar equation terms

3.6.2.1
detection threshold
DT
ΔL_{DT}
ten times the logarithm to the base 10 of the *sonar signal-to-noise ratio* (3.6.1.9) of a *signal* (3.1.5.8), $R_{SN,T}$, in decibels, for specified *probability of detection* (3.6.1.10) and *probability of false alarm* (3.6.1.11)

Note 1 to entry: In formula form, $\Delta L_{DT} = 10\log_{10} R_{SN,T}$ dB.

Note 2 to entry: Detection threshold is expressed in decibels (dB).

Note 3 to entry: The specified probability of detection is often 0,5.

Note 4 to entry: When the sonar signal-to-noise ratio of a signal is equal to the detection threshold, that signal is referred to as being “just detectable”.

3.6.2.2
signal excess
ΔL_{SE}
amount by which ten times the logarithm to the base 10 of the *sonar signal-to-noise ratio* (3.6.1.9), R_{SN}, in decibels exceeds the *detection threshold* (3.6.2.1), ΔL_{DT}

Note 1 to entry: In formula form, $\Delta L_{SE} = 10\log_{10}R_{SN}$ dB – ΔL_{DT}. The form of R_{SN} depends on the application.

Note 2 to entry: Signal excess is expressed in decibels (dB).

3.6.2.3
sonar equation
equation relating *signal excess* (3.6.2.2) (ΔL_{SE}), *sonar signal-to-noise ratio* (3.6.1.9) (R_{SN}) and *detection threshold* (3.6.2.1) (ΔL_{DT})

Note 1 to entry: According to this document, the terms of the sonar equation are levels or level differences, in decibels, representing ratios of *mean-square sound pressure* (3.1.3.1). In principle, these ratios could be ratios of other power quantities such as *equivalent plane wave sound intensity* (3.1.3.12), or *mean-square sound particle velocity* (3.1.3.3), or their time-integrated equivalents.

Note 2 to entry: The sonar signal-to-noise ratio, R_{SN}, is usually related to the *source level* (3.3.2.1), *propagation loss* (3.4.1.4), noise level, etc., via the *passive sonar equation* (3.6.2.7) or *active sonar equation* (3.6.2.11), often in the form $\Delta L_{SE} = 10\log_{10}R_{SN}$ dB – ΔL_{DT}.

Note 3 to entry: For passive sonar, R_{SN} can be determined by the formula $10\log_{10}R_{SN}$ dB = $L_S - N_{PL} - L_N + \Delta L_{PG}$. Substitution of this equation into the equation for signal excess gives the passive sonar equation in the form $\Delta L_{SE} = L_S - N_{PL} - L_N + \Delta L_{PG} - \Delta L_{DT}$.

Note 4 to entry: For active sonar, R_{SN} can be approximated by the formula $10\log_{10}R_{SN}$ dB $\approx L_S - N_{PL,Tx} + N_{TS} - N_{PL,Rx} - L_N + \Delta L_{PG}$. Substitution of this approximation into the equation for signal excess gives the active sonar equation in the form $\Delta L_{SE} \approx L_S - N_{PL,Tx} + N_{TS} - N_{PL,Rx} - L_N + \Delta L_{PG} - \Delta L_{DT}$.

Note 5 to entry: If in the active sonar equation, the *target strength* (3.6.2.8) (N_{TS}) is replaced with the *equivalent target strength* (3.6.2.10) ($N_{TS,eq}$), the equation becomes an exact one $\Delta L_{SE} = L_S - N_{PL,Tx} + N_{TS,eq} - N_{PL,Rx} - L_N + \Delta L_{PG} - \Delta L_{DT}$.

3.6.2.4
array gain
AG
ΔL_{AG}
ten times the logarithm to the base 10 of the ratio $R_{SN,out}/R_{SN,in}$, in decibels, where $R_{SN,in}$ and $R_{SN,out}$ are the *sonar signal-to-noise ratio* (3.6.1.9) at the input to and output from a beamformer of a sonar receiver, for a specified steer direction

Note 1 to entry: In formula form, $\Delta L_{AG} = 10\log_{10}(R_{SN,out}/R_{SN,in})$ dB.

Note 2 to entry: Array gain is expressed in decibels (dB).

Note 3 to entry: This definition assumes the input sonar signal-to-noise ratio is the same for all input channels.

Note 4 to entry: For a plane wave *sonar signal sound pressure* (3.6.1.1) and isotropic *background noise* (3.6.1.5), the array gain is referred to as the "directivity index".

