IEC 60565-1

Edition 1.0 2020-04

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Underwater acoustics – Hydrophones – Calibration of hydrophones – Part 1: Procedures for free-field calibration of hydrophones

Acoustique sous-marine – Hydrophones – Étalonnage des hydrophones – Partie 1: Procédures d'étalonnage en champ libre des hydrophones



IEC 60565-1:2020-04(en-fr)

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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Underwater acoustics – Hydrophones – Calibration of hydrophones – Part 1: Procedures for free-field calibration of hydrophones

Acoustique sous-marine – Hydrophones – Étalonnage des hydrophones – Partie 1: Procédures d'étalonnage en champ libre des hydrophones

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UNDERWATER ACOUSTICS – HYDROPHONES – CALIBRATION OF HYDROPHONES –

Part 1: Procedures for free-field calibration of hydrophones

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FOREWORD

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International Standard IEC 60565-1 has been prepared by IEC technical committee 87: Ultrasonics.

This first edition of IEC 60565-1, together with IEC 60565-2, cancels and replaces the second edition of IEC 60565 published in 2006. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

1) removal of all descriptions of methods for pressure calibrations of hydrophones – these are now included in Part 2;
2) removal of the derivations of formulae for free-field reciprocity calibration (both amplitude sensitivity and phase sensitivity) and placement of these into an informative annex;
3) inclusion within the scope of the calibration of the transmitting response of individual source **transducer**s and hydrophones (but not sonar arrays);
4) re-ordering of the sections within the document such that the more general procedures for calibration such as guidance on obtaining conditions of acoustic free-field, far-field, and

steady-state, appear before the descriptions of procedures for absolute or relative calibrations;

5) revision of informative Annex A to include guidance on measurement of directional response of a hydrophone or projector;
6) addition of a new informative Annex B on measurement of electrical impedance of hydrophones and projectors;
7) revision of the previous informative annex on electrical loading corrections to include corrections to account for electrical loading by added cables (now Annex C);
8) addition of a new informative Annex D on acoustic far-field criteria in underwater acoustic calibration;
9) revision of the previous informative annex on pulsed techniques in free-field calibrations (now Annex E);
10) revision of the previous informative annex on assessment of uncertainty in the calibration of hydrophones (now Annex F);
11) deletion of the previous informative annex on equivalent circuit of the excitation system for calibration with a vibrating column;
12) addition of a new informative Annex G on derivation of the formulae for three-**transducer** spherical-wave reciprocity calibration;
13) addition of a new informative Annex H on calibration using travelling-wave tubes;
14) addition of a new informative Annex I on calibration of hydrophones using optical interferometry.
15) addition of a new informative Annex J on calibration in reverberant water tanks using continuous **signal**s.

The text of this standard is based on the following documents:

CDV	Report on voting
87/708/CDV	87/736/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

NOTE Words that appear in **bold** in the text are terms explicitly defined in Clause 3.

A list of all parts in the IEC 60565 series, published under the general title *Underwater acoustics – Hydrophones – Calibration of hydrophones*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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INTRODUCTION

Underwater acoustic measurements are made to provide validation and qualification in a wide range of ocean applications, including oceanography, defence, fisheries, geophysics and in developments in the off-shore energy industries. In addition, the increasing concern about the effect of anthropogenic sound on the marine environment has led to regulation which requires absolute acoustic measurement of the sound radiated by specific sources, and of the ambient sound field.

To be meaningful, it is important that measurements be performed in a technically sound manner, be related to common standards of measurement, and be made using calibrated sensors. **Hydrophone**s are the most commonly-used sensor to measure sound in the ocean. It is important that the **hydrophone**s used to measure sound pressure are calibrated using agreed standard methodologies, with valid uncertainties.

The purpose of this document is to establish procedures for calibration under free-field conditions of **hydrophone**s used in underwater acoustics for ocean applications. Also covered are calibration procedures for individual underwater **electroacoustic transducer**s which can be used as a **hydrophone** and/or source **transducer**. Principles, procedures, and sources of uncertainty are also provided in this document. The calibration methods described include absolute methods which do not require an acoustic reference **transducer**, and relative methods which make use of a calibrated acoustic reference **hydrophone** or **projector**. The methods described cover the frequency range from 200 Hz to 1 MHz.

