INTERNATIONAL STANDARD

ISO 20339

First edition
2017-03

Non-destructive testing — Equipment for eddy current examination — Array probe characteristics and verification

Essais non destructifs — Appareillage pour examen par courants de Foucault — Caractéristiques des capteurs multiéléments et vérifications

Reference number
ISO 20339:2017(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 4, *Eddy current testing.*

Non-destructive testing — Equipment for eddy current examination — Array probe characteristics and verification

1 Scope

This document identifies the functional characteristics of eddy current array probes and their interconnecting elements and provides methods for their measurement and verification.

The evaluation of these characteristics permits a well-defined description and comparability of eddy current array probes.

Where relevant, this document gives recommendations for acceptance criteria for the characteristics.

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.

ISO 12718, *Non-destructive testing — Eddy current testing — Vocabulary*

ISO 15548-1, *Non-destructive testing — Equipment for eddy current examination — Part 1: Instrument characteristics and verification*

ISO 15548-2:2013, *Non-destructive testing — Equipment for eddy current examination — Part 2: Probe characteristics and verification*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12718 and the following apply.

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

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

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

3.1
element
single physical component such as a coil, a GMR or a Hall probe which has a basic function of excitation or reception

3.2
pattern
single physical and electronic arrangement of simultaneously active elements

3.3
sequencing
chronology of the activation of patterns

3.4
threshold
lowest acceptable sensitivity value defined in an application document

4 Probe and interconnecting elements characteristics

4.1 General characteristics

4.1.1 Application

Probes and interconnecting elements are selected to satisfy the requirements of the intended application.

The design is influenced by the instrument with which they are used.

4.1.2 Probe types

The probe is described by the following:

— type of material to be examined, i.e. ferromagnetic, non-ferromagnetic with high or low conductivity;

— the geometry of the examined zone;

— whether it is conformable or not;

— family, e.g. coaxial probe, surface probe;

— the receiver type;

— the number of elements (transmitters and/or receivers);

— shape and assembly of elements and spacing;

— purpose of the examination, e.g. detection of discontinuities, sorting or thickness measurement, etc.;

— specific features, e.g. focused, shielded, etc.;

— the function of the elements (transmission or reception) as well as the type of measurement (absolute or differential) may coexist in the same array probe depending on the patterns, the sequencing and the instrument software.

4.1.3 Interconnecting elements

They may include the following:

— active devices, e.g. multiplexer (built-in or external), amplifier;

— cables and/or extensions;

— connectors;

— slip rings;

— rotating heads;

— polarizers.

4.1.4 Physical characteristics

The following are to be stated among others:

— external size and shape;

— weight;

— information for mechanical mounting;

- model number and serial number;
- material of probe housing;
- composition and thickness of facing material;
- presence and purpose of core or shield;
- type of interconnecting elements (see 4.1.3);
- at least one position mark (electrical centre; see 8.5).

4.1.5 Safety

The probe and its interconnecting elements shall meet the applicable safety regulations regarding electrical hazard, surface temperature, or explosion.

Normal use of the probe should not create a hazard.

4.1.6 Environmental conditions

The temperature and humidity for normal use, storage and transport should be specified for the probe and its interconnecting elements.

The tolerance of the probe and its interconnecting elements to the effects of interference noise and electromagnetic radiation shall conform to electromagnetic compatibility (EMC) regulations.

Materials used in the manufacture of the probe should be resistant to contaminants.

4.2 Electrical characteristics

The electrical characteristics of a probe connected to a specified length and type of cable are the following:

- recommended range of excitation voltage for safe operation;
- recommended range of excitation frequencies.

The electrical characteristics of any extension cable are the following:

- resistance and capacitive reactance per length unit.

4.3 Functional characteristics

The functional characteristics of an array probe shall be determined for a defined system.

The measurement of the functional characteristics of a probe requires the use of reference blocks. The material used for the reference block is determined by the application.

The functional characteristics of a probe are the following:

- angular sensitivity;
- response to elementary discontinuities or variations (hole, slot, deposit, etc.);
- length and width of coverage for a given pattern;
- area of coverage for a given pattern;
- minimum dimensions of discontinuities for constant response;
- penetration characteristics;

— geometric effects;

— cross-talk;

— number of dead elements.

These characteristics cannot be used alone to establish the performance (e.g. resolution, largest undetectable discontinuity, etc.) of the probe in a given test system for a given application.

When relevant, the functional characteristics shall be measured on the probe with the interconnecting elements required by the application.

5 Verification

5.1 Level of verifications

Two levels of verification may be required:

a) basic level: addresses detection performance;

b) advanced level: addresses characterization performance:

  — verification of a motion system where there is a need for mechanization of some measurements (movement of the probe);

  — digitization and scanning speed: number of measurement points per millimetre.

The qualification of a process which may imply an agreement between manufacturer and customer is not considered in this document.

5.2 Characteristics to be verified

The characteristics to be verified are listed in Table 1.

Table 1 — Array probe characteristics

Characteristic	Basic level	Advanced level
Outer dimensions	I	M
Conformability of the probe	I	M
Area of coverage	I	M
Number of elements	I	M
Arrangement	M	M
Excitation frequencies	M	M
Nature of elements	I	I
Element dimensions	I	I
Distances between elements	I	I
Assembly	I	I
External or built-in multiplexer	I	I
Length and type of supplied cable	I	I
I: measured by the manufacturer or design data, reported on the technical specification.		
M: measured by the manufacturer and/or the user.		
The manufacturer should add what type and orientation of discontinuity the probe is designed for.		
Where more information on the elements is needed by the user (e.g. for simulation), then it may be part of a specific agreement.		

6 Measurement of electrical and functional characteristics of an array probe

6.1 Electrical characteristics

6.1.1 General

The electrical characteristics alone do not define the probe characteristics in its application.

The methods and measuring instruments given below are for guidance; other equivalent methods and instrumentation can be used. When characteristics are measured using modelling, this shall be clearly stated.

6.1.2 Measurement conditions

Array probes (surface probes and coaxial probes) are in most cases specific to one application.

They are delivered with a cable, the design of which depends on the number of elements and which cannot be removed for measurements. The characteristics of the cable are generally proprietary information.

The manufacturer provides a cable, the length of which is compatible in terms of resonance and attenuation with the future use of the probe as described by the customer.

