Saturn

Developing Solutions for Underwater Radiated Noise

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SATURN Deliverable 2.3
SATURN Acoustical Terminology Standard

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Table of Contents

Figures

Tables

Executive Summary

This document is produced by Work Package 2 (WP2) 'Standardisation'. The purposes of WP2 are to develop and validate standardised methods to cost-effectively measure underwater radiated noise (URN) and to facilitate the assessment of impacts from underwater noise generated by shipping and boats. These purposes are achieved by harmonising terminology, metrics, and methodology for measurements and modelling, including particle motion.

The purpose of this terminology standard is to facilitate effective communication, especially inter-disciplinary communication, between physicists, biologists, and end users. Its scope is acoustical and bioacoustical terminology related to URN and the effects of vessel URN on aquatic life.

There is a need to distinguish between the properties of a sound field and those of a sound source that might contribute to the sound field. Properties of the sound field include sound pressure and sound exposure. Properties of the source include source level and sound power.

There is a need to distinguish between 'sound' and 'noise'. 'Noise' can mean unwanted or undesirable sound, and it can also refer to non-acoustic noise such as electrical or flow noise. When referring to underwater sound, the term 'sound' is preferred unless there is a special reason to use 'noise', for example when referring to the denominator in a signal-to-noise ratio, in the context of adverse effects of sound on aquatic life, or for a term of the trade such as 'radiated noise level' or 'underwater radiated noise'.

This standard (D2.3) builds on and is compatible with ISO 18405:2017. It considers five general categories of terms: general terminology, quantities expressed in decibels, bioacoustical terminology, vessel acoustics terminology, and sound mapping terminology.

1. Introduction

1.1. Background

1.1.1. WP2 'Standardised Methods to Facilitate Impact Assessment and Cost-effective URN Measurement'

The purposes of Work Package 2 (WP2) are to develop and validate standardised methods to cost-effectively measure underwater radiated noise (URN) and to facilitate the assessment of impacts from underwater noise generated by shipping and boats. These aims are achieved by harmonising terminology, metrics, and methodology for measurements and modelling, including particle motion.

We facilitate intra- and inter-project compatibility by developing harmonised acoustic metrics, test signals, and terminology. The harmonised terminology, built on the international standard ISO 18405:2017, facilitates effective communication and avoids misunderstandings by defining terms that characterise radiated sound from surface vessels, dose-response relationships, and the statistical distribution of the underwater sound field. The use of harmonised metrics and signals ensures that different researchers in the SATURN project can select characteristic ship sounds that are the same as those used by other researchers.

International standards exist for measuring URN from surface vessels in deep water (ISO 17208-1, ISO 17208-2). Sometimes a shallow-water measurement of URN is preferred because shallow-water sites tend to be more accessible than deep-water ones. However, the sound arriving at a receiver located near a surface vessel in shallow water depends not only on the vessel's characteristics but also on water depth and seabed composition (e.g., sand, mud, rock), making it necessary to compensate for bottom reflections. WP2 standardises URN measurements in shallow water by reviewing and testing existing URN procedures developed by classification societies and international standards, quantifying errors incurred when applying these in shallow water, and working with the International Organization for Standardization (ISO) to develop a shallow-water URN standard (ISO 17208-3). WP2 investigates the feasibility for cost-effective, on-board, URN monitoring and assess measurement uncertainties.

When measuring or modelling underwater sound, it is common to think in terms of sound pressure, but many aquatic animals sense the water motion associated with the sound rather than the pressure. WP2 will model the particle motion associated with surface vessels using competing theoretical approaches, comparing with available measurements, and visualising the sound field by producing maps of particle motion.

1.1.2. Task 2.1 'Standardisation'

The purpose of Task 2.1 is to develop standardised metrics, test signals, and terminology and to standardise URN characterisation in shallow water. Annex A describes some principles and related agreements used in the development of this SATURN standard.

1.1.3. Task 2.1.4 'Standardise Acoustical Terminology' and this Document

This document is the SATURN acoustical terminology standard. It is Deliverable 2.3, due in M45.

1.2. Objectives

The purpose of T2.1.4 is to facilitate effective communication, especially inter-disciplinary communication between physicists, biologists, and end users, whether internally between SATURN WPs or externally with other projects or organisations. This is achieved by developing standard terms and their definitions, which are to be adopted by all WPs of the SATURN project.

1.3. Scope

The scope of T2.1.4 is acoustical and bioacoustical terminology related to underwater radiated noise (URN) and the effects of vessel URN on aquatic life.

1.4. Approach

The definitions are based on consensus reached after multiple meetings between February 2021 and April 2024.

This standard was previously issued as a series of drafts during the SATURN project. At each iteration, feedback was sought from SATURN project partners on the proposed terms and their definitions.

2. Discussion of Selected Topics

The following three topics were selected for discussion in this section:

- The difference between source level and sound pressure level
- The difference between sound and noise
- The meaning of 'level of onset of biologically adverse effects' (LOBE)

2.1. Source and Receiver Properties

There is a need to distinguish clearly between the properties of a sound field and those of the sound sources that generate this sound field.

2.1.1. Properties of the Sound Field

Properties of the sound field can be derived from measurements or predictions of sound pressure and sound particle motion. Observed sound field properties depend on the location of sources and receivers and on the environment in which they are determined.

The following quantities are examples of properties of the sound field:

- Sound pressure
- Sound exposure
- Sound pressure kurtosis
- Sound particle acceleration
- Sound particle velocity
- Sound pressure level
- Sound intensity

2.1.2. Properties of Sound Sources

Properties of sound sources provide a characterisation independent of the environment and receiver locations.

The following sections describe properties of the source.

2.1.2.1. Source Factor

In underwater acoustics, sound sources are commonly characterised in terms of the far-field sound pressure that would have been radiated by the source into a hypothetical infinite uniform lossless medium (of the same density and sound speed as the real medium at the location of the source). In such an environment, the product of mean-square sound pressure (in the far field) and the square of the distance to the source, called source factor, is invariant and characterises the source.

2.1.2.2. Source Level

Source level (SL, symbol L_S) is ten times the logarithm to the base 10 of the ratio of this source factor to a specified reference value, in decibels. Source level is sometimes incorrectly defined, described, and understood as the sound pressure level (SPL, symbol L_p) at the source or at 1 m from the source (see Figure 1). However, source level is a property of the source, not of the sound field.

The source level varies with direction, with the highest value in the axial direction of a source with axial symmetry sometimes referred to as "axial source level". [1] In a free field, SL (re 1 μPa^2 m^2) in a specified direction can be calculated from a far-field measurement of SPL (re 1 μPa^2) at range r by adding propagation loss (re 1 m^2) (PL, symbol N_{PL}), evaluated in the same direction, i.e.,

$$L_S(\theta) = L_p(r,\theta) + N_{\mathrm{PL}}(r,\theta)\,, \tag{1}$$

where θ represents the specified direction in elevation and azimuth. Equation (1) is valid for any distance r in the acoustic far field. If the source is small enough and far enough from the nearest boundary for a distance r = 1 m to be in its acoustic far field, the equation becomes (ignoring the angle dependence)

$$L_S = L_p(1\ \mathrm{m}) + N_{\mathrm{PL}}(1\ \mathrm{m})\,. \tag{2}$$

Equation (2) implies that, even though SPL at 1 m and SL are conceptually different quantities, the first being a property of the sound field, while the second is a property of the source, there are circumstances in which they can be numerically equal if PL(1 m) = 0 dB.

In turn, PL at 1 m is equal to zero if the source and receiver are far from the nearest boundary and absorption is negligible. Annex B quantifies how far from a boundary the source would need to be. This reasoning does not apply to ships. Instead, it applies to sources that are small on a scale of 1 m.