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UNDERWATER ACOUSTICS – HYDROPHONES – CALIBRATION OF HYDROPHONES –

Part 1: Procedures for free-field calibration of hydrophones

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1 Scope

This part of IEC 60565 specifies methods and procedures for free-field calibration of **hydrophone**s, as well as individual **electroacoustic transducer**s that can be used as **hydrophone**s (receivers) and/or **projector**s (source **transducer**s). Two general types of calibration are covered within this document: absolute calibration using the method of three-**transducer** spherical-wave reciprocity, and relative calibration by comparison with a reference device which has already been the subject of an absolute calibration.

The maximum frequency range of the methods specified in this document is from 200 Hz to 1 MHz. The lowest acoustic frequency of application will depend on a number of factors, and will typically be in the range 200 Hz to 5 kHz depending mainly on the dimensions of the chosen test facility, The highest frequency of application for the methods described here is 1 MHz.

Procedures for pressure **hydrophone** calibration at low frequencies can be found in IEC 60565-2 [1][1]. Procedures for **hydrophone** calibration at acoustic frequencies greater than 1 MHz are covered by IEC 62127-2 [2].

Excluded from the scope of this document are low-frequency pressure calibrations of **hydrophone**s, which are described in IEC 60565-2 [1]. Also excluded are calibrations of digital **hydrophone**s and systems, calibration of marine autonomous acoustic recorders, calibration of acoustic vector sensors such as particle velocity sensors and pressure gradient **hydrophone**s, calibration of passive sonar arrays consisting of multiple **hydrophone**s, and calibration of active sonar arrays consisting of projectors and **hydrophone**s.

This document presents a description of the requirements for free-field calibration in terms of test facility, equipment and instrumentation, **signal** processing, and frequency limitations. A description of achievable uncertainty and rules for the presentation of the calibration data are provided. Also included are informative annexes that provide additional guidance on

- measurement of directional response of a **hydrophone** or projector,
- measurement of electrical impedance of **hydrophone**s and projectors,
- electrical loading corrections,
- **acoustic far-field** criteria in underwater acoustic calibration,
- pulsed techniques in free-field calibrations,
- assessment of uncertainty in the free-field calibration of **hydrophone**s and projectors,
- derivation of the formulae for three-**transducer** spherical-wave reciprocity calibrations,
- calibration using travelling-wave tubes,
- calibration of **hydrophone**s using optical interferometry, and
- calibrations in reverberant water tanks using continuous **signal**s.

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1 Numbers in square brackets refer to the Bibliography.

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.

IEC 60050-801, *International Electrotechnical Vocabulary – Chapter 801: Acoustics and electroacoustics* (available at http://www.electropedia.org/)

IEC 60500:2017, *Underwater acoustics – Hydrophones – Properties of the hydrophone in the frequency range 1 Hz to 500 kHz*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-801, IEC 60500:2017 and the following 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
acoustic far-field
sound field at a sufficient distance from a sound source in a uniform medium where the sound pressure and sound particle velocity are substantially in phase and the direct-path sound pressure amplitude, compensated for absorption loss, varies inversely with distance

Note 1 to entry: The range (distance from the source) is taken along a direct path between the source and the receiver.

Note 2 to entry: The inverse dependence on range does not imply that the source radiates equally in all directions.

[SOURCE: IEC 60050-801:1994, 801-23-30, modified – In the definition, "and the direct-path sound pressure amplitude, compensated for absorption loss, varies inversely with distance" has been added, sourced from ISO 18405:2017, 3.3.1.1.]

3.2
electrical transfer impedance
$\underline{Z}_{\mathrm{PH}}$
<of a transducer pair> quotient of the Fourier transform of the **hydrophone** open-circuit output voltage $\mathcal{F}(U_{\mathrm{H}}(t))$ to the Fourier transform of the electrical drive current through the **projector** $\mathcal{F}(I_{\mathrm{P}}(t))$, for a **transducer** pair at a specified separation distance with one used as a **hydrophone** and one as a **projector**

$$\underline{Z}_{\mathrm{PH}} = \frac{\mathcal{F}\left(U_{\mathrm{H}}(t)\right)}{\mathcal{F}\left(I_{\mathrm{P}}(t)\right)} \tag{1}$$

Note 1 to entry: The **electrical transfer impedance** is a complex-valued parameter. The modulus of the **electrical transfer impedance** is expressed in units of ohm, Ω. The phase angle of the **electrical transfer impedance** is the argument of the **electrical transfer impedance** and represents the phase difference between the **hydrophone** voltage and the **projector** current [IEC 60050-351:2013, 351-45-45]. The unit of phase angle is the radian.

Note 2 to entry: Because the **electrical transfer impedance** depends on the field conditions, the hydrostatic pressure, water temperature and the length of the cable attached to the **transducer**, these parameters, as well as the frequency are specified.

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