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Edition 2.0 2023-01

TECHNICAL SPECIFICATION

colour inside

Ultrasonics – Pulse-echo scanners – Simple methods for periodic testing to verify stability of an imaging system's elementary performance



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IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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Ultrasonics – Pulse-echo scanners – Simple methods for periodic testing to verify stability of an imaging system's elementary performance

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ULTRASONICS – PULSE-ECHO SCANNERS –

Simple methods for periodic testing to verify stability of an imaging system's elementary performance

FOREWORD

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IEC TS 62736 has been prepared by IEC technical committee 87: Ultrasonics. It is a Technical Specification.

This second edition cancels and replaces the first edition published in 2016. This edition constitutes a technical revision.

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

a) expansion of the applicable types of transducers and the frequency range of application;
b) extension of test protocols and image assessments, including for **very-low-echo spheres**;
c) revision of **phantom** designs and their acoustic properties, consistent with the second edition of IEC TS 62791;
d) inclusion of luminance tests for system-image display consistency at scanner and remote monitors;

e) addition of special considerations for 3D-imaging transducers (Annex D) and workbook examples (Annex E).

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
87/777/DTS	87/791/RVDTS

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

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are defined in greater detail at www.iec.ch/standardsdev/publications.

Terms **in bold** in the text are defined in Clause 3.

Symbols and formulae are in *Times New Roman italic*.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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

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INTRODUCTION

An ultrasonic pulse-echo scanner produces images of tissue in a scan plane by sweeping a narrow, pulsed beam of ultrasound through the section of interest and detecting the echoes generated by reflection at tissue boundaries and by scattering within tissues. Various transducer types are employed to operate in a transmit/receive mode to generate/detect the ultrasonic signals. Ultrasonic scanners are widely used in medical practice to produce images of soft-tissue organs throughout the human body. As ultrasound systems are usually employed under rigorous time restrictions and in diverse environments to help make decisions that are often critical to patients' wellbeing, it is important that the systems perform consistently at the level initially provided and accepted in initial tests, for example, those of IEC TS 62791, IEC 61391-1, 61391-2, and IEC 62563-2. This document provides methods to verify the stability of an imaging system's elementary performance.

This document is deemed necessary because substandard ultrasound-system performance is often accepted or remains undetected in the absence of unequivocal and documented tests. The most common of the failures, in all but the oldest systems nearing retirement, are sub-performance of a transducer-array element or lens or of a cable or electronic channel. There is approximately a 14 % transducer-failure rate and a 10 % system-failure rate per year on first testing [1],[2],[3],[4],[5],[5],[7],[8],[9],[10],[11],[12][1]. Sensitive image uniformity tests for these transducer- and channel-failures are presented here for use daily to monthly (Level 1), annually (Level 2) and biennially (Level 3).

This common occurrence of suboptimal diagnostic examinations has created an urgent need to standardize quality-assurance (**QA**) and performance-evaluation procedures to promote improved efficacy of diagnostic examinations through widespread use of effective **QA** procedures and to dispel myths as to their utility. Proposers believe, however, that existing national and international standards and guides [1],[3],[12],[13],[14] specify or recommend too many tests and inappropriate tests for detecting and discriminating the common flaws in diagnostic ultrasound systems during routine **QA**. These practices include tests, such as spatial resolution, which are low-yield and belong in performance-evaluation procedures, rather than **QA**.

Modern flat-panel display technology is more stable than, and generally far superior to, earlier cathode ray tube (CRT) displays. However, these displays can still exhibit luminance drift, as well as problems such as defective pixels. They still need to be evaluated periodically.

Detection of failures by these recommended pulse-echo tests will probably also detect most failures affecting the operation of other modes, such as colour-flow, harmonic-, elasticity- and compound-imaging. The failures might be more pronounced in these other modes and the fraction of failures in other modes detected by these tests has not been reported.

Image-uniformity **QA** is applicable to transducers operating in the wide 1 MHz to 40 MHz frequency range, as the requirements for phantoms are not stringent for this test. The other tests could be made applicable up to 40 MHz [15],[16] when the depth of penetration measurement is allowed to be relative, rather than absolute, and phantom stability is verified.

NOTE Phantom manufacturers are encouraged to extend the frequency range to which phantoms are specified to enable relative depth-of-penetration tests of systems operating at fundamental and harmonic frequencies above 23 MHz.

