

**SLOVENSKI STANDARD
SIST EN IEC 60565-1:2020****01-oktober-2020****Nadomešča:
SIST EN 60565:2008**

Podvodna akustika - Hidrofoni - Kalibracija hidrofonov - 1. del: Postopki za kalibracijo hidrofonov v odprtem prostoru (IEC 60565-1:2020)

Underwater acoustics - Hydrophones - Calibration of hydrophones - Part 1: Procedures for free-field calibration of hydrophones (IEC 60565-1:2020)

Wasserschall - Hydrophone - Kalibrierung von Hydrophonen - Teil 1: Verfahren für die Freifeldkalibrierung von Hydrophonen (IEC 60565-1:2020)

Acoustique sous-marine - Hydrophones - Étalonnage des hydrophones - Partie 1: Procédures d'étalonnage en champ libre des hydrophones (IEC 60565-1:2020)

Ta slovenski standard je istoveten z: EN IEC 60565-1:2020**ICS:**

17.140.50 Elektroakustika Electroacoustics

SIST EN IEC 60565-1:2020 en

iTeh STANDARD PREVIEW
(standards.iteh.ai)

SIST EN IEC 60565-1:2020

<https://standards.iteh.ai/catalog/standards/sist/c17e8ec5-884a-43db-83d2-2ba6ef232326/sist-en-iec-60565-1-2020>

EUROPEAN STANDARD

EN IEC 60565-1

NORME EUROPÉENNE

EUROPÄISCHE NORM

June 2020

ICS 17.140.50

Supersedes EN 60565:2007 (partially)
and all of its amendments and corrigenda (if any)

English Version

Underwater acoustics - Hydrophones - Calibration of hydrophones - Part 1: Procedures for free-field calibration of hydrophones (IEC 60565-1:2020)

Acoustique sous-marine - Hydrophones - Étalonnage des
hydrophones - Partie 1: Procédures d'étalonnage en champ
libre des hydrophones
(IEC 60565-1:2020)

Wasserschall - Hydrophone - Kalibrierung von
Hydrophonen - Teil 1: Verfahren für die Freifeldkalibrierung
von Hydrophonen
(IEC 60565-1:2020)

This European Standard was approved by CENELEC on 2020-05-29. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.



European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

EN IEC 60565-1:2020 (E)**European foreword**

The text of document 87/708/CDV, future edition 1 of IEC 60565-1, prepared by IEC/TC 87 "Ultrasonics" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 60565-1:2020.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2021-03-01
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2023-05-29

This document supersedes (partially) EN 60565:2007 and all of its amendments and corrigenda (if any).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

ITeH STANDARD PREVIEW
(standards.iteh.ai)

SIST EN IEC 60565-1:2020
Endorsement notice
<https://standards.iteh.ai/catalog/standards/sist/25-884a-43db-83d2-2ba6ef232326/sist-en-iec-60565-1-2020>

The text of the International Standard IEC 60565-1:2020 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60565-2	NOTE	Harmonized as EN IEC 60565-2
IEC 62127-2	NOTE	Harmonized as EN 62127-2

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60050-801	-	International Electrotechnical Vocabulary - Chapter 801: Acoustics and electroacoustics	-	-
IEC 60500	2017	Underwater acoustics - Hydrophones - Properties of hydrophones in the frequency range 1 Hz to 500 kHz	EN 60500	2017

[SIST EN IEC 60565-1:2020](https://standards.iteh.ai/catalog/standards/sist/c17e8ec5-884a-43db-83d2-2ba6ef232326/sist-en-iec-60565-1-2020)

<https://standards.iteh.ai/catalog/standards/sist/c17e8ec5-884a-43db-83d2-2ba6ef232326/sist-en-iec-60565-1-2020>

iTeh STANDARD PREVIEW
(standards.iteh.ai)

SIST EN IEC 60565-1:2020

<https://standards.iteh.ai/catalog/standards/sist/c17e8ec5-884a-43db-83d2-2ba6ef232326/sist-en-iec-60565-1-2020>



