



BSI Standards Publication

Ultrasonics – Field characterization – Test methods for the determination of thermal and mechanical indices related to medical diagnostic ultrasonic fields (IEC 62359:2010)

National foreword

This British Standard is the UK implementation of EN 62359:2011+A1:2018. It is identical to IEC 62359:2010, incorporating amendment 1:2017. It supersedes BS EN 62359:2011, which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by **A1** **A1**.

The UK participation in its preparation was entrusted to Technical Committee EPL/87, Ultrasonics.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Amendments/corrigenda issued since publication

Date	Text affected
30 June 2018	Implementation of IEC amendment 1:2017 with CENELEC endorsement A1:2018

**Ultrasonics -
Field characterization -
Test methods for the determination of thermal and mechanical indices
related to medical diagnostic ultrasonic fields
(IEC 62359:2010)**

Ultrasons – Caractérisation du champ –
Méthodes d'essai pour la détermination
d'indices thermique et mécanique des
champs d'ultrasons utilisés pour le
diagnostic médical
(CEI 62359:2010)

Ultraschall -
Charakterisierung von Feldern -
Prüfverfahren für die Ermittlung des
thermischen und des mechanischen
Indexes bezogen auf medizinische
Ultraschalldiagnostikfelder
(IEC 62359:2010)

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CENELEC

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

Management Centre: Avenue Marnix 17, B - 1000 Brussels

European Foreword

The text of document 87/445/FDIS, future edition 2 of IEC 62359, prepared by IEC TC 87, Ultrasonics, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62359 on 2011-02-01.

This European Standard supersedes EN 62359:2005.

Major changes with respect to EN 62359:2005 include the following:

- The methods of determination set out in EN 62359:2005 were based on those contained in the American standard for Real-Time Display of Thermal and Mechanical Acoustic Output Indices on Diagnostic Ultrasound Equipment (ODS) and were intended to yield identical results. While EN 62359:2010 also follows the ODS in principal and uses the same basic formulae and assumptions (see Annex A), it contains a few significant modifications which deviate from the ODS.
- One of the primary issues dealt with in preparing EN 62359:2010 was “missing” *TI* equations. In EN 62359:2005 there were not enough equations to make complete “at-surface” and “below-surface” summations for *TIS* and *TIB* in combined-operating modes. Thus major changes with respect to EN 62359:2005 are related to the introduction of new calculations of thermal indices to take into account both “at-surface” and “below-surface” thermal effects.

For the specific technical changes involved please see Annex E.

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

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement (dop) 2011-11-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2014-02-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62359:2010 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC 61689 NOTE Harmonized as EN 61689.

Foreword to amendment A1

The text of document 87/661/FDIS, future edition 1 of IEC 62359:2010/A1:2017, prepared by IEC/TC 87 "Ultrasonics" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62359:2011/A1:2018.

The following dates are fixed:

- latest date by which this document has (dop) 2018-08-03
to be implemented at national level by
publication of an identical national
standard or by endorsement
- latest date by which the national (dow) 2020-11-03
standards conflicting with this
document have to be withdrawn

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Endorsement notice

The text of the International Standard IEC 62359:2010/A1:2017 was approved by CENELEC as a European Standard without any modification.

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 When 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.

Publication	Year	Title	EN/HD	Year
IEC 60601-2-37	2007	Medical electrical equipment -- Part 2-37: Particular requirements for the basic safety and essential performance of ultrasonic medical diagnostic and monitoring equipment	EN 60601-2-37	2008
-	-		+ A11	2011
+ A1	2015		+ A1	2015
IEC 61157	2007	Standard means for the reporting of the acoustic output of medical diagnostic ultrasonic equipment	EN 61157	2007
+ A1	2013		+ A1	2013
IEC 61161	2013	Ultrasonics - Power measurement - Radiation force balances and performance requirements	EN 61161	2013
IEC 61828	2001	Ultrasonics - Focusing transducers - Definitions and measurement methods for the transmitted fields	EN 61828	2001
IEC 62127-1	2007	Ultrasonics - Hydrophones -- Part 1: Measurement and characterization of medical ultrasonic fields up to 40 MHz	EN 62127-1	2007
+ A1	2013		+ A1	2013
IEC 62127-2	2007	Ultrasonics - Hydrophones -- Part 2: Calibration for ultrasonic fields up to 40 MHz	EN 62127-2	2007
IEC 62127-3	2007	Ultrasonics - Hydrophones -- Part 3: Properties of hydrophones for ultrasonic fields up to 40 MHz	EN 62127-3	2007

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**ULTRASONICS –
FIELD CHARACTERIZATION –
TEST METHODS FOR THE DETERMINATION OF THERMAL
AND MECHANICAL INDICES RELATED TO
MEDICAL DIAGNOSTIC 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.
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 *Text deleted* 

International standard IEC 62359 has been prepared by IEC technical committee 87: Ultrasonics.

This second edition It constitutes a technical revision.

Major changes with respect to the previous edition include the following:

- The methods of determination set out in the first edition of this standard were based on those contained in the American standard for Real-Time Display of Thermal and Mechanical Acoustic Output Indices on Diagnostic Ultrasound Equipment (ODS) and were intended to yield identical results. While this second edition also follows the ODS in principal and uses the same basic formulae and assumptions (see Annex A), it contains a few significant modifications which deviate from the ODS.
- One of the primary issues dealt with in preparing this second edition of IEC 62359 was "missing" *TI* equations. In Edition 1 there were not enough equations to make complete "at-surface" and "below-surface" summations for *TIS* and *TIB* in combined-operating modes. Thus major changes with respect to the previous edition are related to the introduction of new calculations of thermal indices to take into account both "at-surface" and "below-surface" thermal effects.

For the specific technical changes involved please see Annex E.

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

This standard may be used to support the requirements of IEC 60601-2-37.

In this particular standard, the following print types are used:

- requirements, compliance with which can be tested, and definitions: in roman type
- notes, explanations, advice, introductions, general statements, exceptions, and references: in smaller type
- *test specifications: in italic type*
- words in **bold** are defined terms in Clause 3

The committee has decided that the contents of the base publication and its amendment 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.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

Medical diagnostic ultrasonic equipment is widely used in clinical practice for imaging and monitoring purposes. Equipment normally operates at frequencies in the low megahertz frequency range and comprises an ultrasonic transducer acoustically coupled to the patient and associated electronics. There is an extremely wide range of different types of systems in current clinical practice.