3.6.2.5
sonar noise level
L_N
ten times the logarithm to the base 10 of the ratio of the *equivalent mean-square sonar noise sound pressure* (3.6.1.15), $p_{N,eq}^2$, for specified receiver-circuit impedance, to the specified reference value, p_0^2, in decibels

Note 1 to entry: Sonar noise level is the level of the power quantity equivalent mean-square sonar noise sound pressure, denoted $p_{N,eq}^2$. In formula form, $L_N = 10\log_{10}(p_{N,eq}^2/p_0^2)$ dB.

Note 2 to entry: Sonar noise level is expressed in decibels (dB).

Note 3 to entry: The reference value of equivalent mean-square sonar noise sound pressure, p_0^2, is 1 μPa². The reference value shall be specified.

Note 4 to entry: The frequency band for the *sonar noise voltage* (3.6.1.8) shall be specified.

3.6.2.6
sonar processing gain
PG
ΔL_{PG}
ten times the logarithm to the base 10 of the ratio $R_{SN,out}/R_{SN,in}$, in decibels, where $R_{SN,in}$ and $R_{SN,out}$ are the *sonar signal-to-noise ratios* (3.6.1.9) at the hydrophone output and point in the receiver processing chain at which the detection decision is made, respectively

Note 1 to entry: In formula form, $\Delta L_{PG} = 10 \log_{10}(R_{SN,out}/R_{SN,in})$ dB.

Note 2 to entry: Sonar processing gain is expressed in decibels (dB).

Note 3 to entry: The frequency band for the *sonar noise voltage* (3.6.1.8) shall be specified.

Note 4 to entry: The detection decision is a choice between *signal* present and *signal* absent. See *probability of detection* (3.6.1.10) and *probability of false alarm* (3.6.1.11).

Note 5 to entry: The gain from beamforming (i.e. array gain) is included in the sonar processing gain.

Note 6 to entry: The gain from time domain processing, such as a replica correlator, is included in the sonar processing gain.

Note 7 to entry: The gain from frequency domain processing, such as a pre-whitening filter, is included in the sonar processing gain.

Note 8 to entry: The sonar signal-to-noise ratio at the hydrophone output is the open circuit output signal-to-noise ratio.

3.6.2.7
passive sonar equation
sonar equation (3.6.2.3) for passive sonar obtained by relating *sonar signal-to-noise ratio* (3.6.1.9) (R_{SN}) to *source level* (3.3.2.1) (L_S), *propagation loss* (3.4.1.4) (N_{PL}), *sonar noise level* (3.6.2.5) (L_N) and *sonar processing gain* (3.6.2.6) (ΔL_{PG}) by means of the formula $10\log_{10}R_{SN}$ dB = $L_S - N_{PL} - L_N + \Delta L_{PG}$

Note 1 to entry: The passive sonar equation applies to the detection of sound from a continuous sound source.

Note 2 to entry: If the sonar processing includes a beamformer, the sonar processing gain includes the *array gain* (3.6.2.4) associated with that beamformer.

3.6.2.8
target strength
TS
N_{TS}
ten times the logarithm to the base 10 of the ratio of the target *differential scattering cross section* (3.4.2.1), σ_Ω, to the specified reference value, $\sigma_{\Omega,0}$, in decibels

Note 1 to entry: In formula form, $N_{TS}\left(\theta_i,\phi_i;\theta_s,\phi_s\right) = 10\log_{10}\left[\sigma_\Omega\left(\theta_i,\phi_i;\theta_s,\phi_s\right)/\sigma_{\Omega,0}\right]$dB, where θ_i, and θ_s are the incident and scattering elevation angles, and ϕ_i and ϕ_s the incident and scattering horizontal azimuthal angles, respectively.

Note 2 to entry: Target strength is expressed in decibels (dB).

Note 3 to entry: The reference value of differential scattering cross section is $\sigma_{\Omega,0} = 1\ \mathrm{m}^2\ \mathrm{sr}^{-1}$. The reference value shall be specified.

Note 4 to entry: Target strength is a bistatic quantity depending on the incident (θ_i) and scattering (θ_s) elevation angles and the incident (ϕ_i) and scattering (ϕ_s) horizontal azimuthal angles. This angle-dependence may be indicated by means of its arguments, as in $N_{TS}\left(\theta_i, \phi_i; \theta_s, \phi_s\right)$. The target strength in the backscattering direction, i.e. $N_{TS}\left(\theta_i, \phi_i; \theta_i, \phi_i\right)$ may be referred to as the “monostatic target strength”.