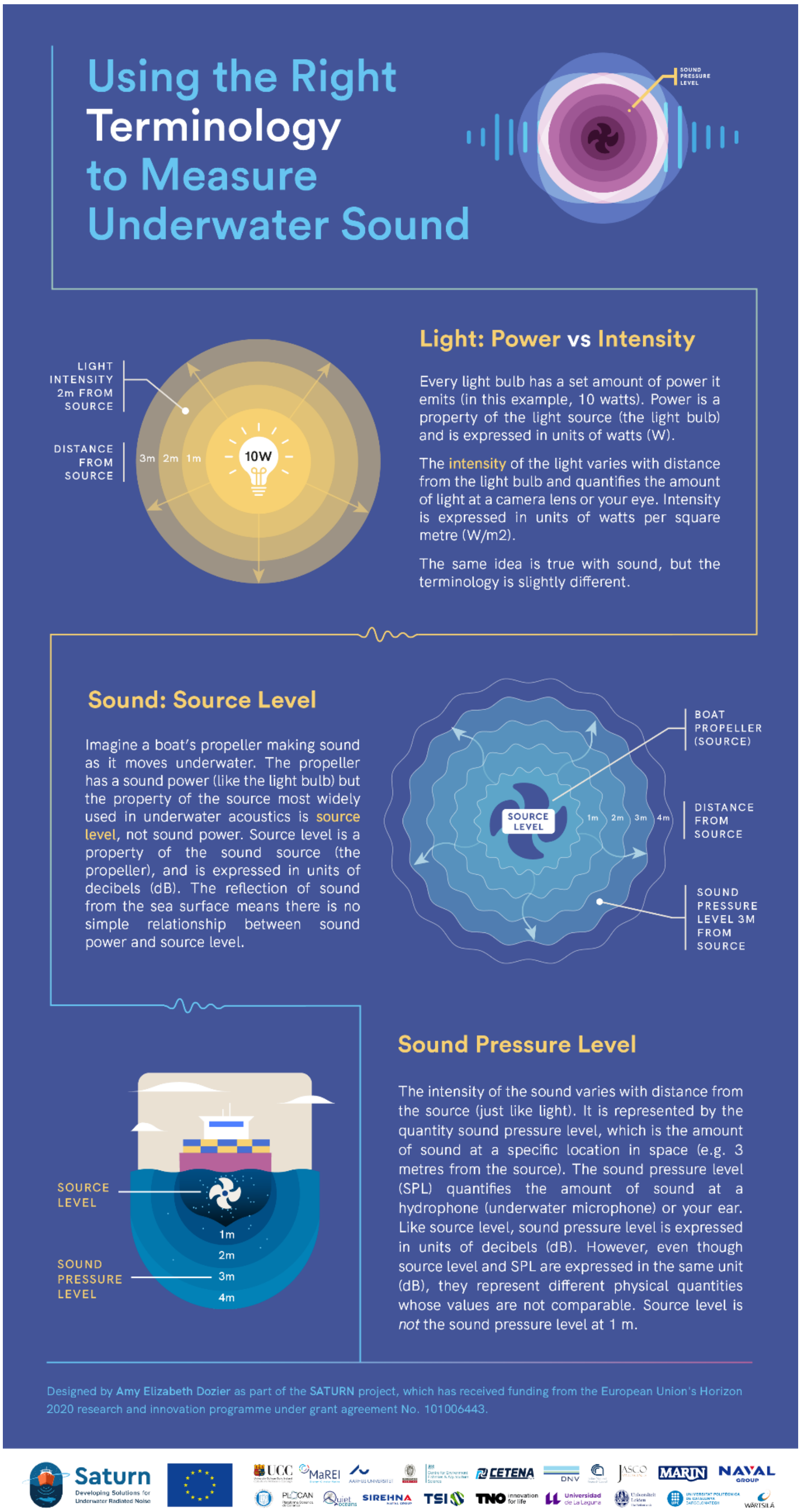

Figure 1. Poster: 'Using the Right Terminology in Underwater Acoustics'.The purpose of this graphic is to clarify that source level (SL) is a property of the source (like the power of a light bulb), while sound pressure level (SPL) is a property of the sound field (like the intensity of light surrounding the bulb). The units of intensity are watts per square metre (W/m²).

2.2. Sound and Noise

Although 'sound' and 'noise' are sometimes used interchangeably, this is inappropriate because they are not synonymous. 'Noise' can mean unwanted or undesirable sound and can also refer to non-acoustic noise such as electrical or flow noise. Further, the same sound (say a dolphin click) can be a signal from the perspective to one listener (say, a conspecific), but noise to another (a human sonar operator). To summarise, while "sound" is always applicable, applicability of "noise" depends on context and perspective. For this reason, when referring to underwater sound, SATURN prefers the term 'sound' unless there is a special reason to use 'noise', for example when referring to the denominator in a signal-to-noise ratio, or when the sound causes detrimental effects on aquatic organisms.

2.3. Level of Onset of Biologically Adverse Effects

2.3.1. TG Noise Definition

The level of onset of biologically adverse effects[1] (LOBE) is a concept introduced by TG Noise 2023, which defines LOBE as "noise level at which individual animals start to have adverse effects that could affect their fitness".

Recognising that the TG Noise definition of LOBE is the outcome of multiple viewpoints, SATURN has identified and discussed the following questions:

- What is "noise level"?
- What is meant by "start to have"?
- What is meant by "adverse effects"?
- What is meant by "could affect their fitness"?

2.3.2. What is "Noise Level"?

The definition of LOBE from TG Noise 2023 includes the clarifying remark "For continuous noise D11C2, noise level that can be spatially averaged sound pressure level or excess level". SATURN interprets the term "noise level" to mean "underwater noise metric" in the sense of Table 5.

2.3.3. What is Meant by "Start to Have"?

In the phrase "individual animals start to have adverse effects", the word "have" is interpreted as meaning "experience". Further, interpretations of the phrase "[level] at which individual animals start to [experience] adverse effects" that were considered include "[level] at which the probability of an adverse effect of noise exceeds some value" and "[level] at which an adverse effect is considered to occur with some probability".

2.3.4. What is Meant by "Adverse Effects"?

The definition of LOBE from TG Noise 2023 includes the clarifying remark: "Examples of adverse effect include behavioural disturbance, stress, reduced communication space, and temporary or permanent habitat loss."

[1] An equivalent alternative name also used by TG Noise 2023 is 'level of onset of biological adverse effect'.

2.3.5. What is Meant by "Could Affect Their Fitness"?

The definition of LOBE from TG Noise 2023 includes the clarifying remark: "Fitness is the ability of an individual to successfully reproduce relative to other individuals in the population. If an animal experiences a loss in fitness, it means that its reproductive output is affected negatively, even if only slightly."

2.3.6. Remark

The authors of the present report did not reach a consensus on the interpretation of the TG Noise definition of LOBE. The onus is on individual authors using this term to provide a definition of what they mean by it.

3. Terms and Definitions

This document considers five general categories of terms: general acoustical terminology (Section 3.1), quantities usually expressed in decibels (Section 3.2), bioacoustical terminology (Section 3.3), vessel acoustics terminology (Section 3.4), and sound mapping terminology (Section 3.5). Many terms are defined by ISO 18405:2017 (Section 3.6) [2].

3.1. General Acoustical Terminology

Tables 1 and 2 list terms of general use.

