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Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships —

Part 2: Determination of source levels from deep water measurements

Acoustique sous-marine — Grandeurs et modes de description et de mesurage de l'acoustique sous-marine des navires —

Partie 2: Détermination des niveaux de source à partir des mesures par grands fonds

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

A list of all parts in the ISO 17208 series can be found on the ISO website.

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

Introduction

This document has been developed in response to the demand, noted by the International Maritime Organization (IMO) and its Marine Environment Protection Committee (MEPC), for an International Standard for measurement of underwater sound radiated from ships. In this document, the sound radiated by the ship under test is described in terms of an equivalent monopole source level.

The scientific research on the impact of underwater sound on the marine ecosystem necessitates the accumulation of reliable acoustic output data for common sources such as surface vessels. These data can be obtained through at-sea measurement by relevant organizations, such as research institutes, by applying the measurement methodology described in ISO 17208-1. The methodology and measurement configuration are sufficient to give technically sound acoustic data, but are also suitable for end users to conduct the measurements *in situ* in the ocean without access to large fixed noise ranges.

The measurement of underwater sound radiated from ships depends upon various conditions related to the vessel under test and its surrounding environment. Specifically, the speed, draught and operational conditions of the engine(s) of the ship influence the level of radiated underwater sound. Waves, current, depth, temperature and salinity of the water also influence the propagation of underwater sound. The sea surface and bottom can reflect acoustical waves. Ambient noise sources, such as traffic, industry, biological, geological or meteorological noise can also interfere with the measurement of underwater sound radiated from the target ship.

In this document, the radiated noise level measured in deep water (3.1) according to ISO 17208-1 is converted to monopole source level. The conversion formulae are derived based on the assumption that the surface is a perfect pressure release boundary.

Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships —

Part 2: Determination of source levels from deep water measurements

1 Scope

This document specifies methods for calculating an equivalent monopole source level by converting radiated noise level values obtained in deep water according to ISO 17208-1. Procedures are also given for direct calculation from measurements made in deep water with specific hydrophone geometry. The source level calculated by the procedure in this document is that of an equivalent monopole source at a specified nominal source depth, and for broadside aspect only. The nominal source depth is intended to be reported with the equivalent monopole broadside source level value.

2 Normative references

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

ISO 17208-1:2016, *Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships — Part 1: Requirements for precision measurements in deep water used for comparison purposes*

ISO 18405, *Underwater acoustics — Terminology*

IEC 61260-1, *Electroacoustics — Octave-band and fractional-octave-band filters — Part 1: Specifications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 18405 and the following apply.

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

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

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

3.1
deep water
water the depth of which is more than 150 m, or 1,5 times the overall length of the ship under test, whichever is greater

3.2
averaged RNL correction
ΔL
difference between source level and radiated noise level

3.3
ship reference point
point on the ship from which the distances are defined

Note 1 to entry: For the purposes of this document, the ship reference point is located transversely at the ship centreline, longitudinally a quarter-length forward of the stern and vertically at the height of the sea surface.

Note 2 to entry: The location for the ship reference point applies for all frequencies.

3.4
closest point of approach
CPA
point where the horizontal distance (during a test run) from the *ship reference point* (3.3) of the ship under test to the hydrophone(s) is the smallest

3.5
radiated noise level
RNL
L_{RN}
level of the product of the distance from a *ship reference point* (3.3) of a sound source, r, and the far-field root-mean-square sound pressure, $p_{RMS}(r)$, at that distance for a specified reference value

Note 1 to entry: $L_{RN} = 20 \log_{10} (p_{RMS}/p_0)$ dB + $20 \log_{10}(r/r_0)$ dB.

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

Note 3 to entry: The reference value for pressure (p_0) is 1 µPa. The reference value for distance (r_0) is 1 m. The combined RNL reference value, $p_0 r_0$, is 1 µPa·m.

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 aspects in the far field. This procedure determines an azimuthal sector averaged about the hydrophone position and vertical-elevation averaged quantity in the broadside aspect about the ship reference point.

3.6
nominal source depth
source depth
d_s
nominal depth of the monopole point source from which the sound is considered to originate, and equal to 0,7 times the ship's draft

Note 1 to entry: This depth is used for conversion of radiated noise level to equivalent monopole source level.

Note 2 to entry: The calculation is given by Formula (1).

$$d_s = 0{,}7D \tag{1}$$

where D is the draught of the ship.

Note 3 to entry: The draught of the ship is considered to be the average of the stern and bow draughts.

Note 4 to entry: The choice of the nominal source depth is somewhat arbitrary, and the choice of 70 % of the mean draft represents a compromise. The value of the nominal source depth is to be reported alongside the equivalent monopole broadside source level value.

3.7
broadside aspect
aspect normal to ship centre line from bow to stern

Note 1 to entry: For the purposes of this document, the broadside aspect is measured over ±30° angles from the normal in the horizontal plane and 15° to 45° from the sea surface in the vertical plane.

4 Conversion of acoustic source level from radiated noise level measured in deep water

4.1 Measurement procedure

According to ISO 17208-1, three hydrophones are used to measure the underwater radiated noise level. The three hydrophones are positioned vertically in the water column at depths that result from nominal 15°, 30° and 45° angles from the sea surface at a distance equal to the nominal distance at the closest point of approach, d_{CPA}, which is defined as 100 m or one overall ship length, whichever is the greater. The hydrophone geometry refers to ISO 17208-1:2016, Figure 1.