Note 5 to entry: Target strength is a free-field quantity, defined in terms of an incident plane wave. It relates the *mean-square sound pressure level* (3.2.1.1), $L_{p,s}$, of the scattered sound in the far field to the mean-square sound pressure level $L_{p,i}$ of an incident plane wave. For an omnidirectional target in an infinite uniform lossless medium, the target strength is equal to $L_{p,s} + 10\log_{10}(r/r_0)^2$ dB – $L_{p,i}$.

3.6.2.9
target echo level
EL
L_{TE}
mean-square sound pressure level (3.2.1.1) of the *target echo* (3.6.1.3)

Note 1 to entry: Target echo level is expressed in decibels (dB).

Note 2 to entry: In underwater acoustics, the reference value of mean-square sound pressure, p_0^2, is 1 μPa^2. The reference value shall be specified.

3.6.2.10
equivalent target strength
TS$_{eq}$
$N_{TS,eq}$
difference between sum of *target echo level* (3.6.2.9) (L_{TE}), *propagation loss* (3.4.1.4) from sonar transmitter to target ($N_{PL,Tx}$), and propagation loss from target to sonar receiver ($N_{PL,Rx}$), and *source level* (3.3.2.1) (L_S)

Note 1 to entry: In formula form, $N_{TS,eq} = L_{TE} + N_{PL,Tx} + N_{PL,Rx} - L_S$.

Note 2 to entry: Equivalent target strength is expressed in decibels (dB).

Note 3 to entry: The reference value for equivalent target strength, r_0^2, is 1 m^2. The reference value shall be specified.

Note 4 to entry: Equivalent target strength is applicable to both monostatic and bistatic sonar.

Note 5 to entry: For a target whose *differential scattering cross section* (3.4.2.1) is independent of both incident and scattering elevation angles, the equivalent target strength is equal to the target strength (see Reference [20], pp 607–610).

3.6.2.11
active sonar equation
sonar equation (3.6.2.3) for active sonar obtained by relating *sonar signal-to-noise ratio* (3.6.1.9) (R_{SN}) to the *source level* (3.3.2.1) of the sonar transmitter (L_S), *propagation loss* (3.4.1.4) from sonar transmitter to target ($N_{PL,Tx}$), *equivalent target strength* (3.6.2.10) ($N_{TS,eq}$), propagation loss from target to sonar receiver ($N_{PL,Rx}$), *sonar noise level* (3.6.2.5) (L_N) and *sonar processing gain* (3.6.2.6) (ΔL_{PG}) by means of the approximation $10\log_{10}R_{SN}$ dB, $\approx L_S - N_{PL,Tx} + N_{TS,eq} - N_{PL,Rx} - L_N + \Delta L_{PG}$

Note 1 to entry: For monostatic sonar, and for an omnidirectional source and omnidirectional target, $N_{PL,Tx}$ and $N_{PL,Rx}$ are related via the reciprocity principle. They are equal if the medium density at the target position, ρ_T, is equal to that at the sonar, ρ_S. More generally, they are related via the formula $N_{PL,Rx} = N_{PL,Tx} + 10\log_{10}\frac{\rho_T^2}{\rho_S^2}$ dB.

See Reference [20], p.493.

Note 2 to entry: For the propagation loss from sonar transmitter to target, the source level is that of the sonar transmitter and the *mean-square sound pressure level* (3.2.1.1) is that at the target position in the absence of the target.

Note 3 to entry: For the propagation loss from target to sonar receiver, the source level is that of the target and the mean-square sound pressure level is the *target echo level* (3.6.2.9). The source level of the target is equal to the sum of the equivalent target strength and the mean-square sound pressure level at the target position.

3.6.2.12
reverberation level
RL
L_R
ten times the logarithm to the base 10 of the ratio of the *mean-square sound pressure* (3.1.3.1) associated with *sonar reverberation* (3.6.1.4), p_R^2, to the specified reference value, p_0^2, in decibels

Note 1 to entry: Reverberation level is the level of the power quantity equal to the mean-square sound pressure associated with sonar reverberation, denoted p_R^2. In formula form, $L_R = 10 \log_{10}(p_R^2/p_0^2)$ dB.

Note 2 to entry: Reverberation level is expressed in decibels (dB).