Table 1. General acoustical terminology: Concepts

Term	Definition
broadband sound	sound that is spread across a wide range of frequencies **remark:** This is a relative term, not a quantitative one. If used to describe a quantity (e.g., broadband sound pressure level), then bandwidth shall be specified.
narrow-band sound	sound that is concentrated in a narrow range of frequencies **remarks:** This is a relative term, not a quantitative one. If used to describe a quantity (e.g., narrow-band sound pressure level), then bandwidth shall be specified. If a narrow-band sound is generated by a resonator, its bandwidth can be quantified in terms of the resonance’s Q factor, defined as the ratio of the resonance frequency to the bandwidth (full-width at half maximum).
pure tone	sound with a sinusoidal waveform **remarks:** A pure tone has infinite duration. It does not exist in nature. In psychoacoustics, the term ‘pure tone’ is used to describe human perception of a tonal sound. For example, Roederer [3]: “when a sound causes a simple harmonic motion of the eardrum with constant characteristics (frequency, amplitude, phase), we hear what is called a pure tone”.
complex tone	combination of two or more pure tones **remark:** A complex tone can be formed by combining a pure tone with its harmonics. Each harmonic is a pure tone.
tonal sound **abbreviation:** tonal	sound characterised by a predominant single-frequency component **remarks:** A tonal sound may have a time-varying amplitude or frequency. A tonal sound may have a finite (non-zero) bandwidth. A tonal sound may have harmonics. See also ‘pure tone’.

Term	Definition
complex tonal sound **abbreviation:** complex tonal	sound characterised by two or more predominant single-frequency components
impulsive sound	sound characterised by one or more brief bursts of sound pressure **remarks:** This definition of 'impulsive sound' is based on ISO 1996-1:2016 [4] ('sound characterized by brief bursts of sound pressure'). Impulsive sound is a relative term. The duration of the impulsive sound should be specified. The classification of certain sounds as impulses is done within two different regulatory frameworks in slightly different ways. - In relation to the MSFD, TG Noise defines "*impulsive sound*" as "*a sound for which the effective time duration of individual sound pulses is less than ten seconds and whose repetition time exceeds four times this effective time duration. In this interpretation, it is proposed that all sounds of duration less than 10 s that are not repeated are also impulsive*". - In relation to injury from noise exposure, [5, p42] writes: "*Harris [6] proposed a measurement-based distinction of pulses and nonpulses that is adopted here in defining sound types. Specifically, a ≥ 3-dB difference in measurements between continuous and impulse [sound level meter] settings indicates that a sound is a pulse; a < 3-dB difference indicates that a sound is a nonpulse. We note the interim nature of this distinction for underwater signals and the need for an explicit distinction and measurement standard such as exists for aerial signals [7].*"
continuous sound	sound for which the mean square sound pressure is approximately constant for a specified range of averaging times, within a specified time window **remark:** This is a relative term. The timescale over which the averaging times are varied should be specified. The maximum change in mean square sound pressure should be specified.
transient sound	sound with a start and an end within a specified time window
transient source	source emitting a transient sound
anthropogenic sound	sound emitted by human activity or a man-made source **remarks:** Surface vessels emit anthropogenic sound. Use of 'underwater noise' as a synonym of 'anthropogenic sound' is discouraged.

Term	Definition
natural sound	sound other than anthropogenic sound **remark:** Natural sound is sound emitted by biotic or geophonic sources (hereafter referred to as natural sources). Examples of natural sound sources include marine mammal vocalisations, fish choruses, lightning, wind, and earthquakes.
biotic sound	sound resulting from a living organism **remark:** Biotic sound (biophony) is an example of natural sound.
acoustic near field	spatial region between a source and its acoustic far field **remarks:** See 'acoustic far field' (ISO 18405, entry 3.3.1.1). In the acoustic near field, the direct-path sound pressure amplitude does not vary inversely with distance from the source. Most sources have a hydrodynamic and an acoustic near field. However, point sources only have a hydrodynamic near field.
hydrodynamic near field	region close to a sound source within which the particle velocity and the pressure are nearly in quadrature Note 1 to entry: Two sinusoidal signals are said to be in quadrature when they differ in phase by $\pi/2$. Note 2 to entry: Most sources have a hydrodynamic and an acoustic near field. However, point sources only have a hydrodynamic near field. Note 3 to entry: See also Morse and Ingard [8, p311] . **source**: adapted from Morfey [9] (see also de Jong et al. [10]) **remarks**: Morfey [9] further states: "Typically, in [the hydrodynamic near field] the peak particle velocity is much greater than $p_{\text{max}}/\rho c$, where p_{max} is the peak acoustic pressure and ρ, c are the fluid density and sound speed. The hydrodynamic near field of a compact source or scattering object typically extends a distance of $\lambda/4$ from the source, where λ is a typical acoustic wavelength. Within this region the motion is effectively incompressible. large radiating surface can also have a hydrodynamic near field, if its surface motion is dominated by wavenumber components larger than the acoustic wavenumber; the field within a distance $\lambda/4$ from the surface is then mainly evanescent."

Term	Definition
cavitation	process of formation of the vapour phase of a liquid when it is subjected to reduced pressure at constant ambient temperature **remark:** In general, a liquid is said to cavitate when vapour bubbles are observed to form and grow as a consequence of pressure reduction. **based on**: International Towing Tank Conference (ITTC) Dictionary of Hydrodynamics [11]
sound emergence	increase in the total sound in a given situation that results from the introduction of some specific sound **source**: ISO 1996-1:2016(en)
cavitation sound	sound caused by cavitation **remark**: The sound made by a snapping shrimp to stun its prey is an example of cavitation sound.
flow-induced sound	sound generated by fluid motion **remarks:** An example of fluid motion is the flow of water around a surface vessel. The flow of water around a surface vessel can cause flow-induced sound.
structure-borne sound	sound that propagates via elastic deformation in a solid structure

Table 2. General acoustical terminology: Quantities (excluding quantities usually expressed in decibels).

Term	Definition
signal-to-noise ratio **symbol:** R_{SN}	ratio of signal power to noise power Note 1 to entry: The signal-to-noise power ratio depends on the position in the processing chain, or in the propagation medium, at which it is determined. Note 2 to entry: The position in the processing chain at which the signal-to-noise power ratio is determined shall be specified. Note 3 to entry: Reference to ‘signal’ in ‘signal-to-noise ratio’ excludes noise. **source**: Haykin [12, p3]
signal plus noise-to-noise ratio	ratio of signal plus noise power to noise power **remark**: This term is defined to facilitate a clear distinction between signal-to-noise ratio and signal plus noise-to-noise ratio.

Term	Definition
rise time **unit:** s	time a sound pressure signal takes to rise from 10 to 90 % of its maximum absolute value for sound pressure **remark:** See Kastelein et al. [13] and Lathi [14].
sound pressure propagation factor **unit:** Pa^2 / $(Pa\ m)^2$	synonym of *propagation factor*
sound particle velocity propagation factor **synonym:** particle velocity propagation factor **unit:** $(m/s)^2$ / $(Pa\ m)^2$	mean-square sound particle velocity at a specified position divided by the source factor in a specified direction
sound particle acceleration propagation factor **synonym:** particle acceleration propagation factor **unit:** $(m/s^2)^2/(Pa\ m)^2$	mean-square sound particle acceleration at a specified position divided by the source factor in a specified direction
scaled acoustic impedance	ratio of the modulus of the specific acoustic impedance to the characteristic acoustic impedance

Term	Definition
free-field voltage sensitivity **abbreviation:** FFVS **symbol:** $M_\mathrm{f}(f)$ **unit:** V/Pa	<of a hydrophone> quotient of the Fourier transform of the hydrophone open-circuit voltage signal to the Fourier transform of the acoustic pressure signal, for specified frequency and specified direction of plane wave sound incident on the position of the reference centre of the hydrophone in the undisturbed free-field if the hydrophone was removed Note 1 to entry: In formula form, $$M_\mathrm{f}(f) = \frac{\int_{-\infty}^{+\infty} \exp(-2\pi \mathrm{i} f t) v(t) \mathrm{d}t}{\int_{-\infty}^{+\infty} \exp(-2\pi \mathrm{i} f t) p(t) \mathrm{d}t},$$ where $v(t)$ is the hydrophone open-circuit voltage and $p(t)$ is the sound pressure. Note 2 to entry: Free-field receive sensitivity is expressed in volt per pascal ($\mathrm{V\ Pa^{-1}}$). Note 3 to entry: The hydrophone free-field receive sensitivity is a complex-valued parameter. The modulus of the free-field receive sensitivity of a hydrophone is expressed in units of volt per pascal, V·Pa^{-1}. The phase angle is the argument of the sensitivity and represents the phase difference between the hydrophone electrical voltage and the sound pressure. The unit of phase angle is the radian. Note 3 [sic] to entry: The term “response” is sometimes used instead of “sensitivity”. **source:** IEC 60565-1
sensor sensitivity to pressure **unit:** V/Pa	modulus of the free-field voltage sensitivity **remark:** Sensor sensitivity to pressure is used in the definition of ‘sound pressure calibration factor’.
sound pressure calibration factor **unit:** Pa/V	reciprocal of the sensor sensitivity to pressure at a specified frequency **remark:** The sound pressure calibration factor is sometimes stated as an average over frequency.

