SLOVENSKI STANDARD
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Neporušitvene preiskave - Akustična emisija - Določanje značilnosti opreme - 2. del: Preverjanje lastnosti delovanja

Non-destructive testing - Acoustic emission testing - Equipment characterisation - Part 2: Verification of operating characteristics

Zerstörungsfreie Prüfung - Schallemissionsprüfung - Charakterisierung der Prüfausrüstung - Teil 2: Überprüfung der Betriebskenngrössen

Essais non destructifs - Essais d'émission acoustique - Caractérisation de l'équipement - Partie 2 : Vérifications des caractéristiques de fonctionnement

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19.100 Neporušitveno preskušanje Non-destructive testing

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English Version

Non-destructive testing - Acoustic emission testing - Equipment characterisation - Part 2: Verification of operating characteristics

Essais non destructifs - Essais d'émission acoustique - Caractérisation de l'équipement - Partie 2 : Vérifications des caractéristiques de fonctionnement

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This European Standard was approved by CEN on 30 May 2021.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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European foreword

This document (EN 13477-2:2021) has been prepared by Technical Committee CEN/TC 138 “Non-destructive testing”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2022, and conflicting national standards shall be withdrawn at the latest by April 2022.

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

This document supersedes EN 13477-2:2010.

In comparison with the previous edition, the following technical modifications have been made:

— Improvement of Clause 3 “Terms & Definitions”;

— Improvement of Clause 5 “Sensor verification”;

— Improvement of Clause 6 “Pre-amplifier verification”;

— Improvement of Clause 7 “Acoustic emission signal processor verification”;

— Improvement of Clause 8 “Verification of the system performance”.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This document specifies test routines for the periodic verification of the performance of acoustic emission (AE) test equipment, i.e. sensors, pre-amplifiers, signal processors, external parametric inputs.

It is intended for use by qualified personnel to implement an automated verification process.

Verification of the measurement characteristics is advised after purchase of equipment, in order to obtain reference data for later verifications. Verification is also advised after repair, modifications, use under extraordinary conditions, or if one suspects a malfunction.

The procedures specified in this document do not exclude other qualified methods, e.g. verification in the frequency domain. These procedures apply in general unless the manufacturer specifies alternative equivalent procedures.

Safety aspects of equipment for use in potentially explosive zones are not considered in this document.

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.

EN 1330-1:2014, *Non destructive testing - Terminology - Part 1: List of general terms*

EN 1330-2:1998, *Non destructive testing - Terminology - Part 2: Terms common to the non-destructive testing methods*

EN 1330-9:2017, *Non-destructive testing - Terminology - Part 9: Terms used in acoustic emission testing*

EN 13477-1:2001, *Non-destructive testing - Acoustic emission - Equipment characterisation - Part 1: Equipment description*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1330-1:2014, EN 1330-2:1998 and EN 1330-9:2017, and the following apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
acoustic emission signal processor
ASP
part of an AE channel for the conversion of the output of the pre-amplifier to digital signal parameters

Note 1 to entry: An AE signal processor can include additional support functions, e.g. pre-amplifier power supply, test pulse control, transient recorder and more.

3.2
arbitrary function generator
AFG
electronic device for generating programmable test signals, various waveforms and direct current (DC)

3.3
high-accuracy digital voltmeter
HADVM
electronic device for precise measurement of the DC voltages used for stimulation of external parametric inputs

3.4
current measurement adapter
CMA1
electrical device for the convenient measurement of DC consumption of a pre-amplifier, supplied by an AE signal processor

3.5
50 Ω terminator
coaxial plug (BNC style) with an internal 50 Ω resistor between inner wire and shielding

3.6
high impedance
HiZ
high impedance condition of an electrical connection, which is usually terminated by 50 Ω

3.7
DC blocker
BNC male to BNC female connector piece with a capacitor, 10 µF/50 V, non-polarized, between the inner wires of both connectors, feeding an alternating current (AC) signal through but blocking off its DC component from an arbitrary function generator (AFG) or a 50 Ω terminator

3.8
distinction of designations from text
distinction in which normal text is reproduced in standard font (Cambria 11 Pt.) and designations in bold italic font, when it indicates a ***variable*** and in bold non-italic font, when it indicates a **constant**

Note 1 to entry: For optimized legibility, superscripts are avoided with the exemption of "^{2}" (for "square", e.g. "$\sin^2$"), and subscripts are avoided with the exemption of "dB_{AE}", "V_P", "V_{PP}", and "V_{RMS}".