The following measurements are only applicable to elements consisting of coils.

In the case where receiving elements are not coils, specific measurements shall be defined.

The measurements are made at the probe connector which is at one end of the connecting cable, without the use of interconnecting elements of the inspection system. The probe is placed in air and away from any conductive or magnetic material. These measurements are only possible if no electronic components (such as amplifiers, multiplexers, etc.) are active in the probe.

The measurements are made for each element of the probe accessible at the probe connector. The other elements are left open circuit.

When the probe is designed for use under particular conditions, e.g. temperature or pressure, then any additional measurements that are required shall be specified in the application document.

6.1.3 Impedance of coil elements

The impedance of all coil elements shall be measured using an impedance meter or impedance analyser as long as the measurement is not prevented by built-in amplifiers. The measured impedance can be given as the values of an equivalent circuit (resistance, inductance and capacitance) or as curve vs. frequency (Bode plot or Nyquist plot).

6.1.4 Impedance of a pattern

This measurement is not normally performed by the user as it is not possible once the probe is assembled. It is the manufacturer's responsibility.

— **Impedance mode**

  Measure the complex impedance at the central frequency

— **Separate transmit receive**

  Feed a voltage with the central frequency at the input of the transmitting element and measure the voltage at the output

Repeat the measurements on each pattern.

Verify the homogeneity of the results.

In case of significant deviation (greater than 5 %), apply the adequate corrections (connections, etc.).

6.1.5 Channel assignment — Sequencing

Verification of channel assignment is essential. The following operating procedure is for guidance.

Measurements are carried out at the central frequency.

Produce a C-scan type cartography of a defect at angle with the direction of scanning: a slot at 45° (Block A1) for a surface probe, a helix on a tube wall (Block B2) for coaxial probes.

The value of the angle shall be chosen in accordance with the scanning step and the dimensions of a pattern.

Verify the channel assignment and the uniformity of the signals obtained on those channels.

In the case of complex configurations, the verification procedure is left to the manufacturer's initiative.

The case of static probes in which scanning is performed electronically is not covered by this measurement; a case-by-case procedure shall be produced.

6.1.6 Cross-talk

Cross-talk always exists in array probes. It is actually attenuated by multiplexing non-neighbouring elements in order to achieve an acceptable signal to noise ratio.

The level of acceptable cross-talk is very much dependent on the application; therefore, acceptance criteria cannot be given in this document.

6.2 Functional characteristics

6.2.1 General

This document characterizes commonly used array probe types. Probes which are designed for special (unusual) applications shall be characterized in accordance with an application document which follows the methodology of this document. The characteristics described in this document can give useful information about such probes.

The functional characteristics are defined for two classes of array probes: surface probes and coaxial probes.

6.2.2 Measurement conditions

6.2.2.1 General

A multi-channel eddy current instrument suitable for array probes and characterized in accordance with ISO 15548-1 can be used, provided that it has the required accuracy.

Alternatively, sufficient instrumentation comprising a voltage/current generator, synchronous detection amplifier and a voltmeter, oscilloscope or digitizer can be used.

When the probe does not feature a connecting cable, then the characteristics of the cable used for the measurements shall be documented.

The probe characteristics are measured within the frequency range specified by the probe manufacturer using reference blocks containing known features such as slots and holes.

The reference blocks shall be made from the material, metallurgical properties and surface finish specified in the application document. Its geometry shall comply with the requirements included in the following subclauses. Where necessary, blocks made with ferromagnetic material could be demagnetized before use.

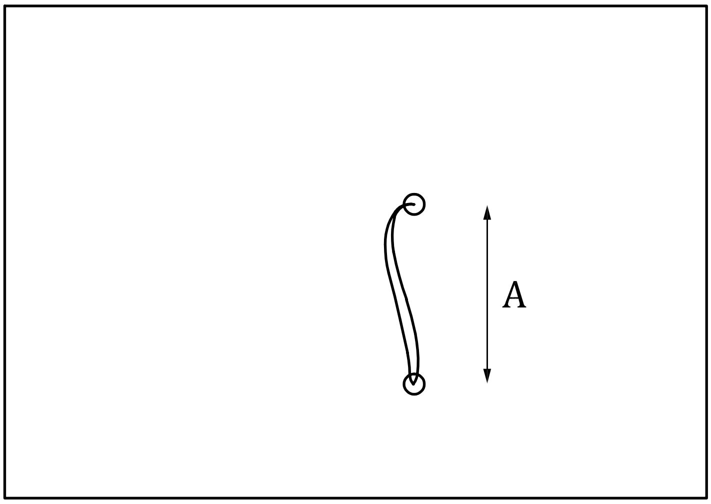
The reference block can be replaced by any other device, the equivalence of which shall be demonstrated for the measured characteristic (alternative blocks, electric circuit, coil, ball, etc.).

The functional characteristics can be affected by the presence of any perturbing electromagnetic field or ferromagnetic material in the zone of influence of the probe. Care shall be taken to avoid these effects when making the measurements described below.

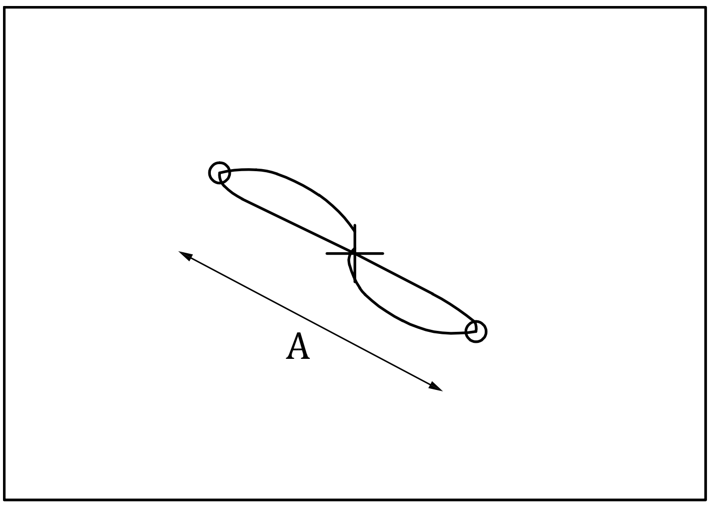
The measurement conditions for each characteristic shall be recorded, e.g. excitation frequency and voltage/current, details of the reference block, etc.