Term	Definition
free-field voltage acceleration sensitivity **symbol:** $M_\mathrm{a}(f)$ **unit:** V/(m s⁻²)	<of an accelerometer> quotient of the Fourier transform of the open-circuit voltage signal to the Fourier transform of the sound particle acceleration signal, for specified frequency and specified direction of plane wave sound incident on the position of the reference centre of the accelerometer in the undisturbed free-field if the accelerometer was removed Note 1 to entry: In formula form, $$M_\mathrm{a}(f)=\frac{\int_{-\infty}^{+\infty}\exp(-2\pi\mathrm{i}ft)v(t)\mathrm{d}t}{\int_{-\infty}^{+\infty}\exp(-2\pi\mathrm{i}ft)a(t)\mathrm{d}t},$$ where $v(t)$ is the hydrophone open-circuit voltage and $a(t)$ is the magnitude of the sound particle acceleration. Note 2 to entry: The accelerometer free-field voltage acceleration sensitivity is a complex-valued parameter.
sensor sensitivity to acceleration **unit:** V/Pa	modulus of the free-field voltage acceleration sensitivity **remark**: Sensor sensitivity to acceleration is used in the definition of ‘sound particle acceleration calibration factor’.
sound particle acceleration calibration factor **unit:** (m s⁻²)/V	reciprocal of the sensor sensitivity to acceleration at a specified frequency **remark**: The sound particle acceleration calibration factor is sometimes stated as an average over frequency.
source to sound pressure factor **unit:** (Pa² m²)/ Pa²	ratio of source factor to mean-square sound pressure **remarks:** The sound pressure can be measured by a microphone, a hydrophone or a “pressure sensor”. Microphones and hydrophones are pressure sensors. However, for the purpose of the SATURN project, the term “pressure sensor” refers to a transducer attached to the hull of a vessel with the purpose of measuring the pulsations around the propeller.

Term	Definition
mean-square vibratory velocity component **unit:** m^2/s^2	integral over a specified time interval of the square of a specified component of the vibratory velocity, divided by the duration of the time interval, for a specified frequency range Note 1 to entry: In formula form, $$\overline{u_i^2} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} u_i^2(t)\ \mathrm{d}t\ ,$$ where $u_i(t)$ is the vibratory velocity component, and t_1 and t_2 are the start and end times, respectively. Note 2 to entry: Mean-square vibratory velocity component is expressed in units of (metre per second) squared [(m/s)^2]. **source:** based on entry 3.1.3.3 of ISO 18405:2017
mean-square vibratory velocity magnitude **unit:** m^2/s^2	integral over a specified time interval of the square of the magnitude of the vibratory velocity, 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 vibratory velocity, and t_1 and t_2 are the start and end times, respectively. Note 2 to entry: Mean-square vibratory velocity magnitude is expressed in units of (metre per second) squared [(m/s) ^{2}]. Note 3 to entry: The square root of the mean-square vibratory velocity magnitude is a field quantity known as the root-mean-square vibratory velocity. This field quantity may be denoted u_{rms}. **source:** based on entry 3.1.3.3 of ISO 18405:2017
mean-square vibratory acceleration component **unit:** m^2/s^4	integral over a specified time interval of the square of a specified component of the vibratory acceleration, divided by the duration of the time interval, for a specified frequency range Note 1 to entry: In formula form, $$\overline{a_i^2} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a_i^2(t)\ \mathrm{d}t\ ,$$ where $ai(t)$ is the vibratory acceleration component, and t_1 and t_2 are the start and end times, respectively. Note 2 to entry: Mean-square vibratory acceleration component is expressed in units of (metre per second) squared [(m/s)^2]. **source:** based on entry 3.1.3.3 of ISO 18405:2017

Term	Definition
mean-square vibratory acceleration magnitude **unit:** m²/s⁴	integral over a specified time interval of the square of the magnitude of the vibratory acceleration, 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 vibratory acceleration, and t_1 and t_2 are the start and end times, respectively. Note 2 to entry: Mean-square vibratory acceleration magnitude is expressed in units of (metre per second squared) squared [(m/s²)²]. Note 3 to entry: The square root of the mean-square vibratory acceleration magnitude is a field quantity known as the root-mean-square vibratory acceleration. This field quantity may be denoted a_{rms}. **source**: based on entry 3.1.3.3 of ISO 18405:2017
source to vibratory acceleration factor **unit:** (Pa² m²)/ (m²/s⁴)	ratio of source factor to mean-square vibratory acceleration magnitude

3.2. Quantities Expressed in Decibels

In underwater acoustics, physical quantities such as sound power or squared sound pressure are often converted to levels and expressed in decibels by summing or averaging over time, dividing by a standard reference value, taking a base-10 logarithm, and multiplying by 10. The decibel is a unit of logarithmic power ratio.

For example, the SI unit of power, and therefore of sound power, is the watt (W). The reference value for sound power is one picowatt (1 pW = 10^{-12} W), meaning that a sound power level of 0 dB corresponds to a sound power of 1 pW. Adding 10 dB corresponds to multiplying the power by 10, which means that a sound power level of 10 dB corresponds to a sound power of 10 pW, while 120 dB corresponds to 10^{12} pW = 1 W. The shorthand 'dB re 1 pW' is sometimes used to indicate a value of sound power level expressed in dB with a reference sound power of 1 pW.

The SI unit of pressure, and therefore of sound pressure, is the pascal (Pa). The reference value of sound pressure in water is one micropascal (1 μPa = 10^{-6} Pa), corresponding to a mean-square sound pressure of one micropascal squared (1 μPa²). This means that a sound pressure level (with reference to 1 μPa²) of 0 dB corresponds to a mean-square sound pressure of 1 μPa². Adding 10 dB corresponds to multiplying the mean-square sound pressure by 10, which means that a sound pressure level (with reference to 1 μPa²) of 10 dB corresponds to a mean-square sound pressure of 10 μPa², while 120 dB corresponds to 10^{12} μPa² = 1 Pa². The shorthand 'dB re 1 μPa' is sometimes used to indicate a value of mean-square sound pressure level expressed in dB with a reference sound pressure of 1 μPa.

The mathematical identity

$$10 \log_{10} X = 20 \log_{10} X^{1/2} \tag{3}$$

results in equivalence between the alternative definitions

$$L_p = 10 \log_{10} \frac{\overline{p^2}}{p_0^2} \text{ dB} \tag{4}$$

and

$$L_p = 20 \log_{10} \frac{\left(\overline{p^2}\right)^{1/2}}{p_0} \text{ dB} . \tag{5}$$

Thus, the reference value for sound pressure level can be stated either as $p_0 = 1\ \mu\text{Pa}$ or $p_0^2 = 1\ \mu\text{Pa}^2$. The two statements are mathematically equivalent.

