

Ultrasonics — Hydrophones

Part 1: Measurement and characterization of medical ultrasonic fields up to 40 MHz

ICS 17.140.50

National foreword

This British Standard is the UK implementation of EN 62127-1:2007+A1:2013. It is identical to IEC 62127-1:2007, incorporating amendment 1:2013. It supersedes BS EN 62127-1:2007, which will be withdrawn on 15 March 2016.

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

Ultrasons -
Hydrophones -
Partie 1: Mesures et caractérisation
des champs ultrasonores médicaux
jusqu'à 40 Mhz
(CEI 62127-1:2007)

Ultraschall -
Hydrophone -
Teil 1: Messung und Charakterisierung
von medizinischen Ultraschallfeldern
bis zu 40 MHz
(IEC 62127-1:2007)

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European Committee for Electrotechnical Standardization
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Foreword

The text of document 87/352/CDV, future edition 1 of IEC 62127-1, prepared by IEC TC 87, Ultrasonics, was submitted to the IEC-CENELEC parallel Unique Acceptance Procedure and was approved by CENELEC as EN 62127-1 on 2007-09-01.

EN 62127-1, EN 62127-2 and EN 62127-3 are being published simultaneously. Together these European Standards cancel and replace EN 61101:1993, EN 61102:1993 + A1:1994, EN 61220:1995 and EN 62092:2001.

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Endorsement notice

The text of the International Standard IEC 62127-1:2007 was approved by CENELEC as a European Standard without any modification.

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Endorsement notice

The text of the International Standard IEC 62127-1:2007/A1:2013 was approved by CENELEC as a European Standard without any modification.

CONTENTS

INTRODUCTION.....	6
1 Scope and object.....	7
2 Normative references	7
3 Terms, definitions and symbols	8
4 List of symbols	28
5 Measurement requirements	30
5.1 Requirements for hydrophones and amplifiers	30
5.1.1 Introduction	30
5.1.2 General	30
5.1.3 Sensitivity of a hydrophone.....	30
5.1.4 Directional response of a hydrophone.....	30
5.1.5 Effective hydrophone radius	31
5.1.6 Choice of the size of a hydrophone active element	31
5.1.7 Bandwidth	32
5.1.8 Linearity	32
5.1.9 Hydrophone signal amplifier	33
5.1.10 Hydrophone cable length and amplifiers	33
5.2 Requirements for positioning and water baths	33
5.2.1 General	33
5.2.2 Positioning systems.....	34
5.2.3 Water bath.....	35
5.3 Requirements for data acquisition and analysis systems	36
5.4 Recommendations for ultrasonic equipment being characterized	36
6 Measurement procedure	36
6.1 General	36
6.2 Preparation and alignment.....	37
6.2.1 Preparation.....	37
6.2.2 Aligning an ultrasonic transducer and a hydrophone	37
6.3 Measurement	37
6.4 Analysis	37
6.4.1 Corrections for restricted bandwidth and spatial resolution	37
6.4.2 Uncertainties	37
7 Beam characterization	38
7.1 General	38
7.2 Primary pressure parameters	39
7.2.1 General	39
7.2.2 Peak-compressional acoustic pressure and peak-rarefactional acoustic pressure	40
7.2.3 Spatial-peak rms acoustic pressure	40
7.2.4 Nonlinear propagation parameter	40
7.2.5 Intensity parameters using instantaneous acoustic pressure.....	41
7.2.6 Intensity parameters using pulse-pressure-squared integral	41
7.2.7 Derived ultrasonic power	43
8 Requirements for specific ultrasonic fields	44

8.1	General	44
8.2	Diagnostic fields	44
8.2.1	Simplified procedures and guidelines	44
8.2.2	Pulsed wave diagnostic equipment	45
8.2.3	Continuous wave diagnostic equipment	45
8.3	Therapy fields	46
8.3.1	Physiotherapy equipment	46
8.3.2	Hyperthermia	46
8.4	Surgical fields	46
8.4.1	Lithotripters and pressure pulse sources for other therapeutic purposes	46
8.4.2	Low frequency surgical applications	47
8.5	Fields from other medical applications	47
9	Compliance statement	47
9.1	General	47
9.2	Maximum probable values	48
9.3	Sampling	48
Annex A (informative)	General rationale	49
Annex B (informative)	Hydrophones and positioning	51
Annex C (informative)	Acoustic pressure and intensity	57
Annex D (informative)	Voltage to pressure conversion	59
Annex E (informative)	Correction for spatial averaging	64
Annex F (informative)	Acoustic output parameters for multi-mode medical ultrasonic fields in the absence of scan-frame synchronization	67
Annex G (informative)	Propagation medium and degassing	73
Annex H (informative)	Specific ultrasonic fields	74
Annex I (informative)	Assessment of uncertainty in the acoustic quantities obtained by hydrophone measurements	77
Annex J (informative)	Transducer and hydrophone positioning systems	79
Annex K (informative)	Beamwidth midpoint method	80
Annex ZA (normative)	Normative references to international publications with their corresponding European publications	86
Bibliography		81
Figure 1	– Schematic diagram of the different planes and lines in an ultrasonic field (see also IEC 61828)	10
Figure 2	– Schematic diagram of the method of determining pulse duration	39
[A1] Figure 3	– Several apertures and planes for a transducer of unknown geometry [IEC 61828]	25
Figure 4	– Parameters for describing an example of a focusing transducer of a known geometry [IEC 61828 modified]	26 [A1]
Figure D.1	– A flow diagram of the hydrophone deconvolution process	60
Figure D.2	– Example of waveform deconvolution	65
Figure J.1	– Schematic diagram of the ultrasonic transducer and hydrophone degrees of freedom	79

