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Non-destructive testing — Ultrasonic testing with arrays — Vocabulary

Essais non destructifs — Contrôle à l'aide de réseaux ultrasonores — Vocabulaire

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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 135, *Non-destructive testing,* Subcommittee SC 3, *Ultrasonic testing,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 138, *Non-destructive testing,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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Introduction

This document follows a structure similar to that in ISO 5577 but only takes into account terms related to ultrasonic arrays.

The general terms already defined in ISO 5577 are also valid for ultrasonic arrays.

Non-destructive testing — Ultrasonic testing with arrays — Vocabulary

1 Scope

This document defines terms used in ultrasonic testing with arrays. This includes phased array technology and signal processing technology using arrays, e. g. the full-matrix capture (FMC) (3.3.1.28) and the total focusing technique (TFM) (3.3.1.35).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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 http://www.electropedia.org/

3.1 Terms related to sound

3.1.1
main lobe
main beam
sound beam in the intended direction, typically with the highest pressure within the sound field

Note 1 to entry: This applies to conventional and *array probes* (3.2.1.3).

3.1.2
side lobe
part of the sound field which corresponds to a local maximum in the far field, deviating from the direction of the *main lobe* (3.1.1) and typically lower in amplitude

Note 1 to entry: This applies to conventional and *array probes* (3.2.1.3).

3.1.3
grating lobe
parasitic replication of the *main lobe* (3.1.1) caused by spatial undersampling (low ratio between wavelength and *pitch* (3.2.1.16)), deviating from the direction of the main lobe and possibly of similar amplitude

Note 1 to entry: This applies to *array probes* (3.2.1.3) only.

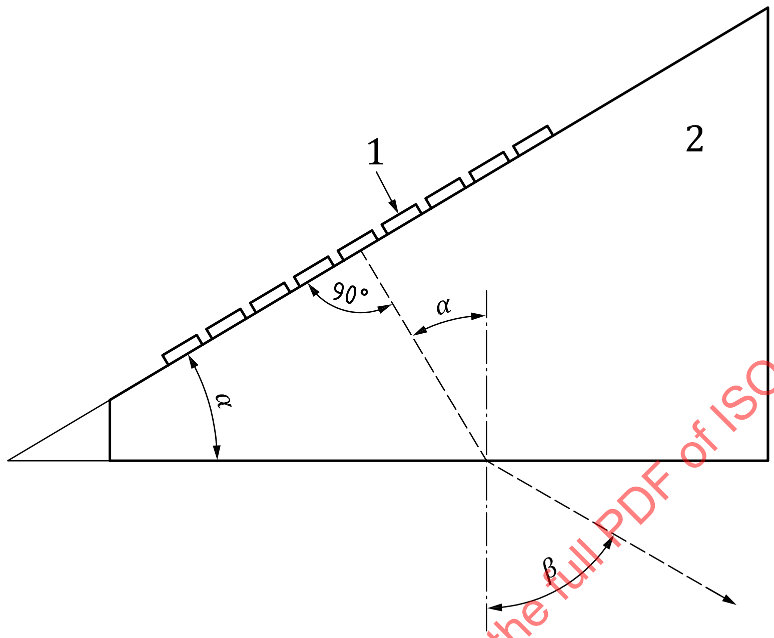
3.2 Terms related to the test equipment

3.2.1 Probes

3.2.1.1
array
piezoelectric plate divided into several *elements* (3.2.1.2), which are acoustically and electrically separated

3.2.1.2
array element
element
smallest part of the *array* (3.2.1.1) acting as a transducer

Note 1 to entry: See Figure 1.



Key
1 array element
2 wedge
α wedge angle
β *natural refracted beam angle* (3.2.1.26)

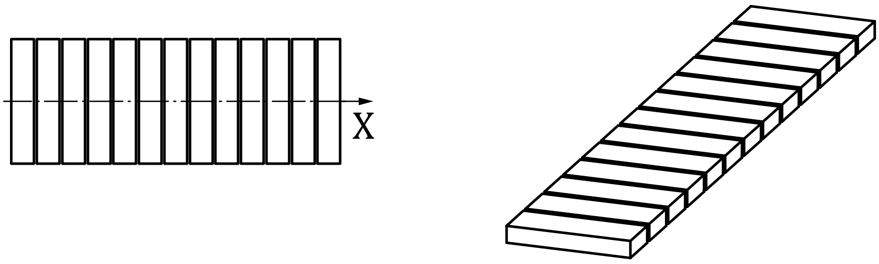
Figure 1 — Wedge and array with relevant parameters

3.2.1.3
array probe
probe with an *array* (3.2.1.1) of *elements* (3.2.1.2) for transmitting and/or receiving

3.2.1.4
arrangement of the array
spatial distribution of all the *elements* (3.2.1.2) in an *array* (3.2.1.1)

3.2.1.5
linear array
1-D-linear array
array (3.2.1.1) of *elements* (3.2.1.2) arranged in a single straight line allowing steering in one direction (*primary axis* (3.2.1.18)) and focusing in the depth direction

Note 1 to entry: See Figure 2.