The measured values are the amplitude of the signal and, when applicable, the phase of the signal.

6.2.2.2 Measurement of the amplitude of the signal



a) Absolute signal



b) Differential signal

Figure 1 — Amplitude measurement

a) **Absolute measurements**

The amplitude of the signal is the length of the vector joining the balance point to the point corresponding to the maximum excursion of the signal from the balance point, unless otherwise specified in an application document (see Figure 1a).

b) **Differential measurements**

The amplitude of the signal is the length of the line joining the two extreme points of the signature, i.e. peak to peak value, unless otherwise specified in an application document (see Figure 1b).

c) **Other measurements**

The method shall be specified in an application document.

6.2.2.3 Measurement of the phase angle of a signal

The phase angle is the angle between the reference line and the line representing the signal amplitude determined in 6.2.2.2.

The reference line for the measurement of phase angle shall be specified.

The span and polarity of measurements shall be in accordance with ISO 15548-2:2013, 6.2.2.3.

7 Surface array probes

Unless otherwise specified, the measurements shall be conducted with constant probe clearance, which will be specified in the application document.

In case there are several different types of sequencing (impedance mode, separate transmit receive) patterns, the measurement shall be repeated for each of them.

7.1 Reference blocks

The design shall be optimized in order to avoid any end effect. For each of these reference blocks, the length and width shall be at least the length and width of the probe increased by at least twice the length of the zone of action of the probe as defined in the probe specifications. When this feature is not known, it shall be replaced by the largest (active) dimension of the probe in the scanning plane. A verification can be made after having measured the length of coverage as described in 7.5.

The thickness of the reference block shall be at least three times the standard depth of penetration for the lowest frequency nominated in the probe specification.

The material used to manufacture the block shall be sound and homogeneous. The physical properties (electrical conductivity and magnetic permeability) shall be close to those of the application.

Each block shall have a reception sheet including dimensional measurements: roughness, parallelism of sides and metrology of reference defects.

Block A1

It contains a slot in its centre (see Figure 2).

As a minimum:

— the slot shall be longer than the “minimum slot length for constant probe response” determined according to the methodology described in 7.7;

— the slot shall be deeper than the “minimum depth of surface-breaking slot for constant probe response” determined according to the methodology described in 7.10;

— the slot width shall be defined in the application document.

In addition, the block features

— either a groove, the width of which is greater than the active part of the probe, filled with a non-conductive material, to perform phase normalization (simulation of a lift-off effect), or

— one or more shims of non-conductive material.

Block A2 (see Figure 2)

It contains the following:

— one hole, the diameter of which shall be smaller than the pitch of the elements in the probe;

— two holes, of the same diameter as the single hole; the distance between the two holes shall be optimized in relation to the size of the probe elements, the size of the pattern and the application.

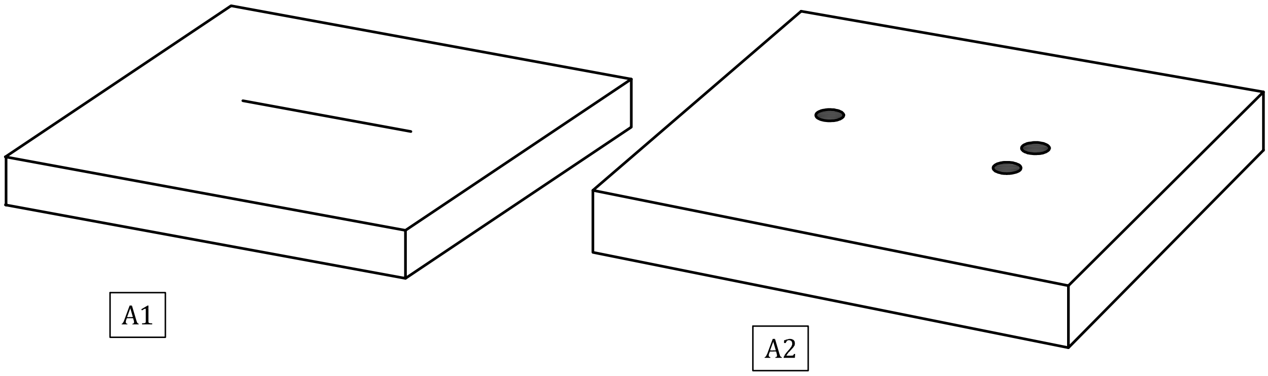


Figure 2 — Reference blocks for surface probes

7.2 Probe motion

Experimental verifications have shown that measurements on array probes are drastically dependent on scanning conditions. The scans shall be accurately reproducible.

For all the following measurements, pressure to ensure contact of the probe on the reference block surface and orientation of the probe shall be rigorously reproducible.

7.3 Reference signal — Normalization

Reference block: Block A1 shall be used for this measurement.

Balancing

Balance the probe on the block with the probe mid-way between the slot and the adjacent edge of the block.

Verify that no significant change occurs when moving the probe in the vicinity of this position, in the direction of the slot and that of the edge.

The scan and the slot shall be adapted to the pattern.

Probe motion

A linear scan is performed over the middle of the slot with the preferred orientation of the probe perpendicular to the slot (see Figure 3). For this measurement, the preferred orientation shall be the one defined by the manufacturer.

Adapt the scanning to the type of pattern (separate transmit receive or not, combined transmit receive in absolute measurement).

In the case where the probe is explicitly designed for scanning slots non-perpendicular to the probe motion (e.g. parallel), an alternative procedure shall be described in the application document.

Settings

1) The instrument shall be set so that the amplitude of the slot signal obtained is maximized without saturation. The amplitude of the background noise (static measurement) should then be 6dB less than the amplitude of the signal corresponding to the sensitivity threshold as per definition 3.4. The absence of any saturation signal shall be checked in all subsequent measurements.

2) Perform normalization in order to obtain the same amplitude and phase for the reference slot on all the channels; this amplitude shall range between 25 % and 80 % of the dynamic range of the instrument.

This setting shall be kept for all the measurements.

Results

The reference signal S_{ref} is the maximum value of the signal of all the channels during the scan. This value shall be recorded.

As an example, the phase of the signal obtained when scanning the filled groove (or the non-conductive over layers) may be taken as the origin of phases for subsequent measurements.

