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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Ultrasonics – Transducers – Definitions and measurement methods regarding focsusing for the transmitted fields

Ultrasons – Transducteurs – Définitions et méthodes de mesure pour la focalisation des champs transmis

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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ULTRASONICS –TRANSDUCERS – DEFINITIONS AND MEASUREMENT METHODS REGARDING FOCUSING FOR THE TRANSMITTED FIELDS

FOREWORD

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International Standard IEC 61828 has been prepared by IEC technical committee 87: Ultrasonics.

This second edition cancels and replaces the first edition published in 2001. This edition constitutes a technical revision.

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

a) Clause 6 on Measurement procedures has been replaced by Clause 6: "Acoustic field measurement: equipment" and Clause 7: "Measurement procedure" and related definitions.
b) Reorganization of definitions and measurement section to accommodate specific sets of measurements for focusing, nonlinearity, beam axis alignment, beam area, beam maximum, numerical projection, plane wave, high intensity therapeutic ultrasound, multiple sources, spatial impulse response and compound plane waves. Clause 3 has been moved to Annex B.
c) The normative references have been updated and the Bibliography has been expanded from 8 to 40 references.

d) Twelve figures have been updated and seven new figures (B.1, B.3, B.7, B.10, B.11, B.12, B.13, B.14) have been added to facilitate measurements and be consistent with measurement terminology.

e) New measurements have been added for time delays, arrays, plane waves and spatial impulse response.

f) Annex A has been expanded to provide general guidance on pulsed waves, system responses, focusing gains and minimum beamwidth estimation.

g) New annexes have been added:

- Annex B (informative) Rationale for focusing and nonfocusing definitions
- Annex E (informative) Uncertainties;
- Annex F (informative) Transducer and hydrophone positioning systems;
- Annex G (informative) Planar scanning of a hydrophone to determine acoustic output power;
- Annex H (informative) Properties of water;

In addition, Annex A was reorganized and new Clauses A.1, A.5 and A.6 were added.

h) Guidelines for remaining within the manufacturer's pressure and intensity hydrophone limits and the determination of the extent of nonlinearity in the field have been added.

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

FDIS	Report on voting
87/746/FDIS	87/749/RVD

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

NOTE 1 The following print types are used:

– Requirements: in roman type.
– Notes: small roman type.
– Words in **bold** in the text are defined in Clause 3.

NOTE 2 There are some inconsistencies in font type for symbols and formulae between some of the normative references and this document. They will be resolved in a future revision of the normative references.

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

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

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INTRODUCTION

Focusing transducers are essential in medical applications for obtaining high-resolution images, Doppler and flow data and for concentrating ultrasonic energy at desired sites for therapy. This document provides specific definitions appropriate for describing the focused field from a theoretical viewpoint for transducers with known characteristics intended by design. Other specific definitions included in this document, based on measurement methods, provide a means of determining **focusing** properties, if any, of a transducer of unknown field characteristics. The measurement method and definitions provide criteria for determining if the transducer is focusing, as well as a means of describing the **focusing** properties of the field. **Beam axis** alignment methods and field characterization measurements are given for both **focusing** and **nonfocusing** transducers.

ULTRASONICS –TRANSDUCERS – DEFINITIONS AND MEASUREMENT METHODS REGARDING FOCUSING FOR THE TRANSMITTED FIELDS

1 Scope

This document

- provides definitions for the transmitted field characteristics of focusing and nonfocusing transducers for applications in medical ultrasound;
- relates these definitions to theoretical descriptions, design, and measurement of the transmitted fields of focusing transducers;
- gives measurement methods for obtaining defined field characteristics of focusing and nonfocusing transducers;
- specifies beam axis alignment methods appropriate for focusing and nonfocusing transducers.

This document relates to focusing ultrasonic transducers operating in the frequency range appropriate to medical ultrasound (0,5 MHz to 40 MHz) for both therapeutic and diagnostic applications. It shows how the characteristics of the transmitted field of transducers can be described from the point of view of design, as well as measured by someone with no prior knowledge of the construction details of a particular device. The transmitted ultrasound field for a specified excitation is measured by a hydrophone in either a standard test medium (for example, water) or in a given medium. This document applies only to media where the field behaviour is essentially like that in a fluid (i.e. where the influence of shear waves and elastic anisotropy is small), including soft tissues and tissue-mimicking gels. Any aspects of the field that affect their theoretical description or are important in design are also included. These definitions would have use in scientific communications, system design and description of the performance and safety of systems using these devices.

This document incorporates definitions from other related standards where possible, and supplies more specific terminology, both for defining focusing characteristics and for providing a basis for measurement of these characteristics.

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 61689:2013, *Ultrasonics – Physiotherapy systems – Field specifications and methods of measurement in the frequency range 0,5 MHz to 5MHz*

IEC 62127-3:2007, *Ultrasonics – Hydrophones – Part 3: Properties of hydrophones for ultrasonic fields up to 40 MHz*
IEC 62127-3:2007/AMD1:2013

IEC TS 62556:2014, *Ultrasonics – Field characterization – Specification and measurement of field parameters for high intensity therapeutic ultrasound (HITU) transducers and systems*

IEC 61161, *Ultrasonics – Power measurement – Radiation force balances and performance requirements*

IEC 62555, *Ultrasonics – Power measurement –High intensity therapeutic ultrasound (HITU) transducers and systems*

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 following terms and definitions 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, a single **tone-burst**, or one cycle of a **continuous wave**

Note 1 to entry: In some cases such as an amplitude-modulated pulse, the overall pulse train can appear as a group of nearly contiguous pulses with spacings much smaller than the overall pulse repetition time.