Table 1 – Acoustic parameters appropriate to various types of medical ultrasonic equipment.....	38
Table B.1 – Typical specification data for hydrophones, in this case given at 1 MHz	56
Table C.1 – Properties of distilled or de-ionized water as a function of temperature	58
Table D.1 – Method of conversion from a double- to a single-sided spectrum	61
Table D.2 – Method of conversion from a single- to a double-sided spectrum	62
Table F.1 – Main parameters defined in IEC standards	68
Table F.2 – List of parameters that are to be used or are to be deleted.....	69
Table K.1 – dB beamwidth levels for determining midpoints	80

INTRODUCTION

The main purpose of this part of IEC 62127 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 standard for appropriate acoustic parameters.

A1 The philosophy behind this standard 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. **A1**

Intensity parameters are specified in this standard, 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 up to 40 MHz

1 Scope and object

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 operating in the frequency range up to 40 MHz.

The objectives of this standard are:

- to define a group of acoustic parameters that can be measured on a physically sound basis;
- to define a second group of parameters that can be derived under certain assumptions from these measurements, and called derived intensity parameters;
- to define a measurement procedure that may be used for the determination of acoustic pressure parameters;
- to define the conditions under which the measurements of acoustic parameters can be made in the frequency range up to 40 MHz using calibrated hydrophones;
- to define procedures for correcting, for limitations caused by the use of hydrophones with finite bandwidth and finite active element size.

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

A1 NOTE 2 The hydrophone as defined may be of a piezoelectric or an optic type. The introduction however implies that optical hydrophones are not covered. **A1**

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 60050-801:1994, *International Electrotechnical Vocabulary – Chapter 801: Acoustics and electroacoustics*

IEC 60565, *Underwater acoustics – Hydrophones – Calibration in the frequency range 0,01 Hz to 1 MHz*

IEC/TR 60854:1986, *Methods of measuring the performance of ultrasonic pulse-echo diagnostic equipment*

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

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

IEC 61846, *Ultrasonics – Pressure pulse lithotripters – Characteristics of fields*

IEC 61847, *Ultrasonics – Surgical systems – Measurement and declaration of the basic output characteristics*

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*

ISO 16269-6:2005, *Statistical interpretation of data – Part 6: Determination of statistical tolerance intervals*

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

NOTE The following standards rely on the proper use of this document.

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

IEC 62359, *Ultrasonics – Field characterization – Test methods for the determination of thermal and mechanical indices related to medical diagnostic ultrasonic fields*

IEC 61847, *Ultrasonics – Surgical systems – Measurement and declaration of the basic output characteristics.*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in IEC 62127-2, IEC 62127-3 and the following apply. It also includes definitions related to subjects in this document to be used in particular medical ultrasound device standards.

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

Note deleted

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

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 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 and 3.3.4.

NOTE 2 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 **Acoustic frequency** is expressed in hertz (Hz).

3.3.1 zero-crossing acoustic-working frequency

$\boxed{A_1}$ 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 None of the n consecutive half-cycles should show evidence of phase change.

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.

NOTE 4 This frequency is intended for continuous-wave systems only. $\boxed{A_1}$

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 This frequency is intended for pulse-wave systems only.

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

$\boxed{A_1}$ NOTE 3 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 magnitude is 3 dB below the peak magnitude. $\boxed{A_1}$

3.3.3 peak pulse acoustic frequency

$\boxed{A_1} f_p \boxed{A_1}$
arithmetic-mean acoustic-working frequency of the pulse with the largest peak negative acoustic pressure measured at the point of maximum peak negative acoustic pressure

NOTE **Peak pulse acoustic frequency** is expressed in hertz (Hz).

3.3.4 time average acoustic frequency

f_t
arithmetic-mean acoustic-working frequency of the time averaged acoustic pressure spectrum of the acoustic signal measured at the point of maximum **temporal average intensity**