In the following subclauses, all results shall be expressed relatively to S_{ref}.

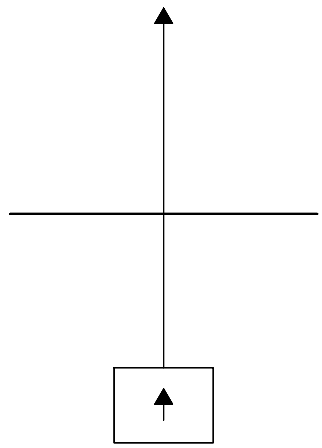


Figure 3 — Probe motion to obtain the reference signal

7.4 Edge effect (measurable in the case of simple geometry, e.g. metal sheets, disks)

Reference block: Block A1 shall be used for this measurement.

Probe motion

2 perpendicular directions.

With the probe mid-way between the slot and the adjacent edge of the block, the probe is moved from the former balance position on a scanning line to the closest edge of the reference block:

1) along its preferred orientation (perpendicular to the slot orientation);

2) perpendicular to its preferred orientation.

Results

1) Scanning in the preferred orientation: The edge effect is characterized by the distance from the probe marked extremity of the active part closest to the edge concerned by the measurement to the edge of the block at which the signal S is such that:

   $S / S_{ref} = A$, e.g. absolute value of $S - S_{ref} / S_{ref} = 0{,}5$

   (A is a value mentioned in the application document.)

2) Scanning perpendicular to the preferred orientation: Take into account the relative position of the transmitting element. The effect is stronger in one direction than in the opposite direction.

   $S / S_{ref} = A$

   (A is a value mentioned in the application document.)

7.5 Response to a slot

Reference block: Block A1 shall be used for this measurement.

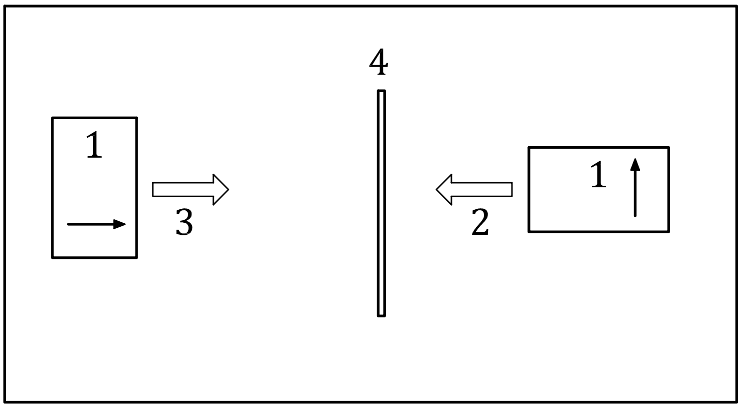
Probe motion

a) **Non-directional probes**

   Scan the block with the length of the array perpendicular or parallel to the slot (see Figure 4, scan A or T).

b) **Directional probes**

   Scan the block with the expected preferential orientation of the probe perpendicular to the slot (see Figure 4, scan T).



Key

1 eddy current array probe
2 scan A
3 scan T
4 reference slot

NOTE Arrow on probe indicates probe preferred orientation.

Figure 4 — Probe motion for the measurement of the response to a slot

Results

The maximum value S_{max}/S_{ref} of the signal over the whole scan is taken.

For each scanning path, the points corresponding to the signal which is 6dB less than S_{max}/S_{ref} shall be plotted to form a map of the probe response to the slot.

The scanning path shall be related to the mapping by the representation of the slot and the probe position mark for the first recorded point (e.g. bottom left).

A more complete representation can be achieved through the use of more level lines or any equivalent representation (3D mapping, coloured map, etc.).

7.6 Response to a hole

Reference block: Block A2 shall be used for this measurement.

Probe motion

Perform successive scans using only one pattern from one side of the single hole to the other. The step between scanning paths shall be equal to 1/5 of the pitch between patterns.

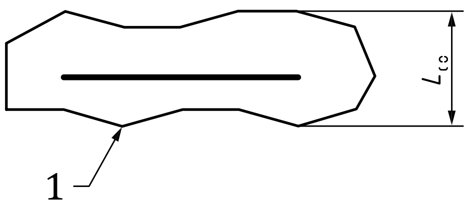
Results

For each scan, record the maximum signal amplitude and plot the corresponding curve (bell shape). Knowing the pitch between patterns, it is then easy to extrapolate the result and measure the amplitude decrease between two adjacent patterns.

7.7 Length of coverage

The length of coverage is derived from the map of the probe response to the slot, made in 7.5, by taking the maximum width of the envelope in the scanning direction (see Figure 5).

In case there are several different types of sequencing (impedance mode, separate transmit receive) patterns, the measurement shall be repeated for each of them.



Key

1 6 dB line

Figure 5 — Example of determination of the length of coverage (L_{cov})

7.8 Variation in sensitivity between patterns

Purpose of the measurement

This measurement enables an evaluation of sensitivity homogeneity from one pattern to another. It is the manufacturer's responsibility and results shall be provided to users.

Normalization shall always be first carried out as described in 7.3.

Reference block: Block A1 shall be used for this measurement.

Probe motion

A linear scan is performed over the surface of the reference block with the centre of the probe passing over the middle of the slot.

Results

In the impedance plane, observe the signal obtained on each channel.

a) **Rigid probes**

- The phase angle of the signals shall not vary by more than ±3°.
- The amplitude of the signals shall not vary by more than ±10 %.

b) **Conformable probes**

- The phase angle of the signals shall not vary by more than ±3°.
- The amplitude of the signals shall not vary by more than ±10 %.

When reproducibility cannot be ensured, this will affect the variation of the phase angle of signals; in such case:

— the phase angle of the signals shall not vary by more than ±5°.

When variations exceed the above values, the probe does not conform to this document.

7.9 Minimum slot length for constant probe response

This verification is limited to the pattern. See ISO 15548-2.

7.10 Lift-off effect

Reference block: Block A1 shall be used for this measurement.

Probe motion

The probe is located over the balance area of the block and is moved vertically in defined steps. Balance the probe when in contact with the reference block, i.e. z = 0. Lift-off may be obtained using non-conductive shims or an appropriate device delivering a measurable mechanical lift-off (probe on a scanner).