Precisely the same reasoning applies to source level, except the mean-square sound pressure is replaced by the source factor: A source level of 0 dB corresponds to a source factor of 1 μPa^2 m^2. Adding 10 dB corresponds to multiplying the power by 10, which means that a source level of 10 dB corresponds to a source factor of 10 μPa^2 m^2, while 120 dB corresponds to 10^{12} μPa^2 m^2 = 1 Pa^2 m^2. The shorthand 'dB re 1 μPa m' is sometimes used to indicate a value of source level expressed in dB with a reference sound pressure of 1 μPa and reference distance of 1 m.

Historically, the shorthand 'X dB re 1 μPa @ 1 m' has been used as an alternative to 'X dB re 1 μPa m', giving the misleading impression that the sound pressure level at 1 m from the source is X dB re 1 μPa. Source level is not sound pressure level at 1 m, although they can be equal in numerical value (Section 2.1).

Table 3 lists definitions of quantities usually expressed in decibels.

Table 3.General acoustical terminology: Quantities usually expressed in decibels.

Term	Definition
steady state source level **abbreviation:** SSSL **unit**: dB **reference value**: 1 μPa² m²	source level measured over a temporal observation window that is long enough for the source level to be independent of the duration of the window
steady state sound pressure level **abbreviation:** SSSPL **unit**: dB	for specified sources, sound pressure level that would arise (at position x) if the specified sources were stationary at their actual positions, but with the same steady state source level that the sources would have had if they had remained moving at their actual speed **remarks**: SSSPL is a hypothetical construct. It is not physically realisable. The term SSSPL applies to various anthropogenic and natural sources, including ships and wind. The steady state sound pressure level can be spatially averaged. The spatial observation window shall be specified.
excess level **unit:** dB	SSSPL (for all ambient sound) minus SSSPL (for natural ambient sound) at the same position and time **remark**: Sometimes a statistic of excess level, such as the median in space and time, is represented on a map.
sound pressure propagation loss **unit:** dB **reference value**: 1 m⁻²	synonym of propagation loss
sound particle velocity propagation loss **synonym:** particle velocity propagation loss **symbol:** $N_{PL,u}(\boldsymbol{x})$ **unit:** dB **reference value**: 1 (nm/s)²/(μPa m)²	difference between source level, LS, in a specified direction and mean-square sound particle velocity level, $Lu(\boldsymbol{x})$, at a specified position Note 1 to entry: In formula form, $N_{PL,u}(\boldsymbol{x}) = L_S - L_u(\boldsymbol{x})$. Note 2 to entry: The reference value shall be specified. Note 3 to entry: The averaging time and frequency range shall be specified. Note 4 to entry: Sound particle velocity propagation loss applies to a statistically stationary sound source. Note 5 to entry: Sound particle velocity propagation loss is equal to $10\log10[F_{p,u}^{-1}/((\mu Pa\ m)^2/1\ (nm/s)^2)]$ dB, where $F_{p,u}$ is the sound particle velocity propagation factor.

Term	Definition
sound particle acceleration propagation loss **synonym:** particle acceleration propagation loss **symbol:** $N_{\mathrm{PL,a}}(\boldsymbol{x})$ **unit:** dB **reference value:** 1 (μm/s²)²/(μPa m)²	difference between source level, L_S, in a specified direction and mean-square sound particle acceleration level, $L_a(\boldsymbol{x})$, at a specified position Note 1 to entry: In formula form, $N_{\mathrm{PL,a}}(\boldsymbol{x}) = L_S - L_a(\boldsymbol{x})$. Note 2 to entry: The reference value shall be specified. Note 3 to entry: The averaging time and frequency range shall be specified. Note 4 to entry: Sound particle acceleration propagation loss applies to a statistically stationary sound source. Note 5 to entry: Sound particle acceleration propagation loss is equal to $10\log10[F_{\mathrm{p,a}}^{-1}/((\mu\mathrm{Pa\ m})^2/1\ (\mu\mathrm{m/s}^2)^2)]$ dB, where $F_{\mathrm{p,a}}$ is the *sound particle acceleration propagation factor*.
level of X **unit**: dB	ten times the base-10 logarithm of the ratio of a power quantity X to a specified reference value X_0, multiplied by 1 decibel In equation form, the level of X is given by $$L_X = 10\log_{10}\frac{X}{X_0}\ \mathrm{dB}\,.$$ **remarks:** The multiplication by 1 dB is an essential part of the definition. Without it, the defining equation would become $L_X = 10\log_{10}\frac{X}{X_0}$. If this (incorrect) definition were applied to a ratio X/X_0 equal to 100, the resulting level would be $L_X = 20$, when the correct value is $L_X = 20$ dB. ISO 18405 addresses this issue by using the words “in decibels” instead of “multiplied by 1 decibel”. The reason for preferring “multiplied by 1 decibel” here is that the words “in decibels”, in normal use of English, mean divided by 1 dB, when here the intended meaning is multiplied by 1 dB. The wording “multiplied by 1 dB” makes this explicit.

Term	Definition
vibratory velocity component level **unit:** dB **reference value:** (1 nm/s)^2 or (50 nm/s)^2	level of a specified mean-square vibratory velocity component In equation form, $$L_{u,i} = 10 \log_{10} \frac{u_i^2}{u_0^2} \text{ dB},$$ where u_i is the RMS vibratory velocity component Note 1 to entry: In ISO 1683, two reference values for the velocity level are mentioned: u_0 = 10^{-9} m/s and 5 × 10^{-8} m/s. The latter is intended for cases of airborne and structure vibration generated sound and is therefore used in ISO/TS 7849-1 and ISO/TS 7849-2. A choice of u_0 = 10^{-9} m/s results in a vibratory velocity level that is 34 dB higher than the level used in both parts of ISO/TS 7849. **source:** adapted from ISO 3740:2019
vibratory velocity magnitude level **unit:** dB **reference value:** (1 nm/s)^2 or (50 nm/s)^2	level of the mean-square vibratory velocity magnitude In equation form, $$L_u = 10 \log_{10} \frac{u^2}{u_0^2} \text{ dB},$$ where u is the RMS magnitude of the vibratory velocity Note 1 to entry: For airborne and structure vibration generated sound, the reference value u_0 = 50 nm/s has the property that it leads, together with p_0 = 2 × 10^{-5} Pa, to the reference value of the intensity level I_0 = 1 × 10^{-12} W/m^2 and to a characteristic impedance of air of p_0/u_0 = 400 Pa·s/m. Note 2 to entry: In ISO/TS 7849-1, the vibratory velocity level is applied as A-weighted vibratory velocity level, L_{uA}, by substituting u^2 for the A-weighted RMS u_A^2 in ISO/TS 7849-1:2009, Formula (6). Note 3 to entry: In ISO 1683, two reference values for the velocity level are mentioned: u_0 = 10^{-9} m/s and 5 × 10^{-8} m/s. The latter is intended for cases of airborne and structure vibration generated sound and is therefore used in ISO/TS 7849-1 and ISO/TS 7849-2. A choice of u_0 = 10^{-9} m/s results in a vibratory velocity level which is 34 dB higher than the level used in both parts of ISO/TS 7849. **source:** adapted from ISO 3740:2019
vibratory acceleration component level **unit:** dB **reference value:** (1 µm/s^2)^2	level of a specified mean-square vibratory acceleration component In equation form, $$L_{a,i} = 10 \log_{10} \frac{a_i^2}{a_0^2} \text{ dB},$$ where a_i is the RMS vibratory acceleration component

Term	Definition
vibratory acceleration magnitude level **unit:** dB **reference value:** $(1\ \mu m/s^2)^2$	level of the mean-square vibratory acceleration magnitude In equation form, $L_a = 10 \log_{10} \frac{a^2}{a_0^2}$ dB , where a is the RMS magnitude of the vibratory acceleration

3.3. Bioacoustical Terminology

Tables 4 and 5 list terms most likely to be used in Work Package 3 (WP3).