The ultrasound entering the patient interacts with the patient's tissue, and this interaction can be considered in terms of both thermal and non-thermal effects. The purpose of this International standard is to specify methods of determining thermal and non-thermal exposure indices that can be used to help in assessing the hazard caused by exposure to a particular ultrasonic field used for medical diagnosis or monitoring. It is recognised that these indices have limitations, and knowledge of the indices at the time of an examination is not sufficient in itself to make an informed clinical risk assessment. It is intended that these limitations will be addressed in future revisions of this standard and as scientific understanding increases. While such increases remain pending, several organizations have published **prudent-use statements**.

Under certain conditions specified in IEC 60601-2-37, these indices are displayed on medical ultrasonic equipment intended for these purposes.

INTRODUCTION to Amendment

The second edition of IEC 62359 was published in 2010. Since then, IEC 60601-2-37:2007/AMD1:2015 has been published and calls for provision of **attenuated spatial peak temporal average intensity**, $I_{\text{spta},\alpha}$, and **attenuated spatial peak pulse average intensity**, $I_{\text{sppa},\alpha}$, at specific spatial maximum points in the ultrasonic field on the **beam axis**. No IEC standard describes the determination of these quantities at these specific positions. IEC 62359 for determining the thermal indices currently uses similar values at other positions, therefore, the determination of **attenuated spatial peak temporal average intensity**, $I_{\text{spta},\alpha}$, and **attenuated spatial peak pulse average intensity**, $I_{\text{sppa},\alpha}$, has been added as an annex in this amendment.

Additionally, references to newly published collateral standards have been updated. 

ULTRASONICS – FIELD CHARACTERIZATION – TEST METHODS FOR THE DETERMINATION OF THERMAL AND MECHANICAL INDICES RELATED TO MEDICAL DIAGNOSTIC ULTRASONIC FIELDS

1 Scope

This International standard is applicable to medical diagnostic ultrasound fields.

This standard establishes

- parameters related to thermal and non-thermal exposure aspects of diagnostic ultrasonic fields;
- methods for the determination of an exposure parameter relating to temperature rise in theoretical tissue-equivalent models, resulting from absorption of ultrasound;
- methods for the determination of an exposure parameter appropriate to certain non-thermal effects.

NOTE 1 In Clause 3 of this standard, SI units are used (per ISO/IEC Directives, Part 2, ed. 5, Annex I b) in the Notes below definitions of certain parameters, such as beam areas and intensities; it may be convenient to use decimal multiples or submultiples in practice. Users must take care of decimal prefixes used in combination with the units when using and calculating numerical data. For example, beam area may be specified in cm^2 and intensities in W/cm^2 or mW/cm^2 .

NOTE 2 Underlying calculations have been done from 0,25 MHz to 15 MHz for MI and 0,5 MHz to 15 MHz for TI.

NOTE 3 The thermal indices are steady state estimates based on the acoustic **output power** required to produce a 1°C temperature rise in tissue conforming to the “homogeneous tissue 0,3 $\text{dBcm}^{-1}\text{MHz}^{-1}$ attenuation model” [1] 1) and may not be appropriate for radiation force imaging, or similar techniques that employ pulses or pulse bursts of sufficient duration to create a significant transient temperature rise. [2]

2 Normative references

The following referenced documents are indispensable for the application 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 60601-2-37:  2007 , *Medical electrical equipment – Part 2-37: Particular requirements for the basic safety and essential performance of ultrasonic medical diagnostic and monitoring equipment*

 IEC 60601-2-37:2007/AMD1:2015 

IEC 61157:2007, *Standard means for the reporting of the acoustic output of medical diagnostic ultrasonic equipment*

 IEC 61157:2007/AMD1:2013 

IEC 61161:  2013 , *Ultrasonics – Power measurement – Radiation force balances and performance requirements*

IEC 61828:2001, *Ultrasonics – Focusing transducers – Definitions and measurement methods for the transmitted fields*

1) Figures in square brackets refer to Bibliography.

IEC 62127-1:2007, *Ultrasonics – Hydrophones – Part 1: Measurement and characterization of medical ultrasonic fields up to 40 MHz*

Ⓐ IEC 62127-1:2007/AMD1:2013 Ⓐ

IEC 62127-2:2007, *Ultrasonics – Hydrophones – Part 2: Calibration for ultrasonic fields up to 40 MHz*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in Ⓐ IEC 60601-2-37 Ⓐ, IEC 62127-1Ⓐ Text deleted Ⓐ, IEC 62127-2Ⓐ Text deleted Ⓐ, IEC 62127-3Ⓐ Text deleted Ⓐ, IEC 61157Ⓐ Text deleted Ⓐ and IEC 61161Ⓐ Text deleted Ⓐ apply. Ⓐ Several of these are repeated below for convenience and others are listed because they have been modified for application to this standard. Ⓐ

NOTE Units below definitions are given in SI units as per ISO/IEC Directives, Part 2, ed. 5, Annex I b). Users must be alert to possible need to convert units when using this standard in situations where data are received in units that are different from those used in the SI system.

3.1

acoustic attenuation coefficient

α

coefficient intended to account for ultrasonic attenuation of tissue between the **external transducer aperture** and a specified point

NOTE 1 A linear dependence on frequency is assumed.

NOTE 2 **Acoustic attenuation coefficient** is expressed in decibels per metre per hertz ($\text{dB m}^{-1} \text{Hz}^{-1}$).

3.2

acoustic absorption coefficient

μ_a

coefficient intended to account for ultrasonic absorption of tissue in the region of interest

NOTE 1 A linear dependence on frequency is assumed.

NOTE 2 **Acoustic absorption coefficient** is expressed in neper per metre per hertz ($\text{Np m}^{-1} \text{Hz}^{-1}$).

3.3

acoustic repetition period

arp

time interval between corresponding points of consecutive cycles, Ⓐ pulses or scans, depending on the current operating mode Ⓐ

NOTE 1 The **acoustic repetition period** is equal to the **pulse repetition period** for non-automatic scanning systems and to the **scan repetition period** for automatic scanning systems.

Ⓐ NOTE 2 For continuous wave modes, the **acoustic repetition period** is the time interval between corresponding points of consecutive cycles

NOTE 3 For **combined operating modes** where transmit pulsing of the constituent modes may be interrupted, the *arp* determination should take into account non-pulsing time to calculate an average period. Ⓐ

NOTE Ⓐ 4 Ⓐ The **acoustic repetition period** is expressed in seconds (s).