Note 3 to entry: The reference value of mean-square sound pressure, p_0^2, is 1 μPa². The reference value shall be specified.

Note 4 to entry: Reverberation level (L_R) is equal to the *sonar noise level* (3.6.2.5) (L_N) if there is no *ambient noise* (3.1.5.11) and no *self-noise* (3.6.1.7).

3.6.2.13
reverberation-limited active sonar equation
sonar equation (3.6.2.3) for active sonar when *ambient noise* (3.1.5.11) and *self-noise* (3.6.1.7) are both negligible compared to *sonar reverberation* (3.6.1.4)

Note 1 to entry: In the reverberation-limited active sonar equation, *sonar noise level* (3.6.2.5) (L_N) is equal to *reverberation level* (3.6.2.12) (L_R).

3.7 Terms related to underwater bioacoustics

3.7.1 Auditory frequency weighting

3.7.1.1
weighted sound pressure
p_w
output of a specified linear filter when the input is the *sound pressure* (3.1.2.1), $p(t)$

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

Note 2 to entry: The weighted sound pressure is the convolution of the impulse response function $h(t)$ of the filter and the sound pressure, $p(t)$. In formula form, $p_w(t) = \int_{-\infty}^{\infty} h(\tau) p(t-\tau) d\tau$. The impulse response function is the inverse Fourier transform (see ISO 80000-2) of the *sound pressure transfer function* (3.7.1.5), $H(f)$. See ANSI S1.42.

Note 3 to entry: Weighted sound pressure is expressed in pascals (Pa).

Note 4 to entry: A filter is a process that removes from a signal some component or feature.

Note 5 to entry: The linear filter might be chosen to characterize a specified frequency-dependent characteristic of hearing sensitivity in a particular type of animal.

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

3.7.1.2
weighted time-integrated squared sound pressure
weighted sound pressure exposure
weighted sound exposure
$E_{p,\mathrm{w}}$
integral of the square of the *weighted sound pressure* (3.7.1.1), p_w, over a specified time interval or event

Note 1 to entry: In formula form, $E_{p,\mathrm{w}} = \int_{t_1}^{t_2} p_\mathrm{w}^2 \mathrm{d}t$, where t_1 and t_2 are the start and end times, respectively.

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

Note 3 to entry: The integration time and frequency range shall be specified.

Note 4 to entry: According to the continuous form of Parseval's theorem (also known as Plancherel's theorem), the weighted sound exposure can be written as the frequency-integrated weighted sound exposure spectral density. In formula form, $E_{p,\mathrm{w}} = \int_{-\infty}^{+\infty} p_\mathrm{w}^2 \left(t\right) \mathrm{d}t = \int_{0}^{+\infty} w\left(f\right) E_f \left(f\right) \mathrm{d}f$, where E_f is the *sound exposure spectral density* (3.1.3.9) (i.e. the spectral density of the unweighted sound exposure) and $w(f)$ is the *frequency weighting function* (3.7.1.6), given by $w(f) = |H(f)|^2$, where $H(f)$ is the *sound pressure transfer function* (3.7.1.5).

Note 5 to entry: If a specific frequency weighting function is applied, this should be indicated by appropriate subscripts.

3.7.1.3
mean-square weighted sound pressure level
weighted sound pressure level
SPL$_\mathbf{w}$
$L_{p,\mathrm{w}}$
ten times the logarithm to the base 10 of the ratio of the mean-square *weighted sound pressure* (3.7.1.1) to the specified reference value, p_0^2, in decibels

Note 1 to entry: Mean-square weighted sound pressure level is the level of the power quantity equal to the mean-square weighted sound pressure, denoted $\overline{p_\mathrm{w}^2}$. In formula form, $L_{p,\mathrm{w}} = 10\log_{10}\left(\overline{p_\mathrm{w}^2} / p_0^2\right)\mathrm{dB}$.

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

Note 3 to entry: In underwater acoustics, the reference value of mean-square weighted sound pressure, p_0^2, is 1 $\mu\mathrm{Pa}^2$. The reference value shall be specified.

Note 4 to entry: The averaging time and frequency range shall be specified.

Note 5 to entry: The type of weighting (e.g. frequency weighting or time weighting) shall be specified.