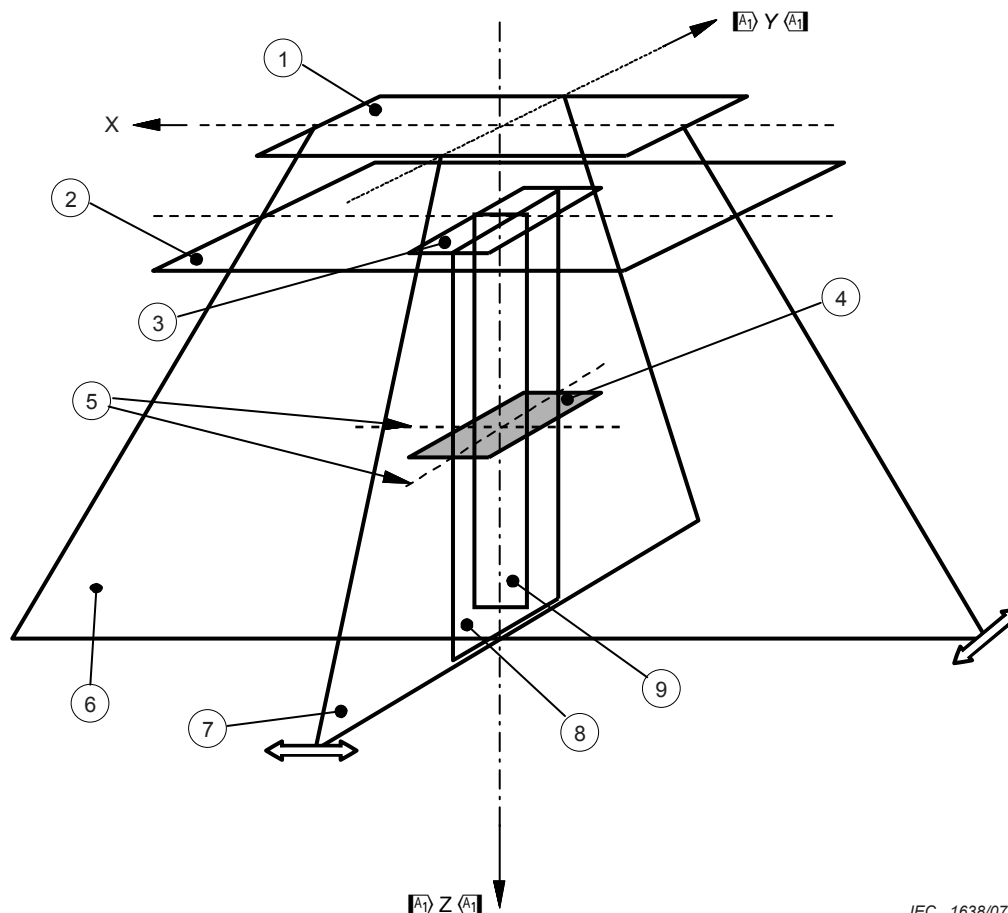
NOTE **Time average acoustic frequency** is expressed in hertz (Hz).

3.4 azimuth axis

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

NOTE 1 Definition adopted from IEC 61828:2001.

NOTE 2 See Figure 1.



IEC 1638/07

Key

X azimuth axis

$\boxed{A_1} Y$ elevation axis $\boxed{A_1}$

Z $\boxed{A_1}$ beam axis $\boxed{A_1}$

1 external transducer aperture plane

2 source aperture plane

3 aperture plane

4 beam area plane

5 beamwidth lines

6 azimuth plane, scan plane

7 elevation plane

8 longitudinal plane

9 principle longitudinal plane

**Figure 1 – Schematic diagram of the different planes and lines in an ultrasonic field
(see also IEC 61828)**

3.5

azimuth plane

for a scanning **ultrasonic transducer**: this is the **scan plane**; for a non-scanning **ultrasonic transducer**: this is the **principal longitudinal plane**

NOTE 1 Definition adopted from IEC 61828:2001.

NOTE 2 See Figure 1.

3.6

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 **Bandwidth** is expressed in hertz (Hz).

3.7

beam area

$A_{b,6}$, $A_{b,20}$ A_1

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

A_1 NOTE 1 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. A_1

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

NOTE 3 Some specified A_1 fractions A_1 are 0,25 and 0,01 for the –6 dB and –20 dB beam areas, respectively.

NOTE 4 Beam area is expressed in square metres (m²).

NOTE 5 Definition is modified compared to that used in IEC 61828:2001.

3.8

beam axis

straight line that passes through the **beam centrepoin**ts 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 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 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 synchronisation with the scanframe is not available the term **pulse-pressure-squared integral** may be replaced by **temporal average intensity**.

NOTE 3 See Figure 1.

NOTE 4 Definition is modified compared to that used in IEC 61828:2001.

3.9

beam centrepoin

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

NOTE Definition adopted from IEC 61828:2001.

3.10

beamwidth midpoint

linear average of the location of the centres of **beamwidths** in a plane

NOTE 1 The average is taken over as many **beamwidth** levels given in Table K.1 as signal level permits.

NOTE 2 Definition adopted from IEC 61828:2001.

3.11 **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, 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 synchronisation with the scanframe 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 of the ratios of the integrals.

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

NOTE 4 Definition slightly modified to that in IEC 61828:2001.

3.12 **broadband transducer**

transducer that generates an acoustic pulse of which the **bandwidth** is greater than the **arithmetic-mean acoustic-working frequency**

3.13 **central scan line**

for automatic scanning systems, the ultrasonic scan line closest to the symmetry axis of the **scan plane**

3.14 **diametrical beam scan**

set of measurements of the hydrophone output voltage made while moving the hydrophone in a straight line passing through a point on the beam axis and in a direction normal to the beam axis.

NOTE The **diametrical beam scan** may extend to different distances on either side of the **beam axis**.

3.15 **distance z_r**

z_r

distance along the **beam axis** between the plane containing the **peak-rarefactional acoustic pressure** and the **external transducer aperture**

NOTE The **distance z_r** is expressed in metres (m).

3.16 **distance z_c**

z_c

distance along the **beam axis** between the plane containing the **peak-compressional acoustic pressure** and the **external transducer aperture**

NOTE The **distance z_c** is expressed in metres (m).