IEC 60565-1

Edition 1.0 2020-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**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**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 17.140.50

ISBN 978-2-8322-8039-3

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

CONTENTS

FOREWORD.....	7
INTRODUCTION.....	9
1 Scope.....	10
2 Normative references	11
3 Terms and definitions	11
4 Symbols and abbreviated terms.....	16
5 General procedures for calibration.....	17
5.1 General alibration requirements	17
5.1.1 Types of calibration	17
5.1.2 Acoustic field requirements.....	18
5.2 Acoustic free-field requirements.....	18
5.2.1 Continuous signals	18
5.2.2 Time-limited signals.....	18
5.3 Acoustic far-field requirements.....	18
5.4 Requirements for steady-state conditions.....	19
5.5 Equipment requirements	20
5.5.1 Calibration facility	20
5.5.2 Instrumentation.....	20
5.6 Positioning and alignment.....	22
5.6.1 Coordinate system.....	22
5.6.2 Reference direction	22
5.6.3 Transducer mounting and support.....	22
5.6.4 Alignment.....	23
5.6.5 Separation distance.....	23
5.7 Representation of the frequency response	23
5.8 Frequency limitations	24
5.8.1 High-frequency limit.....	24
5.8.2 Low-frequency limit.....	24
5.9 Checks for acoustic interference	24
6 Electrical measurements.....	25
6.1 Signal type.....	25
6.2 Electrical earthing.....	25
6.3 Measurement of hydrophone output voltage.....	25
6.3.1 General	25
6.3.2 Signal analysis	26
6.3.3 Electrical loading by measuring instruments	26
6.3.4 Electrical loading by extension cables	26
6.3.5 Electrical noise	26
6.3.6 Cross-talk	27
6.3.7 Integral preamplifiers	27
6.4 Measurement of projector drive current.....	27
6.4.1 Instrumentation.....	27
6.4.2 Signal analysis	27
6.5 Measurement of projector drive voltage	28
6.5.1 Instrumentation.....	28
6.5.2 Signal analysis	28

7	Preparation and conditioning of transducers	28
7.1	Soaking	28
7.2	Wetting	28
7.3	Extending the hydrophone cable	29
7.4	Environmental conditions (temperature and depth)	29
8	Free-field three-transducer spherical-wave reciprocity calibration	29
8.1	General principle	29
8.2	Calibration to determine sensitivity modulus (without phase).....	30
8.2.1	Acoustic field requirements.....	30
8.2.2	Separation distance	30
8.2.3	Transducer preparation, mounting and alignment	31
8.2.4	Signal type	31
8.2.5	Measurement of electrical transfer impedance	31
8.2.6	Calculation of the receive sensitivities	31
8.2.7	Calculation of the transmit sensitivities	32
8.2.8	Repeatability	32
8.2.9	Verification and checks.....	32
8.2.10	Uncertainty	34
8.3	Calibration to determine phase of the hydrophone sensitivity	34
8.3.1	General principle.....	34
8.3.2	Transducer preparation.....	35
8.3.3	Acoustic field requirements.....	36
8.3.4	Signal type	36
8.3.5	Transducer mounting and alignment	36
8.3.6	Measurement of electrical transfer impedance	36
8.3.7	Calculation of sensitivity phase angle	36
8.3.8	Repeatability	37
8.3.9	Verification and checking.....	37
8.3.10	Uncertainty	37
9	Free-field calibration by comparison with an acoustic reference device.....	37
9.1	Principles.....	37
9.2	Types of comparison calibration method	38
9.2.1	Hydrophone calibration using a calibrated reference hydrophone	38
9.2.2	Hydrophone calibration using calibrated reference projector	38
9.2.3	Projector calibration using a calibrated reference hydrophone	38
9.3	Hydrophone calibration by comparison with a reference hydrophone	38
9.3.1	Acoustic field requirements.....	38
9.3.2	Separation distance	38
9.3.3	Transducer preparation, mounting and alignment	39
9.3.4	Signal type	39
9.3.5	Measurement of electrical voltage	39
9.3.6	Free-field sensitivity	39
9.3.7	Repeatability	39
9.3.8	Verification and checks.....	40
9.3.9	Uncertainty	40
9.4	Hydrophone calibration using a calibrated projector	40
9.4.1	Acoustic field requirements.....	40
9.4.2	Separation distance	40
9.4.3	Transducer preparation, mounting and alignment	41