System-manufacturing and repair companies, as well as those performing more complete **performance evaluation** for acceptance, replacement, or research might well employ other or additional tests that are not within the scope of this document. More complete tests than those included in the three levels for periodic testing and for assessment at times of particular importance or concern are specified in IEC 61391-1, IEC 61391-2 and IEC TS 62791. These more complete tests are categorized as **performance evaluation**, rather than **quality**

[1] Numbers in square brackets refer to the Bibliography.

assurance or frequent periodic testing. It is possible that good, automated analysis of the high-contrast sphere tests will reduce both the need for optional tests listed here, and for most, more complete **performance evaluation**. Full assessment of distance-measurement accuracy might still be required if automated, 3D distance measurement calibration is not added to the high-contrast sphere tests.

Uniformity tests of transducers not readily amenable to transducer-element testing by the simple image-uniformity procedures specified here (for example, phased-array and 2D-array transducers) are not included in the scope. They are usually evaluated well by careful performance of the high-contrast sphere tests. System manufacturers are encouraged to provide pulsing patterns of the transducer elements to allow testing of individual elements or small-enough groups of elements to enable users to detect significant element failure or to provide access to another implemented and explained element-test programme.

ULTRASONICS – PULSE-ECHO SCANNERS –

Simple methods for periodic testing to verify stability of an imaging system's elementary performance

1 Scope

This document, which is a Technical Specification, specifies requirements and methods for periodic testing of the quality of diagnostic medical ultrasound systems using reflection-mode (pulse-echo) imaging. Image measurement and interpretation workstations are included.

NOTE Usually, "periodic testing" is referred to as "quality control (QC)" or **quality assurance (QA)**.

This document includes minimum sets of such tests intended for frequent users of medical ultrasound systems, for **quality assurance** professionals in their organizations, or those hired from other quality-control and/or service-provider organizations. The procedures are for a wide range of more common diagnostic ultrasound systems, currently operating from 1 MHz to 40 MHz, although available phantoms meet the specifications only from 1 MHz to 23 MHz.

The tests are defined in three levels, with the simplest and most cost-effective performed most frequently:

Level 1 comprises five quick tests/observations to be performed daily to monthly by those normally operating the systems.

Level 2 includes one necessary test for all systems in addition to those of Level 1, two Level 1 tests performed more rigorously, two tests that are for special situations or equipment, and one that is just optional, included because it is highly developed. Level 2 tests are performed annually by those with meaningful **quality assurance** training.

Level 3 extends the two special situations tests to all systems, adds one optional test and includes a periodic review of the QA programme.

Frequent distance-measurement accuracy tests are recommended in this document only for certain classes of position encoding that are not now known to be highly stable and without bias. **QA** in all dimensions is recommended in this document as the first test for such systems.

The test methodology is applicable for transducers operating in the 1 MHz to 23 MHz frequency range. The types of transducers used with these scanners include

a) electronic phased arrays,

b) linear arrays,

c) convex arrays,

d) mechanical transducers,

e) two-dimensional arrays operated in a 2D imaging mode,

f) transducers operating in 3D imaging mode for a limited number of sets of reconstructed 2D images, and

g) three-dimensional scanning transducers based on a combination of the above types.

All tests on scanners considered here evaluate basic pulse-echo techniques and might detect most failures in other modes. Dedicated Doppler systems, or other systems for detection of blood motion, are excluded from this scope as specialized equipment is required to test them. Such test equipment can be specific to the intended application of the Doppler system.

This document includes definition of terms and specifies methods for measuring the **maximum relative depth of penetration** of real-time ultrasound B-MODE scanners, though this penetration measure is listed as less frequently applied.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-802, *International Electrotechnical Vocabulary – Part 802: Ultrasonics* (available at <http://www.electropedia.org>)

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-802 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
quality assurance
QA
regularly performed procedures to ensure consistent performance

Note 1 to entry: Quality control is a part of quality assurance. Another term used is quality maintenance.

3.2
performance evaluation
set of tests performed to assess specific absolute performance of the object tested

Note 1 to entry: Typical times for ultrasound system **performance evaluation** are at pre-purchase evaluation, new and repaired system acceptance testing, according to IEC 61391-1 and IEC 61391-2 and [1],[17],[18],[19],[20],[21],[22], and at times of performance difficulties and end-of-useful-life evaluations. Level 3 **QA** tests include many of those recommended for such **performance evaluation**.

3.3
phantom
device designed to mimic some aspects of the human body for the purposes of testing or training

3.4
addressable patch
smallest addressable group of transducer elements

3.5
pixel value
integer value of a processed signal level or integer values of processed colour levels, provided to the display for a given pixel

Note 1 to entry: In a grey-scale display the **pixel value** is converted to a luminance by some, usually monotonic, function. The set of integer values representing the grey scale runs from 0 (black) to $(2^M - 1)$ (white), where M is a positive integer, commonly called the bit depth. Thus, if $M = 8$, the largest **pixel value** in the set is 255.