[IEC 62127-1:2007, definition 3.2, modified]

3.4 acoustic working frequency

frequency of an acoustic signal based on the observation of the output of a **hydrophone** placed in an acoustic field $\langle A_1 \rangle$ on the **beam axis**, beyond the **break-point depth**, corresponding to **depth of maximum pulse-intensity integral** $z_{pii} \cdot \langle A_1 \rangle$

NOTE 1 The signal is analysed using either the **zero-crossing acoustic-working frequency** technique or a spectrum analysis method. Specific acoustic-working frequencies are defined in 3.4.1 and 3.4.2.

NOTE 2 For pulsed waveforms the **acoustic-working frequency** shall be measured at the $\langle A_1 \rangle$ **depth for peak pulse-intensity integral**. $\langle A_1 \rangle$

NOTE 3 **Acoustic frequency** is expressed in hertz (Hz).

[IEC 62127-1:2007, definition 3.3, modified]

3.4.1 zero-crossing acoustic-working frequency

f_{awf}

number 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 Any half-cycle in which the waveform shows evidence of phase change shall not be counted.

NOTE 2 The measurement should be 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 This frequency is determined according to the procedure specified in IEC/TR 60854 [3].

NOTE 4 This frequency is intended for continuous-wave systems only.

3.4.2 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 This frequency is intended for pulse-wave systems only.

NOTE 2 It is assumed that $f_1 < f_2$.

NOTE 3 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 from the peak magnitude.

3.5 attenuated bounded-square output power

$P_{1x1,\alpha}(z)$

The maximum value of the **attenuated output power** passing through any one square centimeter of the plane perpendicular to the **beam axis** at depth z

NOTE 1 At $z = 0$ (the transducer surface) $P_{1x1,\alpha}(z)$ becomes the **bounded-square output power**, that is, at $z = 0$, $P_{1x1,\alpha} = P_{1x1}$.

NOTE 2 **Attenuated bounded-square output power** is expressed in watts (W).

3.6 attenuated output power

$P_\alpha(z)$

value of the acoustic **output power** after attenuation, at a specified distance from the **external transducer aperture**, and given by

$$P_\alpha(z) = P 10^{(-\alpha z f_{awf}/10 \text{ dB})}$$

(1)

where

α is the **acoustic attenuation coefficient**;

z is the distance from the **external transducer aperture** to the point of interest;

f_{awf} is the **acoustic working frequency**;

P is the **output power** measured in water.

NOTE 1 **Attenuated output power** is expressed in watts (W).

NOTE 2 In the case of stand-offs the P should represent the **output power** emanating from the stand-off.

3.7 attenuated peak-rarefactional acoustic pressure

$p_{r,\alpha}(z)$

value of the **peak-rarefactional acoustic pressure** after attenuation, $\boxed{A_1}$ on a plane perpendicular to the **beam axis** $\langle A_1 \rangle$ at a specified distance $\boxed{A_1} z \langle A_1 \rangle$ from the **external transducer aperture**, and given by

$$p_{r,\alpha}(z) = p_r(z) 10^{(-\alpha z f_{\text{awf}}/20 \text{ dB})} \quad (2)$$

where

α is the **acoustic attenuation coefficient**;

z is the distance from the **external transducer aperture** $\boxed{A_1}$ along the **beam axis** $\langle A_1 \rangle$ to $\boxed{A_1}$ the plane containing $\langle A_1 \rangle$ the point of interest;

f_{awf} is the **acoustic working frequency**;

$p_r(z)$ is the **peak-rarefactional acoustic pressure** measured in water.

NOTE Attenuated peak-rarefactional acoustic pressure is expressed in pascals (Pa).

3.8 attenuated pulse-intensity integral

$p_{ii,\alpha}(z)$

value of the **pulse-intensity integral** after attenuation, $\boxed{A_1}$ on a plane perpendicular to the **beam axis** $\langle A_1 \rangle$ at a specified distance $\boxed{A_1} z \langle A_1 \rangle$ from the **external transducer aperture**, and given by

$$p_{ii,\alpha}(z) = p_{ii} 10^{(-\alpha z f_{\text{awf}}/10 \text{ dB})} \quad (3)$$

where

α is the **acoustic attenuation coefficient**;

z is the distance from the **external transducer aperture** $\boxed{A_1}$ along the **beam axis** $\langle A_1 \rangle$ to $\boxed{A_1}$ the plane containing $\langle A_1 \rangle$ the point of interest;

f_{awf} is the **acoustic working frequency**;

p_{ii} is the **pulse-intensity integral** measured in water.

NOTE $\boxed{A_1}$ 1 $\langle A_1 \rangle$ **Attenuated pulse-intensity integral** is expressed in joules per metre squared, (J m^{-2}).

$\boxed{A_1}$ NOTE 2 For measurement purposes of this standard, $p_{ii,\alpha}$ is equivalent to $1/(\rho c)$ times the **attenuated pulse-pressure-squared integral** at depth z , with ρc denoting the characteristic acoustic impedance of pure water. $\langle A_1 \rangle$

3.9 attenuated spatial-average temporal-average intensity

$I_{\text{sata},\alpha}(z)$

value of the **spatial-average temporal-average intensity** after attenuation, $\boxed{A_1}$ on a plane perpendicular to the **beam axis** $\langle A_1 \rangle$ at a specified distance $\boxed{A_1} z \langle A_1 \rangle$ from the **external transducer aperture**, and given by

$$I_{\text{sata},\alpha}(z) = I_{\text{sata}} 10^{(-\alpha z f_{\text{awf}}/10 \text{ dB})}$$

where

- α is the **acoustic attenuation coefficient**;
- z is the distance from the **external transducer aperture** $\langle A_1 \rangle$ along the **beam axis** $\langle A_1 \rangle$ to $\langle A_1 \rangle$ the plane containing $\langle A_1 \rangle$ the point of interest;
- f_{awf} is the **acoustic working frequency**;
- I_{sata} is the **spatial-average temporal-average intensity**, at a specified distance z measured in water.

NOTE **Attenuated spatial-average temporal-average intensity** is expressed in watts per metre squared, (W m^{-2}).