Results:

Plot $S(z)/S_{ref}$ for height z varying by defined steps.

The effect of lift-off is characterized by the curve $S(z)$ against z.

7.11 Effect of probe clearance on slot response

Reference block: Block A1 shall be used for this measurement.

Probe motion

A linear scan is performed over the middle of the slot: the orientation of the probe with respect to the slot depends on the type of channels generated by the pattern (transverse or axial).

The probe clearance varies from zero to a value representative of the exit from the zone of influence, specified in the application document.

The probe is balanced for each value of probe clearance on the balance area of the block.

Results

For each value of the probe clearance z, repeat the measurements described in 7.4.

The effect of probe clearance on a defect signal is characterized by plotting $S_{max}(z)/S_{ref}$ against z.

7.12 Effective depth of detection of a sub-surface slot

This verification is limited to the pattern. See ISO 15548-2.

7.13 Resolution

By definition, resolution is the shortest distance between two defects enabling the probe to deliver two distinct signals.

This functional characteristic depends on the application for which the probe is designed.

Reference block: Reference Block A2 shall be used.

Two measurements are proposed.

1) The first proposed measurement leads to an approximation of the resolution:
   - the orientation of the probe with respect to the hole modifies the signal generated by the pattern (axial or transverse). For this measurement, only the axial scan is relevant;
   - scan the reference defect using one pattern;
   - plot the response curve;
   - set the threshold at −6dB with respect to the maximum. Measure the width;
   - the measured width corresponds to a conservative value of the pattern resolution (see Annex A).
2) The second measurement is a verification of the resolution of the complete array:
   - scan holes 2 and 3 with an axial motion (array parallel to the holes);
   - a response curve comparable to the curve in Annex A (simulation 3) enables to verify that the probe resolution is at best the same as that of the pattern.

7.14 Defective element or pattern

Manufacturer: no defective element or pattern is acceptable.

User: the acceptance criteria shall be specified in the application document.

8 Coaxial array probes

8.1 General conditions

Unless otherwise specified:

- the measurements apply to inner or encircling coaxial probes with cylindrical geometry and circular section, and they shall be conducted with constant probe clearance, which will be specified in the application document;
- the results will concern the amplitude and the phase of the signal.

The case of coaxial probes with non-circular sections shall be examined on a case by case basis in the application document.

8.2 Reference blocks

Reference blocks (B1 to B3, C1 to C3) are described in general terms.

They consist of tubes or bars.

- The length L of the tube (bar) shall be greater than four times the end effect dimension of the probe as defined by the manufacturer. When this feature is not known, it shall be replaced by the active dimension of the probe in the scanning direction.
- The distance between artificial discontinuities shall be at least three times the active dimension of the probe.
- The thickness of the tube wall (or the diameter of the bar) is defined in the application document. The wall thickness (or the diameter) shall remain constant on the whole length of the tube (or the bar).

In the case of tubes, if this is industrially achievable, any influence from wall thickness variation is safely reduced if the thickness of the reference block is at least three times the standard depth of penetration for the lowest frequency nominated in the probe specification.

The detailed requirements of each block shall be given in a procedure.

The only probe motion considered for characterization is a translation parallel to the reference block axis.

Block B1 for tubes (C1 for bars)

3 EDM axial slots and 3 EDM transverse slots. The length of the slots is at least three times the pattern length. The depth of the slots is 20 %, 40 %, 60 %, respectively.

OD circumferential groove, 30 % deep and 5 mm wide (see Figure 6).

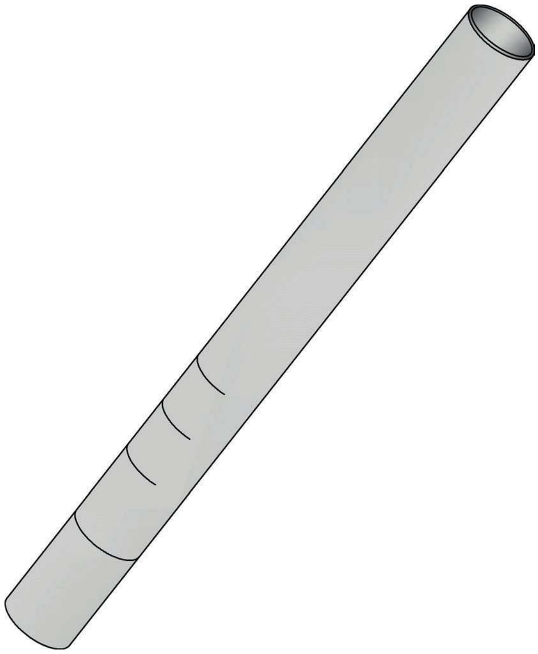


Figure 6 — Block B1

Block B2 (or C2)

A tube (or a bar) with a helical groove 30 % deep over 400°. The width is not critical (0,5 mm wide to 1 mm); see Figure 7.

Pitch of the helix: twice the required period of spatial sampling multiplied by the number of elements (example: where the sampling frequency is two points per millimetre, the period is 0,5; for a 32 element probe, the recommended pitch will therefore be 0,5 × 2 × 32 = 32 mm).

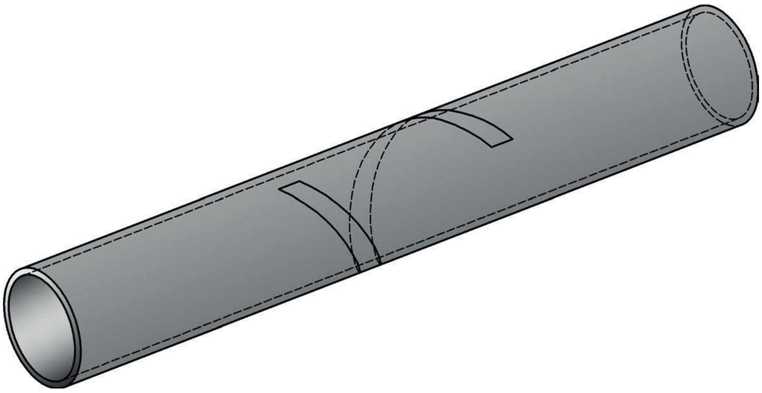


Figure 7 — Block B2

Block B3 (or C3)

A tube (or a bar) with four circumferential grooves, 0,2 mm wide. Their depth is 10 %, 30 %, 50 %, 70 %, respectively, see Figure 8.

