IEC 62127-1

Edition 2.0 2022-03

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

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INTERNATIONAL
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ULTRASONICS – HYDROPHONES –

Part 1: Measurement and characterization of medical ultrasonic fields

FOREWORD

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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. The main document types developed by IEC are described in greater detail at 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 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.

ULTRASONICS – HYDROPHONES –

Part 1: Measurement and characterization of medical ultrasonic fields

1 Scope

This part of IEC 62127 specifies methods of use of calibrated **hydrophones** for the measurement in liquids of acoustic fields generated by ultrasonic medical equipment including **bandwidth** criteria and calibration frequency range requirements in dependence on the spectral content of the fields to be characterized.

This document:

– defines a group of acoustic parameters that can be measured on a physically sound basis;
– defines a second group of parameters that can be derived under certain assumptions from these measurements, and called derived intensity parameters;
– defines a measurement procedure that can be used for the determination of acoustic pressure parameters;
– defines the conditions under which the measurements of acoustic parameters can be made using calibrated **hydrophones**;
– defines procedures for correcting for limitations caused by the use of **hydrophones** with finite **bandwidth** and finite active element size, and for estimating the corresponding **uncertainties**.

NOTE 1 Throughout this document, SI units are used. In the specification of certain parameters, such as **beam areas** and intensities, it can be convenient to use decimal multiples or submultiples. For example, **beam area** is likely to be specified in cm^2 and intensities in W/cm^2 or mW/cm^2.

NOTE 2 The **hydrophone** as defined can be of a piezoelectric or an optic type.

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 60565-1, *Underwater acoustics – Hydrophones – Calibration of hydrophones – Part 1: Procedures for free-field calibration of hydrophones*

IEC 61689, *Ultrasonics – Physiotherapy systems – Field specifications and methods of measurement in the frequency range 0,5 MHz to 5 MHz*

IEC 62127-2, *Ultrasonics – Hydrophones – Part 2: Calibration for ultrasonic fields up to 40 MHz*

IEC 62127-3, *Ultrasonics – Hydrophones – Part 3: Properties of hydrophones for ultrasonic fields up to 40 MHz*

IEC 63009, *Ultrasonics – Physiotherapy systems – Field specifications and methods of measurement in the frequency range 20 kHz to 500 kHz*

ISO 16269-6, *Statistical interpretation of data – Part 6: Determination of statistical tolerance intervals*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62127-2, IEC 62127-3 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 pulse waveform
temporal waveform of the **instantaneous acoustic pressure** at a specified position in an acoustic field and displayed over a period sufficiently long to include all significant acoustic information in a single pulse or tone-burst, or one or more cycles in a continuous wave

Note 1 to entry: Temporal waveform is a representation (e.g. oscilloscope presentation or equation) of the **instantaneous acoustic pressure**.

3.2
acoustic repetition period
arp
pulse repetition period for non-automatic scanning systems and the **scan repetition period** for automatic scanning systems, equal to the time interval between corresponding points of consecutive cycles for continuous wave systems

Note 1 to entry: The **acoustic repetition period** is expressed in seconds (s).

3.3
acoustic-working frequency
acoustic frequency
frequency of an acoustic signal based on the observation of the output of a **hydrophone** placed in an acoustic field at the position corresponding to the **spatial-peak temporal-peak acoustic pressure**

Note 1 to entry: The signal is analysed using either the **zero-crossing acoustic-working frequency** technique or a spectrum analysis method. Acoustic-working frequencies are defined in 3.3.1, 3.3.2, 3.3.3, 3.3.4 and 3.3.5.

Note 2 to entry: In a number of cases the present definition is not very helpful or convenient, especially for **broadband transducers**. In that case, a full description of the frequency spectrum is expected to be given in order to enable any frequency-dependent correction to the signal.

Note 3 to entry: **Acoustic frequency** is expressed in hertz (Hz).

3.3.1
zero-crossing acoustic-working frequency
f_{awf}
number, n, of consecutive half-cycles (irrespective of polarity) divided by twice the time between the commencement of the first half-cycle and the end of the n-th half-cycle

Note 1 to entry: None of the n consecutive half-cycles are expected to show evidence of phase change.

Note 2 to entry: The measurement are performed at terminals in the receiver that are as close as possible to the receiving transducer (**hydrophone**) and, in all cases, before rectification.

Note 3 to entry: This frequency is determined according to the procedure specified in IEC TR 60854.

Note 4 to entry: This frequency is intended for continuous-wave systems only.

3.3.2
arithmetic-mean acoustic-working frequency
f_{awf}
arithmetic mean of the most widely separated frequencies f_1 and f_2, within the range of three times f_1, at which the level of the acoustic pressure spectrum is 3 dB below the peak level

Note 1 to entry: This frequency is intended for pulse-wave systems only.