3.10 attenuated spatial-peak temporal-average intensity

$I_{spta,\alpha}(z)$

value of the **spatial-peak temporal-average intensity** after attenuation, $\langle A_1 \rangle$ on a plane perpendicular to the **beam axis** $\langle A_1 \rangle$ at a specified distance $\langle A_1 \rangle z \langle A_1 \rangle$ from the **external transducer aperture**, and given by

$$I_{spta,\alpha}(z) = I_{spta} 10^{(-\alpha z f_{awf}/10\text{dB})} \quad (5)$$

where

- α is the **acoustic attenuation coefficient**;
- z is the distance from the **external transducer aperture** $\langle A_1 \rangle$ along the **beam axis** $\langle A_1 \rangle$ to $\langle A_1 \rangle$ the plane containing $\langle A_1 \rangle$ the point of interest;
- f_{awf} is the **acoustic working frequency**;
- I_{spta} is the **spatial-peak temporal-average intensity**, at a specified distance z measured in water.

NOTE **Attenuated spatial-peak temporal-average intensity** is expressed in watts per metre squared, (W m^{-2}).

3.11 attenuated temporal-average intensity

$I_{ta,\alpha}(z)$

value of the **temporal-average intensity** after attenuation, $\langle A_1 \rangle$ on a plane perpendicular to the **beam axis** $\langle A_1 \rangle$ at a specified distance $\langle A_1 \rangle z \langle A_1 \rangle$ from the **external transducer aperture**, and given by

$$I_{ta,\alpha}(z) = I_{ta}(z) 10^{(-\alpha z f_{awf}/10\text{dB})} \quad (6)$$

where

- α is the **acoustic attenuation coefficient**;
- z is the distance from the **external transducer aperture** $\langle A_1 \rangle$ along the **beam axis** $\langle A_1 \rangle$ to $\langle A_1 \rangle$ the plane containing $\langle A_1 \rangle$ the point of interest;
- f_{awf} is the **acoustic working frequency**;
- $I_{ta}(z)$ is the **temporal-average intensity** measured in water.

NOTE **Attenuated temporal-average intensity** is expressed in watts per metre squared, (W m^{-2}).

3.12 beam area

$A_b(z)$

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 If the position of the plane is not specified, it is the plane passing through the point corresponding to the **spatial-peak temporal-peak acoustic pressure** in the whole acoustic field.

NOTE 2 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 [4];
- b) in cases where signal synchronisation with the scanframe is not available, the term **pulse-pressure-squared integral** may be replaced by **temporal average intensity**.

NOTE 3 Some specified levels are 0,25 and 0,01 for the -6 dB and -20 dB beam areas, respectively.

NOTE 4 Beam area is expressed in metres squared (m^2).

[IEC 62127-1:2007, definition 3.7, modified]

3.13

beam axis

straight line that passes through the beam centrepoinets 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

NOTE 1 See Figure 1.

NOTE 2 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 3 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 synchronisation with the scan frame is not available the term **pulse-pressure-squared integral** may be replaced by **temporal average intensity**.

[IEC 62127-1:2007, definition 3.8]

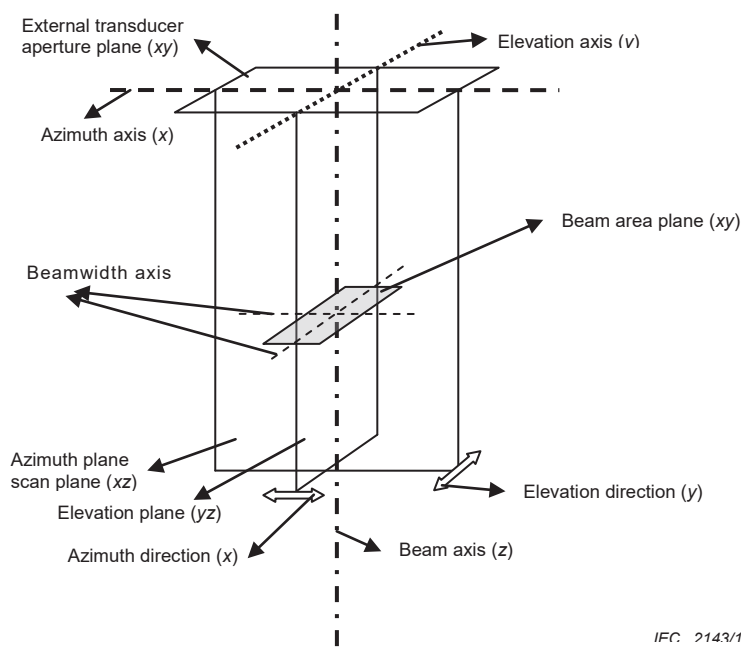


Figure 1 – Schematic diagram of the different planes and lines in an ultrasonic field
(modified from IEC 61828 and IEC 62127-1)

3.14**beam centrepoint**

position determined by the 2D centroid of a set of **pulse-pressure-squared integrals** measured over the -6dB beam-area in a specified plane

NOTE Methods for determining 2D centroids are described in Annex B and C of IEC 61828.

3.15**beamwidth midpoint**

linear average of the coordinates of the locations midway between each pair of points determining a **beamwidth** in a specified plane

NOTE The average is taken over as many **beamwidth** levels given in B.2 of IEC 61828 as signal level permits.

[IEC 62127-1:2007, definition 3.10, modified]

3.16**beamwidth**

w_6 , w_{12} , w_{20}

greatest distance between two points on a specified axis perpendicular to the **beam axis** where the **pulse-pressure-squared integral** falls below its maximum on the specified axis by a specified amount

NOTE 1 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 [4],
- b) in cases where signal synchronisation with the scan frame is not available the term **pulse-pressure-squared integral** may be replaced by **temporal average intensity**.

NOTE 2 Commonly used **beamwidths** are specified at -6 dB, -12 dB and -20 dB levels below the maximum. The decibel calculation implies taking 10 times the logarithm to the base of 10 of the ratios of the integrals.

NOTE 3 **Beamwidth** is expressed in metres (m).

[IEC 62127-1:2007, definition 3.11]

3.17**bone thermal index**

TIB

thermal index for applications, such as foetal (second and third trimester) A1 Text deleted A1, in which the ultrasound beam passes through soft tissue and a focal region is in the immediate vicinity of bone

NOTE 1 See 5.4.2 and 5.5.2 for methods of determining the bone thermal index.

NOTE 2 See Annex A for rationale and derivation notes.

3.18**bounded-square output power**

P_{1x1}

maximum value of the time average **acoustic output power** emitted from any one-centimetre square region of the active area of the transducer, the one-centimetre square region having 1 cm dimensions in the x- and y-directions

NOTE 1 The side of the 1 cm × 1 cm square should be aligned with the azimuth axis in accordance with Figure 1. See A.4.1.4 and Annex B for more detail.