Key

X primary axis

Figure 2 — Linear array; 1-D-linear array

3.2.1.6
annular array

array (3.2.1.1) of ring-shaped *elements* (3.2.1.2) arranged concentrically allowing focusing in the depth direction

Note 1 to entry: See Figure 3.

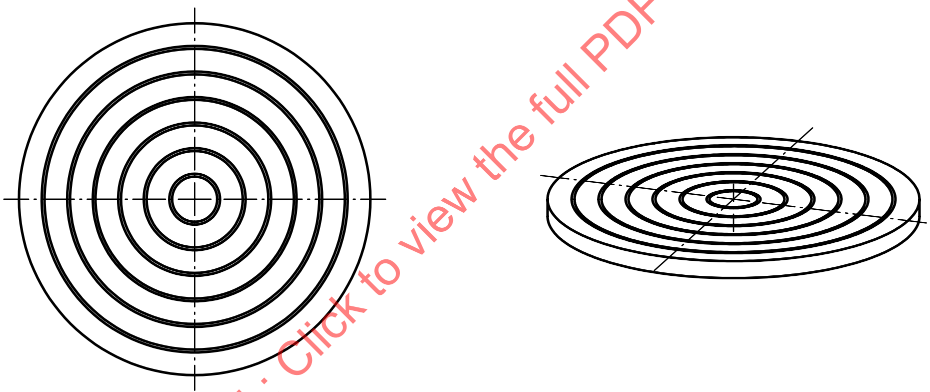


Figure 3 — Annular array

3.2.1.7
sectorial annular array

annular array (3.2.1.6) with the rings divided into sectors allowing steering in two directions and focusing in the depth direction

Note 1 to entry: See Figure 4 and Figure 5.

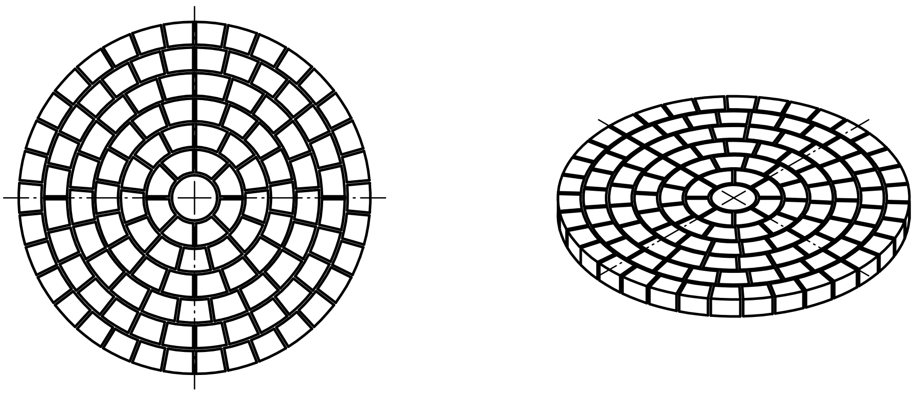


Figure 4 — Sectorial annular array

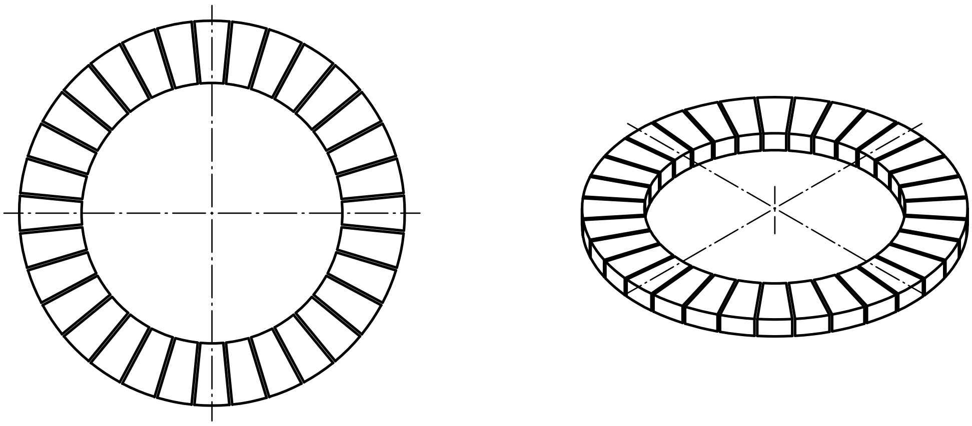


Figure 5 — Partial sectorial annular array

3.2.1.8
1-D-curved array
array (3.2.1.1) arranged on a complete or partial cylinder, where the major transmitting axis is radial

Note 1 to entry: See Figure 6 and Figure 7.