For measurements that deviate from ISO 17208-1, ship noise source level correction formulae are given in Annex B.

4.2 Calculation of source level from radiated noise level performed as in ISO 17208-1

In the calculation described below, the measured radiated noise level in deep water obtained from the procedure described in ISO 17208-1 is converted to equivalent monopole source level for broadside aspect, for an assumed nominal source depth below the ship reference position.

The conversion formula is derived based on the assumption that the water surface is an ideal pressure release boundary; see Annex A. The effect of wind on the sea surface is not considered in these formulae.

When the radiated noise level, L_{RN}, has been measured in deep water and calculated according to ISO 17208-1, and the measurements have been averaged over depression angles of 15°, 30° and 45° as required by the procedure of that document, then the source level, L_s, can be calculated from the final result for the radiated noise level by using an averaged RNL correction, ΔL, as shown by Formula (2):

$$L_s = L_{RN} + \Delta L \tag{2}$$

The correction, ΔL, is given in Formula (3):

$$\Delta L = -10 \log_{10} \left(\frac{2(kd_s)^4 + 14(kd_s)^2}{14 + 2(kd_s)^2 + (kd_s)^4} \right) \text{dB} \tag{3}$$

where

$k = 2\pi f/c$	is the acoustic wavenumber, in rad/m;
f	is the central frequency of the one-third-octave (base 10) band, in Hz;
c	is the sound speed in water, in m/s;
d_s	is the nominal source depth from which the sound is considered to originate, in m.

The derivation of this formula, its uncertainty and alternative formulations are provided in Annex A.

The one-third-octave bands referenced throughout this document (and their centre frequencies) shall be calculated using base 10 arithmetic, as described in IEC 61260-1.

NOTE In ISO 17208-1 and IEC 61260-1, one-third-octave (base 10) bands are simply termed "one-third-octave band", but a base 10 calculation is intended.

5 Measurement uncertainty

The proposed conversion from the measured radiated noise level to equivalent monopole source level is aimed at providing input for long range sound propagation models that are based on a monopole sound source description. The starting point is the postulation that the far-field radiated noise of a surface ship can be approximately described as the radiated noise from an omni-directional point source under the sea surface. It is recognized that ship radiated noise is generated by multiple source mechanisms, which can be roughly grouped into machinery, propeller and hydrodynamic noise sources. Each source has its own location in the ship and its own frequency spectrum. Moreover, the water surface around the ship acts as a strong reflector of sound. Consequently, a surface ship is a directional sound source, both in the vertical and in the horizontal planes, and this directionality is frequency dependent. These effects are largely ignored for the purposes of this document. Only the interaction with the water surface, known as the *Lloyd's mirror* effect, is taken into account in the proposed description of the ship as a monopole sound source at a specified distance below the sea surface. A single frequency-independent source depth is postulated for this purpose. The reported source level shall be accompanied by this source depth for a proper interfacing to propagation modelling.

The uncertainty in the reported source level is a combination of

1) the uncertainty in the measured radiated noise level, as quantified in ISO 17208-1,
2) the uncertainty in Formula (3), and
3) the uncertainty associated with the postulated description of the ship as a monopole sound source under the sea surface.

The combined expanded measurement uncertainty of the radiated noise level (RNL) values is given in ISO 17208-1. The combined uncertainty is divided into low, mid and high frequency ranges. The uncertainty values for the specified one-third-octave (base 10) bands are:

— 5 dB for the low frequency (10 Hz to 100 Hz) bands,

— 3 dB for the mid frequency (125 Hz to 16 000 Hz) bands, and

— 4 dB for the high frequency (>20 000 Hz) bands.

These values are expressed as the typical value for applicable one-third-octave (base 10) bands. The estimates are provided as representative values for guidance and should not be considered to be exact. As described in ISO 17208-1, for the RNL calculation to be valid, the signal-plus-noise-to-noise level difference must not be less than 3 dB.

The uncertainty in Formula (3) results from uncertainty in kd_s and in the fit of the correction formula to the full formula for the Lloyd's mirror effect. Since the source depth, d_s, is postulated, the uncertainty in kd_s is determined by the uncertainty in the assumed sound speed. A maximum uncertainty of 10 % in the sound speed results in an uncertainty less than 1 dB in the conversion. The uncertainty of the fitted conversion formula relative to the full formula is less than 2 dB in nearly all one-third-octave (base 10) bands.

NOTE There is one exception: the difference between the one-third-octave (base 10) band averages of the approximation formula and the full formula is about 4 dB in the frequency band where $kd_s \approx 13$.

The uncertainty associated with the postulated description of the ship as a monopole sound source under the sea surface depends on the specifics of the ship that is being tested and cannot be quantified in general. It is recommended that users of this document determine their own assessment of uncertainty,

making use of published experience with its application and the methods described in the references on expression of uncertainty in measurement[1].

6 Special requirements for reporting of broadside aspect source level

6.1 General

The reporting shall be in accordance with ISO 17208-1. Some additional parameters which are important for conversion of source level are listed in 6.2.

6.2 Special parameters

1) nominal source depth;

2) speed of sound;

3) applied conversion formula.