3.9
item under verification
IUV
general term and placeholder for any designation code

Note 1 to entry: Lists of items under verification, differently sorted, can be found in Annex E, Tables E.1 and E.2.

3.10
designation code
abbreviation of an item under verification, consisting of one or two characters (sometimes more in order to identify further information) and, for certain items, a one or two-digit number, either a setpoint number, or the character “s” as placeholder for the setpoint number, or the number of an external parametric input, or the character “x” as placeholder for the input number

Note 1 to entry: If no extension is appended to a designation code, the measurement value of that code is meant.

EXAMPLE 1 ***Rs*** identifies the measured rise-time of setpoint s, see 7.6.4.

EXAMPLE 2 ***EA1*** identifies the measured energy value of the first setpoint of the maximum amplitude-varied energy verification, see 7.6.6.

EXAMPLE 3 ***BGRMSs*** identifies a measured RMS value of the continuous background noise using the maximum amplitude setpoint **As'T** of the continuous sine wave test signal **C-Sw'T** with a nominal frequency **F'N**, see 7.3.2.

3.11
'N
designation code extension for a nominal value of an IUV for a certain setpoint, defined by the manufacturer or a procedure or calculated by a formula

EXAMPLE 1 **A1’N** defines the first nominal maximum amplitude setpoint of a series to be stimulated, measured and verified against well-defined acceptance criteria, see 7.6.2.

EXAMPLE 2 **EAs’N** defines a series of nominal signal energies, calculated by using a given formula, to be stimulated, measured and verified against well-defined acceptance criteria, see 7.6.6.

3.12
‘S
designation code extension for an AE system setpoint

EXAMPLE **BPN’S** defines the narrow bandpass to be used in the AE signal processor, for measurements as defined in the procedure.

3.13
’T
designation code extension for a test signal setpoint

EXAMPLE 1 **A’T** defines the calculated maximum amplitude setpoint for the test signal of the arbitrary function generator (AFG) output.

EXAMPLE 2 **S2-Sw’T** defines the setpoint for the AFG to generate a $\sin^2$-modulated sine wave burst.

3.14
.MA
designation code extension for a manufacturer-specified acceptable deviation of a measured maximum amplitude from the nominal value, in dB

3.15
.MP
designation code extension for an acceptance factor, which, when multiplied with the nominal value of a linear setpoint, results in the acceptable deviation of a measured value from the nominal value, specified by the manufacturer

Note 1 to entry: For verification of the maximum amplitude, **A.MP** shall be converted from **A.MA** by Formula (33).

3.16
.MB
designation code extension for an acceptable deviation, which is independent of the nominal value, specified by the manufacturer, see Table C.3

3.17
.U
designation code extension for an upper acceptance limit, specified by the manufacturer for certain items

EXAMPLE **NSWP.U** defines an upper limit for the internally generated AE signal processor noise in μV_P.

3.18
.L
designation code extension for a lower acceptance limit, specified by the manufacturer for certain items

EXAMPLE DR.L defines the lower acceptance limit for the dynamic range of a pre-amplifier, see 6.3.5.

3.19
.DP
deviation percentage, i.e. the ratio of an absolute measurement deviation to the acceptable deviation, a number in %; the acceptance criterion is met if ***IUV.DP*** is lower than or equal to 100 %

Note 1 to entry: ***IUV.DP*** lets one simply recognize by one number, whether an IUV passed or failed the verification, independent of the complexity of the acceptance criterion.

Note 2 to entry: Selecting the maximum ***IUV.DP*** value of all verification steps performed indicates in one number whether all verification steps of an IUV succeeded.

3.20
ABS(X)
mathematical function that returns the absolute value of argument X

Note 1 to entry: If X is negative, ABS(X) returns a positive value.