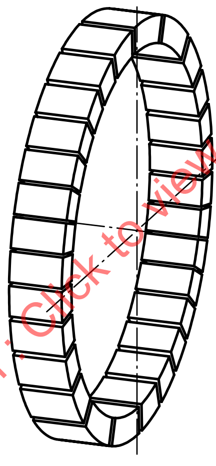


Figure 6 — 1-D-curved array covering a complete circle

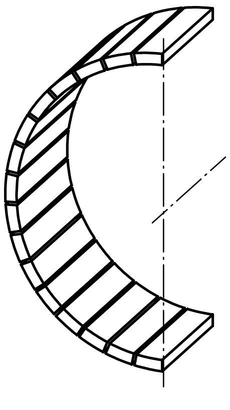


Figure 7 — 1-D-curved array covering part of a circle

3.2.1.9
convex array
1-D-curved array (3.2.1.8) typically used for the testing of tubes from the inside

3.2.1.10
concave array
1-D-curved array (3.2.1.8) typically used for the testing of tubes from the outside

3.2.1.11
dual-array probe
probe with separate *arrays* (3.2.1.1) for transmitting and receiving

Note 1 to entry: See Figure 8.

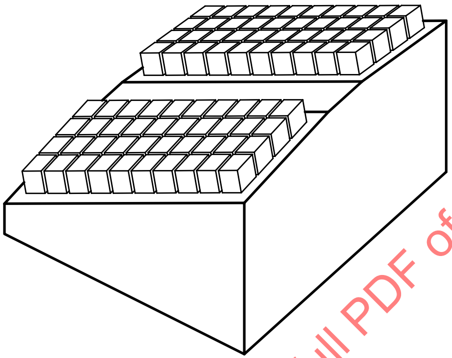
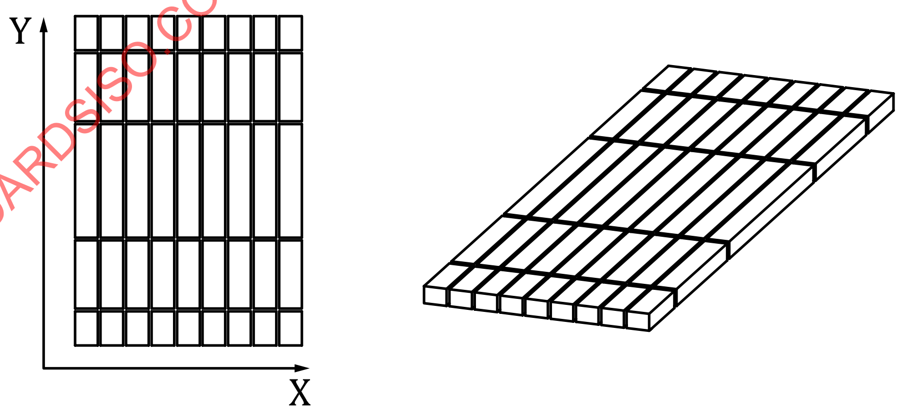


Figure 8 — Example of a dual-array probe

3.2.1.12
2-D-array
matrix array
array (3.2.1.1) of *elements* (3.2.1.2) arranged in a rectangular pattern allowing steering in both directions (*primary axis* (3.2.1.18) and *secondary axis* (3.2.1.19)) and focusing in the depth direction

Note 1 to entry: See Figure 9 and Figure 10.