3.17

distance z_{ppsi}

z_{ppsi}

distance along the **beam axis** between the plane containing the maximum **pulse-pressure-squared integral** and the **external transducer aperture**

NOTE The distance z_{ppsi} is expressed in metres (m).

3.18

distance z_{spta}

z_{spta}

distance along the **beam axis** between the plane containing the **spatial-peak temporal-average intensity** and the **external transducer aperture**

NOTE 1 In practice, this distance is equal to the distance z_{ppsi} .

NOTE 2 The distance z_{spta} is expressed in metres (m).

3.19

distance z_{offset}

z_{offset}

distance along the **beam axis** between the plane containing the active face of the ultrasonic transducer or ultrasonic transducer element group and the **external transducer aperture**

NOTE 1 Distance z_{offset} is expressed in metres (m).

NOTE 2 Definition adopted, with modified symbol, from IEC 61828:2001.

3.20

electric load impedance

Z_L

complex electric input impedance (consisting of a real and an imaginary part) to which the **hydrophone** unit output cable is connected or is to be connected

NOTE The **electric load impedance** is expressed in ohms (Ω).

NOTE 2 Definition adopted from IEC 62127-3.

3.21

effective hydrophone radius

a_h , a_{h3} , a_{h6}

radius of a stiff disc receiver **hydrophone** that has a predicted **directional response** function with an angular width equal to the observed angular width

NOTE 1 The angular width is determined at a specified level below the peak of the **directional response** function. For the specified levels of 3 dB and 6 dB, the radii are denoted by a_{h3} and a_{h6} respectively.

NOTE 2 The **effective hydrophone radius** is expressed in metres (m).

NOTE 3 The radius is usually the function of frequency. For representative experimental data, see [1].

NOTE 4 Definition adopted from IEC 62127-3.

3.22

$\boxed{A_1}$ effective radius of a non-focusing ultrasonic transducer $\boxed{A_1}$

a_t

radius of a perfect disc piston-like ultrasonic transducer that has a predicted axial acoustic pressure distribution approximately equivalent to the observed axial acoustic pressure distribution over an axial distance until at least the last axial maximum has passed

NOTE The $\boxed{A_1}$ effective radius of a non-focusing ultrasonic transducer $\boxed{A_1}$

3.23

elevation axis

line in the **source aperture plane** (measurement) or **transducer aperture plane** (design) that is perpendicular to the **azimuth axis**

NOTE 1 See Figure 1.

NOTE 2 Definition adopted from IEC 61828:2001.

3.24

elevation plane

longitudinal plane containing the elevation axis

NOTE 1 See Figure 1.

NOTE 2 Definition adopted from IEC 61828:2001.

3.25

end-of-cable loaded sensitivity

end-of-cable loaded sensitivity of a hydrophone (or hydrophone-assembly)

$M_L(f)$

ratio of the instantaneous voltage at the end of any integral cable or output connector of a **hydrophone** or **hydrophone-assembly**, when connected to a specified **electric load impedance**, to the **instantaneous acoustic pressure** in the undisturbed free field of a plane wave in the position of the reference centre of the **hydrophone** if the **hydrophone** were removed

NOTE 1 **End-of-cable loaded sensitivity** is expressed in volts per pascal (V/Pa).

NOTE 2 Definition adopted from IEC 62127-3.

3.26

end-of-cable open-circuit sensitivity

end-of-cable open-circuit sensitivity of a hydrophone

$M_c(f)$

ratio of the instantaneous open-circuit voltage at the end of any integral cable or output connector of a **hydrophone** to the **instantaneous acoustic pressure** in the undisturbed free field of a plane wave in the position of the reference centre of the **hydrophone** if the **hydrophone** were removed

NOTE 1 **End-of-cable open-circuit sensitivity** is expressed in volts per pascal (V/Pa).

NOTE 2 Definition adopted from IEC 62127-3.

3.27

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 either directly in contact with the patient or is in contact with a water or liquid path to the patient.

NOTE 2 See Figure 1.

NOTE 3 Definition adopted from IEC 61828:2001.

3.28

far field

A1 region of the field where $z > z_T$ aligned along the **beam axis** for planar non-focusing transducers

NOTE 1 In the **far field**, the sound pressure appears to be spherically divergent from a point on or near the radiating surface. Hence the pressure produced by the sound source is approximately inversely proportional to the distance from the source.

NOTE 2 The term “**far field**” is used in this International Standard only in connection with non-focusing source transducers. For focusing transducers a different terminology for the various parts of the transmitted field applies (see IEC 61828). **A1**

A1 NOTE 3 If the shape of the transducer aperture produces several **transition distances**, the one furthest from the transducer is used. **A1**

3.29 hydrophone geometrical radius

a_g
radius defined by the dimensions of the active element of a **hydrophone**

NOTE The **hydrophone geometrical radius** is expressed in metres (m).

NOTE 2 Definition adopted from IEC 62127-3.

3.30 hydrophone

transducer that produces electric signals in response to waterborne acoustic signals

[IEV 801-32-26]

3.31 hydrophone assembly

combination of **hydrophone** and **hydrophone pre-amplifier**

NOTE Definition adopted from IEC 62127-3.