Table 4. Bioacoustical terminology: General concepts and quantities

Term	Definition
animal signal	sound generated by an animal that serves to communicate information **remark**: Communication is evident when an animal signal of one individual has an effect on the behaviour of another (e.g., acoustic signals generated during territorial displays or courtship that deter competitors or attract mates).
acoustic cue	sound that can be exploited by an animal to gather information about its environment, except an animal signal **remark:** For example, sounds made by prey that attract predators or sounds generated by the surf that make animals move towards or away from the coast.
acoustic habituation	waning of a response to a sound after repeated or continuous exposure to that same sound **remark:** This definition of acoustic habituation is based on Bejder et al. [15], which cites Thorpe [16, p61].
acoustic sensitisation	increased behavioural responsiveness over time when an animal learns that a repeated or ongoing acoustic stimulus has significant consequences for the animal **remark:** This definition of acoustic sensitisation is from Bejder et al. [15], which cites Richardson et al. [17, p543].
acoustic tolerance	capacity to endure exposure to sound without changing the quality or quantity of baseline behavioural or metabolic activity **remarks:** Metabolic activity includes stress physiology. One can distinguish between behavioural acoustic tolerance and physiological acoustic tolerance. Capturing food in the presence of sound can be associated with behavioural acoustic tolerance. The presence of acoustic tolerance implies absence of acoustic disturbance and vice versa.

Term	Definition
acoustic disturbance	changes in the quality or quantity of baseline behavioural or physiological response to sound **remarks:** One can distinguish between behavioural acoustic disturbance and physiological acoustic disturbance. The presence of acoustic disturbance implies absence of acoustic tolerance. While behavioural acoustic disturbance also implies physiological acoustic disturbance, the other way around is not necessarily true. A behavioural or physiological change in quality or quantity of the baseline activity means there is an effect but not necessarily an impact.
communication space	region centred on a vocalising animal within which conspecific communication is possible **remark**: The sonar equation can be used to calculate communication space. Information required includes the sender's call structure, ambient noise, and propagation conditions. In low noise conditions, the communication space also depends on the animal's hearing threshold and critical ratio.
listening space	region surrounding a listener within which a biologically important signal can be detected **remark**: The sonar equation can be used to calculate listening space. Information required includes the source properties, ambient noise, and propagation conditions. In low noise conditions, the listening space also depends on the listener's hearing threshold and critical ratio.
interclick interval **synonym**: click interval **abbreviation**: ICI **units**: s	time between the peaks of consecutive clicks Note 1 to entry: entry 3.23 of ISO 14708-2:2019(en) defines "pulse interval" as "interval between equivalent points of two consecutive pulses". **source**: adapted from Miller et al. [18]

Table 5. Bioacoustical terminology: Dose and response

Term	Definition
dose	quantity characterising the magnitude of a stimulus **remark**: In underwater acoustics, the dose is typically an underwater noise metric.
biological response	behavioural or physiological reaction to a stimulus
dose-response curve **synonym**: dose-effect curve	graph or table of a specified quantity characterising a biological response versus a specified dose **remarks:** Dose-response curve is also known as dose-reaction curve. The response can be behavioural or physiological. Examples of acoustical quantity are SEL, SPL, and kurtosis. Examples of quantities used to characterise biological response are TTS, PTS, swimming speed, stress hormone level, and reaction time. The dose-response relationship is the concept that is quantified by a dose-response curve.
response threshold **synonym**: effect threshold	dose resulting in a specified biological response with a specified probability **remark:** See dose-response curve.
underwater sound metric **abbreviation**: USM	specified quantitative characteristic of underwater sound
underwater noise metric **abbreviation**: UNM	specified quantitative characteristic of underwater sound that is related to a potential adverse effect on marine life
underwater noise limit value **abbreviation**: UNLV	value of a specified UNM, as determined by an appropriate authority, above which management action is considered **remarks:** UNLV may be different for different types of noise, different surroundings, and different noise sensitiveness of marine life. UNLV may also be different for existing situations and for new situations. UNLV is not presently used by TG Noise in the advice about the threshold values.

3.4. Vessel Acoustics Terminology

Terms most likely to be used in Work Package 4 (WP4) are listed here. Concepts and quantities are listed in Table 7 and levels are listed in Table 8. It follows from Table 8 that the radiated noise level (RNL) in deep water can be written:

$$L_{\mathrm{RN}} = 10\log_{10}\frac{\overline{p^2}}{p_0^2}\ \mathrm{dB} + 10\log_{10}\frac{d^2}{d_0^2}\ \mathrm{dB}\,, \tag{6}$$

where d is the distance at which the mean-square sound pressure $\overline{p^2}$ is measured. Equivalently,

$$L_{\mathrm{RN}} = 10\log_{10}\frac{\overline{p^2}d^2}{(p_0 d_0)^2}\ \mathrm{dB} \tag{7}$$

and the corresponding reference value for RNL is $(p_0 d_0)^2$ = 1 μPa²·m².

Other URN metrics are sometimes calculated as:

$$L_{\mathrm{URN},X} = 10\log_{10}\frac{\overline{p^2}}{p_0^2}\ \mathrm{dB} + \frac{X}{2}\log_{10}\frac{d^2}{d_0^2}\ \mathrm{dB} \tag{8}$$

and

$$L_{\mathrm{URN},X} = 10\log_{10}\frac{\overline{p^2}d^{X/10}}{p_0^2 d_0^{X/10}}\ \mathrm{dB}\,. \tag{9}$$

The reference value of $L_{\mathrm{URN},X}$ is $p_0^2 d_0^{X/10}$ = 1 μPa² m$^{X/10}$.

Radiated noise level (RNL) is closely related to source level (ISO 18405:2017). ISO/DIS 17208-3 clarifies the difference in their intended use (Table 6).

Table 6. Intended use of radiated noise level (RNL) and source level (SL)

Metric	Preferred use
RNL	The intended use of radiated noise level is to show compliance with contract requirements or criteria, for comparison of one ship to another ship, to enable periodic signature assessments, and for research and development. **source**: ISO/DIS 17208-3
SL	The intended use of source level, with associated source depth, is to perform far-field sound predictions such as needed for environmental impact studies or for creating underwater sound contour maps. **source**: ISO/DIS 17208-3 **remark:** Source level is incomplete unless accompanied by the associated source depth.

The reference value of vibratory velocity can be 1 nm/s or 50 nm/s. When stated in decibels, two values of vibratory velocity level may be stated, one with each reference value. The international standard reference value of vibratory velocity is 1 nm/s (ISO 1683:2015). Therefore, if a reference value of 50 nm/s is used, a conversion to a reference value of 1 nm/s should be provided.