3.7.1.4
weighted sound exposure level
weighted sound pressure exposure level
SEL$_\mathbf{w}$
$L_{E,p,\mathrm{w}}$
ten times the logarithm to the base 10 of the ratio of the *weighted time-integrated squared sound pressure* (3.7.1.2), $E_{p,\mathrm{w}}$, to the specified reference value, $E_{p,0}$, in decibels

Note 1 to entry: Weighted sound exposure level is the level of the power quantity weighted time-integrated squared sound pressure, denoted $E_{p,\mathrm{w}}$. In formula form, $L_{E,p,\mathrm{w}} = 10 \log_{10}(E_{p,\mathrm{w}}/E_{p,0})$ dB.

Note 2 to entry: Weighted sound exposure level is expressed in decibels (dB).

Note 3 to entry: In underwater acoustics, the reference value of weighted time-integrated squared sound pressure, $E_{p,0}$, is 1 $\mu\mathrm{Pa}^2$ s. The reference value shall be specified.

Note 4 to entry: The integration time and frequency range shall be specified.

Note 5 to entry: If a specific frequency weighting is applied, this should be indicated by appropriate subscripts.

Note 6 to entry: This definition is in accordance with ISO 80000-8:2007, Clause 3.

Note 7 to entry: Integration time shall be specified.

[SOURCE: ISO/TR 25417:2007, 2.7, modified]

3.7.1.5
sound pressure transfer function
H
ratio of the Fourier transform of the *weighted sound pressure* (3.7.1.1) to the Fourier transform of the *sound pressure* (3.1.2.1)

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

Note 2 to entry: In formula form, $H(f) = P_\mathrm{w}(f)/P(f)$, where $P_\mathrm{w}(f)$ is the Fourier transform (see ISO 80000-2) of the weighted sound pressure and $P(f)$ is the Fourier transform of the sound pressure.

3.7.1.6
frequency weighting function
w
squared magnitude of the *sound pressure transfer function* (3.7.1.5)

Note 1 to entry: Frequency weighting function is a function of frequency, which may be indicated by means of an argument f, as in $w(f)$, where w is the frequency weighting function and f is frequency.

Note 2 to entry: In formula form, $w(f) = |H(f)|^2$, where $H(f)$ is the sound pressure transfer function.

Note 3 to entry: The frequency weighting function is used in the calculation of spectrally weighted quantities when expressed as an integral over frequency using the continuous version of Parseval's theorem (also known as Plancherel's theorem). An example of a spectrally weighted quantity is the *weighted time-integrated squared sound pressure* (3.7.1.2).

Note 4 to entry: Compare *auditory frequency weighting function* (3.7.1.7).

3.7.1.7
auditory frequency weighting function
w_aud
frequency weighting function (3.7.1.6) chosen to represent a specified frequency-dependent characteristic of hearing sensitivity in a particular type of animal, by which an acoustic quantity is adjusted to reflect the importance of frequency dependence to that animal

Note 1 to entry: Auditory frequency weighting function is a function of frequency, which may be indicated by means of an argument f, as in $w_\mathrm{aud}(f)$, where w_aud is the auditory frequency weighting function and f is frequency.

Note 2 to entry: An example of auditory frequency weighting function for marine mammals is "M-weighting". The auditory frequency weighting function corresponding to M-weighting is $w_\mathrm{aud}\left(f\right) = \left[\frac{R\left(f\right)}{\max R\left(f\right)}\right]^2$, where $R(f)$ is given by Formula (8) of Reference [37] in terms of the lower and upper "functional" hearing limits (f_low and f_high, respectively): $R\left(f\right) = \frac{f_\mathrm{high}^2 f^2}{\left(f^2 + f_\mathrm{high}^2\right)\left(f^2 + f_\mathrm{low}^2\right)}$.

Note 3 to entry: Compare frequency weighting function.

3.7.2 Sound reception

3.7.2.1
behavioural hearing threshold
behavioural threshold of hearing
minimum level of a specified sound *signal* (3.1.5.8) that is capable of evoking a behaviourally measurable auditory sensation in a specified fraction of trials, for a specific subject and for specified conditions, including measurement geometry

Note 1 to entry: Behavioural hearing threshold is expressed in decibels (dB).

Note 2 to entry: The type of level, e.g. *mean-square sound pressure level* (3.2.1.1) or mean-square sound-particle velocity level, and its reference value shall be specified.

Note 3 to entry: As behavioural responses are sensitive to signal structure [e.g. tone pip, click, pure tone (see ANSI/ASA S3.20)], the characteristics of the signal and the manner in which it is presented to the subject shall be specified.