3.21
MAX(X1; X2; ...; XN)
mathematical function that returns the greatest value of arguments X1 to XN

3.22
MIN(X1; X2; ...; XN)
mathematical function that returns the least value of arguments X1 to XN

4 Required test equipment and test signals

4.1 List of required equipment

The following minimum test equipment is required:

a) test block;

b) shielding test plate;

c) Hsu-Nielsen source, for sensor sensitivity verification;

d) multimeter for voltage and current measurements of DC during pre-amplifier verification (the model given in f) can be used for this purpose);

e) test signal generator, an arbitrary function generator (AFG) with the capability to deliver loadable arbitrary signals, sine waves, rectangle waves, pulses, and also DC for manual or automated verification of external parametric inputs. The output socket shall be isolated from protective earth, which is the usual case with standard AFGs, e.g. Keysight model 33511B[1]. Key specifications for accuracy: AC amplitude in mV_{PP} ± (1 % of setting +1,0) at 1 kHz, frequency ± 0,01 % of setting, DC voltage in mV ± (1 % of setting + 2,0);

f) high-accuracy digital voltmeter (HADVM) to measure the DC test signal from AFG in sufficient accuracy for the verification of the external parametric inputs e.g. AGILENT Model 34401A[1]. Key specifications for accuracy: DC voltage in µV ± (0,003 5 % of reading + 100);

g) variable attenuator, graduated in decibels, matching 50 Ω impedance on input and output, accuracy: ± 0,15 dB;

h) DC power supply, for pre-amplifier supply, with a proper circuit to decouple and terminate the AE signal, if power is fed in via the signal wire. Can be substituted by a verified AE signal processor, see also k) and n);

i) RMS voltmeter, with known or settable time constant or time window. Can be substituted by a verified AE signal processor and appropriate software; key specification: AC accuracy 20 kHz to 1 MHz: ± 0,2 dB;

j) dual-channel storage oscilloscope, for detecting any artefact or non-plausibility in various setups;

k) current measurement adapter (CMA1), if h) is substituted by a verified AE signal processor. Resistor accuracy: ± 1 %;

l) DC blocker;

m) 50 Ω BNC terminator;

n) verified AE signal processor (two units), can be substituted by h) and i).

All electric/electronic test items shall be subject to the quality management system.

4.2 Test signal waveforms

4.2.1 Continuous sine wave

This type of test signal may be used to verify the frequency response and gain of the pre-amplifier and it shall be used to verify the accuracy of the continuous signal level of the AE signal processor. The designation of this signal is **C-Sw'T**. It is defined by amplitude *A* and frequency *F*.

[1] This information is given for the convenience of users of this document and does not constitute an endorsement by CEN of the product named. Equivalent products may be used if they can be shown to lead to the same results.

4.2.2 Triangular-modulated sine wave burst signal

This type of waveform simulates an AE burst signal, see Figure 1. The designation is **Tri-Sw'T**. It is defined by the following parameters:

— maximum amplitude *A*;

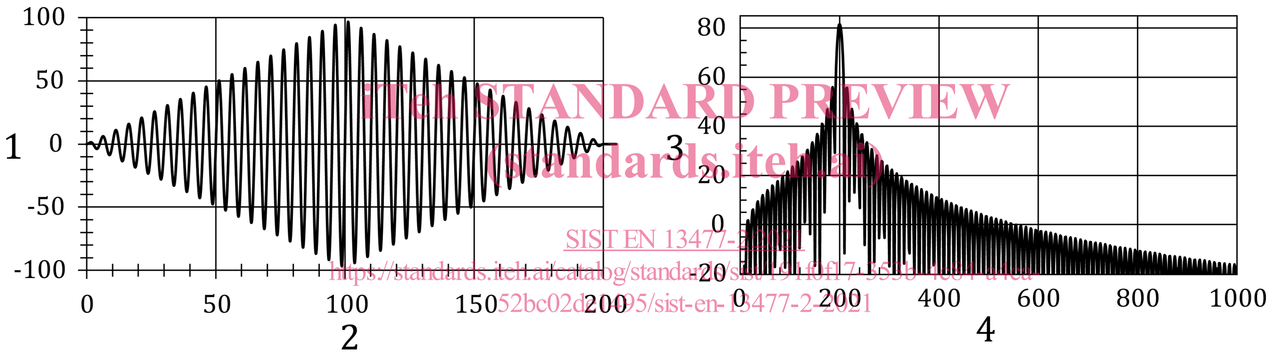
— rise-time *R*;

— decay-time *DEC*;

— carrier frequency *FC*.

Figure 1 a) shows a voltage signal in time domain, horizontally scaled in µs, vertically in mV. Figure 1 b) shows the FFT of the voltage signal in a), horizontally scaled in kHz, vertically in dB. The magnitude in dB corresponds to dB_{AE}, if a continuous sine wave occupies the FFT input buffer. For burst signals in a zero-padded FFT input buffer the scaling is influenced by the duration and the waveform of the signal.