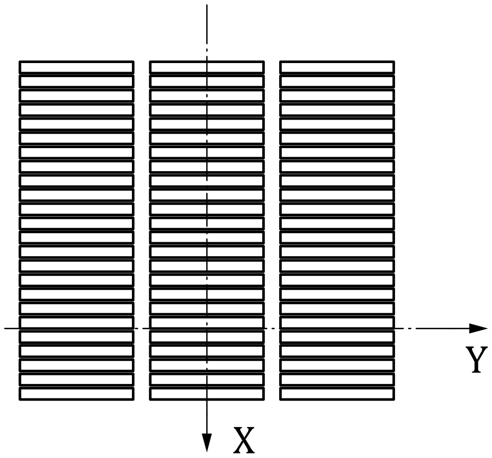


Key

X primary axis

Y secondary axis

Figure 9 — Example of a 2-D-matrix array



Key

X primary axis

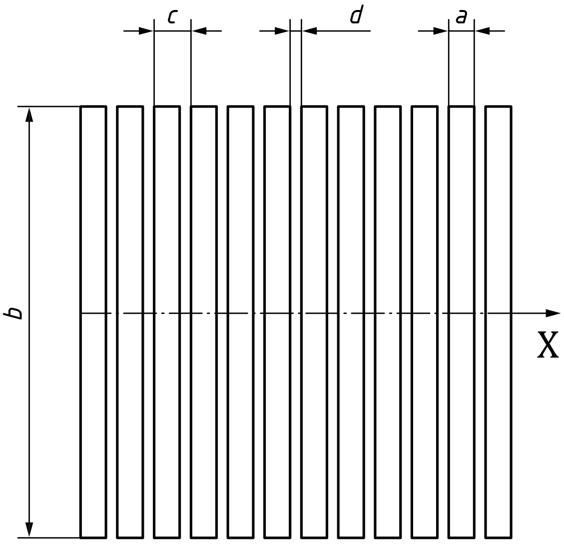
Y secondary axis

Figure 10 — Axes of a 2-D-matrix array

3.2.1.13
sparse array
array (3.2.1.1) with a limited number of *elements* (3.2.1.2) distributed over a relatively large area, with irregular distances between the elements, for example according to a Poisson-disk distribution

3.2.1.14
width of an element
dimension of the *element* (3.2.1.2) along the *primary axis of an array* (3.2.1.18)

Note 1 to entry: For *linear arrays* (3.2.1.5) see Figure 11.



Key

a width of an element
b *length of an element* (3.2.1.15)
c *pitch* (3.2.1.16)
d *space/gap between elements* (3.2.1.17)
X primary axis

Figure 11 — Linear array

3.2.1.15
length of an element
dimension of the *element* (3.2.1.2) along the *secondary axis of an array* (3.2.1.19)

Note 1 to entry: For *linear arrays* (3.2.1.5) see Figure 11.

3.2.1.16
pitch
distance between the same edges or between centres of two adjacent *elements* (3.2.1.2)

Note 1 to entry: For *linear arrays* (3.2.1.5) see Figure 11.

3.2.1.17
space between elements
gap between elements
distance between two adjacent *elements* (3.2.1.2)

Note 1 to entry: For *linear arrays* (3.2.1.5) see Figure 11.

3.2.1.18
primary axis of an array
primary axis
active direction
main axis for beam steering parallel to the *width of the elements* (3.2.1.14)

Note 1 to entry: See Figure 10 and Figure 11.

3.2.1.19
secondary axis of an array
secondary axis
passive direction
axis perpendicular to the *primary axis* (3.2.1.18)

Note 1 to entry: See Figure 10.

Note 2 to entry: Typically the term "passive direction" is only used for *1-D linear arrays* (3.2.1.5) and *1-D curved arrays* (3.2.1.8).

3.2.1.20
reference point on the wedge
coordinates of the point on the wedge which is used to position a defined point of the *array* (3.2.1.1)

Note 1 to entry: Typically the distances from the reference point to the wedge contact surface and to the front of the wedge are used.

3.2.1.21
active aperture
group of active *elements* (3.2.1.2) operated together when transmitting and/or receiving

3.2.1.22
elementary aperture
active aperture (3.2.1.21) made of only one *element* (3.2.1.2)

3.2.1.23
virtual probe
active aperture (3.2.1.21) operated with one *delay law* (3.2.2.12)

3.2.1.24
virtual source aperture
VSA
group of active *elements* (3.2.1.2) operated together during transmission using a *delay law* (3.2.2.12) chosen to mimic a source at a virtual point

3.2.1.25
sensitivity curve of an array
representation of the sensitivity of each *element* (3.2.1.2) successively connected to the same *channel* (3.2.2.1)

Note 1 to entry: Typically a flat reflector much larger than the aperture of the *array* (3.2.1.1) is used.

3.2.1.26
natural refracted beam angle
angle between the refracted beam axis and the normal to the interface without *electronic beam steering* (3.3.1.13)

Note 1 to entry: See Figure 1.