Table 7. Vessel acoustics terminology: Concepts and quantities not expressed in decibels

Term	Definition
cavitation noise	unwanted cavitation sound
flow noise	self-noise resulting from the flow of fluid passed a hydrophone and its supports **remark**: Self-noise can include acoustic (acoustic self-noise) and non-acoustic (non-acoustic self-noise) contributions.
radiated flow-induced sound	sound radiated by a vessel that is generated by flow around the vessel **remark**: Radiated flow-induced sound excludes sound generated by the flow around the propeller and cavitation sound.
vessel underwater radiated noise **synonym**: vessel underwater radiated sound **abbreviations**: underwater radiated noise, vessel URN, URN	general term, referring either to a property of a single vessel (e.g., RNL, SL), the sound field generated by one or more vessels, or a property of that sound field (e.g., SPL, SEL) **remark**: The appearance of the word ‘noise’ in ‘underwater radiated noise’ does not necessarily imply noise.
non-cavitating propeller sound	flow-induced sound emitted by a propeller not produced by cavitation
overall ship length **unit:** m	longitudinal distance between the forward-most and aft-most part of a ship **source**: ISO/DIS 17208-3
shallow water <in vessel acoustics>	water of depth less than the larger of 150 m and 1.5× overall ship length **source**: ISO/DIS 17208-3
deep water <in vessel acoustics>	water of depth greater than the larger of 150 m and 1.5× overall ship length **source**: ISO/DIS 17208-3

Term	Definition
length between perpendiculars **abbreviation:** LPP	Length between perpendiculars, L pp, is the distance, in metres, on the waterline at draught T, from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post. **source:** Clasifications [sic] Register Rules and Regulations - Rules and Regulations for the Classification of Ships, July 2022 – Part 3 Ship Structures (General) – Chapter 1 General – Section 6 Definitions [19]

Table 8. Vessel acoustics terminology: Quantities usually expressed in decibels

Term	Definition
radiated noise level **abbreviation:** RNL **symbol:** L_{RN} **unit:** dB **reference value:** μPa·m	level of the product of the distance from a ship reference point of a sound source, d, and the far field root-mean-square sound pressure, $p_{rms}(d)$, at that distance for a specified reference value, in deep water Note 1 to entry: L_{RN} = 20 log$_{10}$ $(p_{rms}/\ p_0)$ dB + 20 log$_{10}$ (d/d_0) dB. Note 2 to entry: Radiated noise level is expressed in decibels (dB). Note 3 to entry: The reference value for sound pressure (p_0) is 1 μPa. The reference value for distance (d_0) is 1 m. The combined RNL reference value is p_0d_0 is 1 μPa·m [sic]. Note 4 to entry: The resulting level is denoted "L_{RN}, dB re 1 μPa·m". This designation replaces the past use of "L_p, dB re 1 μPa @ 1 m". Note 5 to entry: RNL varies in both horizontal and vertical aspect in the far field. This procedure determines an azimuthal sector averaged about the hydrophone position and vertical-elevation averaged quantity in the beam aspect about the ship reference point. Note 6 to entry: Deep water is any location where the water depth is in accordance with the minimum test site requirements of ISO 17208-1. **source:** entry 3.21 of ISO 17208-1:2016 [20] and ISO 17208-1:2016 FDAM 1. **further clarification:** The above definition, and associated notes, are cited verbatim from ISO 17208-1. The verbatim definition applies the '20 log' rule [21], leading to a reference value of 1 μPa m. In the rest of this document, the '10 log' rule is followed, leading to a reference value of 1 μPa^2 m^2, with no difference in intended meaning. The appearance of the word "noise" in "radiated noise level" does not necessarily imply noise.

Term	Definition
source spectral density level **synonym:** source spectrum level **abbreviation:** SSL **symbol:** $L_{\mathrm{S},f}$ **unit:** dB **reference value:** $1\ \mu\mathrm{Pa}^2\mathrm{m}^2/\mathrm{Hz}$	source level in a specified bandwidth minus $10\log_{10}(\Delta f/\Delta f_0)$ dB, where Δf is the specified bandwidth and Δf_0 is the reference bandwidth of 1 Hz **remarks:** Reference bandwidth Δf_0 = 1 Hz ADEON definition: Level of the source factor spectral density In equation form, $$L_{\mathrm{S},f} = 10\log_{10}\frac{F_{\mathrm{S},f}}{F_{\mathrm{S},f,0}}\ \mathrm{dB}\,.$$ The reference value, $F_{\mathrm{S},f,0}$, is equal to $1\ \mu\mathrm{Pa}^2\mathrm{m}^2/\mathrm{Hz}$. Source factor spectral density is a power quantity. The source factor spectral density of a tone varies with the size of the specified bandwidth Δf. An efficient implement can be achieved by use of a digital Fourier transform.
URN limit **unit:** dB **reference value:** $1\ \mu\mathrm{Pa}^2 \cdot \mathrm{m}^{X/10}$	value of a specified URN characteristic (e.g., SL or RNL) above which a vessel is considered not to qualify for the defined criteria for the limit **remark**: The URN limit could be specified by a ship classification society, port authority, etc.
URN excess **unit:** dB	amount by which a specified URN quantity (e.g., SL or RNL) exceeds a specified URN limit
insertion loss **unit:** dB	reduction in sound pressure level or sound exposure level caused by insertion of an object between source and receiver
facility transfer function **unit:** dB **reference value:** $1\ \mathrm{m}^{-2}$	propagation loss between a source location and a receiver location, within a specified facility **remark**: The source is omnidirectional.

3.5. Sound Mapping Terminology

Tables 9 and 10 list terms most likely to be used in work package 6 (WP6).

Table 9. Sound mapping terminology: Concepts.

Term	Definition
temporal observation window **abbreviation:** TOW	interval of time within which a statistic of the sound field is calculated or estimated **source**: ADEON terminology standard [22] **remarks:** Example statistics include rms sound pressure, peak sound pressure, and sound pressure kurtosis. An example is rms sound pressure calculated using a temporal observation window of 1 min duration.
temporal analysis window **abbreviation:** TAW	interval of time during which statistics are calculated over multiple temporal observation windows **source**: ADEON terminology standard [22] **remark:** An example is a 24 h distribution of rms sound pressure calculated using a temporal observation window of 1 min duration. In this example, the duration of the temporal analysis window is 24 h and the duration of the temporal observation window is 1 min.
spatial observation window **abbreviation:** SOW	region of space within which a statistic of the sound field is calculated or estimated, for a specified duration of the temporal observation window **source**: adapted from ADEON terminology standard [22] **remarks:** The volume of a spatial observation window is specified by means of an area (e.g., 1000 km^2) and a depth range (e.g., 50 to 200 m). The statistic can be the mean-square sound pressure.
spatial analysis window **abbreviation:** SAW	region of space within which statistics are calculated over multiple spatial observation windows **source**: ADEON terminology standard [22] **remark:** The volume of a spatial analysis window is specified by means of an area (e.g., 100 000 km^2) and a depth range (e.g., 50 to 200 m).

Term	Definition
sound map	map representing the spatial dependence of a specified acoustic quantity **remark:** Characteristics of the acoustic quantity to be specified include: - The nature of the physical quantity plotted (e.g., SPL, SEL, PAL, kurtosis) - The nature of the statistic where relevant (e.g., median, arithmetic mean of squared sound pressure) - Temporal observation window - Spatial observation window where spatial averaging is involved - Temporal and spatial analysis windows where relevant

Table 10. Sound mapping terminology: Quantities

Term	Definition
temporal N% exceedance level **unit:** dB	level above which N % of observations fall in a specified temporal analysis window **remarks:** The temporal 50 % exceedance level corresponds to the median. The type of level shall be specified.
temporal N% percentile level **unit:** dB	level below which N % of observations fall in a specified temporal analysis window **remarks:** The temporal 50 % percentile level corresponds to the median. The type of level shall be specified.
spatial N% exceedance level **unit:** dB	level above which N % of observations fall in a specified spatial analysis window **remarks:** The spatial 50 % exceedance level corresponds to the median. The type of level shall be specified.
spatial N% percentile level **unit:** dB	level below which N % of observations fall in a specified spatial analysis window **remarks:** The spatial 50 % percentile level corresponds to the median. The type of level shall be specified (could be a temporal percentile or temporal exceedance and vice versa).

3.6. Terms Defined by ISO 18405

Many relevant terms are already included in ISO 18405. All definitions in ISO 18405 are implicitly a part of the draft SATURN standard. Definitions of selected terms from ISO 18405 are not included explicitly. Relevant terms defined by ISO 18405 include the following:

- Acoustic far field
- Behavioural hearing threshold
- Characteristic acoustic impedance
- Decidecade
- Electrophysiological hearing threshold
- Noise
- One-third octave
- Propagation factor
- Propagation loss
- Permanent hearing threshold shift (PTS)
- Self-noise
- Signal
- Sound
- Sound exposure
- Sound exposure level (SEL)
- Sound pressure
- Sound pressure level (SPL)
- Soundscape
- Source level (SL)[2]
- Specific acoustic impedance
- Temporary hearing threshold shift (TTS)
- Transmission loss

[2] Source level is sometimes referred to as "monopole source level", but this term is misleading because a monopole is (by definition) omnidirectional, while source level can have directionality. Use of the term "monopole source level" to mean "source level" for a directional source is discouraged.