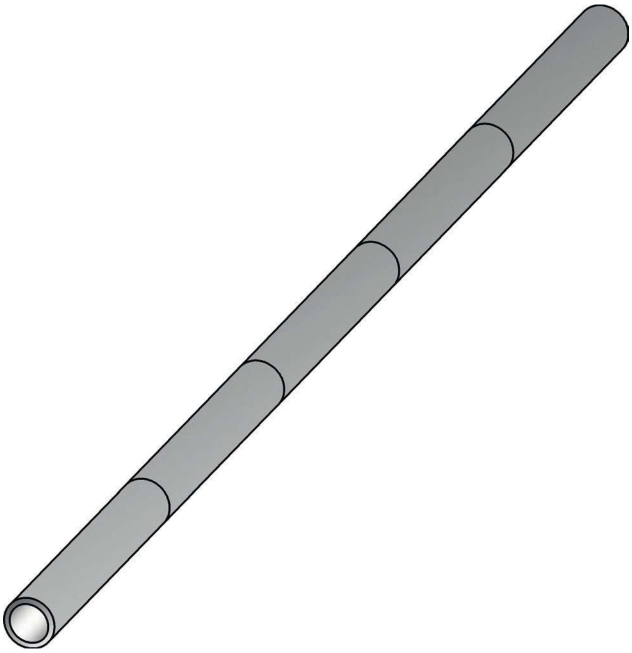


Figure 8 — Block B3

8.3 Reference signal

Reference block: B1 (or C1) shall be used for this measurement.

Measurements

Ensure the probe is centred.

Results

Balance the probe on a discontinuity-free portion of the tube (or the bar). Move the probe over the circumferential *groove*.

The instrument is adjusted so that the maximum signal corresponds to a given value of the instrument dynamic range (e.g. 25 %). It shall be verified that no signal saturation occurs in the subsequent measurements.

The reference signal S_{ref} is the maximum value of the signal during the scan.

The phase of the reference signal is taken as the origin of phases for subsequent measurements. If more convenient, another reference may be chosen, provided that it is reported.

In the following subclauses, all results shall be expressed relatively to S_{ref}.

8.4 Absence of defective elements

Reference block: Block B2 (or C2) shall be used for this measurement.

Measurement

Balance the probe on a defect-free portion of the tube (or the bar).

Scan the helical groove by pulling the probe out of the tube (or the bar).

The presence of defective elements shall be observed on the display.

Acceptance criterion

Manufacturer: no defective element is acceptable.

User: the acceptance criterion shall be specified in the application document.

8.5 Position mark of the probe (mainly for positioning)

The probe position mark placed on the probe body unambiguously defines the electrical centre of the probe according to the measurement method given below.

A position mark can be applied where the size and shape of the probe body or the probe response permits.

Where this is not possible, it shall be defined by means of a sketch, or the distance of the position mark from a fixed point of the probe can be recorded.

Reference block: Block B1 (or C1) shall be used for this measurement.

Measurement mode and results

— With the probe mechanically set on an adapted fixture, move Reference Block B1 (or C1) in order to scan the OD circumferential groove. Find and keep the position of the block corresponding to the maximum signal. Place a mark on the probe cable (or on the test bench) then record the length corresponding to the distance from the groove to the block end from which the scanning was initiated on the probe body.

— Engrave a mark on the probe body.

8.6 End effect

This verification is limited to the pattern. See ISO 15548-2.

8.7 Length of coverage

Block B1: reference defect: a circumferential groove.

Repeat the measurements described in 7.5.

On the curve obtained, mark the two extreme points at −6dB.

The distance between the two points is the length of coverage of the probe.

8.8 Homogeneity of axial response

Reference defect: a through-wall hole with an area less than 1/10th of the area of coverage of the pattern (reference block to be defined).

Results

Define an angular origin on the blocks.

Move the probe on the whole length of the block. Report the maximum amplitude S_{max}.

Rotate the block (or the probe) with an angle α in relation with the pitch between elements (e.g. 1/5th of the pitch).

Repeat the scanning in order to cover 360° (check that there is an overlap of examined zones).

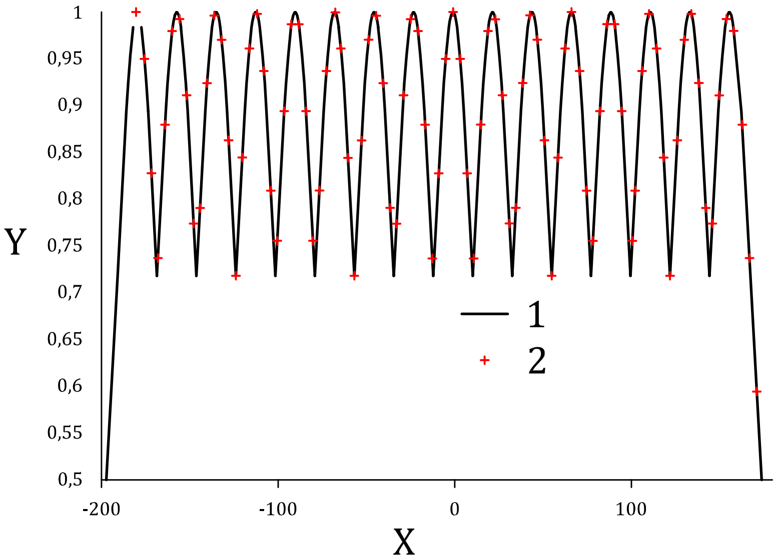
Plot $S_{max}(\alpha) / S_{ref}$ against α.

The curve obtained is known as the radar curve (see Figure 9).

Interpretation:

— the difference in amplitude between two maximum amplitude points corresponds to the homogeneity of axial response;

— the difference between vertical coordinates of the highest maximum and the lowest minimum amplitude (crossing point) corresponds to the variation in sensitivity.



Key

Y measured amplitude (a.u.)

X minimum distance between the hole and the probe (a.u.)

1 function

2 measure

Figure 9 — Theoretical curve

Alternative measurement mode

Scan the hole with an element centred on the defect. Report the maximum amplitude S_{max}.

Rotate the probe with an angle corresponding to half the distance between two elements.