Note 4 to entry: The *background noise* (3.6.1.5) levels should be measured and reported.

Note 5 to entry: The behavioural hearing threshold is referred to as an "unmasked behavioural hearing threshold" if a decrease in the background noise does not result in a change to the behavioural hearing threshold.

Note 6 to entry: If the background noise is high enough to raise the behavioural hearing threshold above the unmasked behavioural hearing threshold, the behavioural hearing threshold is referred to as a "masked behavioural hearing threshold".

Note 7 to entry: The method for threshold estimation shall be specified.

Note 8 to entry: The pure-tone behavioural hearing threshold measurement procedure prescribed in ISO 8253-1 recommends that the behavioural hearing threshold be defined as the lowest input level at which responses occur in at least 50 % of a series of ascending trials.

Note 9 to entry: The description of the measurement geometry and conditions shall be sufficient for the results to be duplicated. The geometry is especially important if the subject's hearing is known or suspected to be sensitive to a quantity other than that being reported. For example, if a fish is sensitive to *sound particle velocity* (3.1.2.10) and its hearing threshold is reported in terms of *sound pressure* (3.1.2.1), the information would need to be sufficiently detailed to permit the reconstruction of the sound field, with the same sound pressure and sound particle velocity at the fish location as in the original measurement.

3.7.2.2
electrophysiological hearing threshold
electrophysiological threshold of hearing
minimum level of a specified *signal* (3.1.5.8) that is capable of evoking a detectable and reproducible electrophysiological response, for a specific subject and for specified conditions, including measurement geometry

Note 1 to entry: Electrophysiological hearing threshold is expressed in decibels (dB).

Note 2 to entry: The type of level, e.g. *mean-square sound pressure level* (3.2.1.1) or mean-square sound-particle velocity level, and its reference value shall be specified.

Note 3 to entry: As electrophysiological responses are sensitive to signal structure [e.g. tone pip, click, pure tone (see ANSI/ASA S3.20)], the characteristics of the signal and the manner in which it is presented to the subject shall be specified.

Note 4 to entry: Both the *background noise* (3.6.1.5) and the background electrophysiological noise should be reported. Electrophysiological noise is the *non-acoustic self-noise* (3.6.1.6) consisting of myogenic and neurogenic sources plus any artefact caused by non-biological electrical interference.

Note 5 to entry: The electrophysiological hearing threshold is referred as an "unmasked electrophysiological hearing threshold" if a decrease in the background noise does not result in a change to the electrophysiological hearing threshold.

Note 6 to entry: If the background noise is high enough to raise the electrophysiological hearing threshold above the unmasked electrophysiological hearing threshold, the electrophysiological hearing threshold is referred to as a "masked electrophysiological hearing threshold".

Note 7 to entry: Objective, statistically-based and subjective analyses can be used for detecting the presence of an electrophysiological response to an acoustic stimulus. Similarly, threshold estimation can be determined through various means, each of which carries with it associated errors and assumptions. The method for threshold estimation shall be specified.

Note 8 to entry: Electrophysiological hearing threshold estimates can be determined from different physiological processes (e.g. auditory brainstem response, cortical evoked responses and microphonic potentials), which characterize auditory processing at different levels of the auditory system. Electrophysiological methods are not equivalent to psychophysical procedures and electrophysiological hearing thresholds will differ from *behavioural hearing thresholds* (3.7.2.1), which provide an integrated, whole organism response to signal detection.

Note 9 to entry: The description of the measurement geometry and conditions shall be sufficient for the results to be duplicated. The geometry is especially important if the subject's hearing is known or suspected to be sensitive to a quantity other than that being reported. For example, if a fish is sensitive to *sound particle velocity* (3.1.2.10) and its hearing threshold is reported in terms of sound pressure, the information would need to be sufficiently detailed to permit the reconstruction of the sound field, with the same sound pressure and sound particle velocity at the fish location as in the original measurement.

3.7.2.3
audiogram
graph or table of *behavioural hearing threshold* (3.7.2.1) or *electrophysiological hearing threshold* (3.7.2.2) as a function of frequency

Note 1 to entry: Frequency is the centre frequency of the specified signal.

Note 2 to entry: It shall be stated whether the audiogram is for a behavioural hearing threshold or an electrophysiological hearing threshold.