3.32 hydrophone pre-amplifier

active electronic device connected to, or to be connected to, a particular **hydrophone** and reducing its output impedance

NOTE 1 A **hydrophone pre-amplifier** requires a supply voltage (or supply voltages).

NOTE 2 The **hydrophone pre-amplifier** may have a forward voltage transmission factor of less than one, i.e. it need not necessarily be a voltage amplifier in the strict sense.

NOTE 3 Definition adopted from IEC 62127-3.

3.33 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 (see also IEV 801-01-19)

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

3.34 instantaneous intensity

$I(t)$
acoustic energy transmitted per unit time in the direction of acoustic wave propagation per unit area normal to this direction at a particular instant in time and at a particular point in an acoustic field

A1 NOTE 1 **Instantaneous intensity** is the product of **instantaneous acoustic pressure** and particle velocity. It is difficult to measure intensity in the ultrasound frequency range. For the measurement purposes referred to in this International Standard and under conditions of sufficient distance from the **external transducer aperture** (at least one transducer diameter, or an equivalent transducer dimension in the case of a non-circular transducer) the **instantaneous intensity** can be approximated by the **derived instantaneous intensity**. **A1**

NOTE 2 **Instantaneous intensity** is expressed in W/m^2 .

3.35

longitudinal plane

plane defined by the **beam axis** and a specified orthogonal axis

NOTE 1 Definition adopted from IEC 61828:2001, 4.2.43

NOTE 2 See Figure 1.

3.36

mean peak acoustic pressure

p_m

the arithmetic mean of the peak-rarefactional acoustic pressure and the peak-compressional acoustic pressure

NOTE Definition adopted from IEC 61949.

3.37

near field

region of the field where $z < z_T$ aligned along the **beam axis** for planar non-focusing transducers

NOTE 1 For circular planar transducers, this is at a distance less than $A_{ob}/\pi\lambda$, where A_{ob} is the **output beam area** and λ is the wavelength of the ultrasound corresponding to the **acoustic frequency**.

NOTE 2 If the shape of the transducer aperture produces several **transition distances**, the one closest to the transducer shall be used.

3.38

local distortion parameter

σ_q

index which permits the prediction of nonlinear distortion of ultrasound for a specific **ultrasonic transducer**, and is given by σ_q from:

$$\sigma_q = z p_m \frac{2\pi f_{awf} \beta}{\rho \cdot c^3} \frac{1}{\sqrt{F_a}} \quad (2)$$

where:

z is the axial distance of the point of interest to the transducer face;

p_m is the **mean-peak acoustic pressure** at the point in the acoustic field corresponding to the **spatial-peak temporal-peak acoustic pressure**;

β is the nonlinearity parameter ($\beta = 1 + B/2A = 3,5$ for pure water at 20 °C);

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

F_a is the **local area factor** .

[SOURCE: IEC/TS 61949:2007, definition 3.12, modified – the text of the definition has changed substantially, the equation however is unchanged.]

3.39 operating mode

3.39.1 combined-operating mode

mode of operation of a **system** that combines more than one **discrete-operating mode**

NOTE Examples of **combined-operating modes** are real-time B-mode combined with M-mode (B+M), real-time B-mode combined with pulsed Doppler (B+D), colour M-mode (cM), real-time B-mode combined with M-mode and pulsed Doppler (B+M+D), real-time B-mode combined with real-time flow-mapping Doppler (B+rD), i.e. flow-mapping in which different types of acoustic pulses are used to generate the Doppler information and the imaging information.

3.39.2 discrete-operating mode

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

NOTE Examples of **discrete-operating modes** are A-mode (A), M-mode (M), static B-mode (sB), real-time B-mode (B), continuous wave Doppler (cwD), pulsed Doppler (D), static flow-mapping (sD) and real-time flow-mapping Doppler (rD) using only one type of acoustic pulse.

3.39.3 inclusive mode

combined-operating mode having acoustic output levels (p_r and I_{spta}) less than those corresponding to a specified **discrete-operating mode**

3.39.4 non-scanning mode

mode of operation of a **system** that involves a sequence of ultrasonic pulses which give rise to **ultrasonic scan lines** that follow the same acoustic path

3.39.5 scanning mode

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

NOTE The sequence of pulses is not necessarily made up of identical pulses. For instance, the use of sequential multiple focal-zones is considered a scanning mode.

3.40 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 square metres (m^2).

3.41 output beam dimensions

$X_{\text{ob}}, Y_{\text{ob}}$
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).

3.42

output beam intensity

I_{ob}

temporal-average power output divided by the **output beam area**

NOTE **Output beam intensity** is expressed in W/m^2 (W/m²).

3.43

peak acoustic pressure

p_r (or p_-) or p_c (or p_+)

either the **peak-compressional acoustic pressure** or the **peak-rarefactional acoustic pressure**

NOTE 1 The term is used in relative determinations.

NOTE 2 **Peak acoustic pressure** is expressed in pascal (Pa).

3.44

peak-rarefactional acoustic pressure

p_r (or p_-)

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 pascal (Pa).

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

3.45

peak-compressional acoustic pressure

p_c (or p_+)

maximum positive **instantaneous acoustic pressure** in an acoustic field or in a specified plane during an **acoustic repetition period**

NOTE 1 **Peak-compressional acoustic pressure** is expressed in pascal (Pa).

