

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

---

**Ultrasonics – Hydrophones –  
Part 1: Measurement and characterization of medical ultrasonic fields**

**Ultrasons – Hydrophones –  
Partie 1: Mesurage et caractérisation des champs ultrasoniques médicaux**





## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2022 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Secretariat  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

#### IEC publications search - [webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

#### IEC Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [sales@iec.ch](mailto:sales@iec.ch).

#### IEC Products & Services Portal - [products.iec.ch](http://products.iec.ch)

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

### A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

### A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

#### Recherche de publications IEC -

##### [webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

#### Service Clients - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: [sales@iec.ch](mailto:sales@iec.ch).

#### IEC Products & Services Portal - [products.iec.ch](http://products.iec.ch)

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 300 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 19 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.



# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

---

**Ultrasonics – Hydrophones –  
Part 1: Measurement and characterization of medical ultrasonic fields**

**Ultrasons – Hydrophones –  
Partie 1: Mesurage et caractérisation des champs ultrasoniques médicaux**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

---

ICS 17.140.50

ISBN 978-2-8322-1080-1

**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.....	6
INTRODUCTION.....	8
1 Scope.....	9
2 Normative references .....	9
3 Terms and definitions .....	10
4 Symbols .....	32
5 Measurement requirements .....	34
5.1 Requirements for hydrophones and amplifiers.....	34
5.1.1 Preface.....	34
5.1.2 General .....	34
5.1.3 Sensitivity of a hydrophone.....	35
5.1.4 Directional response of a hydrophone.....	35
5.1.5 Effective hydrophone size.....	35
5.1.6 Choice of the size of a hydrophone active element .....	35
5.1.7 Bandwidth.....	37
5.1.8 Linearity .....	40
5.1.9 Hydrophone signal amplifier .....	40
5.1.10 Hydrophone cable length and amplifiers .....	40
5.2 Requirements for positioning and water baths.....	41
5.2.1 General .....	41
5.2.2 Positioning systems .....	41
5.2.3 Water bath.....	42
5.3 Requirements for data acquisition and analysis systems.....	43
5.4 Recommendations for ultrasonic equipment being characterized.....	43
6 Measurement procedure .....	43
6.1 General.....	43
6.2 Preparation and alignment .....	44
6.2.1 Preparation.....	44
6.2.2 Aligning an ultrasonic transducer and a hydrophone .....	44
6.3 Measurement.....	44
6.4 Analysis .....	44
6.4.1 Corrections for restricted bandwidth and spatial resolution .....	44
6.4.2 Uncertainties .....	44
7 Beam characterization .....	45
7.1 General.....	45
7.2 Primary pressure parameters .....	46
7.2.1 General .....	46
7.2.2 Peak-compressional acoustic pressure and peak-rarefactional acoustic pressure .....	47
7.2.3 Spatial-peak RMS acoustic pressure .....	47
7.2.4 Local distortion parameter .....	48
7.3 Intensity parameters derived from acoustic pressure.....	48
7.3.1 General .....	48
7.3.2 Intensity parameters using pulse-pressure-squared integral .....	49
8 Requirements for specific ultrasonic fields.....	52

8.1	General.....	52
8.2	Diagnostic fields .....	52
8.2.1	Simplified procedures and guidelines.....	52
8.2.2	Pulsed wave diagnostic equipment .....	52
8.2.3	Continuous wave diagnostic equipment .....	53
8.2.4	Diagnostic equipment with low acoustic output .....	54
8.3	Therapy fields .....	54
8.3.1	Physiotherapy equipment.....	54
8.3.2	High intensity therapeutic ultrasonic fields .....	55
8.3.3	Non-focused and weakly focused pressure pulses .....	55
8.4	Surgical fields .....	55
8.4.1	Lithotripters and pressure pulse sources for other therapeutic purposes .....	55
8.4.2	Low frequency surgical applications.....	56
8.5	Fields from other medical applications .....	56
9	Conformity statement.....	56
9.1	General.....	56
9.2	Maximum probable values.....	56
9.3	Sampling.....	57
Annex A (informative) General rationale.....		58
Annex B (informative) Hydrophones and positioning .....		60
B.1	General.....	60
B.2	Electrical loading considerations .....	60
B.3	Hydrophone signal amplifier.....	60
B.4	Hydrophone cable length and amplifiers.....	60
B.5	Transducer positioning.....	61
B.6	Alignment of hydrophones.....	62
B.7	Water bath lining material .....	62
B.8	Recommendations for ultrasonic equipment being characterized.....	62
B.9	Types of hydrophones.....	63
B.9.1	Ceramic needle hydrophones .....	63
B.9.2	PVDF needle hydrophones .....	63
B.9.3	PVDF membrane hydrophones .....	63
B.9.4	Fibre-optic and optic hydrophones .....	64
B.9.5	Relative performance of different types.....	65
B.10	Typical specification data for hydrophones.....	65
Annex C (informative) Acoustic pressure and intensity .....		66
Annex D (informative) Voltage to pressure conversion .....		68
D.1	General.....	68
D.2	Hydrophone deconvolution procedure .....	69
D.3	Converting the data between double-sided and single-sided spectra .....	70
D.4	Use of hydrophone calibration data .....	72
D.4.1	Calibration data interpolation .....	72
D.4.2	Calibration data extrapolation .....	72
D.4.3	Regularization filtering .....	73
D.5	Implication of the hydrophone deconvolution process on measurement duration .....	74
D.6	Validation of deconvolution implementation.....	75
Annex E (informative) Correction for spatial averaging.....		76