[SOURCE: ANSI/ASA S3.20-2015, 4.01, modified]

3.7.2.4
auditory masking
auditory process by which the *behavioural hearing threshold* (3.7.2.1) or *electrophysiological hearing threshold* (3.7.2.2) for a sound (the signal) is raised by the presence of another sound (the noise)

Note 1 to entry: The masking phenomenon can also be related to thresholds of discrimination and recognition.

Note 2 to entry: The sound whose presence results in the raised threshold for detecting the signal is known as a "masking sound". See ISO 8253-1:2010, 3.16.

3.7.2.5
auditory critical band
critical band
band of frequencies on either side of a specified frequency within which the presence of sound at a second frequency will interfere with the detection of sound at the specified frequency

Note 1 to entry: An auditory critical band can be defined for various measures of sound perception that involve frequency, including but not limited to audibility, loudness, and annoyance.

Note 2 to entry: In mammals, the auditory critical band is one of a number of contiguous bands of frequency into which the audio-frequency range may be notionally divided, such that sounds in different frequency bands are heard independently of one another, without mutual interference.

Note 3 to entry: The auditory critical band was originally examined by comparing the degree of masking of a pure tone by white noise (see ANSI/ASA S1.1–2013, 2.37) of progressively narrower bandwidth. It is also possible to demonstrate the critical band by comparing the degree of masking brought about by exposure to tones at different frequencies or to narrow bands of noise centred at different frequencies.

[SOURCE: Reference [35].]

3.7.2.6
auditory critical bandwidth
bandwidth of a specified *auditory critical band* (3.7.2.5)

Note 1 to entry: Auditory critical bandwidth is expressed in hertz (Hz).

3.7.2.7
critical ratio
CR
mean-square sound pressure (3.1.3.1) of the *signal* (3.1.5.8) divided by the *mean-square sound pressure spectral density* (3.1.3.13) of the *noise* (3.1.5.9), for a just detectable pure tone signal masked by white noise

Note 1 to entry: Critical ratio is expressed in hertz (Hz).

Note 2 to entry: Critical ratio has dimensions of bandwidth. See Reference [40]. In Reference [31], it was postulated that when white noise (see ANSI/ASA S1.1–2013, 2.37) just masks a tone, the power of the noise in the *auditory critical band* (3.7.2.5) is equal to the power in the tone, in which case the critical ratio would be equal to the *auditory critical bandwidth* (3.7.2.6). However, in Reference [40], it was showed that the critical ratio obtained from noise-masked tone studies, with both human and nonhuman animal subjects, is not a good indicator of critical bandwidth.

Note 3 to entry: The mean-square sound pressure spectral density, $\left(\overline{p^2}\right)_f$, of white noise is independent of the bandwidth, δf, in the formula $\left(\overline{p^2}\right)_f = \delta\overline{p^2} / \delta f$, where $\delta\overline{p^2}$ is the contribution to the mean-square sound pressure from a given frequency band, and δf is the bandwidth of that frequency band.

Note 4 to entry: Critical ratio can be defined in terms of *sound particle velocity* (3.1.3.7) instead of sound pressure.

Note 5 to entry: The duration of the tone signal is assumed to be sufficiently long for the hearing threshold to be independent of that duration.

3.7.2.8
critical signal-to-noise ratio level
critical ratio level
CRL
L_{CR}
ten times the logarithm to the base 10 of the ratio of the *critical ratio* (3.7.2.7), R_c, to the specified reference value, $(R_c)_0$, in decibels

Note 1 to entry: In formula form, $L_{CR} = 10\log_{10}(R_c / (R_c)_0)$ dB.

Note 2 to entry: Critical ratio level is expressed in decibels (dB).

Note 3 to entry: The reference value for critical ratio level, $(R_c)_0$, is 1 Hz. The reference value shall be specified.

Note 4 to entry: The critical ratio level is equal to the difference between the masked *behavioural hearing threshold* (3.7.2.1) at the tonal frequency and the *mean-square sound pressure spectral density level* (3.2.1.10) of the noise at the same frequency.

3.7.2.9
hearing threshold shift
threshold shift
change in the *behavioural hearing threshold* (3.7.2.1) or *electrophysiological hearing threshold* (3.7.2.2)

Note 1 to entry: Hearing threshold shift is expressed in decibels (dB).

Note 2 to entry: An increase in behavioural hearing threshold or electrophysiological hearing threshold corresponds to a decrease in hearing sensitivity.

[SOURCE: ANSI/ASA S3.20-2015, 4.63, modified]