NOTE 2 The definition of **peak-compressional acoustic pressure** also applies to peak-positive acoustic pressure which is also in use in literature.

3.46

principal longitudinal plane

plane containing the **beam axis** and the minimum –6 dB **beamwidth**

NOTE 1 For rectangular ultrasonic transducers, it is the plane parallel to their longest side.

NOTE 2 Definition adopted from IEC 61828:2001, 4.2.59.

NOTE 3 See Figure 1.

3.47

pulse-average intensity

I_{pa}

quotient of the **pulse-intensity integral** to the **pulse duration** at a particular point in an acoustic field

NOTE 1 This definition applies to pulses and bursts.

NOTE 2 **Pulse-average intensity** is expressed in watts per square metre (W/m^2).

3.48 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.

3.49 pulse-intensity integral

p_{ii}

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 standard, **pulse-intensity integral** is proportional to **pulse-pressure-squared integral**.

NOTE 2 The **pulse-intensity integral** is expressed in joules per metre squared (J/m^2).

3.50 pulse-pressure-squared integral

p_{psi}

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).

3.51 pulse repetition period

prp

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

NOTE 1 This applies to single element non-automatic scanning systems and automatic scanning systems.

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

3.52 pulse repetition rate

pr

reciprocal of the pulse repetition period

Note deleted

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

3.53 rms acoustic pressure

p_{rms}

root-mean-square (rms) of the **instantaneous acoustic pressure** at a particular point in an acoustic field

NOTE 1 The mean should be taken over an integral number of **acoustic repetition periods** unless otherwise specified.

NOTE 2 **rms acoustic pressure** is expressed in pascal (Pa).

3.54

scan-area

A_s

for automatic scanning systems, the area on a specified plane (or surface) consisting of all points within the **beam area** of any beam passing through the surface during the scan

NOTE 1 The specified plane (or surface) follows the same shape as the **external transducer aperture**.

NOTE 2 The **scan-area** is expressed in square metres (m²).

3.55

source aperture plane

closest possible measurement **plane** to the **external transducer aperture**, that is perpendicular to the **beam axis**

NOTE 1 Definition adopted from IEC 61828:2001, 4.2.67.

NOTE 2 See Figure 1.

3.56

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**.

3.57

scan repetition period

s_{rp}

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 standard assumes that an individual scan line repeats exactly after a number of acoustic pulses. In case an **ultrasonic transducer** or **ultrasonic transducer element group** radiates ultrasound without any sequence of repetition, it will not be possible to characterize a scanned mode in the way described in this standard. The approach described in Annex F can be useful when synchronization cannot be achieved.

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

3.58

scan repetition rate

s_{rr}

reciprocal of the scan repetition period

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

3.59

spatial-average temporal-average intensity

I_{sata}

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

NOTE **Spatial-average temporal-average intensity** is expressed in W/m^2 watts per square metre (W/m²).

3.60 spatial-peak pulse-average intensity

I_{sppa}
maximum value of the **pulse-average intensity** in an acoustic field or in a specified plane

NOTE **Spatial-peak pulse-average intensity** is expressed in W/m^2 (W/m²).

3.61 spatial-peak rms acoustic pressure

p_{spr}
maximum value of the **rms acoustic pressure** in an acoustic field or in a specified plane-

NOTE **Spatial-peak rms acoustic pressure** is expressed in pascal (Pa).

3.62 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**, the time interval over which the temporal average is taken is sufficient to include any period during which scanning may not be taking place

NOTE 2 **Spatial-peak temporal-average intensity** is expressed in W/m^2 (W/m²).

3.63 spatial-peak temporal-peak acoustic pressure

p_{sptp}
larger of the **peak-compressional acoustic pressure** or the **peak-rarefactional acoustic pressure**

NOTE **Spatial-peak temporal-peak acoustic pressure** is expressed in pascal (Pa).

3.64 spatial-peak temporal-peak intensity

I_{sptp}
maximum value of the **temporal-peak intensity** in an acoustic field or in a specified plane

NOTE **Spatial-peak temporal-peak intensity** is expressed in W/m^2 (W/m²).

3.65 temporal-average intensity

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

NOTE 1 The time-average should be taken over an integral number of **acoustic repetition periods**.

NOTE 2 (Relating to ultrasonic medical diagnostic systems) in principle, the **temporal-average intensity** is an average over a relatively long time interval. For non-auto-scanning systems, the **instantaneous intensity** should be averaged over one or more **pulse repetition periods**. For auto-scanning systems, the **instantaneous intensity** should be averaged over one or more **scan repetition periods** for a specified operating mode.

NOTE 3 **Temporal-average intensity** is expressed in W/m^2 (W/m²).

3.66 temporal-peak intensity

I_{tp}
maximum value over time of the **instantaneous intensity** at a particular point in an acoustic field

NOTE **Temporal-peak intensity** is expressed in W/m^2 (W/m²).

3.67

temporal-peak acoustic pressure

p_{tp}

maximum value of the modulus of the **instantaneous acoustic pressure** at a particular point in an acoustic field

NOTE Temporal-peak acoustic pressure is expressed in pascal (Pa).