[SOURCE: IEC TS 62791:2022, 3.6]

3.6
mean pixel value
MPV
mean of **pixel values** detected over a designated area or volume in an image or 3D stack of images

Note 1 to entry: For **low-echo spheres** here, MPV is defined for an area A or volume in a **phantom** image or stack of images, where A is somewhat smaller than the area of a circle of diameter D. The phrase "somewhat smaller than" is introduced as partial compensation for the partial volume effect, primarily in the elevational dimension.

Note 2 to entry: The partial volume effect is a term common in computed tomographic, magnetic resonance and ultrasound imaging. This process refers to the effect of the finite imaging resolution, particularly the slice thickness. The signal (ie, **pixel values**) at points near the object boundaries will include contribution from that object and contributions from the material around it. For example, if the object is a sphere with a diameter close to the thickness of the slice, then you cannot define a good measurement region in the image of the sphere in which the signal does not include components from material lying outside the sphere.

3.7
maximum depth of penetration
maximum range in a **phantom**, with properties meeting the specifications of IEC 61391-2, at which the **mean pixel value** corresponding to signals from the weakly reflecting, background scatterers are 1,4 times the **mean pixel value** corresponding to images displaying only electronic noise at that same depth

Note 1 to entry: The **maximum depth of penetration** is expressed in metres (m) and conventionally in centimetres (cm).

3.8
maximum relative depth of penetration
maximum range in a **phantom**, at which the **mean pixel value** corresponding to images displaying echoes from weakly reflecting and background scatterers are 1,4 times the **mean pixel value** corresponding to images displaying only electronic noise at that same depth

Note 1 to entry: The specified properties of the phantom are somewhat relaxed from those specified in IEC 61391-2, as modified in IEC/TS 62791:2022, 3.2.

Note 2 to entry: The adjective "relative" is used because the **phantom** specifications defined in this document are so loose that measurements of the "maximum range" with different **phantoms** cannot be compared. The measurements are only for tests of stability, i.e. comparisons between measurements on the same **phantom** over time.

Note 3 to entry: For available **phantoms** and specifications, see [16],[17], and for a potential alternative measure of depth of penetration, see [15].

Note 4 to entry: The **maximum relative depth of penetration** is, by international standards, expressed in metres (m) and conventionally in centimetres (cm).

3.9
median absolute deviation
MAD
median of the absolute value of the deviations from the median of a data set

Note 1 to entry: The MAD is similar to the standard deviation but, as the median of linear deviations rather than squared deviations, it is more resilient to outliers [18].

3.10
specific attenuation coefficient
attenuation coefficient at a specified frequency divided by the frequency

Note 1 to entry: The **specific attenuation coefficient** is usually expressed in decibels per centimetre per megahertz (dB $cm^{-1}MHz^{-1}$); extrapolation to other frequencies makes the explicit assumption of linear dependence of the attenuation coefficient on frequency.

[SOURCE: IEC 61391-2:2010, 3.33, modified by rephrasing "at a specified frequency, the slope of attenuation coefficient plotted against frequency", which assumes a broadband measurement.]

3.11
equivalent sensitivity
sensitivity that is statistically the same or has smaller variance and bias

3.12
backscatter coefficient
intrinsic backscatter coefficient
η
intrinsic property of a material at some frequency, equal to the differential scattering cross-section per unit volume for a scattering angle of 180°

[SOURCE: IEC TS 62791:2022, 3.2, modified – the note has been deleted.]

3.13
low-echo sphere
hypoechoic sphere
spherical inclusion in a **phantom** with a **backscatter coefficien**t lower than the **backscatter coefficient** of the surrounding tissue-mimicking material

[SOURCE: IEC TS 62791:2022, 3.3]

3.14
very-low-echo sphere
high-contrast, low-echo sphere
sphere with −40 dB, or greater, contrast with its background material

3.15
low-echo sphere diameter
D
diameter of the low-echo spherical inclusions in a **phantom**

Note 1 to entry: It is generally assumed that all **low-echo sphere**s in a particular **phantom** have the same diameter D. The diameter tolerance is ±1 %.

3.16
lesion signal-to-noise ratio
$LSNR$
ratio of the **mean pixel value** over a region of a detected target in an image, minus the **mean pixel value** over a specified region of the background echo signals, to the standard deviation of the **mean pixel values** contributing to the background

Note 1 to entry: This term might also be referred to as the lesion contrast-to-noise ratio.

[SOURCE: IEC TS 62791:2022, 3.11, modified – the note has been replaced with a new note.]

3.17
lesion signal-to-noise ratio for the *n*th low-echo sphere
$LSNR_n$
numerical value quantifying the **detectability** of the nth macroscopically uniform, **low-echo sphere** surrounded by a macroscopically uniform, background material and existing in the volume of a **phantom** for which image data has been obtained

[SOURCE: IEC TS 62791:2022, 3.12, modified – the notes have been deleted.]