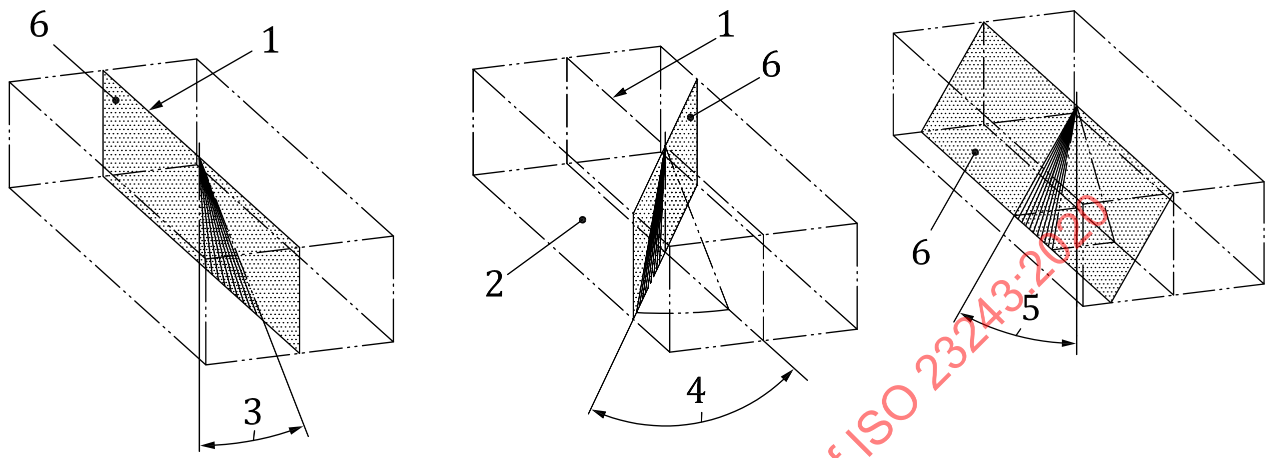
Note 2 to entry: The natural refracted beam angle corresponds to the nominal probe angle (see ISO 5577) of a conventional probe.

3.2.1.27
natural refracted beam
beam in the direction of the *natural refracted beam angle* (3.2.1.26)

[SOURCE: ISO 18563-3:2015, 3.6]

3.2.1.28
plane of natural refraction
deflection plane (3.2.1.29) without *skewing* (3.2.1.32) and without *tilting* (3.2.1.35)

Note 1 to entry: See Figure 12 a) and b).



a) Steering angle b) Skew angle c) Tilt angle

Key

1 *plane of natural refraction* (3.2.1.28)
2 test object
3 *steering angle* (3.2.1.30)
4 *skew angle* (3.2.1.33)
5 *tilt angle* (3.2.1.36)
6 *deflection plane* (3.2.1.29)

Figure 12 — Definitions of angles

3.2.1.29
deflection plane
plane in which *electronic scanning* (3.3.1.20) is performed

Note 1 to entry: See Figure 12.

3.2.1.30
steering angle
angle between the beam axis and the projection of the normal to the test surface on the *deflection plane* (3.2.1.29)

Note 1 to entry: See Figure 12 a).

3.2.1.31
steering range
range of *steering angles* (3.2.1.30)

3.2.1.32
skewing
rotating the *deflection plane* (3.2.1.29) by a certain angle around the normal to the surface of the test object

3.2.1.33
skew angle
angle on the test surface between the *deflection plane* (3.2.1.29) and the *plane of natural refraction* (3.2.1.28)

Note 1 to entry: See Figure 12 b).

Note 2 to entry: If the *plane of natural refraction* (3.2.1.28) at the test surface corresponds to the probe axis, then the *skew angle* (3.2.1.33) corresponds to the squint angle as defined in ISO 5577 (the angle between the probe axis and the projection of the beam axis on the test surface).

3.2.1.34
skewing range
range of *skew angles* (3.2.1.33)

3.2.1.35
tilting
rotation of the *deflection plane* (3.2.1.29) around its trace on the test surface

3.2.1.36
tilt angle
angle between the *deflection plane* (3.2.1.29) and the normal to the test surface

Note 1 to entry: See Figure 12 c).