3.68

transducer aperture plane

plane that is orthogonal to the **beam axis** of the **unsteered beam**, or the axis of symmetry of the **azimuth plane** for an automatic scanner, and is adjacent physically to the **ultrasonic transducer**

NOTE 1 If the **ultrasonic transducer** is flat, the plane is coplanar with the radiating surface of the **ultrasonic transducer**; if it is concave, the plane touches the periphery of the radiating surface; if it is convex, the plane is tangent to the centre of the radiating surface at the point of contact (see Figure 1).

NOTE 2 Definition adopted from IEC 61828:2001, 4.2.72.

3.69

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.

3.70

ultrasound instrument console

electronic unit to which the **transducer assembly** is attached

3.71

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 In general, this standard assumes that an individual scan line repeats exactly after a given number of acoustic pulses. In case an **ultrasonic transducer** or **ultrasonic transducer element group** radiates ultrasound without any sequence of repetition, it will not be possible to characterize a scanned mode in the way described in this standard. The approach described in Annex F can be useful when synchronization cannot be achieved.

NOTE 3 The case where a single excitation produces ultrasonic beams propagating along more than one **beam axis** is not considered.

3.72

ultrasonic scan line separation

s_s

for automatic scanning systems, the distance between the points of intersection of two consecutive **ultrasonic scan lines** of the same type and a specified line in the scan plane

NOTE 1 It is assumed here that consecutive ultrasonic scan lines are spatially adjacent; this is not true for all types of scanning equipment.

NOTE 2 The **ultrasonic scan line separation** is expressed in metres (m).

3.73

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

3.74

ultrasonic transducer element

element of an **ultrasonic transducer** that is excited in order to produce an acoustic signal

3.75

ultrasonic transducer element group

group of elements of an **ultrasonic transducer** which are excited together in order to produce an acoustic signal

3.76

ultrasonic transducer element group dimensions

dimensions of the surface of the group of elements of an **ultrasonic transducer element group** which includes the distance between the elements, hence representing the overall dimensions

NOTE 1 $\triangleleft$ **ultrasonic transducer element group** $\triangleleft$

NOTE 2 This direction is along the **central scan line** of a sector scan. When the **ultrasonic transducer** is symmetric, the **unsteered beam** may be chosen to be near the symmetry axis or a symmetry plane of the **ultrasonic transducer**.

NOTE 3 Definition adopted from IEC 61828:2001.

3.77

uncertainty

parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

NOTE See the ISO Guide to the Expression of Uncertainty in Measurement [3], 2.2.3.

$\triangleleft$ 3.78

derived instantaneous intensity

quotient of squared **instantaneous acoustic pressure** and characteristic acoustic impedance of the medium at a particular instant in time at a particular point in an acoustic field

$$I(t) = \frac{p(t)^2}{\rho c} \quad (1)$$

where:

$p(t)$ is the **instantaneous acoustic pressure**;

ρ is the density of the medium;

c is the speed of sound in the medium

NOTE 1 For measurement purposes referred to in this International Standard, the **derived instantaneous intensity** is an approximation of the **instantaneous intensity**.

NOTE 2 Increased uncertainty should be taken into account for measurements very close to the transducer.

NOTE 3 **Derived instantaneous intensity** is expressed in $\triangleleft$ watts per square metre $\triangleleft$ (W/m^2).

3.79

local area factor

F_a

square root of the ratio of the **source aperture area** to the **beam area** at the point of interest. The relevant local **beam area**, A_b , is that for which the **pulse-pressure-squared integral** is greater than 0,135 (that is, $1/e^2$) times the maximum value in the cross-section.

$$F_a = \sqrt{\frac{0,69 A_{SAeff}}{A_{b,-6dB}}} \quad (24)$$

NOTE If the beam profile is approximately Gaussian at the distance of interest and the area at the -6dB level, $A_{b,-6dB}$, is known, the local **beam area** can be calculated as $A_b = A_{b,-6dB}/0,69$: ($0,69 = 3\ln(10)/10$).

[SOURCE: IEC/TS 61949:2007, definition 3.11 modified – the third sentence of the original definition has been changed into a note.] $\triangleleft A_1$

$\triangleleft A_1$ 3.80

number of pulses per ultrasonic scan line

n_{pps}

the number of acoustic pulses travelling along a particular **ultrasonic scan line**

NOTE 1 Here **ultrasonic scan line** refers to the path of acoustic pulses on a particular **beam axis** in scanning and non-scanning modes.

NOTE 2 This number can be used in the calculation of any ultrasound temporal average value from **hydrophone** measurements.

NOTE 3 The following shows an example of the **number of pulses per ultrasonic scanline** and the **number of ultrasonic scanlines** (shows the end of a frame):

1 2 3 4; 1 2 3 4; 1 2 3 4... $n_{pps} = 1$; $n_{sl} = 4$
 1 1 2 2 3 3 4 4; 1 1 2 2 3 3 4 4; ... $n_{pps} = 2$; $n_{sl} = 4$
 1 1 1 1 2 2 2 2 3 3 3 3 4 4 4 4; 1 1 1 1 2 2 2 2 3 3 3 3 4 4 4 4; ... $n_{pps} = 4$; $n_{sl} = 4$
 1 1 2 2 3 3 4 4 1 1 2 2 3 3 4 4; 1 1 2 2 3 3 4 4 1 1 2 2 3 3 4 4; ... $n_{pps} = 4$; $n_{sl} = 4$ (within one frame the pulses down each line may not occur contiguously)
 Within one frame, all scan lines may not have the same n_{pps} value.
 An example is: 1 2 2 3 3 4; 1 2 2 3 3 4; ... avg $n_{pps} = 1,5$; max $n_{pps} = 2$; $n_{sl} = 4$

[SOURCE: IEC 61157:2007/Amendment 1—, definition 3.45]

3.81

number of ultrasonic scanlines

n_{sl}

the **number of ultrasonic scanlines** that are excited during one **scan repetition period**

NOTE This number can be used in the calculation of any ultrasound temporal average value from **hydrophone** measurements.