3.18
$LSNR_{\mathrm{m}}$
mean lesion signal-to-noise ratio
conceptual version of this common term (mean signal-to-noise ratio) for detected **low-echo spheres,** whose centres lie within an unspecified volume segment

[SOURCE: IEC TS 62791:2022, 3.13]

3.19
$LSNR_{\mathrm{m}\boldsymbol{d}}$
mean lesion signal-to-noise ratio for depth interval $\boldsymbol{d}$
mean lesion signal-to-noise ratio for detected **low-echo spheres** whose centres lie within the volume segment corresponding to **depth interval label** d

Note 1 to entry: **Low-echo spheres** with centres located less than a distance $D/2$ from a lateral image boundary are excluded.

[SOURCE: IEC TS 62791:2022, 3.14, modified – the term “mean LSNR” has been removed and note 2 has been deleted.]

3.20
reference value of mean lesion signal-to-noise ratio
$LSNR_{\mathrm{m}d,\mathrm{ref}}$
reference values of $\underline{LSNR}_{\mathrm{m}d}$ provided by the manufacturer for a given transducer model and settings, or values acquired in acceptance testing or the first or first-N periodic tests on a given transducer and settings

3.21
useable range
$Я_{\mathrm{u}}$
range or ranges over which the negative of $\underline{LSNR}_{\mathrm{m}}$ is ≥ 1,41

Note 1 to entry: **Useable range** is more fully defined as the **useable range** for imaging **low-echo spheres** of a specified size. It is usually expressed in centimetres [cm].

3.21.1
$Я_1$
minimum depth at which the negative of $\underline{LSNR}_{\mathrm{m}}$ is ≥ 1,41

3.21.2
$Я_2$
first maximum depth at which the negative of $\underline{LSNR}_{\mathrm{m}}$ is ≥ 1,41

3.22
mean useable contrast over the useable range
$|LSNR_{\mathrm{m}Я}|$
mean $|LSNR_{\mathrm{m}}|$ over the **useable range** or combined **useable ranges** of a transducer under given settings

[SOURCE: IEC TS 62791, 3.9 and 3.14 modified]

3.23
clarity index
C_{I}
figure-of-merit for overall performance of a transducer in imaging specified **low-echo spheres** in the employed mode and system, equal to the log absolute value of the **mean lesion signal-to-noise ratio** averaged over the **useable range** times the **useable range**

Note 1 to entry: Symbolically C_{I} represents $\log|LSNR_{\mathrm{m}Я}|$ x $\boldsymbol{Я_{\mathrm{u}}}$, where these symbols are defined in 3.21 and 3.22.

3.24
depth interval
interval between boundaries of contiguous, or overlapping, depth segments into which an image area is subdivided for computation of $LSNR_{\mathrm{m}d}$ values as a function of depth

Note 1 to entry: A rectangular scan area will be subdivided into discrete or overlapping horizontal bands; a sector scan area will be subdivided into annular ring segments, the angular limits being determined by the sector angle. Rectilinear projection of these discrete or overlapping area segments in the elevational direction will create volume segments analogous to slabs and partial cylindrical shells respectively.

[SOURCE: IEC TS 62791:2022, 3.9, modified – in the definition, “or overlapping” has been added, and in the note the reference to the figure and “with thickness equal to the depth interval extent Δ” have been deleted.]

3.25
depth interval label
d
integer for identifying **depth intervals** in an image

Note 1 to entry: d = 1, 2, …, d_{max} where 1 is at the least depth and d_{max} is at the greatest depth.

[SOURCE: IEC TS 62791:2022, 3.9.1]

3.26
detectability
numerical value quantifying the probability that a human observer will detect an object in an image having background speckle

[SOURCE: IEC TS 62791:2022, 3.10]

3.27
signal-to-noise ratio
SNR
ratio of signal plus noise at a given depth in the image to noise obtained with a clean transducer in air at the same depth

Note 1 to entry: The **signal-to-noise ratio** here is defined specifically in this document for the application of the **maximum depth of penetration** measurement. The noise here refers to electronic noise only.

Note 2 to entry: SNR is defined in 61391-2:2010, 7.1.3, in Formula (2).

Note 3 to entry: A more general definition of SNR is given in IEV 702-08-61.

3.28
time gain compensation
TGC
amplification of the signal with time after the transmit pulse to approximately correct for attenuation by the tissues transited and reduce overly strong signals from tissue boundaries close to the transducer

4 Symbols and abbreviated terms

4.1 Symbols

The non-display **QA** parameters defined in this document are listed in Table 1 and sourced from IEC TS 62791 with some modifications.