Scan the defect. Report the amplitude S_{min}.

Rotate the probe with the same angle as previously in order to bring the adjacent element in front of the defect. When scanning the defect with this element, it is expected to obtain the value S_{max} obtained after the previous measurement.

Deviation from axial symmetry is defined as

$$[\mathrm{Max}(S_{max}) - \min(S_{max})]/\mathrm{Max}(S_{max}) \times 100 = d\ \%$$

8.9 Eccentricity effect

This verification is limited to the pattern. See ISO 15548-2.

8.10 Fill effect

This characteristic is not an essential functional feature of a probe as it is rather application related.

Moreover, this verification is limited to the pattern. See ISO 15548-2.

8.11 Effective depth of penetration

This verification is limited to the pattern. Block B3 (or C3).

Balance the probe on a defect-free portion of the block.

S_0 is the maximum signal obtained over the deepest defect.

$S(\mathrm{d})$ is the maximum signal over the groove of depth d.

$S(\mathrm{d})$ is plotted against d.

The effective depth of penetration P_{eff} is the smallest value of d for which:

$$[S_0 - S(\mathrm{d})] / S_0 \leq 10\ \%$$

8.12 Effective depth of detection under ligament

This characteristic shall be verified only for internal coaxial probes.

This verification is limited to the pattern. See ISO 15548-2.

9 Influence of interconnecting elements

Both electrical and functional characteristics can be affected by the addition of interconnecting elements.

This influence shall be evaluated by repeating the measurements described in 6.1 and 6.2.

Of specific importance are the following:

— amplitude response;

— phase response.

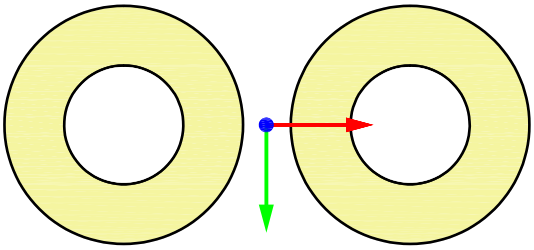
Annex A
(informative)

Simulation of surface probe resolution

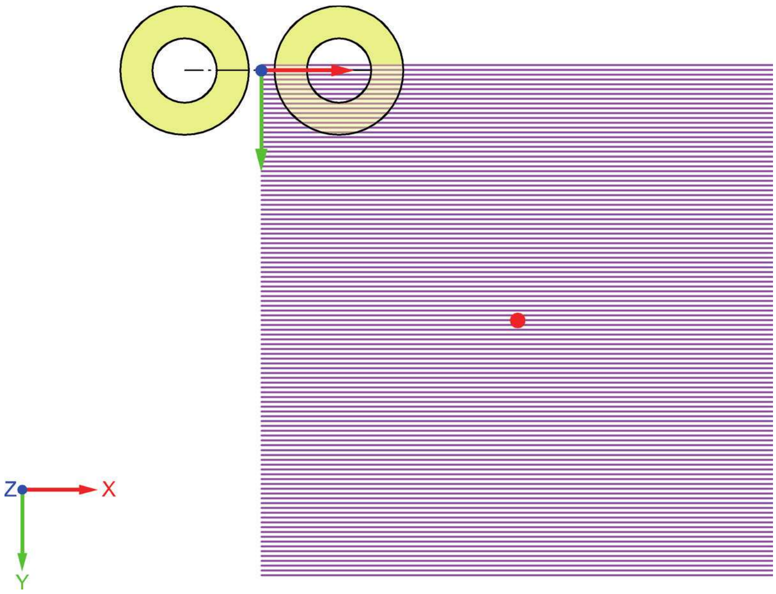
A.1 Simulation 1

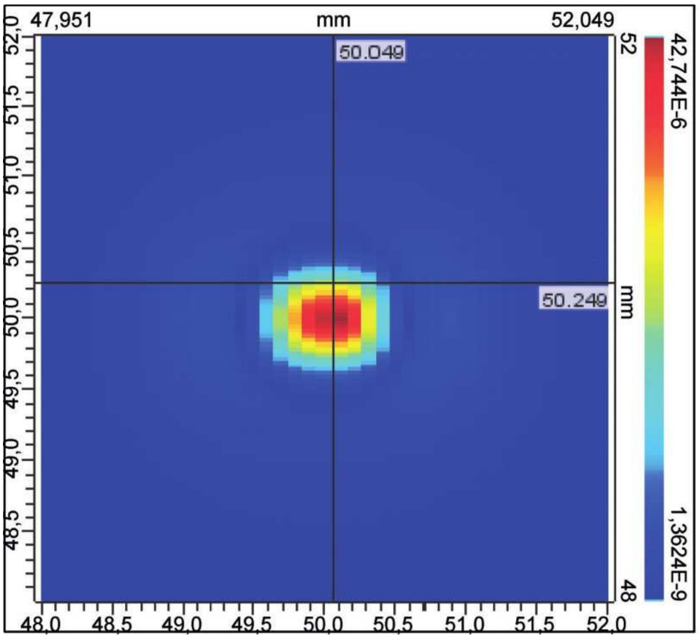
In the following simulation, the discontinuity is a hole, 0,1 mm diameter and 0,2 mm deep.

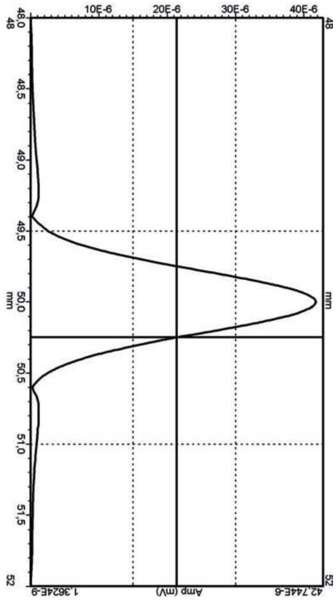
The pattern features two coils, 1 mm diameter. The distance between 2 coils is 1,2 mm. The size of the pattern is 1 mm × 2,2 mm. The pattern operates in separate transmit receive mode.