Example: A single-cycle sine wave of 100 kHz in a zero-padded FFT buffer produces a 6,02 dB higher FFT result than a single-cycle sine wave of 200 kHz, since the 100 kHz cycle lasts twice the time of the 200 kHz cycle.



a) Time domain **b) Frequency domain (FFT)**

Key

1 voltage in mV

2 time in µs

3 magnitude in dB

4 frequency in kHz

Figure 1 — Triangular-modulated sine wave burst signal

The signal shown in Figure 1 a) results from Formula (1):

$$\boldsymbol{U}(\boldsymbol{t}) = \mathbf{UP} \times \sin(2 \times \pi \times \mathbf{F'N} \times \boldsymbol{t}) \times \mathrm{MIN}(1; \boldsymbol{t} / \mathbf{R'N}) \times (1 - \mathrm{MAX}(0; (\boldsymbol{t} - \mathbf{R'N}) / \mathbf{DEC'N})) \quad (1)$$

$$\mathbf{F'T} = 1 / (\mathbf{R'N} + \mathbf{DEC'N}) \quad (2)$$

where

***U*(*t*)**	voltage in mV at time ***t***;
t	time of the stimulated burst signal in µs taking values from ***t*** = 0 till to ***t*** = **R'N** + **DEC'N**;
UP	maximum amplitude (98 mV_P in Figure 1) of the simulated burst signal;
F'N	nominal carrier frequency in MHz (0,2 MHz in Figure 1);
R'N	nominal rise-time in µs (100 µs in Figure 1);
DEC'N	nominal decay-time in µs (100 µs in Figure 1);
F'T	frequency setting at the AFG.

This wave shall be generated by an arbitrary function generator (AFG). The waveform shall be defined as a sequence of voltage samples, according to Formula (1), with **UP** = 1 mV_P, and loaded into the AFG. The maximum amplitude setpoint **A'T** (98 mV_{PP} for 98 mV_P in Figure 1) and the frequency setpoint **F'T**, see Formula (2), shall be entered at the AFG.

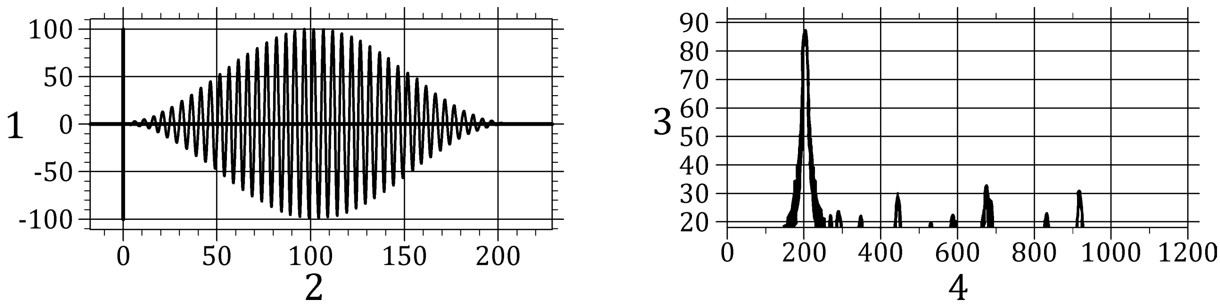
The measured rise-time can be shorter than the visible rise-time of the test signal because rise-time measurement starts at the time of the first threshold crossing. Table 1 shows the theoretical first threshold-crossing delay for five different thresholds in relation the maximum amplitude *A*. In practice, the used bandpass filter can further modify the exact value of the first threshold-crossing delay.

Table 1 — First threshold-crossing delay versus threshold to maximum amplitude relation for a triangular-modulated test signal

Threshold in relation to the maximum amplitude in dB	Triangular-modulated first threshold-crossing delay in % of rise-time
A – 20	10,0
A – 25	5,6
A – 30	3,2
A – 35	1,8
A – 40	1,0

See also additional information in rise-time verification under 7.6.4.

4.2.3 Sin²-modulated sine wave burst signal



a) Time domain **b) Frequency domain (FFT)**

Key

1 voltage in mV

2 time in µs

3 magnitude in dB

4 frequency in kHz

Figure 2 — Sin²-modulated sine wave burst signal

A sin²-modulated signal (see Figure 2), designated **S2-Sw'T**, provides a purer frequency spectrum due to its smooth begin, maximum and end of the burst signal. Compared to the other types of test signals this wave type avoids influences of the bandpass filter on the waveform of the signal, such as overshoots at the beginning and reverberations at the end. Therefore, this type of signal shall be used for the verification of burst signal maximum amplitude related parameters (maximum amplitude, detection threshold, energy and signal strength). This type of signal may also be used to obtain the frequency response of the bandpass of a pre-amplifier or of an AE signal processor based on burst signal maximum amplitude measurement at varied frequency, see 7.5.