9.4.4	Signal type	41
9.4.5	Measurement of electrical transfer impedance	41
9.4.6	Calculation of the receive sensitivities	41
9.4.7	Repeatability	41
9.4.8	Verification and checks	42
9.4.9	Uncertainty	42
9.5	Projector calibration using a calibrated hydrophone	42
9.5.1	Acoustic field requirements	42
9.5.2	Separation distance	42
9.5.3	Transducer preparation, mounting and alignment	42
9.5.4	Signal type	43
9.5.5	Measurement of electrical transfer impedance	43
9.5.6	Calculation of the transmit sensitivity	43
9.5.7	Verification and checks	43
9.5.8	Uncertainty	44
10	Reporting of results	44
10.1	Sensitivity	44
10.2	Sensitivity level	44
10.3	Calibration uncertainties	45
10.4	Auxiliary metadata	45
11	Recalibration periods	45
Annex A (informative)	Directional response of a hydrophone or projector	46
A.1	General principle	46
A.2	Types of measurement implementation	46
A.3	Coordinate system	46
A.4	Acoustic field requirements	47
A.5	Positioning and alignment	47
A.6	Signal type	47
A.7	Measurement of transducer directional response	47
A.7.1	Projector	47
A.7.2	Hydrophone	47
A.8	Calculation of the directional response level (angular deviation loss)	47
A.9	Uncertainty	48
A.10	Graphic representation	48
A.11	Directivity factor	49
A.12	Directivity index	49
Annex B (informative)	Measurement of electrical impedance of hydrophones and projectors	50
B.1	General principles	50
B.2	Measurement of electrical impedance	50
B.3	Derivation of other electrical impedance parameters	51
B.4	Graphical representation	52
Annex C (informative)	Calculation of electrical loading corrections	54
C.1	Electrical loading corrections	54
C.2	Corrections for amplifier loading using complex electrical impedance	54
C.3	Corrections for loading caused by extension cables (using complex electrical impedance)	54
C.4	Corrections using only capacitances	55
Annex D (informative)	Acoustic far-field criteria in underwater acoustic calibration	56

D.1	General.....	56
D.2	The field for piston transducers.....	56
D.3	Criteria for far-field conditions.....	57
D.4	Far-field criteria in directional response measurements.....	58
Annex E (informative) Pulsed techniques in free-field calibrations.....		59
E.1	General.....	59
E.2	Echo-free time.....	59
E.3	Minimum separation distance.....	61
E.4	Turn-on transients.....	61
E.5	Bandwidth considerations.....	62
E.6	Electrical cross-talk.....	63
E.7	Pulse duration.....	63
E.8	Reverberation and pulse repetition rate.....	63
E.9	Typical tank dimensions.....	63
E.10	Spherical-wave conditions.....	64
E.11	Reflections from mounting poles and rigging.....	64
E.12	Analysis methods for tone-burst signals.....	64
E.13	High-frequency limitations.....	65
E.14	Low-frequency limitations.....	66
E.15	Advanced techniques for extending the frequency range beyond the low-frequency limit.....	67
Annex F (informative) Assessment of uncertainty in the calibration of hydrophones and projectors.....		69
F.1	General.....	69
F.2	Type A evaluation of uncertainty.....	69
F.3	Type B evaluation of uncertainty.....	69
F.4	Reported uncertainty.....	69
F.5	Common sources of uncertainty.....	70
Annex G (informative) Derivation of the formulae for three-transducer spherical-wave reciprocity calibration.....		72
G.1	General.....	72
G.2	Calibration to determine the modulus of the sensitivity.....	72
G.3	Calibration to determine the complex sensitivity.....	74
Annex H (informative) Calibration using travelling-wave tubes.....		77
H.1	General.....	77
H.2	Calibration procedure.....	77
H.3	Limitations of the method.....	77
H.4	Extensions of the method.....	78
Annex I (informative) Calibration of hydrophones using optical interferometry.....		79
I.1	General.....	79
I.2	General principles.....	79
I.3	Procedure.....	79
I.4	Discussion of method.....	80
Annex J (informative) Calibration in a reverberant water tanks using continuous signals.....		81
J.1	General principle.....	81
J.2	Using a noise signal.....	82
J.3	Using the LFM signal.....	82
J.4	Uncertainties.....	83