NOTE 2 **Bounded-square output power** is expressed in watts (W).

3.19 break-point depth

z_{bp}

closest distance, to the solid surface of the transducer or the enclosure of any stand-off path, used during a search to determine below-surface TIS and TIB $\langle A_1 \rangle$ **acoustic working frequency** and intensity parameters (such as **attenuated spatial-peak temporal-average intensity**) $\langle A_1 \rangle$

$$z_{bp} = 1,5 \times D_{eq} \quad (7)$$

where D_{eq} is the **equivalent aperture diameter** for $\langle A_1 \rangle$ **non-scanning modes** $\langle A_1 \rangle$.

NOTE 1 Specifically, for the **mechanical index**: the search should continue till the depth z_{MI} . Reasonable care should be taken not to go so close to the transducer face as to risk the integrity of the hydrophone or the validity of the measurement.

NOTE 2 For **scanning modes**, $\langle A_1 \rangle$ use the **non-scanning mode** D_{eq} value calculation [Equation (8)]. Do this using the **output beam area** of one **ultrasonic scan line**; $\langle A_1 \rangle$ the central scan line, corresponding to the **beam axis** (i.e. the line where p_{ii} , MI , and f_{awf} are measured).

NOTE 3 See Annex A for rationale and derivation notes.

NOTE 4 **Breakpoint depth** is expressed in metres (m).

3.20 combined-operating mode

mode of operation of an **equipment** that combines more than one **discrete-operating mode**

[IEC 61157:2007, definition 3.17.1]

3.21 cranial-bone thermal index

TIC

thermal index for applications in which the ultrasound beam passes through bone near the beam entrance into the body, $\langle A_1 \rangle$ such as paediatric and adult cranial or neonatal cephalic applications $\langle A_1 \rangle$

NOTE 1 See 5.4.2.1 and 5.5.2.1 for methods of determining the **cranial bone thermal index**.

NOTE 2 See Annex A for rationale and derivation notes.

3.22 default setting

specific state of control that the $\langle A_1 \rangle$ **medical** $\langle A_1 \rangle$ **diagnostic** $\langle A_1 \rangle$ **ultrasonic** $\langle A_1 \rangle$ **equipment** will enter upon power-up, new patient selection or change from non-foetal to foetal applications

3.23 depth for mechanical index

z_{MI}

depth on the **beam axis** from the **external transducer aperture** to the plane of maximum **attenuated** $\langle A_1 \rangle$ **pulse-pressure-squared-integral** ($ppsi_a$) $\langle A_1 \rangle$

$\langle A_1 \rangle$ NOTE 1 Because z_{MI} may occur closer to the transducer than the **break-point depth** z_{bp} , use of $ppsi_a$ rather than p_{ii}_a is technically more appropriate. If $z_{ppsi,a}$ is larger than z_{bp} , then $z_{ppsi,a}$ and $z_{pii,a}$ are equal. $\langle A_1 \rangle$

NOTE $\langle A_1 \rangle$ 2 $\langle A_1 \rangle$ **Depth for mechanical index** is expressed in metres (m).

3.24 depth for $\langle A_1 \rangle$ maximum $\langle A_1 \rangle$ pulse intensity integral

$\langle A_1 \rangle$ depth z on the **beam axis** and beyond the **break-point depth** z_{bp} from the **external transducer aperture** to the plane of maximum **pulse-intensity integral** (p_{ii}) as approximated by the **pulse-pressure-squared integral** ($ppsi$) $\langle A_1 \rangle$

NOTE 1 **Depth for $\langle A_1 \rangle$ maximum p_{ii}** is expressed in metres (m).

$\langle A_1 \rangle$ NOTE 2 **Depth for maximum p_{ii}** is termed "depth for peak pulse-intensity integral" in IEC 60601-2-37:2007/AMD1:2015.

NOTE 3 At this depth the **acoustic working frequency** is determined. $\langle A_1 \rangle$

3.25 depth for *TIB*

$z_{b,ns}$ for **non-scanning modes**

for **non-scanning modes**, the distance along the **beam axis** from the **external transducer aperture** to the plane where the product of **attenuated output power** and **attenuated spatial-peak temporal-average intensity** is a maximum over the distance range equal to, or greater than, the **break-point depth**, z_{bp}

NOTE 1 **Depth for *TIB*** is expressed in metres (m).

NOTE 2 See Annex A for rationale and derivation notes.

3.26 depth for *TIS*

$z_{s,ns}$ for **non-scanning modes**

for **non-scanning modes**, the distance along the **beam axis** from the **external transducer aperture** to the plane at which the lower value of the **attenuated output power** and the product of the **attenuated spatial-peak temporal-average intensity** and 1 cm^2 is maximized over the distance range equal to, or greater than, the **break-point depth**, z_{bp}

NOTE 1 In this standard, the restricted definition of **spatial-peak temporal-average intensity** from IEC 62127-1, relating to a specified plane, is used where **spatial-peak temporal-average intensity** is replaced by **attenuated spatial-peak temporal-average intensity**.

NOTE 2 Depth for *TIS* is expressed in metres (m).

NOTE 3 See Annex A for rationale and derivation notes.

3.27

$\langle A_1 \rangle$ **discrete-operating $\langle A_1 \rangle$ mode**

mode of operation of $\langle A_1 \rangle$ **medical $\langle A_1 \rangle$ diagnostic $\langle A_1 \rangle$ ultrasonic $\langle A_1 \rangle$ equipment** in which the purpose of the excitation of the **ultrasonic transducer** or **ultrasonic transducer element group** is to utilize only one diagnostic methodology

[IEC 61157:2007, definition 3.17.2, modified]

3.28 equivalent aperture diameter

D_{eq}

diameter of a circle $\langle A_1 \rangle$ the area A of which is the -12 dB **output beam area** A_{ob} for **non-scanning modes** and the -12 dB **scanned aperture area** A_{sa} for **scanning modes**, $\langle A_1 \rangle$ given by

$$\langle A_1 \rangle \text{ Text deleted } \langle A_1 \rangle \quad D_{eq} = \sqrt{\frac{4}{\pi} A} \quad (8)$$

where A_{ob} is the **output beam area**.

NOTE 1 $\langle A_1 \rangle$ Equation (8) is used in the calculation of the **cranial-bone thermal index**; for **non-scanning modes** with $A = A_{ob}$ and for **scanning modes** with $A = A_{sa}$.