Note 2 to entry: It is assumed that $f_1 < f_2$.

Note 3 to entry: If f_2 is not found within the range < $3f_1$, f_2 is to be understood as the lowest frequency above this range at which the spectrum level is 3 dB below the peak level.

3.3.3
magnitude-weighted acoustic-working frequency
f_{awf}
frequency weighted with the spectral acoustic pressure magnitude in the frequency range where the spectral pressure level is equal to or larger than 3 dB below the peak level

$$f_{awf} = \frac{\int f \left|\underline{P}(f)\right| \mathrm{d}f}{\int \left|\underline{P}(f)\right| \mathrm{d}f} \quad \text{with} \quad \left|\underline{P}(f)\right| = \begin{cases} \left|\underline{P}(f)\right| & \text{if } L_P(f) \geq \max L_P(f) - 3\,\text{dB} \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

where

f is the frequency of the acoustic pressure spectrum;

$|\underline{P}(f)|$ is the modulus of the complex-valued spectrum of the **acoustic pulse waveform**;

$L_P(f)$ is the pressure level spectrum given from $L_P(f) = 20\log_{10}\left(\frac{|\underline{P}(f)|}{P_{ref}}\right)$dB with P_{ref} = 1 Pa.

Note 1 to entry: This frequency is intended for pulse-wave systems only.

Note 2 to entry: The integrals in Formula (1) are definite, to be taken from the minimum to the maximum of the acquired signal spectrum.

Note 3 to entry: The restriction to the range with pressure levels equal to or larger than −3 dB of the peak level is required to avoid the influence of higher harmonic frequencies on the **acoustic-working frequency**.

Note 4 to entry: Definition 3.3.3 leads to more stable **acoustic-working frequency** results than definition 3.3.2 if there are peaks in the acoustic pressure spectrum close to the −3 dB threshold. This is particularly relevant for the determination of derated field parameters as required in IEC 62359 using a single derating factor depending on the **acoustic-working frequency**.

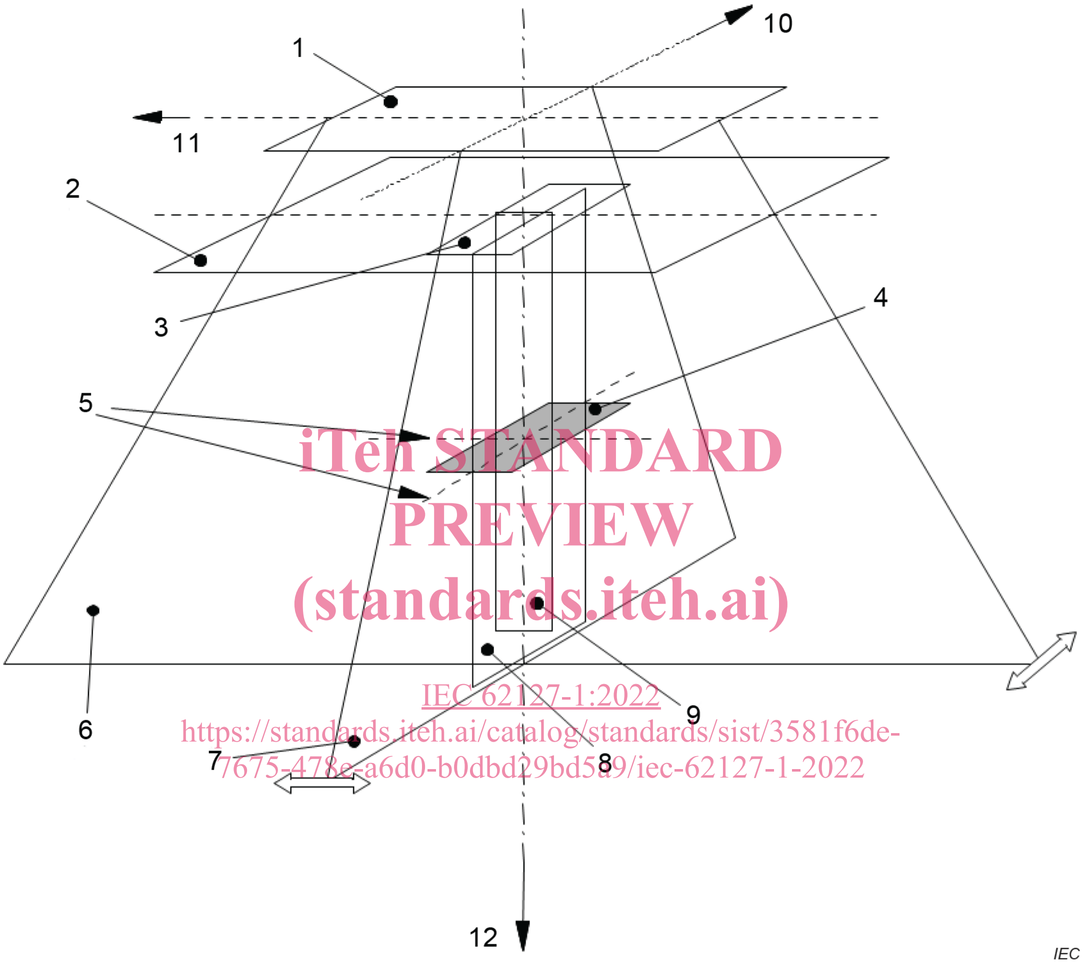
3.3.4
peak pulse acoustic frequency
f_p
acoustic-working frequency of the pulse with the largest **peak negative acoustic pressure** measured at the point of maximum **peak negative acoustic pressure**

