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INTERNATIONAL STANDARD

NORME INTERNATIONALE

AMENDMENT 1
AMENDEMENT 1

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

Ultrasons – Hydrophones –
Partie 1: Mesurage et caractérisation des champs ultrasoniques médicaux jusqu'à 40 MHz

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FOREWORD

This amendment has been prepared by IEC technical committee 87: Ultrasonics.

The text of this amendment is based on the following documents:

FDIS	Report on voting
87/518/FDIS	87/524/RVD

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

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

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- withdrawn,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

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Replace throughout the document:
“non-linear” by “nonlinear”,
This replacement applies to the English text only.

Replace throughout the document:
“non-linearity” by “nonlinearity”
This replacement applies to the English text only.

INTRODUCTION

Delete, in the second paragraph, the term “piezoelectric”.

Delete, in the second paragraph, the last two sentences.

1 Scope

Delete, in Note 2, the second sentence.

2 Normative references

Replace the reference to the ISO Guide to the expression of uncertainty in measurement as follows:

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

3 Terms, definitions and symbols

Replace, throughout this clause, the phrase "watts per metre squared" *by* "watts per square metre" (9 times).

Replace, throughout this clause, the phrase "metres squared" *by* "square metres" (3 times).

3.1
acoustic pulse waveform

Delete Note 2.

3.3
acoustic frequency
acoustic-working frequency

Replace, in the second sentence of Note 1," 3.3.1 and 3.3.2" *by "*3.3.1, 3.3.2, 3.3.3 and 3.3.4*".*

3.3.1
zero-crossing acoustic-working frequency
f_{awf}

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Replace the existing text of the definition by the following:

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

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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.

3.3.2
arithmetic-mean acoustic-working frequency
f_{awf}

Add the following note to the definition:

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.

3.3.3
peak pulse acoustic frequency

Delete the full stop after the symbol f_p.

3.4
azimuth axis

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

In the figure, replace "Y" *by* "Z" *and* "Z" *by* "Y".

In the key of the figure, replace "Y beam axis" *by* "Y elevation axis" *and* "Z elevation axis" *by* "Z beam axis".

3.7
beam area

Replace the symbol by: "$\boldsymbol{A}_{\mathbf{b,6}}$, $\boldsymbol{A}_{\mathbf{b,20}}$"

Replace the existing text of Note 1 by the following:

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.

*Replace, in Note 3, the word "*levels*" by "*fractions*".*

3.22
effective radius of a non-focused ultrasonic transducer

Replace the term by **effective radius of a non-focusing ultrasonic transducer**

Replace the term in the Note by **effective radius of a non-focusing ultrasonic transducer**

3.28
far field

Replace the existing text by the following:

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

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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).

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

3.34
instantaneous intensity

Replace the existing text of Note 1 by the following:

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.**

3.37
near field

Replace the existing definition and note by the following:

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
non-linear propagation parameter

Replace the existing term, symbol and definition by the following:

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:

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

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 (β = 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.]

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3.43
peak acoustic pressure

Replace the existing symbol by: "p_r (or p_-) or p_c (or p_+)".

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3.44
peak-rarefactional acoustic pressure

Replace the existing symbol by: "p_r (or p_-)"

3.45
peak-compressional acoustic pressure

Replace symbol by: "p_c (or p_+)"

3.47
pulse-average intensity
I_{pa}

Replace, in the definition, the word "ratio" *by* "quotient".

Add the following new note and number the existing note as Note 2.:

NOTE 1 This definition applies to pulses and bursts.

3.51
pulse repetition period

Delete, in Note 1, the second sentence ("See also IEC 60469-1:1987, 5.3.2.1.").

3.52
pulse repetition rate

Delete Note 1.

Renumber Note 2 *as* Note.

3.65
temporal-average intensity

Replace the existing Note 1 by the following:

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

Add the following new Note 2 and renumber the existing Note 2 as Note 3:

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.

3.76
ultrasonic transducer element group dimensions

Replace, in the definition, the term "**ultrasonic transducer** element group" *by* "**ultrasonic transducer element group**" *(bold font for the entire term).*

Add the following new definitions:

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

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

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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 watts per square metre (W/m2).

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.

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

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 = 3ln(10)/10).

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

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 npps 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**

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

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

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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).