NOTE 2 Equation (8) with $A = A_{ob}$ is also used in calculating the **break-point depth**. $\langle A_1 \rangle$

NOTE $\langle A_1 \rangle$ 3 $\langle A_1 \rangle$ **Equivalent aperture diameter** is expressed in metres (m).

3.29 equivalent beam area

$A_{eq}(z)$

area of the acoustic beam at the distance z in terms of power and intensity and given by

$$A_{eq}(z) = \frac{P_{\alpha}(z)}{I_{spta, \alpha}(z)} = \frac{P}{I_{spta}} \quad (9)$$

where

$P_{\alpha}(z)$ is the **attenuated output power**, at the distance z ;

$I_{spta, \alpha}(z)$ is the **attenuated spatial-peak temporal-average intensity**, at the distance z ;

P is the **output power**;

I_{spta} is the **spatial-peak temporal-average intensity**, at the distance z ; and

z is the distance from the **external transducer aperture** to the specified point.

NOTE **Equivalent beam area** is expressed in metres squared (m^2).

3.30 equivalent beam diameter

$d_{eq}(z)$

diameter of the acoustic beam at the distance z in terms of the **equivalent beam area** and given by

$$d_{eq}(z) = \sqrt{\frac{4}{\pi} A_{eq}(z)} \quad (10)$$

where

$A_{eq}(z)$ is the **equivalent beam area**;

z is the distance from the **external transducer aperture** to the specified point.

NOTE **Equivalent beam diameter** is expressed in metres (m).

3.31 external transducer aperture

part of the surface of the **ultrasonic transducer** or **ultrasonic transducer** element group assembly that emits ultrasonic radiation into the propagation medium

NOTE 1 This surface is assumed to be either directly in contact with the patient or in contact with a water or liquid path to the patient. See Figure 1.

NOTE 2 The **ultrasonic transducer** element group is usually offset from this surface by a lens, matching layers and possibly fluid.

[IEC 62127-1:2007, definition 3.27, modified]

3.32 mechanical index

MI

mechanical index is given by

$$MI = \frac{p_{r, \alpha}(z_{MI}) f_{awf}^{-1/2}}{C_{MI}} \quad (11)$$

where

$$C_{MI} = 1 \text{ MPa} \cdot \text{MHz}^{-1/2}$$

$p_{r,a}(z_{MI})$ is the **attenuated peak-rarefactional acoustic pressure** at the depth z_{MI}

f_{awf} is the **acoustic-working frequency**.

NOTE 1 See Annex A for rationale and derivation notes.

3.33

medical diagnostic ultrasonic equipment (or system)

combination of the **ultrasound instrument console** and the **transducer assembly** making up a complete diagnostic system

[IEC 61157:2007, definition 3.15]

NOTE ^{A1}1 ^{A1} For the purpose of this standard, **medical diagnostic ultrasonic equipment (or system)** means electrical **equipment** that is intended for *in vivo* ultrasonic examination and monitoring for obtaining a medical diagnosis.

^{A1} NOTE 2 IEC 60601-2-37:2007 uses the term "ultrasonic diagnostic equipment" instead of **medical diagnostic ultrasonic equipment**. ^{A1}

3.34

non-scanning mode

mode of operation of ^{A1} **medical** ^{A1} **diagnostic** ^{A1} **ultrasonic** ^{A1} **equipment** that involves a sequence of ultrasonic pulses which give rise to **ultrasonic scan lines** that follow the same acoustic path

[IEC 62127-1:2007, definition 3.39.4, modified]

3.35

output beam area

A_{ob}

area of the ultrasonic beam derived from the -12 dB **beam area** at the **external transducer aperture**

NOTE 1 For reasons of measurement accuracy, the -12 dB **output beam area** may be derived from measurements at a distance chosen to be as close as possible to the face of the transducer, and, if possible, no more than 1 mm from the face.

NOTE 2 For contact transducers, this area can be taken as the geometrical area of the **ultrasonic transducer** or **ultrasonic transducer** element group.

NOTE 3 The **output beam area** is expressed in metres squared (m^2).

NOTE 4 Methodology for finding the beam area using the **pulse-pressure-squared integral** for focused fields is described in clauses 6.2 and 6.3 of IEC 61828.

[IEC 62127-1:2007, definition 3.40]

3.36

output beam dimensions

X_{ob} , Y_{ob}

dimensions of the ultrasonic beam (-12 dB **beamwidth**) in specified directions perpendicular to each other and in a direction normal to the **beam axis** and at the **external transducer aperture**

NOTE 1 For reasons of measurement accuracy, the -12 dB **output beam dimensions** may be derived from measurements at a distance chosen to be as close as possible to the face of the transducer and, if possible, no more than 1 mm from the face.

NOTE 2 For contact transducers, these dimensions can be taken as the geometrical dimensions of the **ultrasonic transducer** or **ultrasonic transducer** element group.

NOTE 3 **Output beam dimensions** are expressed in metres (m).

NOTE 4 Methodology for finding the beam area using the **pulse-pressure-squared integral** for focused fields is described in 6.2 and 6.3 of IEC 61828.

[IEC 62127-1:2007, definition 3.41, modified]

3.37

output power

P

time-average ultrasonic power emitted by an **ultrasonic transducer** into an approximately free field under specified conditions in a specified medium, preferably water

[IEC 61161:2013, definition 3.3]

NOTE 1 "time-average" means averaged over an integral multiple of the temporal periodicity.

NOTE 2 **Output power** is expressed in watts (W).

3.38

peak-rarefactional acoustic pressure

p_r

maximum of the modulus of the negative **instantaneous acoustic pressure** in an acoustic field or in a specified plane during an **acoustic repetition period**

NOTE 1 **Peak-rarefactional acoustic pressure** is expressed as a positive number.

NOTE 2 **Peak-rarefactional acoustic pressure** is expressed in pascals (Pa).

NOTE 3 The definition of **peak-rarefactional acoustic pressure** also applies to peak-negative acoustic pressure which is also in use in literature.

[IEC 62127-1:2007, definition 3.44]

3.39

power parameter

P_p

beam-related power quantity used in the numerator of the general **thermal index** relationship

NOTE 1 See Equation A.4

NOTE 2 The meaning of this quantity depends on the TI to be evaluated, see A.5.1 and A.5.2. In general terms, it will be the measured quantity responsible for the estimation of the specific temperature rise.