3.2.1.37
tilting range
range of *tilt angles* (3.2.1.36)

3.2.1.38
dead element
element (3.2.1.2) which is no longer able to be active

3.2.2 Instruments

3.2.2.1
channel
electronic device of the test instrument for transmitting (transmitting channel) and/or receiving a signal (receiving channel)

3.2.2.2
multi-channel instrument
test instrument with more than one *channel* (3.2.2.1)

3.2.2.3
phased array instrument
multi-channel instrument (3.2.2.2) capable to apply *delay laws* (3.2.2.12) for the operation of *array probes* (3.2.1.3)

3.2.2.4
FMC instrument
multi-channel instrument (3.2.2.2) capable to collect *full-matrix capture (FMC)* (3.3.1.28) data

3.2.2.5
TFM instrument
multi-channel instrument (3.2.2.2) capable to perform processing according to the *total focusing technique (TFM)* (3.3.1.35)

3.2.2.6
voltage apodisation
applying different voltages to the different transmitting *elements* (3.2.1.2) of an *array* (3.2.1.1) to form a specific shape of the transmitted beam

3.2.2.7
gain apodisation
applying different gain values to the different receiving *elements* (3.2.1.2) of an *array* (3.2.1.1) before summing to match the receiving characteristics

3.2.2.8
voltage apodisation law
set of settings used to control *voltage apodisation* (3.2.2.6)

3.2.2.9
gain apodisation law
set of settings used to control *gain apodisation* (3.2.2.7)

3.2.2.10
transmitting delay
electronic delay applied to the activation of the *elements* (3.2.1.2) of an *array* (3.2.1.1) during transmission

3.2.2.11
receiving delay
electronic delay applied to the received signals from the *elements* (3.2.1.2) of an *array* (3.2.1.1) during reception

3.2.2.12
delay law
set of settings used to control the set of delays for transmission and/or reception to shape the beam

Note 1 to entry: Examples are steering delay law, *skewing* (3.2.1.32) delay law, focusing delay law.

3.2.2.13
amplitude balancing
compensation for the differences in the sensitivity of the *elements* (3.2.1.2) and/or *channels* (3.2.2.1)

3.2.2.14
sensitivity curve
representation of the sensitivity of each *element* (3.2.1.2) connected to its *channel* (3.2.2.1) prior to *amplitude balancing* (3.2.2.13)

3.2.2.15
combined equipment
connected set including the instrument, the probe and connecting cables including adapters

[SOURCE: ISO 18563-3:2015, 3.1]

3.3 Terms related to testing

3.3.1 Testing techniques

3.3.1.1
array technique
ultrasonic testing technique using a *multi-channel instrument* (3.2.2.2) and an *array probe* (3.2.1.3) able to control individual *elements* (3.2.1.2) for transmission and/or reception

3.3.1.2
phased array technique
ultrasonic testing technique using a *phased array instrument* (3.2.2.3) and an *array probe* (3.2.1.3) able to provide *electronic beam steering* (3.3.1.13) and/or *electronic beam shaping* (3.3.1.12) for transmission and/or reception

3.3.1.3
phased array setup
probe arrangement defined by probe characteristics (e.g. frequency, probe *element* (3.2.1.2) size, beam angle, wave mode), *probe position* (3.3.1.4), and the number of probes

[SOURCE: ISO 13588:2019, 3.3]

3.3.1.4
probe position
PP
distance between the front of the wedge and the reference point on the test object

[SOURCE: ISO 13588:2019, 3.4, modified — the words "weld centre line" have been replaced by "reference point on the test object".]

3.3.1.5
scan increment
distance between successive data collection points in the direction of scanning (mechanically or electronically)

[SOURCE: ISO 13588:2019, 3.5]

3.3.1.6
skewed scan
scan performed with a skew angle (3.2.1.33)

Note 1 to entry: The skew angle can be achieved electronically or by means of probe orientation.

[SOURCE: ISO 13588:2019, 3.6, modified — "skewed angle" has been replaced by "skew angle".]

3.3.1.7
mode of operation
specification of *shots* (3.3.1.8) and *active apertures* (3.2.1.21) for each position of the probe

[SOURCE: ISO 18563-3:2015, 3.5, modified — the link to ISO 18563-3: 2015, Clause 6 has been deleted.]

3.3.1.8
shot
combination of single excitation of transmitting *element(s)* (3.2.1.2) and acquisition of the *elementary signal(s)* (3.3.2.1) of receiving element(s)

3.3.1.9
group of shots
multiple *shots* (3.3.1.8) carried out with the *array* (3.2.1.1) in one position dedicated to one type of *electronic scanning* (3.3.1.20)

3.3.1.10
single-aperture technique
ultrasonic testing technique using the same aperture of the *array* (3.2.1.1) for transmitting and receiving for all *shots* (3.3.1.8)

3.3.1.11
multi-aperture technique
ultrasonic testing technique using different apertures of the *array* (3.2.1.1) for transmitting and receiving for all *shots* (3.3.1.8)

3.3.1.12
electronic beam shaping
electronic beam forming
technique used to control the shape of an ultrasonic beam of an *array* (3.2.1.1), e.g. by *delay laws* (3.2.2.12), by the number of *elements* (3.2.1.2) or by *apodisation* (3.2.2.6), (3.2.2.7)

3.3.1.13
electronic beam steering
technique used to control the direction of an ultrasonic beam of an *array* (3.2.1.1)

Note 1 to entry: The beam steering capability is related to the properties of the array, the properties of the wedge or delay path, and can be limited due to the generation of *grating lobes* (3.1.3).