3.3.5
temporal-average acoustic frequency
f_t
acoustic-working frequency of the time averaged acoustic pressure spectrum of the acoustic signals measured at the point of maximum **temporal-average intensity**

3.4
azimuth axis
axis formed by the junction of the **azimuth plane** and the **source aperture plane** (measurement) or **transducer aperture plane** (design)

SEE: Figure 1

[SOURCE: IEC 61828:2020, 3.7]



Key

1	external transducer surface plane	7	azimuth plane, scan plane
2	source aperture plane	8	principal longitudinal plane
3	source aperture	9	longitudinal plane
4	beam area plane	10	X, azimuth axis
5	beamwidth lines	11	Y, elevation axis
6	elevation plane	12	Z, beam axis

[SOURCE: IEC 61828:2020]

Figure 1 – Schematic diagram of the different planes and lines in an ultrasonic field

3.5
azimuth plane
plane containing the **beam axis** and the line of the minimum **full width half maximum beamwidth**

SEE: Figure 1

Note 1 to entry: For an **ultrasonic transducer** array, this is the imaging plane.

Note 2 to entry: For a single **ultrasonic transducer** with spherical or circular symmetry, it is any plane containing the **beam axis**.

[SOURCE: IEC 61828:2020, 3.8]

3.6
bandwidth
BW
difference in the most widely separated frequencies f_1 and f_2 at which the level of the acoustic pressure spectrum becomes 3 dB below the peak level, at a specified point in the acoustic field

Note 1 to entry: **Bandwidth** is expressed in hertz (Hz).

3.7
beam area
$A_{b,6}$, $A_{b,20}$
area in a specified plane perpendicular to the **beam axis** consisting of all points at which the **pulse-pressure-squared integral** is greater than a specified fraction of the maximum value of the **pulse-pressure-squared integral** in that plane

Note 1 to entry: If the position of the plane is not specified, it is the plane passing through the point corresponding to the maximum value of the **pulse-pressure-squared integral** in the whole acoustic field.

Note 2 to entry: In a number of cases, the term **pulse-pressure-squared integral** is replaced everywhere in the above definition by any linearly related quantity, for example

a) in the case of a continuous wave signal the term **pulse-pressure-squared integral** is replaced by mean square acoustic pressure as defined in IEC 61689,

b) in cases where signal synchronization with the scanframe is not available the term **pulse-pressure-squared integral** may be replaced by **temporal average intensity**.

Note 3 to entry: Some specified fractions are 0,25 and 0,01 for the −6 dB and −20 dB beam areas, respectively.

Note 4 to entry: **Beam area** is expressed in units of metre squared (m^2).

3.8
beam axis
straight line that passes through the **beam centrepoints** of two planes perpendicular to the line which connects the point of maximal **pulse-pressure-squared integral** with the centre of the **external transducer aperture**

SEE: Figure 1

Note 1 to entry: The location of the first plane is the location of the plane containing the maximum **pulse-pressure-squared integral** or, alternatively, is one containing a single main lobe which is in the focal Fraunhofer zone. The location of the second plane is as far as is practicable from the first plane and parallel to the first with the same two orthogonal scan lines (x and y axes) used for the first plane.

Note 2 to entry: In a number of cases, the term **pulse-pressure-squared integral** is replaced in the above definition by any linearly related quantity, for example

a) in the case of a continuous wave signal the term **pulse-pressure-squared integral** is replaced by mean square acoustic pressure as defined in IEC 61689,

b) in cases where signal synchronization with the scanframe is not available the term **pulse-pressure-squared integral** may be replaced by **temporal average intensity**.

3.9
beam centrepoint
position determined by the intersection of two lines in the same beam area plane xy passing through the **beamwidth midpoints** of two orthogonal planes, xz and yz, perpendicular to their respective beamwidth lines

[SOURCE: IEC 61828:2020, 3.15, modified – In the definition, "in the same beam area plane xy" and ", perpendicular to their respective beamwidth lines" have been added.]