E.1	Linear and quasilinear fields .....	76
E.2	Linear fields, quasilinear fields, and broadband nonlinearly distorted waveforms .....	78
Annex F (informative) Acoustic output parameters for multi-mode medical ultrasonic fields in the absence of scan-frame synchronization .....		81
F.1	General.....	81
F.2	Current philosophy.....	81
F.3	Need for an alternative approach .....	82
F.4	Proposed approach.....	82
F.4.1	Alternative philosophy .....	82
F.4.2	Alternative parameters.....	83
F.5	Measurement methods.....	84
F.5.1	General .....	84
F.5.2	Peak pressures.....	84
F.5.3	Temporal-average intensity .....	84
F.5.4	Frequency .....	85
F.5.5	Power .....	85
F.6	Discussion .....	85
F.6.1	Relationship to existing standards .....	85
F.6.2	Advantages .....	86
F.6.3	Disadvantages.....	86
Annex G (informative) Propagation medium and degassing.....		87
Annex H (informative) Specific ultrasonic fields.....		88
H.1	Diagnostic fields .....	88
H.1.1	Useful relationships between acoustical parameters .....	88
H.1.2	Pulsed wave diagnostic equipment .....	89
H.1.3	Continuous wave diagnostic equipment .....	89
H.2	Therapy fields .....	90
H.2.1	Physiotherapy equipment.....	90
H.2.2	High intensity therapeutic ultrasonic equipment .....	90
H.2.3	Non-focused and weakly focused pressure pulses .....	90
H.3	Surgical fields .....	90
H.3.1	Lithotripters .....	90
H.3.2	Low frequency surgical applications.....	90
Annex I (informative) Assessment of uncertainty in the acoustic quantities obtained by hydrophone measurements.....		91
I.1	General.....	91
I.2	Overall (expanded) uncertainty .....	91
I.3	Common sources of uncertainty .....	91
Annex J (informative) Transducer and hydrophone positioning systems .....		93
Annex K (informative) Beamwidth midpoint method.....		94
Bibliography.....		95
Figure 1 – Schematic diagram of the different planes and lines in an ultrasonic field .....		12
Figure 2 – Several apertures and planes for a transducer of unknown geometry .....		26
Figure 3 – Parameters for describing a focusing transducer of known geometry.....		29
Figure 4 – Schematic diagram of the method of determining pulse duration .....		46
Figure D.1 – A flow diagram of the hydrophone deconvolution process .....		70

Figure D.2 – Example of waveform deconvolution .....	74
Figure J.1 – Schematic diagram of the ultrasonic transducer and hydrophone degrees of freedom .....	93
Table 1 – Acoustic parameters appropriate to various types of medical ultrasonic equipment.....	45
Table B.1 – Typical specification data for hydrophones, in this case given at 1 MHz [69].....	65
Table C.1 – Properties of distilled or de-ionized water as a function of temperature [71] .....	67
Table D.1 – Method of conversion from a double- to a single-sided spectrum .....	71
Table D.2 – Method of conversion from a single- to a double-sided spectrum .....	71
Table F.1 – Main basic parameters defined in this document or in IEC 61161 .....	82
Table F.2 – List of parameters that are to be used or are to be deleted.....	83
Table K.1 – Decibel beamwidth levels for determining midpoints.....	94

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## ULTRASONICS – HYDROPHONES –

## Part 1: Measurement and characterization of medical ultrasonic fields

## 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.

IEC 62127-1 has been prepared by IEC technical committee 87: Ultrasonics. It is an International Standard.

This second edition cancels and replaces the first edition published in 2007 and Amendment 1:2013. This edition constitutes a technical revision.

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

- a) The upper frequency limit of 40 MHz has been removed.
- b) Hydrophone sensitivity definitions have been changed to recognize sensitivities as complex-valued quantities.
- c) Procedures and requirements for narrow-band approximation and broadband measurements have been modified; details on waveform deconvolution have been added.
- d) Procedures for spatial averaging correction have been amended.
- e) Annex D, Annex E and bibliography have been updated to support the changes of the normative parts.

The text of this International Standard is based on the following documents:

Draft	Report on voting
87/783/FDIS	87/788/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at [www.iec.ch/members\\_experts/refdocs](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/standardsdev/publications](http://www.iec.ch/standardsdev/publications).

A list of all parts of IEC 62127 series, published under the general title *Ultrasonics – Hydrophones*, can be found on the IEC website.

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under [webstore.iec.ch](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.

## INTRODUCTION

The main purpose of this document is to define various acoustic parameters that can be used to specify and characterize ultrasonic fields propagating in liquids, and, in particular, water, using hydrophones. Measurement procedures are outlined that may be used to determine these parameters. Specific device related measurement standards, for example IEC 61689, IEC 61157, IEC 61847 or IEC 62359, can refer to this document for appropriate acoustic parameters. In IEC 62359, some additional measurement methods for attenuated parameters and indices are described addressing the specific needs of acoustic output characterization of ultrasonic diagnostic equipment in accordance with IEC 60601-2-37.

The philosophy behind this document is the specification of the acoustic field in terms of acoustic pressure parameters, acoustic pressure being the primary measurement quantity when hydrophones are used to characterize the field.

Intensity parameters are specified in this document, but these are regarded as derived quantities that are meaningful only under certain assumptions related to the ultrasonic field being measured.