3.2
annular array
ultrasonic transducer element group having radiating elements in the same plane or curved surface and consisting of concentric elements which are electrically phased to control the characteristics of an acoustic beam

3.3
acoustic frequency
acoustic-working 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.

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 should be given in order to enable any frequency-dependent correction to the signal.

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

[SOURCE: IEC 62127-1:2007, 3.3]

3.3.1
zero-crossing acoustic-working frequency
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 should show evidence of phase change.

Note 2 to entry: This frequency is intended for continuous-wave systems only.

[SOURCE: IEC 62127-1:2007/AMD1:2013, 3.3.1, modified – NOTE 2 and NOTE 3 have been deleted.]

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 magnitude of the acoustic pressure spectrum is 3 dB below the peak magnitude

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 < 3 f_1, f_2 is to be understood as the lowest frequency above this range at which the spectrum magnitude is 3 dB below the peak magnitude.

Note 4 to entry: See IEC 62127-1 for methods of determining the arithmetic-mean acoustic-working frequency.

[SOURCE: IEC 62127-1:2007 and IEC 62127-1:2007/AMD1:2013, 3.3.2, modified – Note 4 to entry has been added.]

3.4
aperture path difference
Δ
difference in path lengths from a specified **geometric focus** to the periphery of the **transducer aperture** and to the intersection of the **beam axis** with the **transducer aperture plane** for a specified **longitudinal plane** and for an **unsteered beam**

SEE: Figure A.5.

Note 1 to entry: Δ is expressed in metres, m.

3.5
apodization
amplitude weighting or shading of the **transducer aperture**

3.6
axial field-point path difference
Δ'
difference in path lengths from a specified field point on the **beam axis** to the periphery of the **transducer aperture** and to the intersection of the **beam axis** with the **transducer aperture plane**

SEE: Figure A.5.

Note 1 to entry: It is specified in the same longitudinal plane as the aperture path difference.

Note 2 to entry: Δ' is expressed in metres, m.

3.7
azimuth axis
axis formed by the junction of the **azimuth plane** and the **source aperture plane** (measurement) or **transducer aperture plane** (design)

SEE: Figure B.3, Figure B.13 and Figure B.14.

Note 1 to entry: The selection of this axis is arbitrary for a circularly-symmetric HITU transducer without a hole in its centre but is perpendicular to the elevation axis.

Note 2 to entry: If a HITU transducer has a hole in its centre, within which is a diagnostic imaging transducer, then this axis is aligned with the azimuth axis of the imaging transducer.

3.8
azimuth plane
plane containing the **beam axis** and the line of the minimum **full width half maximum beamwidth**

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**.

SEE: Figure B.3, Figure B.13 and Figure B.14.

3.9
bandwidth
BW
difference in the most widely separated frequencies f_1 and f_2 at which the magnitude of the acoustic pressure spectrum becomes 3 dB below the peak magnitude, at a specified point in the acoustic field

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

[SOURCE: IEC 62127-1:2007, 3.6]

3.10
beam area
$A_{b,6}$, $A_{b,12}$, $A_{b,20}$
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, e.g.:

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** can 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 square metres (m^2).

[SOURCE: IEC 62127-1:2007 and IEC 62127-1:2007/AMD1:2013, 3.7, modified – The symbol $A_{b,12}$ has been added.]

3.11
beam area focal depth
distance along **beam axis** from **source aperture plane** to **beam area focus**

SEE: Figure B.10.

3.12
beam area focal plane
plane perpendicular to the **beam axis** and containing the **beam area focus**

SEE: Figure B.10.

3.13
beam area focus
point on the **beam axis** at which the −6 dB **beam area** is a minimum

SEE: Figure B.10.

3.14
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 surface plane**

SEE: Figure B.3, Figure B.13 and Figure B.14.

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 postfocal 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, e.g.:

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** can be replaced by **temporal-average intensity**.

Note 3 to entry: Refer to Annex C and Annex D.

[SOURCE: IEC 62127-1:2007, 3.8, modified – In the definition, "**external transducer aperture**" has been replaced by "**external transducer surface plane**".]

3.15
beam centrepoint
position determined by the intersection of two lines passing through the **beamwidth midpoints** of two orthogonal planes, xz and yz

3.16
beam maximum
bm
maximum measured **pulse-pressure-squared integral** on the **beam axis**

SEE: Figure B.7.

[SOURCE: IEC TS 62556:2014, 3.10]

3.17
beam maximum depth
L_{bm}
smallest distance between two points on the **beam axis** where the **pulse-pressure-squared integral** falls below its maximum on the **beam axis** by 6 dB

SEE: Figure B.7.

Note 1 to entry: In a number of cases, the term **pulse-pressure-squared** integral is replaced in the above definition by any linearly related quantity, e.g.: 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.

Note 2 to entry: **Beam maximum depth** is expressed in metres (m).

[SOURCE: IEC TS 62556:2014, 3.11]