NOTE 3 **Power parameter** is expressed in watts (W).

3.40

prudent-use statements

affirmations of the principle A_1 that only necessary clinical information should be acquired and that high exposure levels and long exposure times should be avoided A_1

NOTE See Bibliography [5,6,7,8].

3.41

pulse duration

t_d

1,25 times the interval between the time when the time integral of the square of the **instantaneous acoustic pressure** reaches 10 % and 90 % of its final value

NOTE 1 The final value of the time integral of the square of the **instantaneous acoustic pressure** is the **pulse-pressure-squared integral**.

NOTE 2 **Pulse duration** is expressed in seconds (s).

NOTE 3 See Figure 2 of IEC 62127-1.

[IEC 62127-1:2007, definition 3.48]

3.42**pulse-intensity integral***pii*

time integral of the **instantaneous intensity** at a particular point in an acoustic field integrated over the **acoustic pulse waveform**

NOTE 1 For measurement purposes referred to in this International Standard, **pulse-intensity integral** is proportional to **pulse-pressure-squared integral**.

NOTE 2 The **pulse-intensity integral** is expressed in joules per metre squared (Jm^{-2}).

[IEC 62127-1:2007, definition 3.49]

3.43**pulse-pressure-squared integral***ppsi*

time integral of the square of the **instantaneous acoustic pressure** at a particular point in an acoustic field integrated over the **acoustic pulse waveform**

NOTE The **pulse-pressure-squared integral** is expressed in pascal squared seconds (Pa^2s).

[IEC 62127-1:2007, definition 3.50]

3.44**pulse repetition period***prp*

time interval between equivalent points on successive pulses or tone-bursts

^{A1} NOTE 1 In general, for **non-scanning modes** the **pulse repetition period** needs to be adjusted to represent a 'per-second' average taking into account interruptions-in, or non-constant, pulsing; e.g. such as may occur in **combined operating modes**. ^{A1}

NOTE 2 The **pulse repetition period** is expressed in seconds (s).

[IEC 62127-1:2007, definition 3.51]

3.45**pulse repetition rate***prr*

reciprocal of the **pulse repetition period**

NOTE The **pulse repetition rate** is expressed in hertz (Hz).

[IEC 62127-1:2007, definition 3.52]

3.46**scanned aperture area***A_{sa}*

area at the **external transducer aperture** consisting of all points at which the **pulse-pressure-squared integral** is greater than -12 dB of the maximum value of the **pulse-pressure-squared integral** in that plane

NOTE 1 For reasons of measurement accuracy, the -12 dB **scanned aperture area** may be derived from measurements at a distance chosen to be as close as possible to the face of the transducer, and, if possible, no more than 1 mm from the face.

NOTE 2 For contact transducers, this area can be taken as the geometrical area of the active elements during one frame scan of the **ultrasonic transducer** or **ultrasonic transducer** element group.

NOTE 3 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 synchronisation with the scanframe is not available the term **pulse-pressure-squared integral** may be replaced by **temporal average intensity**.

NOTE 4 **Scanned aperture area** is expressed in metres squared (m^2).

3.47

scan direction

for **systems** with scanning modes, the direction in the **scan plane** and perpendicular to a specified **ultrasonic scan line**

NOTE During one acquisition frame the scan direction may be azimuthal (x) and/or elevational (y) and may include combinations, e.g., polar.

[IEC 61157: 2007, definition 3.27]

3.48

scan plane

for automatic scanning systems, a plane containing all the **ultrasonic scan lines**

NOTE 1 See Figure 1.

NOTE 2 Some scanning systems have the ability to steer the ultrasound beam in two directions. In this case, there is no **scan plane** that meets this definition. However, it might be useful to consider a plane through the major-axis of symmetry of the **ultrasound transducer** and perpendicular to the transducer face (or another suitable plane) as being equivalent to the scan plane.

[IEC 62127-1:2007, definition 3.56]

3.49

scanning mode

mode of operation of **A1** a medical **A1** diagnostic **A1** ultrasonic **A1** equipment that involves a sequence of ultrasonic pulses which give rise to scan lines that do not follow the same acoustic path

[IEC 61157:2007, definition 3.17.5]

3.50

scan repetition period

srp

time interval between identical points on two successive frames, sectors or scans, applying to automatic scanning systems with a periodic scan sequence only

NOTE 1 In general, this International Standard assumes that an individual **ultrasonic scan line** repeats exactly after a number of acoustic pulses.

NOTE 2 The scan repetition period is expressed in seconds (s).

3.51

scanwidth

w_s

greatest distance between two points on the axis in the **scan plane** perpendicular to the central **ultrasonic scan line** where the **temporal average intensity** falls below its maximum in the **scan plane** by 12 dB at the distance of interest from the transducer surface

NOTE 1 This dimension may be determined by hydrophone measurements or by calculation using knowledge of the dimensions of the transducer aperture and scanning geometry.

NOTE 2 **Scanwidth** is expressed in metres (m).

3.52

soft tissue thermal index

TIS

thermal index related to soft tissues

NOTE 1 See 5.4.1 and the following sub-clauses and 5.5.1 for methods of determining the **soft tissue thermal index**.

NOTE 2 For the purposes of this document, soft tissue includes all body tissues and fluids except skeletal tissues.

NOTE 3 See Annex A for rationale and derivation notes.

3.53

spatial-average temporal-average intensity

I_{sata}

equal to the **temporal-average intensity** averaged over the **scan-area**, **beam area** or other defined area as appropriate

NOTE **Spatial-average temporal-average intensity** is expressed in watts per metre squared (Wm^{-2}).

[IEC 62127-1:2007, definition 3.59 slightly modified]

3.54

spatial-peak temporal-average intensity

I_{spta}

maximum value of the **temporal-average intensity** in an acoustic field or in a specified plane

NOTE 1 For systems in **combined-operating mode**, $\langle A_1 \rangle$ the averaging time period needs to be sufficient to include periods in which scanning or pulsing is interrupted. $\langle A_1 \rangle$

NOTE 2 **Spatial-peak temporal-average intensity** is expressed in watts per metre squared (Wm^{-2}).

[IEC 62127-1:2007, definition 3.62]

3.55

temporal-average intensity

I_{ta}

time-average of the **instantaneous intensity** at a particular point in an acoustic field

NOTE 1 The time-average is taken normally over an integral number of **acoustic repetition periods**; if not, the period for averaging should be specified.