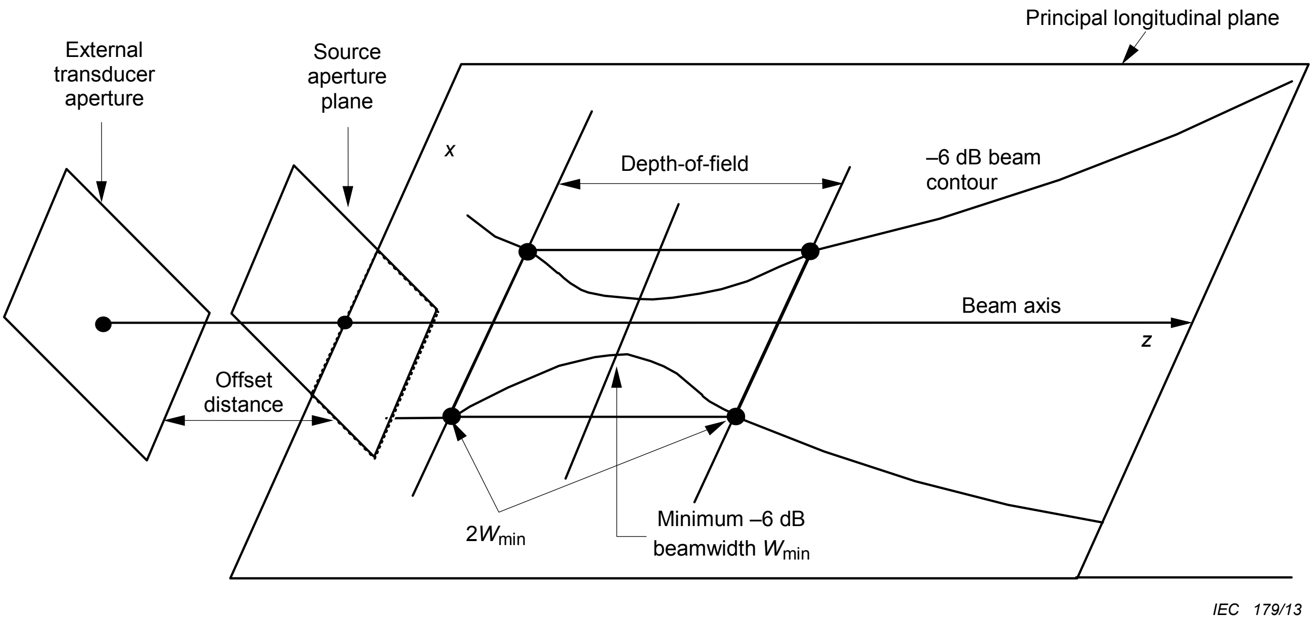

Figure 3 – Several apertures and planes for a transducer of unknown geometry [IEC 61828]

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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]

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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 watts per square metre (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:

$$I_{\mathrm{w},\Delta t/\mathrm{s}}(t) = \frac{1}{\Delta t}\int_{t-\Delta t/2}^{t+\Delta t/2} I(t')dt' \qquad (25)$$

where:

$I(t)$ is the **instantaneous intensity**;

Δt/s is the numerical value of the moving time window width in seconds

t' is the variable of integration

NOTE The time varying **time-window-average intensity** for a time window width of 20 s, for instance, is denoted by $I_{\mathrm{w},20}(t)$

3.87
transducer aperture width
L_{TA}
full width of the transducer aperture along a specified axis orthogonal to the **beam axis** of the unsteered beam at the centre of the transducer

NOTE 1 See Figure 4.

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

[SOURCE: IEC 61828:2006, definition 4.2.74 modified – two notes have been added, and the phrase "at the centre of the transducer" has been added to the definition.]