3.3.1.14
electronic beam focusing
technique used to focus an ultrasonic beam at one or several focal points

3.3.1.15
static electronic focusing
electronic focusing at one focal point

3.3.1.16
dynamic electronic focusing
dynamic depth focusing
electronic focusing used in the receiving mode to move the focal point along the beam axis, typically in real time

3.3.1.17
total electronic focusing
electronic focusing which consists of adapting the *receiving delay laws* (3.2.2.11, 3.2.2.12) to focus at many points which form a *grid* (3.3.2.5), after transmission of a single wide ultrasonic beam

3.3.1.18
adaptive focusing
focusing based on calculation of delays using the signals from reference *shot(s)* (3.3.1.8)

Note 1 to entry: This definition applies to both phased array technology (*electronic beam forming* (3.3.1.12), *summed A-scan presentation* (3.3.2.2)) and to processing technology, e.g. adaptive *TFM* (3.3.1.35).

Note 2 to entry: A typical example of the use of adaptive focusing is the identification of the geometry of refracting, and/or reflecting interface(s) that allow the processing through such interface(s).

3.3.1.19
dynamic receiving aperture
electronic control of the dimension of the receiving *active aperture* (3.2.1.21) of a single *shot* (3.3.1.8), typically in real time

3.3.1.20
electronic scanning
technique used to sequentially move and/or change ultrasonic beams without moving the *array probe* (3.2.1.3)

3.3.1.21
electronic increment
step between two consecutive ultrasonic beams and/or focal points during *electronic scanning* (3.3.1.20)

3.3.1.22
electronic linear scanning
electronic scanning (3.3.1.20) used to control a sequence of ultrasonic beams by moving the *active apertures* (3.2.1.21) of an *array* (3.2.1.1) along a line

3.3.1.23
electronic sectorial scanning
electronic scanning (3.3.1.20) used to control a sequence of ultrasonic beams by electronically changing the beam angles within a defined sector using the same *active aperture* (3.2.1.21)

3.3.1.24
combined electronic scanning
combination of *electronic linear scanning* (3.3.1.22) and *electronic sectorial scanning* (3.3.1.23) by moving the *active aperture* (3.2.1.21) along the *array* (3.2.1.1) and simultaneously changing the beam angles within a defined sector

3.3.1.25
phased array mode
combination of ultrasonic beams created by phased array technology, e.g. fixed angle, *electronic linear scanning* (3.3.1.22), *electronic sectorial scanning* (3.3.1.23)

[SOURCE: ISO 13588:2019, 3.7, modified — the term "mode" has been deleted; "E-scan" and "S-scan" have replaced by "electronic linear scanning" and "electronic sectorial scanning" respectively.]

3.3.1.26
sampling phased array technique
SPA
data acquisition and data processing, where a single *element* (3.2.1.2) or consecutive elements in an *array* (3.2.1.1) are used as transmitters, while a selected number of elements are used as receivers for each transmitted pulse, where acquired data are processed phase-sensitive by the synthetic aperture focusing technique (SAFT) or the *total focusing technique (TFM)* (3.3.1.35)

3.3.1.27
full matrix
matrix data set consisting of $m \times n$ cells corresponding to all possible combinations of m transmitted signals and n received signals with each matrix cell containing an A-scan data set

3.3.1.28
full-matrix capture
FMC
data acquisition process where each *element* (3.2.1.2) in an *array* (3.2.1.1) is successively used as transmitter, while all elements are used as receivers for each transmitted pulse

Note 1 to entry: For m transmitters and n receivers a matrix of $m \times n$ A-scan signals is created.

3.3.1.29
half-matrix capture
HMC
data acquisition process where all *elements* (3.2.1.2) in an *array* (3.2.1.1) are successively used as transmitters, while only elements not used for transmission in previous transmissions, or only elements used in previous transmissions including the current one, are used as receivers for each transmitted pulse

Note 1 to entry: Half-matrix capture makes use of the reciprocity of signals to limit the amount of collected data.