Bibliography.....	84
Figure 1 – Measurement configurations for three-transducer reciprocity.....	30
Figure 2 – Measurement framework for supporting in-line the three transducers: a projector P, a reciprocal transducer T, and a hydrophone H to be calibrated.....	35
Figure A.1 – Examples of graphical representations of the level of the directional response: polar plot (left) and Cartesian plot (right).....	48
Figure B.1 – Examples of plots of transducer electrical impedance for a small spherical hydrophone of capacitance 3 nF.....	53
Figure D.1 – Acoustic pressure as a function of range from the source for a point source and for a piston source of dimensions $ka = 10$	56
Figure D.2 – Difference in measured acoustic pressure on axis compared to spherical spreading measured by a point receiver and a piston receiver.....	57
Figure E.1 – Schematic diagram of a projector and receiver in a water tank showing the main sources of reflections.....	60
Figure E.2 – Echo arrival time in a 6 m × 6 m × 5 m tank with optimally placed transducers.....	61
Figure E.3 – Hydrophone signals for a pair of spherical transducers (projector: 18 kHz resonance frequency, Q-factor of 3,5; hydrophone: 350 kHz resonance frequency; drive frequency: 2 kHz (left) and 18 kHz (right)).....	62
Figure E.4 – Examples of acoustic waveforms showing time-windows for analysis.....	65
Figure E.5 – Values for the sound absorption in pure water and sea water, including contributions due to component factors.....	66
Figure I.1 – Configurations for calibration of hydrophones using heterodyne optical interferometry.....	80

SIST EN IEC 60565-1:2020
<https://standards.iteh.ai/catalog/standards/sist/c17e8ec5-884a-43db-83d2-2ba6ef232326/sist-en-iec-60565-1-2020>

INTERNATIONAL ELECTROTECHNICAL COMMISSION

—————

**UNDERWATER ACOUSTICS – HYDROPHONES –
CALIBRATION OF HYDROPHONES –**
Part 1: Procedures for free-field calibration of hydrophones**FOREWORD**

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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 **transducers** 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 **signals**.

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

SIST EN IEC 60565-1:2020	
https://standards.iteh.org/catalog/standards/sist/7708cdv-83d2-7a6e732326/sist-en-iec-60565-1-2020	Report on voting 43db-83d2-7a6e732326/sist-en-iec-60565-1-2020
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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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. **Hydrophones** are the most commonly-used sensor to measure sound in the ocean. It is important that the **hydrophones** 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 **hydrophones** used in underwater acoustics for ocean applications. Also covered are calibration procedures for individual underwater **electroacoustic transducers** which can be used as a **hydrophone** and/or source **transducer**. Principles, procedures, and sources of uncertainty are related 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.

iTeh STANDARD PREVIEW (standards.iteh.ai)

[SIST EN IEC 60565-1:2020](https://standards.iteh.ai/catalog/standards/sist/c17e8ec5-884a-43db-83d2-2ba6ef232326/sist-en-iec-60565-1-2020)

<https://standards.iteh.ai/catalog/standards/sist/c17e8ec5-884a-43db-83d2-2ba6ef232326/sist-en-iec-60565-1-2020>