NOTE 2 **Temporal-average intensity** is expressed in watts per metre squared (Wm^{-2}).

[IEC 62127-1:2007, definition 3.65]

3.56

thermal index

TI

ratio of **attenuated $\langle A_1 \rangle$ output $\langle A_1 \rangle$ power** at a specified point to the **attenuated $\langle A_1 \rangle$ output $\langle A_1 \rangle$ power** required to raise the temperature at that point in a specific tissue model by 1 °C

NOTE See Annex A for rationale and derivation notes.

3.57

transducer assembly

those parts of **medical diagnostic ultrasonic equipment** comprising the **ultrasonic transducer** and/or **ultrasonic transducer** element group, together with any integral components, such as an acoustic lens or integral stand-off

NOTE The **transducer assembly** is usually separable from the ultrasound instrument console.

[IEC 62127-1:2007, definition 3.69]

3.58

transmit pattern

combination of a specific set of transducer beam-forming characteristics (determined by the transmit aperture size, apodization shape and relative timing/phase delay pattern across the

aperture, resulting in a specific focal length and direction) and an electrical drive waveform of a specific fixed shape but variable amplitude

3.59

ultrasonic scan line

for scanning systems, the **beam axis** for a particular **ultrasonic transducer** element group, or for a particular excitation of an **ultrasonic transducer** or **ultrasonic transducer** element group

NOTE 1 Here an **ultrasonic scan line** refers to the path of acoustic pulses and not to a line on an image on the display screen of a system.

NOTE 2 The case where a single excitation produces ultrasonic beams propagating along more than one **beam axis** is not considered.

[IEC 62127-1:2007, definition 3.71, modified]

3.60

ultrasonic transducer

device capable of converting electrical energy to mechanical energy within the ultrasonic frequency range and/or reciprocally of converting mechanical energy to electrical energy

[IEC 62127-1:2007, definition 3.73]



3.61

instantaneous acoustic pressure

$p(t)$

pressure minus the ambient pressure at a particular instant in time and at a particular point in an acoustic field

NOTE **Instantaneous acoustic pressure** is expressed in pascals (Pa).

[SOURCE: IEC 62127-1:2007, 3.33, modified – The reference to IEV 801-01-19 has been removed in the definition]

3.62

attenuated instantaneous acoustic pressure

$p_{\alpha}(z, t)$

value of the **instantaneous acoustic pressure** at time t after attenuation on a plane perpendicular to the **beam axis** at a specified distance z from the source, and given by

$$p_{\alpha}(z, t) = p(z, t) 10^{(-\alpha z f_{\text{awf}} / 20 \text{ dB})} \quad (26)$$

where

α is the **acoustic attenuation coefficient**;

z is the distance from the source to the point (plane) of interest;

f_{awf} is the **acoustic working frequency**;

$p(z, t)$ is the **instantaneous acoustic pressure**

NOTE **Attenuated instantaneous acoustic pressure** is expressed in pascals (Pa).

3.63

attenuated pulse-pressure-squared integral

$ppsi_{\alpha}(z)$

time integral of the square of the **attenuated instantaneous acoustic pressure**, integrated over the acoustic pulse waveform, on a plane perpendicular to the **beam axis** at a specified distance z in an acoustic field 

$$ppsi_{\alpha}(z) = \int p_{\alpha}^2(z, t) dt = \int \left[p(z, t) 10^{(-\alpha z f_{awf} / 20 \text{ dB})} \right]^2 dt = ppsi(z) \times 10^{(-\alpha z f_{awf} / 10 \text{ dB})} \quad (27)$$

A₁ where

$p(z, t)$ is the **instantaneous acoustic pressure** at depth z .
 α is the **acoustic attenuation coefficient**;
 z is the distance from the source to the point (plane) of interest;
 f_{awf} is the **acoustic working frequency**;
 $ppsi$ is the **pulse-pressure-squared integral**

NOTE 1 **Attenuated pulse-pressure-squared integral** is expressed in pascal squared seconds (Pa²s).

NOTE 2 See definition 3.43 for the non-attenuated version; with the addition here of the perpendicular plane at depth z .

3.64 attenuated scan intensity integral

$sii_{\alpha}(z)$
sum of the **attenuated pulse intensity integrals** in one scan (one frame of **ultrasonic scan lines**) at depth z

NOTE 1 **Attenuated scan intensity integral** is expressed in joules per square metre (Jm⁻²).

NOTE 2 For measurement purposes of this standard, $sii_{\alpha}(z)$ is equivalent to $1/(\rho c)$ times the **sum of attenuated pulse-pressure-squared integrals** at depth z , for $z \geq z_{bp}$, with ρc denoting the characteristic acoustic impedance of pure water.

NOTE 3 See definition 3.79 for the non-attenuated version.

3.65 attenuated spatial-peak pulse-average intensity

$I_{sppa, \alpha}(z)$
maximum value of the **spatial-peak pulse-average intensity** after attenuation, on a plane perpendicular to the **beam axis** at a specified distance z from the source, and given by

$$I_{sppa, \alpha}(z) = \frac{1}{t_d(z)} pii_{\alpha}(z) \quad (28)$$

where

$t_d(z)$ is the **pulse duration** at the same depth z ;
 $pii_{\alpha}(z)$ is the **attenuated pulse-intensity integral** at depth z

NOTE 1 **Attenuated spatial-peak pulse-average intensity** is expressed in watts per square metre (Wm⁻²).

NOTE 2 For measurement purposes of this standard, $pii_{\alpha}(z)$ is equivalent to $1/(\rho c)$ times the **attenuated pulse-pressure-squared integrals** at depth z , $ppsi_{\alpha}(z)$, for $z \geq z_{bp}$, with ρc denoting the characteristic acoustic impedance of pure water.

NOTE 3 See definition 3.81 for the non-attenuated version.

3.66 attenuated sum of pulse-pressure-squared integrals

$s_{ppsi}(z)$
attenuated value of the sum of **pulse-pressure-squared integrals** in one scan (one frame of **ultrasonic scan lines**) at depth z

NOTE 1 **Attenuated sum of pulse-pressure-squared integrals** is expressed in pascal squared seconds (Pa²s).

NOTE 2 The **attenuated sum of pulse-pressure-squared integrals** at depth z will be equal to the **sum of attenuated pulse-pressure-squared integrals** if each **ultrasonic scan line** in the frame which is included in the sum has the same **acoustic working frequency**. **A₁**