[SOURCE: IEC 61157:2007/Amendment 1—, definition 3.46]

3.82

source aperture area

A_{SAeff}

equivalent aperture area for an **ultrasonic transducer** of unknown characteristics, measured as the area inside the -20 dB **pulse-pressure-squared-integral** contour in the closest possible measurement plane (source aperture plane) to the **external transducer aperture**

NOTE 1 See Figure 3.

NOTE 2 **Source aperture area** is expressed in square metres (m^2). $\triangleleft A_1$

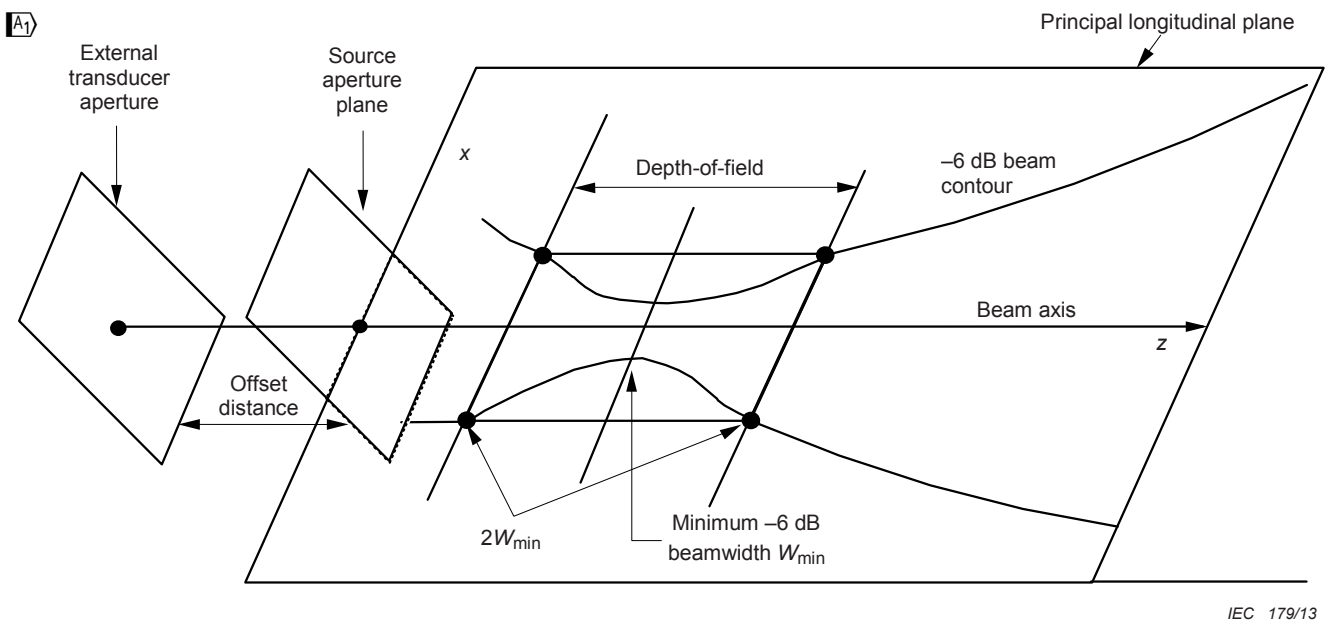


Figure 3 – Several apertures and planes for a transducer of unknown geometry [IEC 61828]

3.83

source aperture plane

closest possible measurement plane to the external transducer aperture that is perpendicular to the **beam axis**

[SOURCE: IEC 61828:2006, definition 4.2.67]

3.84

source aperture width

L_{SA}

in a specified **longitudinal plane**, the greatest **-20 dB beamwidth** along the line of intersection between the designated **longitudinal plane** and the **source aperture plane**

NOTE 1 See Figure 2 in IEC 61828:2001.

NOTE 2 **Source aperture width** is expressed in metres (m).

[SOURCE: IEC 61828:2006, definition 4.2.68, modified – two notes have been added.]

3.85

spatial-average pulse-average intensity

I_{sapa}

pulse-average intensity from one **ultrasonic transducer** or **ultrasonic transducer element group** averaged over the **beam-area** for that particular **ultrasonic transducer** or **ultrasonic transducer element group**

NOTE 1 A burst is also to be understood to be a pulse.

NOTE 2 **Spatial-average pulse-average intensity** is expressed in A_1 watts per square metre A_1 (W/m^2).

3.86

time-window-average intensity

$I_{w,\Delta t/s}(t)$

the time-varying value of the **instantaneous intensity** averaged over a window of duration Δt , given by: A_1