Note 2 to entry: For an array with n elements half-matrix capture leads to $n\,(n + 1)/2$ A-scan signals.

3.3.1.30
sparse-matrix capture
SMC
data acquisition process where some of the *elements* (3.2.1.2) in an *array* (3.2.1.1) are successively used as transmitters, while some elements are used as receivers but different for each transmitted pulse

3.3.1.31
wide-beam transmitting
technique consisting of transmitting simultaneously with all *elements* (3.2.1.2) of the *array* (3.2.1.1) without electronic focusing, and then receiving signals from the individual elements

3.3.1.32
multiple reconstruction using the received signals
technique used to mimic multiple ultrasonic beams by combining each *elementary signal* (3.3.2.1) several times to get several reconstructions or summations

3.3.1.33
paintbrush technique
technique which combines *wide-beam transmitting* (3.3.1.31) and *multiple reconstruction using the received signals* (3.3.1.32)

3.3.1.34
reverse phasing technique
time-reversal mirror
TRM
technique used to control an ultrasonic beam by transmitting twice: firstly with a wide beam to get the time-of-flight values of echoes reflected by the front interface; and secondly with a *delay law* (3.2.2.12) calculated from these time-of-flight values of the first *shot* (3.3.1.8)

3.3.1.35
total focusing technique
TFM
synthetic focusing which consists of a reconstruction, inside an *ROI* (3.3.2.4), to focus at many points which form a *grid* (3.3.2.5), by processing part or all A-scan information of the applicable transmitter-receiver combinations, taking into account the *imaging path* (3.3.1.38)

Note 1 to entry: TFM is typically performed on *full-matrix capture (FMC)* (3.3.1.28) data.

Note 2 to entry: Typically not all transmitter-receiver combinations contribute to each point of the *grid* (3.3.2.5).

Note 3 to entry: This technique is often indicated as TFM (total focusing method), however in ISO the term 'method' in NDT is reserved for applying a physical principle (see ISO 9712).

3.3.1.36
inverse wave field extrapolation technique
IWEX
data acquisition and data processing according to the principle of inverse wave field extrapolation which takes into account the weighted amplitude and the delay time of the signal in order to create a 2D or 3D spatial image of the test object

Note 1 to entry: IWEX is typically performed on *full-matrix capture (FMC)* (3.3.1.28) data.

3.3.1.37
plane wave imaging
PWI
technique consisting of sequential transmission of plane waves in several directions in the inspection medium, recording of the reflected or diffracted waves for each transmission with all the *elements* (3.2.1.2) of the *array(s)* (3.2.1.1), and post-processing of the received signals with a delay-and-sum algorithm to focus on every point within a *region of interest (ROI)* (3.3.2.4)

Note 1 to entry: For q transmitted plane waves and n receivers a matrix of $q \times n$ A-scan signals is created.

3.3.1.38
imaging path
path that ultrasonic waves travel from transmitter to image point and from image point to receiver which is taken into account by the imaging algorithm including refraction(s), reflection(s) and/or mode conversion(s), if applicable

3.3.2 Signals, presentations and indications

3.3.2.1
elementary A-scan presentation
elementary signal
A-scan presentation of the ultrasonic signal received by one *element* (3.2.1.2) for one *shot* (3.3.1.8)

3.3.2.2
summed A-scan presentation
A-scan presentation of the sum of *elementary signals* (3.3.2.1) received by a *virtual probe* (3.2.1.23) for one *shot* (3.3.1.8)

3.3.2.3
sum of signals
summed A-scan
result of the operation of summing the *elementary signals* (3.3.2.1) after applying a *delay law* (3.2.2.12)

3.3.2.4
region of interest
ROI
two- or three-dimensional region, related to the test volume, for which the image is computed

Note 1 to entry: The ROI can have an arbitrary shape and may extend beyond the test volume.

3.3.2.5
grid
collection of points in the *ROI* (3.3.2.4) for which the image is calculated and stored, defined by the position and relative distance between the points in a specified direction

Note 1 to entry: The grid may extend beyond the test volume.

Note 2 to entry: The grid is not necessarily rectangular and not necessarily uniform.

Note 3 to entry: The grid can be two or three dimensional.

Note 4 to entry: The format of the grid is not necessarily the format used to display the results.

3.3.2.6
L-scan presentation
2-D display in the *deflection plane* (3.2.1.29) of the results of *electronic linear scanning* (3.3.1.22) which consists of the *summed A-scans* (3.3.2.3) of the beams of the different *active apertures* (3.2.1.21) and the colour scale representing the amplitude of the signals

Note 1 to entry: See Figure 13.