Axial scan of the hole:





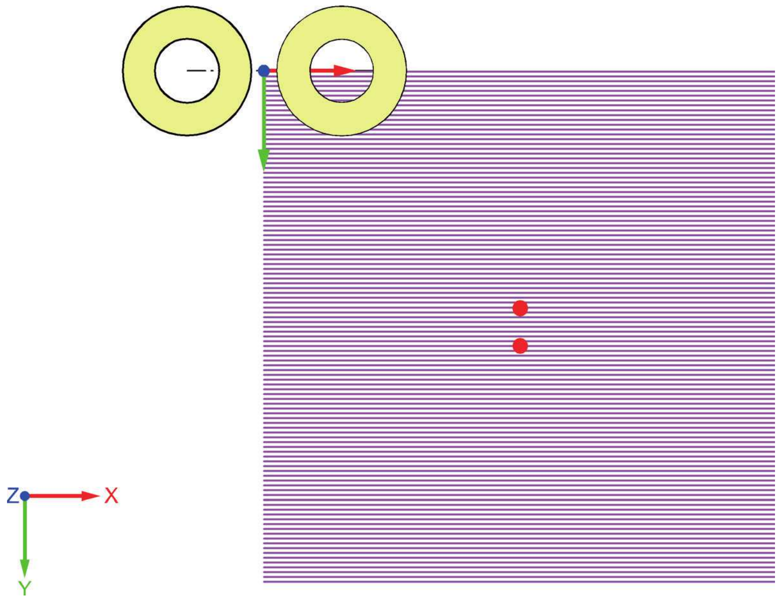


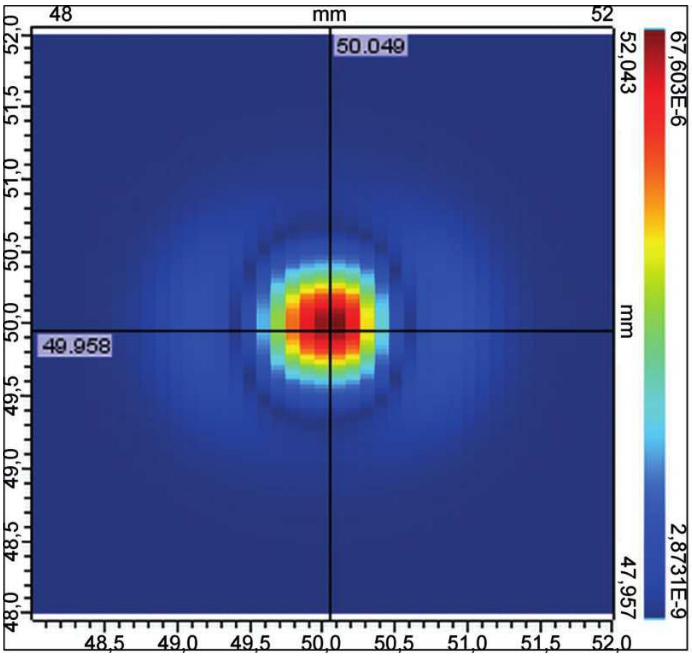
−3dB width = 0,36 mm

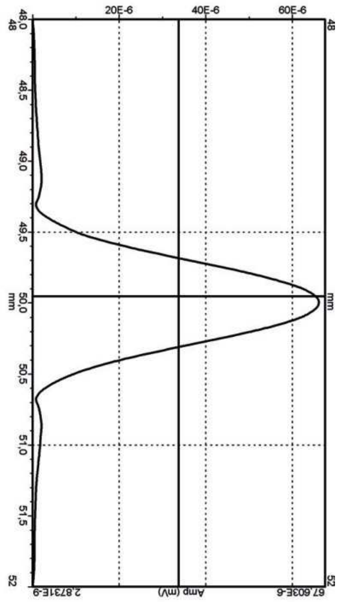
−6dB width = 0,5 mm

A.2 Simulation 2

Consider a block with 2 discontinuities; the distance between them is 0,36 mm (−3dB width).



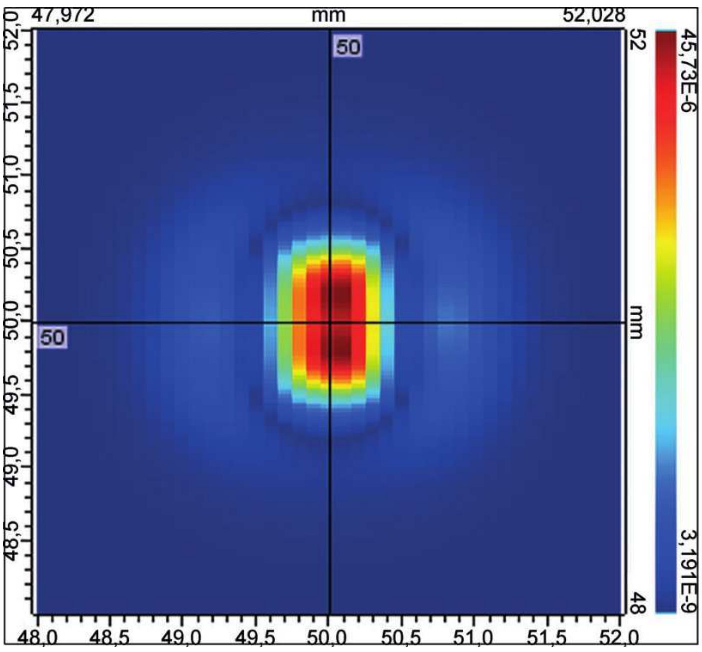


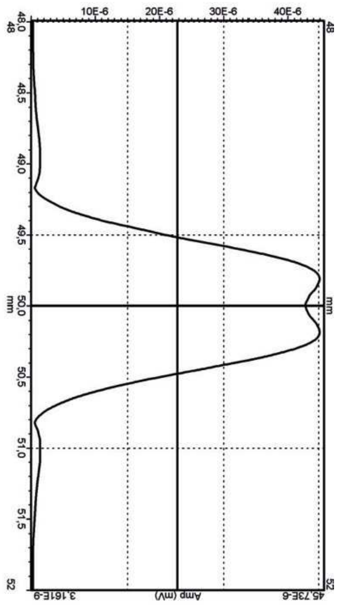


The discontinuities are *not resolved*.

A.3 Simulation 3

In the third simulated case, the distance between discontinuities is 0,5 mm (−6dB width).





The probe starts to resolve the two discontinuities.

ICS 19.100

Price based on 22 pages