Glossary

Abbreviation	Meaning
ADEON	Atlantic Deepwater Ecosystem Observatory Network (https://adeon.unh.edu/)
FFVS	free-field voltage sensitivity
ICI	interclick interval
IMO	International Maritime Organization
ISO	International Organization for Standardization
ITTC	International Towing Tank Conference (https://ittc.info/)
JOMOPANS	Joint Monitoring Programme for Ambient Noise North Sea (https://northsearegion.eu/jomopans/)
LOBE	level of onset of biologically adverse effects'
LPP	length between perpendiculars
M45	month 45 (of the SATURN project)
M6	month 6 (of the SATURN project)
PAL	particle acceleration level
PL	propagation loss
PTS	permanent hearing threshold shift
RNL	radiated noise level
SATURN	Developing solutions to underwater radiated noise (https://www.saturnh2020.eu/)
SAW	spatial analysis window
SDL	spectral density level
SEL	sound exposure level
SL	source level
SOW	spatial observation window
SPL	sound pressure level
SSL	source spectral density level
SSSL	steady state source level
SSSPL	steady state sound pressure level
TAW	temporal analysis window
TL	transmission loss
TOW	temporal observation window
TTS	temporary hearing threshold shift
UNLV	underwater noise limit value
UNM	underwater noise metric
URN	underwater radiated noise
USM	underwater sound metric
WP	work package (of the SATURN project)

Abbreviation	Meaning
WP2	work package 2 (of the SATURN project)
WP3	work package 3 (of the SATURN project)
WP4	work package 4 (of the SATURN project)
WP6	work package 6 (of the SATURN project)

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Annex A. Principles and Related Agreements

A.1. General Principles

The following principles were applied during the development of this document, in order of decreasing precedence:

1. Definitions to be self-consistent (no internal contradictions)
2. Definitions to be compliant with ISO 18405 (underwater acoustics)
3. Definitions to be compliant with ISO/IEC 80000 (International System of Quantities)
4. Definitions strive to be consistent with use in related branches of physics
5. Definitions strive to be consistent with use in related branches of biology
6. Definitions to make best use of existing project standards[3] and related guidelines

A.2. Advice on the Use of This Document

- Follow ISO 18405 (https://www.iso.org/obp/ui/#iso:std:iso:18405:ed-1:v1:en)
- Distinguish between source level (SL) and radiated noise level (RNL)
- Spectrum level
    - Distinguish between sound pressure level (SPL) and spectral density level (SDL)
    - Specify frequency band
- Distinguish between transmission loss (TL) and propagation loss (PL).

$$N_{\mathrm{PL}}(x) = L_S - L_p(x)$$

$$N_{\mathrm{TL}}(x_1, x_2) = L_p(x_1) - L_p(x_2)$$

- Sound versus noise
    - Use the neutral term “sound” in preference to “noise”
    - Ships make broadband sound, not broadband noise (with exceptions stated below)
    - A figure showing the geographical distribution of sound pressure level is a sound map, not a noise map
    - Use “noise” only when there is a special reason to do so. Examples include
        - When the word “noise” is used in a term of the trade: radiated noise level
        - When the word “sound” would convey an incorrect meaning: signal to noise ratio
        - When the sound causes detrimental effects on aquatic organisms
- When discussing adverse effects of sound, distinguish between “signal” and “noise”
- Distinguish between 1/3 oct and 1/10 dec
    - A one-tenth decade (decidecade) is one tenth of a decade (1/10 dec)
    - A one-third octave is one third of an octave (1/3 oct)

[3] Examples of project standards include terminology standards of ADEON, JOMOPANS, ITTC, and the E&P Sound and Marine Life JIP; terminology from ISO 17208 is also relevant.

Annex B. Effect of Sea Surface on Propagation Loss at 1 m Distance from a Point Source

Consider a point source at distance H below the sea surface, with a receiver at 1 m distance from it, directly above it (Figure 2). PL (equal to the difference between $L_p(1\ \mathrm{m})$ and L_S) varies with increasing H in an oscillatory manner, reaching 0 dB asymptotically for large H (Figure 3).

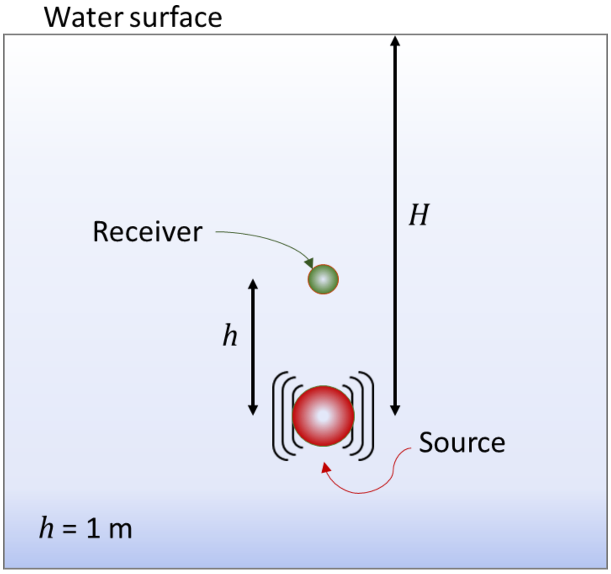

Figure 2. Source-receiver geometry. The source is at a depth H beneath the sea surface. The receiver is at a height h = 1 m above the source. The distance H is varied between 1 to 20 m.

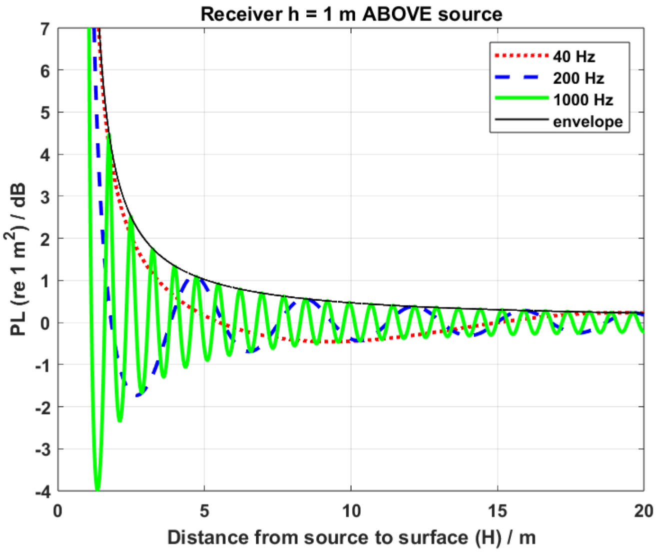

Figure 3. Propagation loss (PL) at 1 m is the difference between source level (SL) and sound pressure level (SPL) at 1 m.

The error incurred by misinterpreting SPL at 1 m as the source level can be quantified as the envelope of the PL curves plotted in Figure 3. The envelope ϵ is calculated as

$$\epsilon = 10 \log_{10} \frac{1/h^2}{\left(\frac{1}{h} - \frac{1}{2H-h}\right)^2} \text{ dB} \tag{10}$$

or (equivalently)

$$\epsilon = 10 \log_{10} \left(1 - \frac{h}{2H-h}\right)^2 \text{ dB} . \tag{11}$$

This error is 1 dB for a source 5 m from the sea surface, decreasing to 0.5 dB at 10 m and to 0.1 dB at 44 m (not shown).