Similar to the triangular modulated sine wave, the rise-time measured by an AE signal processor is shorter than the visible rise-time of the test signal, since rise-time measurement starts at the time of the first threshold crossing.

The signal shown in Figure 2 results from Formula (3):

$$\boldsymbol{U}(\boldsymbol{t}) = \mathbf{UP} \times \sin(2 \times \pi \times \mathbf{F'N} \times \boldsymbol{t}) \times \sin^2(\pi \times \mathbf{F'T} \times \boldsymbol{t}) \quad (3)$$

$$\mathbf{F'T} = \mathbf{F'N} / \mathbf{SWpB} \quad (4)$$

where

U*(*t*)** voltage in mV at time ***t;

t time of the stimulated burst signal in µs taking values from ***t*** = 0 till to ***t*** = 1 / **F'T**;

UP maximum amplitude (98 mV_P in Figure 2) of the simulated burst signal;

F'N nominal carrier frequency in MHz;

SWpB sine waves per burst signal (41 in Figure 2);

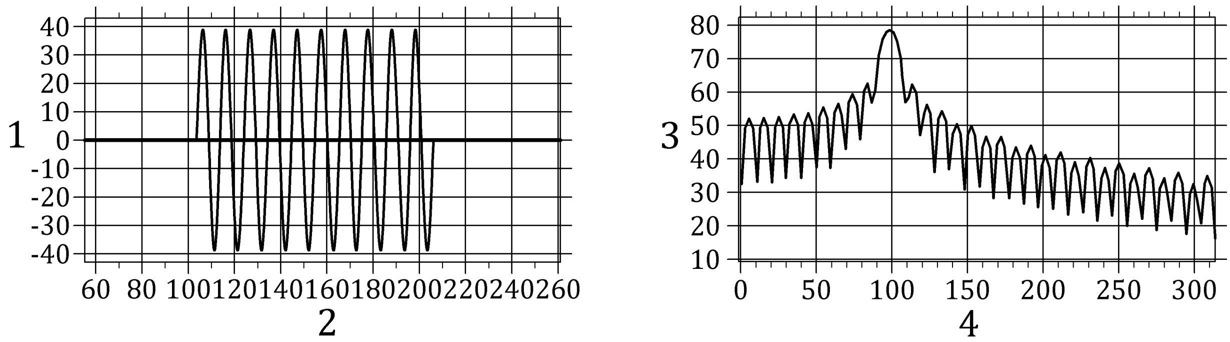
F'T frequency setting at the AFG.

Formula (4) defines the frequency setpoint **F'T** of the arbitrary function generator (AFG) for obtaining the nominal carrier frequency **F'N** at a given number of programmed sine waves per burst signal **SWpB**.

This wave shall be generated by an arbitrary function generator (AFG). The waveform shall be defined as a sequence of voltage samples, according to Formula (3), with **UP** = 1 mV_P, and loaded into the AFG. The maximum amplitude setpoint **A'T** (98 mV_{PP} for 98 mV_P in Figure 2) and the frequency setpoint **F'T**, see Formula (4), shall be entered at the AFG.

Similar with the triangular-modulated sine wave, the rise-time measured by an AE signal processor is shorter than the visible rise-time of the test signal, since rise-time measurement starts at the time of the first threshold crossing.

4.2.4 Rectangular-modulated sine wave burst signal



a) Time domain

b) Frequency domain (FFT)

Key

1 voltage in mV

2 time in µs

3 magnitude in dB

4 frequency in kHz

Figure 3 — Rectangular-modulated sine wave burst signal

This test signal is designated **R-Sw'T**. It is defined by the characteristics *A* (amplitude), *D* (duration) and *FC* (carrier frequency), see Figure 3. It is mainly used for duration-varied verifications.

When using an arbitrary function generator (AFG), the duration in µs (100 µs in Figure 3) results from the setpoint of the number of sine waves per burst signal (10 in Figure 3) divided by the setpoint of frequency in MHz (0,1 MHz in Figure 3).