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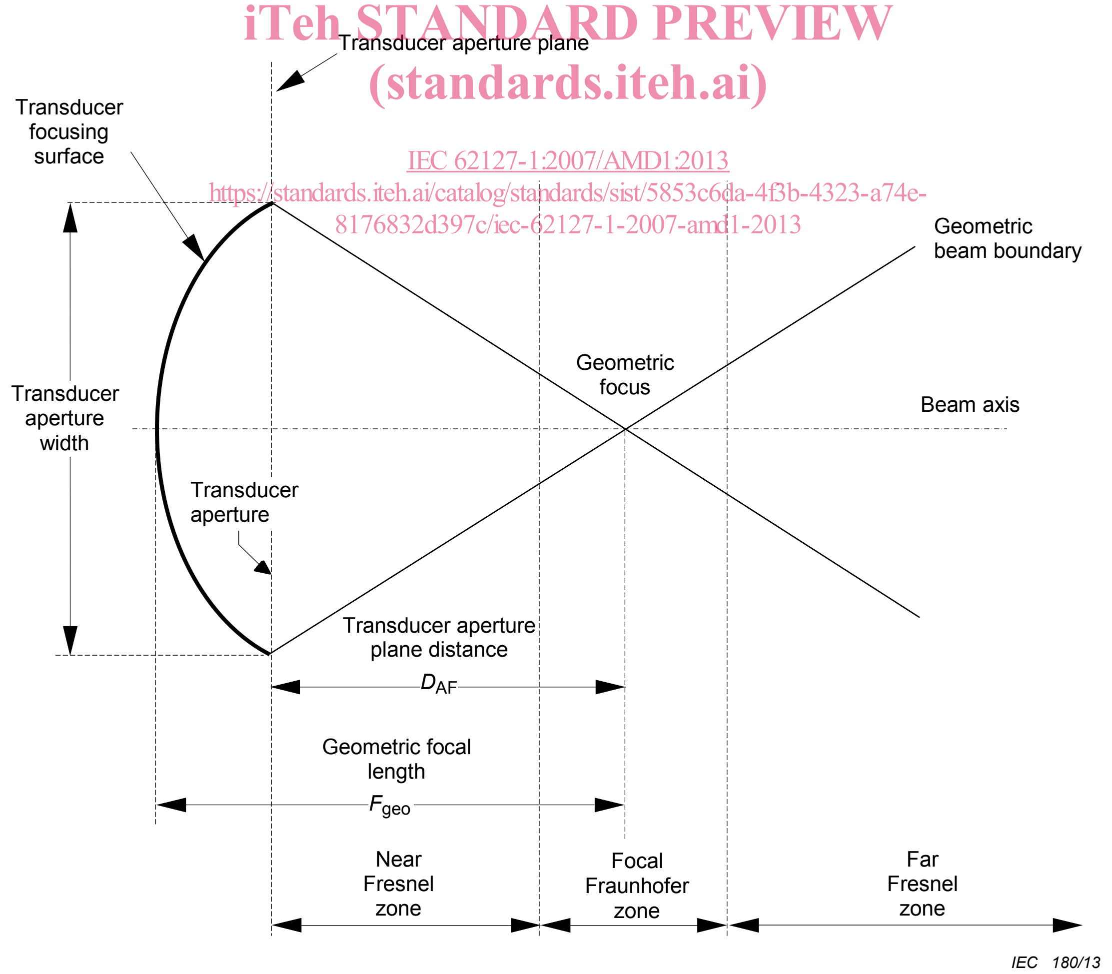

Figure 4 – Parameters for describing an example of a focusing transducer of a known geometry [IEC 61828 modified]

3.88
transition distance
z_T
for a given **longitudinal plane**, the **transition distance** is defined based on the transducer design (when known) or from measurement:

a) from design: the **transition distance** is the equivalent area of the ultrasonic **transducer aperture width** divided by π times the **effective wavelength**, λ;

b) for measurements, the **transition distance** is the equivalent area of the **source aperture width** divided by π times the **effective wavelength.**

NOTE 1 Using method a), an unapodized **ultrasonic transducer** with circular symmetry about the **beam axis,** the equivalent area is πa^2, where a is the radius. Therefore the **transition distance** is $z_T = a^2/\lambda$. For the first example of a square **ultrasonic transducer,** the equivalent area is $(L_{TA})^2$, where L_{TA} is the **transducer aperture width** in the **longitudinal plane**. Therefore, the **transition distance** for both orthogonal **longitudinal planes** containing the sides or **transducer aperture widths**, is $z_T = (L_{TA})^2 /(\pi\lambda)$. For the second example, for a rectangular **ultrasonic transducer** with **transducer aperture widths** L_{TA1} and L_{TA2}, the equivalent area for the first linear transducer aperture width for the purpose of calculating the **transition distance** for the associated **longitudinal plane** is $(L_{TA1})^2$, where L_{TA1} is the **transducer aperture width** in this **longitudinal plane**. Therefore, the **transition distance** for this plane is $z_{T1} = (L_{TA1})^2 /(\pi\lambda)$. For the orthogonal **longitudinal plane** that contains the other **transducer aperture width**, L_{TA2}, the equivalent area for the other for the purpose of calculating the transition distance for the associated **longitudinal plane** is $(L_{TA2})^2$, where L_{TA2} is the **transducer aperture width** in this **longitudinal plane**. Therefore, the **transition distance** for this plane is $z_{T2} = (L_{TA2})^2 /(\pi\lambda)$.

NOTE 2 Using method b) for measurements in a longitudinal plane, the **source aperture width,** L_{SA}, in the same plane is used in $z_T = (L_{SA})^2 /(\pi\lambda)$.

NOTE 3 **Transition distance** is expressed in metre (m).

[SOURCE: IEC 61828:2006, definition 4.2.75, modified – there is significant difference in the layout and content of the definition]

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3.89
treatment head
assembly comprising an **ultrasonic transducer** and associated parts for local application of **ultrasound** to the patient

[SOURCE: IEC 60601-2-5:2009, definition 201.3.214, modified – a note in the original has been deleted.]

4 List of symbols

Replace:

A_b beam area

by:

$A_{b,6}$, $A_{b,20}$ **beam area** corresponding to -6 dB **beam area** and -20 dB **beam area**

Replace:

a_t effective radius of a non-focused ultrasonic transducer

by

a_t **effective radius of a non-focusing ultrasonic transducer**

Replace:

X_{ob} , Y_{ob} output beam dimensions z distance between a hydrophone and an ultrasonic transducer

by: