INTERNATIONAL STANDARD

ISO 18563-1

Second edition
2022-08

Non-destructive testing — Characterization and verification of ultrasonic phased array equipment —

Part 1: Instruments

Essais non destructifs — Caractérisation et vérification de l'appareillage de contrôle par ultrasons en multiéléments —

Partie 1: Appareils

Reference number
ISO 18563-1:2022(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

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 of 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 www.iso.org/iso/foreword.html.

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).

This second edition cancels and replaces the first edition (ISO 18563-1:2015), which has been technically revised.

The main changes are as follows:

— test methods introduced in ISO 22232-1 have been incorporated;

— the layout has been rearranged to follow the layout of ISO 22232-1;

— the sequence of tests has been modified to follow the sequence of tests in ISO 22232-1.

A list of all parts in the ISO 18563 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Non-destructive testing — Characterization and verification of ultrasonic phased array equipment —

Part 1: Instruments

1 Scope

This document specifies the functional characteristics of multi-channel ultrasonic phased array instruments used for array probes and provides methods for their measurement and verification.

This document is also applicable to ultrasonic phased array instruments in automated systems; but other tests can be needed to ensure satisfactory performance. When the phased array instrument is a part of an automated system, the acceptance criteria can be modified by agreement between the parties involved.

This document also can partly be applicable to FMC instruments and TFM instruments.

This document gives the extent of the verification and defines acceptance criteria within a frequency range of 0,5 MHz to 10 MHz.

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 5577, *Non-destructive testing — Ultrasonic testing — Vocabulary*

ISO 22232-1, *Non-destructive testing — Characterization and verification of ultrasonic test equipment — Part 1: Instruments*

ISO 23243, *Non-destructive testing — Ultrasonic testing with arrays — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577, ISO 22232-1, ISO 23243 and the following apply.

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

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

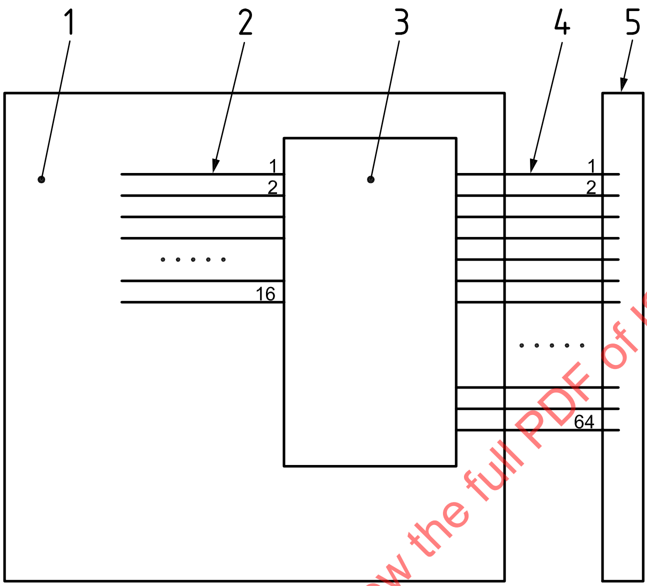
— IEC Electropedia: available at https://www.electropedia.org/

3.1
maximum number of channels that can be simultaneously activated
maximum number of transmitting and/or receiving channels which can be used for one shot

Note 1 to entry: An ultrasonic phased array instrument featuring a *maximum number of channels that can be simultaneously activated* (3.1) equal to the number of channels in the phased array instrument is indicated as parallel ultrasonic phased array instrument.

3.2
multiplexed ultrasonic phased array instrument
ultrasonic phased array instrument featuring a *maximum number of channels that can be simultaneously activated* (3.1) smaller than the number of channels in the ultrasonic phased array instrument and which are controlled by an internal multiplexing device

EXAMPLE In a type 16/64 multiplexed ultrasonic phased array instrument, the maximum number of channels that can be simultaneously activated is 16 and the total number of channels available is 64. See Figure 1.



Key
1 ultrasonic phased array instrument
2 multiplexer input channels (1 to 16)
3 multiplexer
4 multiplexer output channels (1 to 64)
5 array probe

NOTE 16 is the maximum number of channels that can be activated simultaneously.
64 is the number of channels in the ultrasonic phased array instrument.

Figure 1 — Diagram of a 16/64 multiplexed ultrasonic phased array instrument

3.3
time resolution of the ultrasonic phased array instrument
inverse of the maximum digitization frequency without processing

4 Symbols and abbreviated terms

For the purposes of this document, the symbols and abbreviated terms given in Table 1 apply.

Table 1 — Symbols and abbreviated terms and their units and meanings

Symbol/Abbreviated term	Unit	Meaning
A_{min}	%	Minimum amplitudes measured on a screen
A_{max}	%	Maximum amplitudes measured on a screen
A_0, A_n	dB	Attenuator settings used during tests
CT	dB	Cross-talk attenuation
f_0	Hz	Centre frequency
f_u	Hz	Upper frequency limit at −3 dB
f_l	Hz	Lower frequency limit at −3 dB
f_{max}	Hz	Frequency with the maximum amplitude in the frequency spectrum
f_h	Hz	Highest digitized frequency
Δf	Hz	Frequency bandwidth
f_R	Hz	Pulse repetition frequency (PRF)
FMC	-	Full matrix capture
FSH	-	Full screen height
ΔG	dB	Channel gain variation
G_D	dB	Input signal dynamic range
G_i	dB	Instrument gain on channel *i*
H_R	%	Reference screen height
I_{max}	A	Amplitude of the maximum current that can be driven by the proportional gate output
N_{in}	$\frac{V}{\sqrt{Hz}}$	Noise per root bandwidth for receiver input
R_A, R_B, R_l	Ω	Termination resistors
S	dB	Attenuator setting
Δt	s	Time increment
t	s	Time delay
t_0	s	Time to the start of distance-amplitude curve
t_1	s	Dead time
t_d	s	Pulse duration
t_{final}	s	Time to the end of distance-amplitude curve
t_r	s	Transmitter pulse rise time from an amplitude of 10 % to 90 % of peak amplitude
t_{RT}	s	Response time
$t_{Target\ 0}$, $t_{Target\ i}$, t_{Pi}, $t_{P\ 0}$, $t_{dif\ i}$, t_{dif}	s	Transmitter or receiver time delays
TFM	-	Total focusing method
t_{TOF}	s	Time-of-flight
V_A, V_B	V	Pulse voltage amplitudes
V_{ein}	V	Equivalent input noise
V_{in}	V	Input voltage when measuring the equivalent input noise
V_l	V	Output voltage modified when measuring the output impedance of the analogue gate
V_{min}	V	Minimum input voltage of the receiver
V_{max}	V	Maximum input voltage of the receiver

Table 1 *(continued)*

Symbol/Abbreviated term	Unit	Meaning
V_0	V	Output voltage to get an indication at 80 % of FSH when measuring the output impedance of the analogue gate
V_{50}	V	Voltage amplitude of the 50 Ω loaded transmitter pulse
Z_0	Ω	Output impedance of transmitter
Z_A	Ω	Output impedance of proportional output

5 General requirements of conformity

An ultrasonic phased array instrument conforms with this document if it fulfils all of the following requirements:

a) the ultrasonic phased array instrument shall conform with Clause 7;

b) a declaration of conformity shall be available, issued by either the manufacturer operating a quality management system (e.g. in accordance with ISO 9001) or by an organization operating a laboratory (e.g. in accordance with ISO/IEC 17025);

c) the ultrasonic phased array instrument shall carry a unique serial number;

d) a manufacturer's technical specification corresponding to the phased array instrument, which defines the performance criteria in accordance with Clause 6, shall be available.

6 Manufacturer’s technical specification for ultrasonic phased array instruments

The manufacturer’s technical specification relative to a specific model of an ultrasonic phased array instrument shall contain, as a minimum, the information listed in Table 2. Table 2 specifies the information which shall be supplied by the manufacturer in the ultrasonic phased array instrument’s technical specification.

The values obtained from the tests described in Clause 7 shall be established as nominal values, with tolerances given as indicated.

Table 2 — Technical characteristics to be shown in the ultrasonic phased array instrument's technical specification

Information	Type of information	Remarks
General features		
Size	OI	Width (mm) × Height (mm) × Depth (mm)
Weight	OI	At an operational stage including all batteries
Type(s) of power supply	OI	
Type(s) of instrument sockets	OI	Including the wiring diagram
Battery operational time	M	At fully charged new batteries
Number and type of batteries	OI	
Stability against temperature	M	
Stability after warm-up time	M	
Stability against voltage variations	M	
Temperature and voltage (mains and/or batteries) ranges in which the ultrasonic phased array instrument operates in accordance with the technical specification (operation and storage)	OI	When a warm-up time is necessary, its duration shall be stated
Form of indication given when a low battery voltage takes the performance of the ultrasonic phased array instrument outside of specification	OI	
Pulse repetition frequencies	M	Minimum and maximum values
Maximum power consumption	OI	V·A (volt-amperes)
Protection grade	OI	
Environment	OI	For example: restriction of hazardous substances (RoHS), explosive atmosphere (ATEX), vibration, humidity
Multi-channel configuration	OI	Number of channels controlled simultaneously and number of available channels
Extension of the number of channels by interconnection of the ultrasonic phased array instruments	OI	
Available measurement units	OI	For example: mm, inches, %, dB, V
Display		
Screen size and resolution	OI	
Range of sound velocities	OI	
Time base range	OI	
Time base delay range	OI	
List of available views	OI	
Response time for A-scan presentations	M	
Maximum digitization frequency without processing	OI	
Digitization frequency with processing	OI	For example: interpolation
Vertical resolution of digitizer	OI	In bits
Highest digitized frequency	M	
Key		
M Measurement		
OI Other information		

Table 2 *(continued)*

Information	Type of information	Remarks
Deviation of time base	M	
Inputs/outputs		
Signal unrectified output (i.e. radio frequency, RF) and/or rectified available on the output socket	OI	
Number and characteristics of logic and analogue control outputs	OI	Including the wiring diagram
Number and characteristics of encoder inputs	OI	Including the wiring diagram
Power input	OI	AC, DC, voltage range, power (W)
Available power supply for external devices	OI	Voltage, power
Synchronization input/output	OI	
Beam forming		
Maximum number of channels active simultaneously	OI	
Maximum number of delay laws	OI	
Maximum number of groups of shots	OI	
Summation	M	
Transmitter		
Number of transmitters available simultaneously	OI	
Shape of transmitter pulse and where applicable, polarity	OI	I.e. rectangular, unipolar, bipolar, arbitrary pulse
Transmitter voltage rise time	M	
Transmitter voltage fall time	M	
Transmitter voltage duration	M	
Output impedance	M	
Maximum time delay	OI	
Resolution of time delay	M	
Linearity of time delays	M	
Possibility to apply different voltages on each channel	OI	
Maximum power available per transmitter	OI	
Receiver		
Number of receivers available simultaneously	OI	
Characteristics of the gain control, i.e. range in decibels, value of increments	OI	
Characteristics of the logarithmic amplifier	OI	
Input voltage at FSH	OI	
Maximum input voltage	M	
Linearity of vertical display	M	

Key

M Measurement

OI Other information

Table 2 *(continued)*

Information	Type of information	Remarks
Linearity of the vertical display over the frequency ranges of the ultrasonic phased array instrument	M	
Frequency response	M	
Dead time after transmitter pulse	M	
Equivalent input noise	M	
Dynamic range	M	
Input impedance	M	
Maximum time delay	OI	
Resolution of time delay	M	
Time-corrected gain (TCG)	M	
Possibility to apply different gain values on each channel	OI	
Cross-talk attenuation between receivers	M	
Linearity of time delays	M	
Linearity of gain	M	
Variation of channel gain	M	
Data acquisition		
Transfer rate and type of connection between the external storage unit and the ultrasonic phased array instrument	OI	Interface type; Megabytes/s
Maximum number of A-scans stored per second	OI	A-scan characteristics shall be stated
Maximum number of C-scans stored per second	OI	C-scan characteristics shall be stated
Maximum number of samples per A-scan	OI	
Storage capacity	OI	Mbytes
Gates		
Number of gates	OI	
Threshold operation	OI	For example: coincidence or anticoincidence
Measurement mode	OI	For example: threshold, max, zero crossing
Synchronisation of gates	OI	For example: transmission pulse, first echo
Characteristics of gates	OI	Threshold, position, duration
Resolution of measurements	OI	
Trigger of alarms	OI	For example: number of sequences before an alarm is triggered
Linearity of monitor gate amplitude	M	
Linearity of time-of-flight in the gate	M	
Impedance of analogue output	M	
Linearity of analogue output	M	
Influence of the measurement signal position in the gate on the analogue gate output	M	

Key

M Measurement

OI Other information

Table 2 *(continued)*

Information	Type of information	Remarks
Rise time of analogue gate output	M	
Fall time of analogue gate output	M	
Hold time of analogue gate output	M	
Signal processing		
Processing features	OI	For example: averaging, fast Fourier transform (FFT), rectification, envelope, compression, dimensional measurements
Key M Measurement OI Other information		

7 Performance requirements for ultrasonic phased array instruments

In order to fulfil the requirements of this document, ultrasonic phased array instruments shall be verified with the following tests depending on the situation.

— Group 1 tests: to be performed by the manufacturer (or his or her agent) on a representative sample of the ultrasonic phased array instruments.

High-level measuring instruments are required for these tests.

— Group 2 tests: to be performed on every ultrasonic phased array instrument:

a) by the manufacturer (or his or her agent) prior to the supply of the ultrasonic phased array instrument (zero point tests);

b) by the manufacturer, the owner, or a laboratory, at 12-month intervals, to verify the performance of the ultrasonic phased array instrument during its lifetime;

c) following the repair of the ultrasonic phased array instrument.

Only basic electronic measuring instruments are needed for group 2 tests.

By agreement between the parties involved, these tests may be supplemented with additional tests from group 1.

A third group of tests for the combined system (ultrasonic phased array instrument and connected probes) is given in ISO 18563-3, these tests shall be performed at regular intervals on site.

For ultrasonic phased array instruments marketed before the introduction of this document, continuing fitness for purpose shall be demonstrated by performing the periodic group 2 tests every 12 months.

Following the repair, all parameters which can have been influenced by the repair shall be checked using the appropriate group 1 or group 2 tests.

Table 3 contains all tests to be performed on ultrasonic phased array instruments.

Table 3 — List of tests for ultrasonic phased array instruments

Title of the test	Group 1 Manufacturing test	Group 2 Periodic and repair test
	Subclause	Subclause
Physical state and external aspects	9.2	9.2
Portable or battery operated ultrasonic phased array instruments		
Battery operational time	8.2	
Stability		
Stability after warm-up time	8.3	
Stability against temperature	8.4	
Stability against voltage variations	8.5	
Display		
Deviation of time base	8.6	
Highest digitized frequency	8.10	
Response time of ultrasonic phased array instrument	8.11	
Beam forming		
Summation	8.8.9	
Transmitter		
Pulse repetition frequency	8.7.2	
Effective output impedance	8.7.3	
Resolution of time delay	8.7.4	
Transmitter pulse voltage, rise time and duration	9.3.2	9.3.2
Linearity of time delays	9.3.3	9.3.3
Receiver		
Resolution of time delay	8.7.4	
Cross-talk attenuation between receivers	8.8.2	
Dead time after the transmitter pulse	8.8.3	
Dynamic range and maximum input voltage	8.8.4	
Receiver input impedance	8.8.5	
Time-corrected gain (TCG)	8.8.6	
Linearity of vertical display against frequency	8.8.8	
Frequency response	9.4.2	9.4.2
Linearity of gain	9.4.4	9.4.4
Equivalent input noise	9.4.3	9.4.3
Variation of channel gain	9.4.5	9.4.5
Linearity of vertical display	9.4.6	9.4.6
Linearity of time delays	9.4.7	9.4.7
Monitor gate		
Linearity of gate amplitude	8.9.2	
Linearity of time-of-flight in the gate	8.9.3	
Impedance of analogue output	8.9.4.1	
Linearity of the analogue output	8.9.4.2	
Influence of signal position within gate	8.9.4.3	

Table 3 *(continued)*

Title of the test	Group 1 Manufacturing test	Group 2 Periodic and repair test
	Subclause	Subclause
Rise, fall, delay and hold time of analogue output	8.9.4.4	

8 Group 1 tests

8.1 Equipment required for group 1 tests

The equipment utilized to obtain the required information shall not affect the characteristics of the ultrasonic phased array instrument under consideration.

The equipment required for the group 1 tests on ultrasonic phased array instruments includes the following items or functions:

a) oscilloscope with a minimum bandwidth of 100 MHz;

b) (50 ± 0,5) Ω non-reactive resistors;

c) non-reactive resistors with values R_A and $R_{B;}$

d) standard 50 Ω attenuator with 1 dB steps and a total range of 100 dB. The attenuator shall have a cumulative error of less than 0,3 dB in any 10 dB span for signals with a frequency less than or equal to 15 MHz;

e) switching means;

f) pulse generator, capable of producing a trigger pulse with or without a defined delay;

g) signal generator, capable of producing a defined sinusoidal signal or a sinusoidal burst signal;

NOTE An arbitrary waveform generator can be used to replace one or both of the above listed generators due to its multifunctional design.

h) protection circuit (see Figure 2);

i) impedance analyser;

j) environmental test chamber;

k) regulated DC power supply (for testing the performances of battery operated ultrasonic phased array instruments);

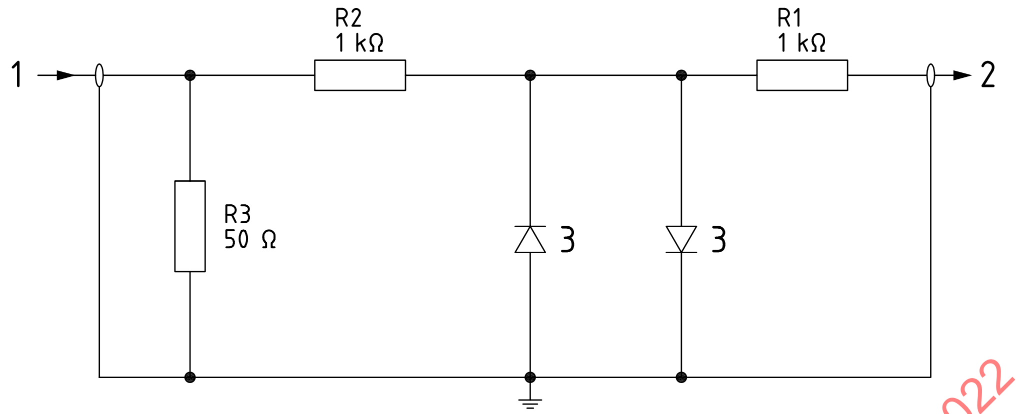
l) array probe (2 MHz to 6 MHz);

m) reference block to generate a back-wall echo (e.g. calibration block no. 1 according to ISO 2400).

All of the tests in group 1, except the test for stability against temperature (see 8.4), require electronic means to produce the necessary signals.

The characteristics and stability of the equipment used shall be adapted to the tests.

Before the oscilloscope is connected to the transmitter of the ultrasonic phased array instrument, as specified in some of the test procedures in this document, it shall be verified that the oscilloscope will not be damaged by the high transmitter voltage.



Key

1 from ultrasonic phased array instrument

2 to the input of the pulse generator, signal generator or oscilloscope

3 silicon switching diodes

R1, R2, R3 resistors

Figure 2 — Circuit to protect the instrument(s) from the transmitter pulse

8.2 Battery operational time

8.2.1 General

This test only applies to ultrasonic phased array instruments featuring a battery operation mode.

8.2.2 Procedure

The battery operational time of the unloaded (without any probe connected) ultrasonic phased array instrument using batteries only shall be measured with the following conditions (i.e. the ultrasonic phased array instrument shall be disconnected from the main power supply):

a) fully charged new battery(ies);

b) ambient temperature between 20 °C and 30 °C;

c) gain set to mid-gain position;

If the ultrasonic phased array instrument features a screen:

d) display A–scan and S-scan presentations;

e) brightness is set at mid-range.

When made possible by the characteristics of the ultrasonic phased array instrument:

f) pulse repetition frequency set to 1 kHz;

g) 16 channels active simultaneously;

h) 10 delay laws;

i) pulse voltage set to 50 V;

j) pulse width set to 100 ns;

k) time base set to 50 µs.

In all other cases, set those parameters to their typical values.

Parameters that have been modified shall be specified by the manufacturer.

8.2.3 Acceptance criterion

The duration measured shall be higher than or equal to the duration stated in the manufacturer's technical specification.

8.3 Stability after warm-up time

8.3.1 Procedure

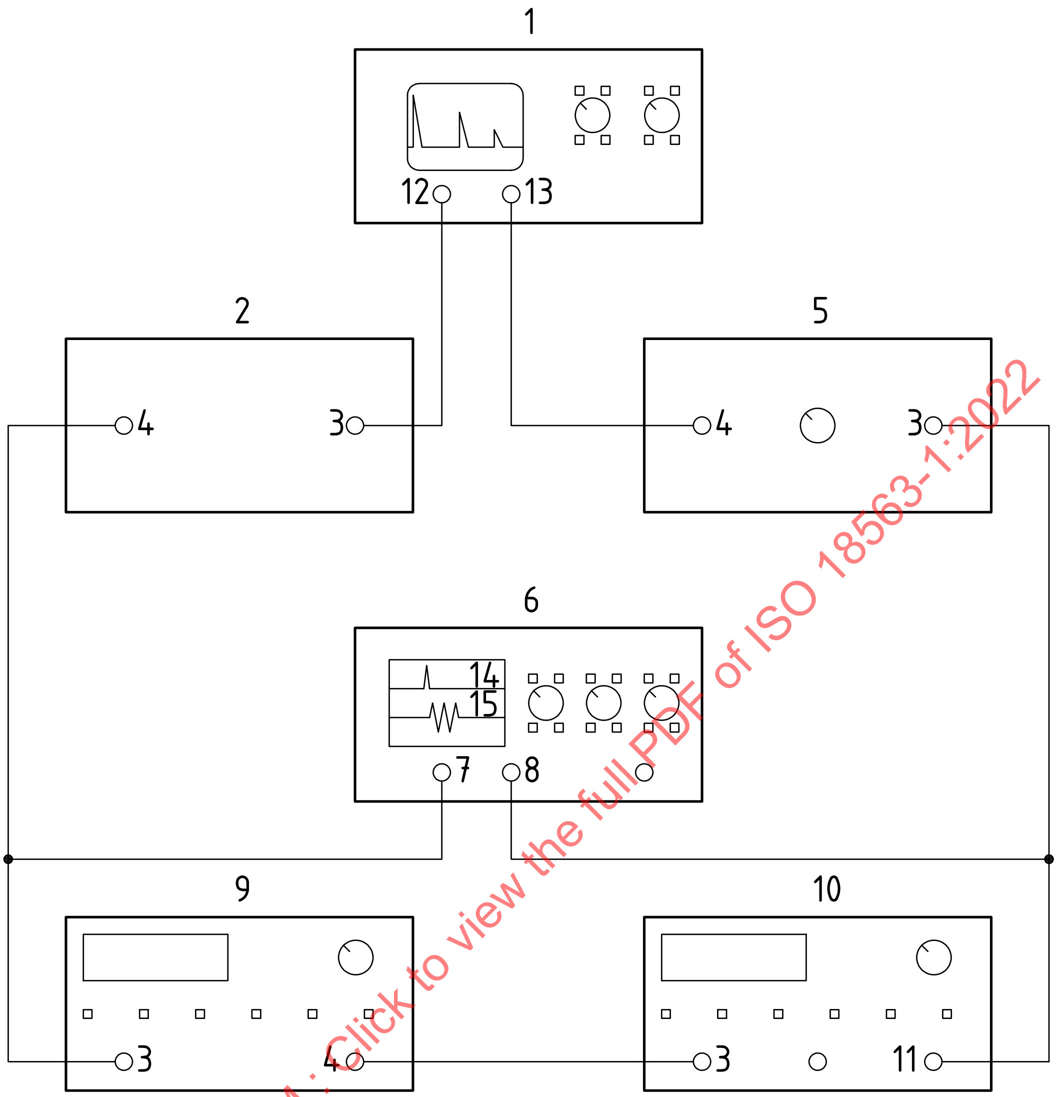
The procedure for the stability check after warm-up time shall be performed as follows:

a) Program the ultrasonic phased array instrument with one active transmitter channel and one different active receiver channel.

b) Use the signal from the active transmitter channel as the trigger for the pulse generator.

c) Connect the output from the pulse generator to the trigger input of the signal generator.

d) Connect the signal generator output via the variable attenuator to the active receiver channel, see Figure 3.



Key

1 ultrasonic phased array instrument
2 protection circuit (see Figure 2)
3 input
4 output
5 variable attenuator
6 100 MHz oscilloscope
7 input channel A
8 input channel B
9 pulse generator
10 signal generator
11 RF output
12 transmitter output
13 receiver input
14 representation of voltage-limited transmitter pulse
15 representation of test signal

Figure 3 — Setup for measuring stability after warm-up time and against temperature

e) Set the ultrasonic phased array instrument range to 50 mm for a velocity of 5 920 m/s, full rectification.

f) Set the delay of the pulse generator to 10 µs.

g) Set the signal generator to generate a burst of three cycles at 2 MHz to 6 MHz.

h) Set the burst amplitude to 100 mV peak-to-peak.

i) Adjust the ultrasonic phased array instrument gain to set the displayed signal to 80 % of the FSH.

j) Observe the amplitude and the position on the time base at 10 min intervals over a period of 30 min.

k) Carry out the test in an environment whose temperature is maintained within ±5 °C of the range specified in the manufacturer's technical specification of the ultrasonic phased array instrument.

l) Ensure that the mains or battery voltage is within the ranges required by the manufacturer's specification.

8.3.2 Acceptance criteria

During a 30 min period following an allowance for warm-up time, in accordance with the manufacturer's specification:

a) the signal amplitude shall not drift by more than ±2 % of the FSH;

b) the maximum shift along the time base shall be less than ±1 % of the full screen width.

8.4 Stability against temperature

8.4.1 Procedure

The procedure for the stability check against temperature shall be performed as follows:

a) Program the ultrasonic phased array instrument with one active transmitter channel and one different active receiver channel.

b) Use the signal from the active transmitter channel to trigger the pulse generator.

c) Connect the output from the pulse generator to the trigger input of the signal generator.

d) Connect the signal generator output via the variable attenuator to the active receiver channel. See Figure 3.

e) Set the ultrasonic phased array instrument range to 50 mm for a velocity of 5 920 m/s, full rectification.

f) Set the delay of the pulse generator to 10 µs.

g) Set the signal generator to generate a burst of three cycles at 2 MHz to 6 MHz.

h) Set the burst amplitude to 100 mV peak-to-peak.

i) Adjust the ultrasonic phased array instrument gain to set the displayed signal to 80 % of the FSH.

j) Place the ultrasonic phased array instrument in a climatic chamber and subjected it to varying ambient temperatures.

k) The height and position of the reference echoes shall be read out and recorded at maximum intervals of 10 °C over the temperature range specified by the manufacturer.

8.4.2 Acceptance criteria

For each 10 °C variation of the temperature, the amplitude and the position of the reference echo shall not drift by more than ±5 % of the FSH and ±1 % of the full screen width respectively.

8.5 Stability against voltage variations

8.5.1 Procedure

The procedure for the stability check against voltage variations shall be performed as follows:

a) Connect the ultrasonic phased array instrument to a regulated power supply.

The applied voltage shall be in the centre of the range specified for the use of the ultrasonic phased array instrument.

b) Apply a nil-delay law simultaneously to all available channels.

c) Display the summed A-scan presentation, e. g. by using an array probe with a centre frequency between 2 MHz and 6 MHz and a test block to generate a back-wall echo.

d) The echo amplitude shall be set to 80 % of the FSH; and the time base shall be set so that the displayed signal is at 50 % of the full screen width, with a distance equal to or greater than 50 mm of steel for longitudinal waves.

During the test, precautions shall be taken to avoid coupling variations.

e) Observe the consistency of amplitude and position on the time base of the reference signal over the range of operation voltage.

f) If an automatic cut-off system or a warning device is fitted, decrease the mains and/or battery voltage and note the signal amplitude at which the cut-off system or warning device operates.

8.5.2 Acceptance criteria

a) The amplitude and position of the reference signal shall remain constant within the limits stated in the manufacturer's technical specification.

b) Operation of the cut-off system or warning light (if fitted) shall occur before the reference signal amplitude varies by more than ±2 % of the FSH or the position on the time base changes by more than ±1 % of the full screen width from the initial setting.

8.6 Deviation of time base

8.6.1 General

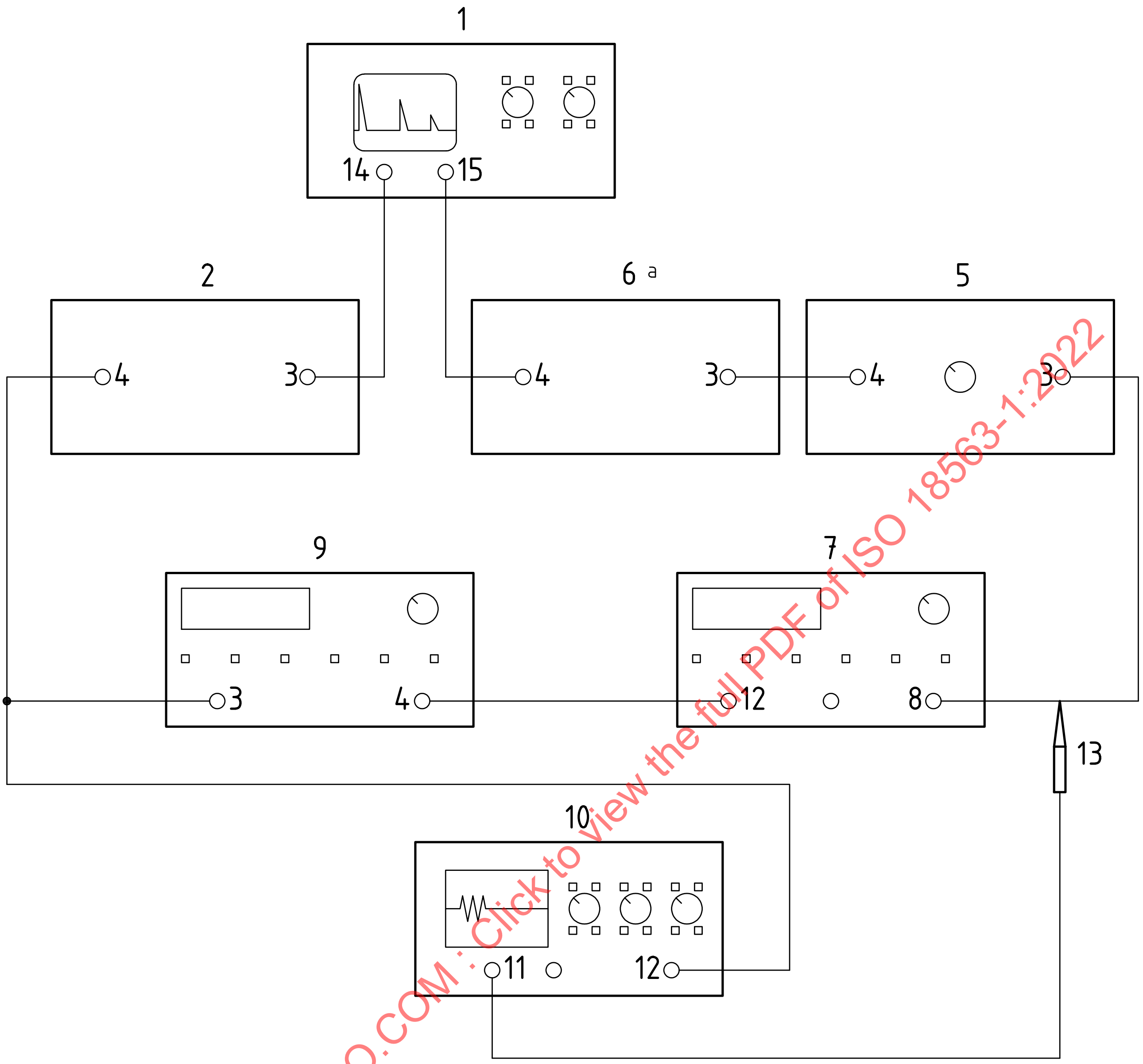
The tests described in 8.6.2 and 8.6.3 shall be performed on at least one channel.

8.6.2 Procedure

This test compares the linearity of time base of the ultrasonic phased array instrument with that of a calibrated signal generator.

a) Connect the ultrasonic phased array instrument as shown in Figure 4.

b) Set the signal generator to produce a single-cycle sine wave, with a frequency at the centre frequency f_0, of the widest frequency range.



Key

1 ultrasonic phased array instrument
2 protection circuit (see Figure 2)
3 input
4 output
5 variable RF attenuator
6 termination pad
7 signal generator
8 RF output
9 pulse generator
10 100 MHz oscilloscope
11 input channel A
12 trigger input
13 ×10 scope probe (100 MHz)
14 transmitter output
15 receiver input

a Termination pad is only required to match the impedance of the ultrasonic phased array instrument to the test setup.

Figure 4 — Setup of equipment for multiple tests

c) Set the time base to minimum, maximum, and mid-range position in turn.

d) At each setting, adjust the trigger delay, the gain of the ultrasonic phased array instrument, and the calibrated attenuator to obtain a signal which is at least 80 % of the FSH at the centre of the time base.

   This step defines the time references of the pulse generator.

e) Vary the delay time value of the pulse generator in increments smaller than or equal to 5 % of the full screen width.

f) Record each delay and measure the instant corresponding to the location of the indication (leading edge or maximum amplitude) on the ultrasonic phased array instrument.

g) For each measurement, calculate the difference between the time read on the ultrasonic phased array instrument and the delay given by the pulse generator.

8.6.3 Acceptance criterion

The maximum difference shall not exceed either ±0,5 % of the screen width or the time resolution of the ultrasonic phased array instrument.

8.7 Transmitter

8.7.1 General

This subclause contains tests for the pulse repetition frequency and the effective output impedance.

Test methods and acceptance criteria for transmitter voltage, rise time and duration are given in 9.3.2.

8.7.2 Pulse repetition frequency

8.7.2.1 Procedure

The procedure for the measurement of the pulse repetition frequency shall be performed as follows:

a) Connect an oscilloscope to one of the transmitter terminals.

b) Measure the pulse repetition frequency, using the oscilloscope, at 10 values equally distributed, including the minimum and maximum values specified in the technical specification.

8.7.2.2 Acceptance criterion

The measured pulse repetition frequencies shall not vary by more than ±5 % of the programmed value.

8.7.3 Effective output impedance

8.7.3.1 Procedure

Before connecting the oscilloscope, it shall be checked that the input of the oscilloscope will not be damaged by the high transmitter voltage.

The measurements shall be carried out at an intermediate pulse voltage, pulse width, and pulse repetition frequency.

The parameters displayed on the ultrasonic phased array instrument used shall be reported.

a) Using the oscilloscope, measure the transmitter pulse voltage V_A, with the transmitter connected to a non-reactive resistor R_A (e.g. 50 Ω).

b) Replace this resistor with R_B resistor (e.g. 75 Ω) and measure the transmitter pulse voltage, V_B.

c) This measurement shall be performed at a mid-range value of the pulse energy and transmitter pulse frequency.

d) Repeat this measurement at least on 10 % of available transmitter channels (e.g. on a 16/64 multiplexed ultrasonic phased array instrument, the measurement shall be carried out on six channels).

e) For each transmitter, calculate the output impedance, Z_0, using Formula (1):

$$Z_0 = R_A \times R_B \times \frac{(V_B - V_A)}{(R_B V_A - R_A V_B)} \tag{1}$$

where V_A and V_B are the values of the amplitude of the respective pulses from the base line, excluding peak values (overshoot or undershoot).

8.7.3.2 Acceptance criterion

The effective output impedance shall be within ±20 % of the value stated in the manufacturer's technical specification or within ±5 Ω, if the impedance is less than 25 Ω.

8.7.4 Resolution of time delay

8.7.4.1 Procedure

The procedure for the measurement of the resolution of time delay shall be performed as follows:

a) Select the maximum number of channels which can be simultaneously activated.

b) Set the amplitude of the transmitter pulse to an intermediate value.

c) Synchronise the oscilloscope using the synchronisation signal of the ultrasonic phased array instrument (by default, the pulse from the first channel can be used).

d) Set the transmitting delays to zero for each channel.

e) For each channel, measure on the oscilloscope the time, t_{P0}, between the synchronisation signal and the pulse.

f) For each channel, apply a transmitting delay equal to the resolution of time delay from the specification.

g) For each channel, measure on the oscilloscope the time, t_{P1}, between the synchronisation signal and the pulse.

   The measured resolution of time delay corresponds to the mean value of time differences $t_{P1} - t_{P0}$ measured on all the channels.

h) Repeat this measurement on each transmitter channel (e.g. on a 16/64 multiplexed ultrasonic phased array instrument, the measurement shall be carried out on 16 channels).

8.7.4.2 Acceptance criterion

The measured resolution of time delay shall be equal to the value stated in the manufacturer's technical specification, plus/minus one resolution step.

8.8 Receiver

8.8.1 General

This subclause gives tests to measure the cross-talk attenuation between different receivers, the receiver sensitivity, the dead time due to transmitter pulse, the dynamic range, the input impedance, the distance-amplitude correction and the time resolution of the ultrasonic phased array instrument.

The methods and acceptance criteria for amplifier bandwidth, equivalent input noise, accuracy of calibrated attenuator, linearity of vertical display are given in 9.4.6.

8.8.2 Cross-talk attenuation between receivers

8.8.2.1 Procedure

Measurement conditions shall be as follows:

— disable all transmitters;

— carry out all measurements in a 50 Ω environment (transmitter and receiver are terminated with 50 Ω load);

— activate one single receiver channel.

The procedure for the measurement of the cross-talk attenuation between receivers shall be performed as follows:

a) On receiver channel 1, set the gain (G_1) of the ultrasonic phased array instrument to its minimum value and then increase it by 10 dB.

b) Using a signal generator, apply on receiver channel 1 a continuous sine wave signal with a frequency of 5 MHz, see Figure 4.

c) Set the amplitude so that the peak amplitude of the signal on receiver channel 1 reaches 60 % of the FSH.

   If needed, increase the gain (G_1) to reach 60 % of the FSH.

d) Change the active receiver channel to receiver channel 2 and increase the gain (G_2) of the ultrasonic phased array instrument so that the peak amplitude of the signal of channel 2 reaches 60 % of the FSH while keeping the signal generator connected to receiver channel 1.

The cross-talk attenuation between receiver channel 1 and receiver channel 2 is defined in dB by Formula (2):

$$CT_{2,1} = G_2 - G_1 \quad (2)$$

e) Repeat the measurement by changing successively the active receiver channel and gain to the other receiver channels of the ultrasonic phased array instrument.

The cross-talk attenuation between receiver channel 1 and receiver channel *i* is defined by Formula (3):

$$CT_{\mathrm{i},1} = G_\mathrm{i} - G_1 \quad (3)$$

The cross-talk attenuation of the ultrasonic phased array instrument is the smallest dB value recorded.

8.8.2.2 Acceptance criterion

The cross-talk attenuation of the ultrasonic phased array instrument shall be greater than the value stated in the manufacturer's technical specification.

8.8.3 Dead time after the transmitter pulse

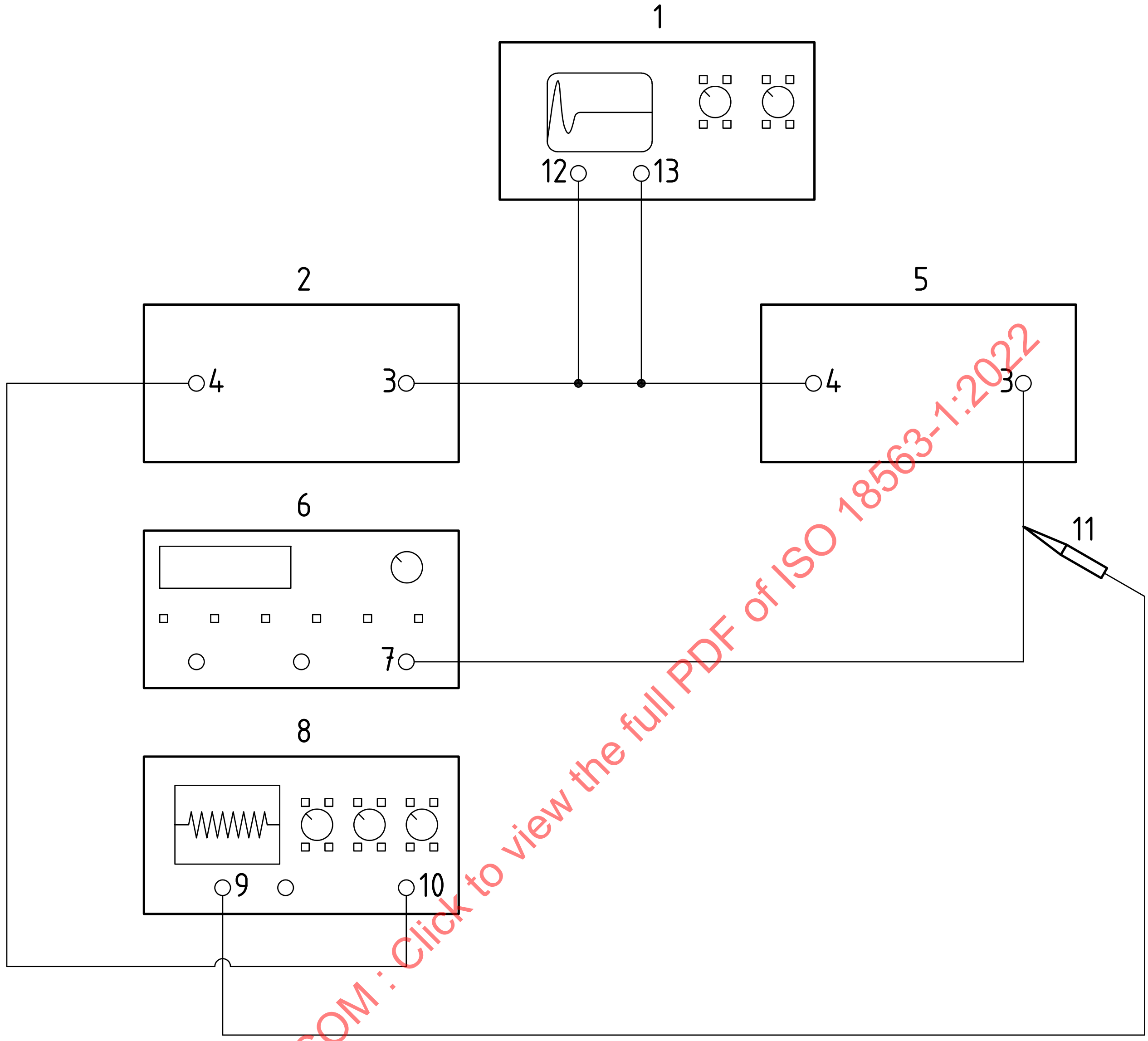
8.8.3.1 Procedure

The procedure for the measurement of the dead-time after transmitter pulse shall be performed as follows:

a) Set the ultrasonic phased array instrument screen width from 0 µs to 25 µs at full scale.

b) Then adjust the zero offset so that the leading edge of the transmitter pulse coincides with the zero screen division.

c) Use the equipment setup as shown in Figure 5 with the ultrasonic phased array instrument in single-transducer mode (connected transmitter and receiver).



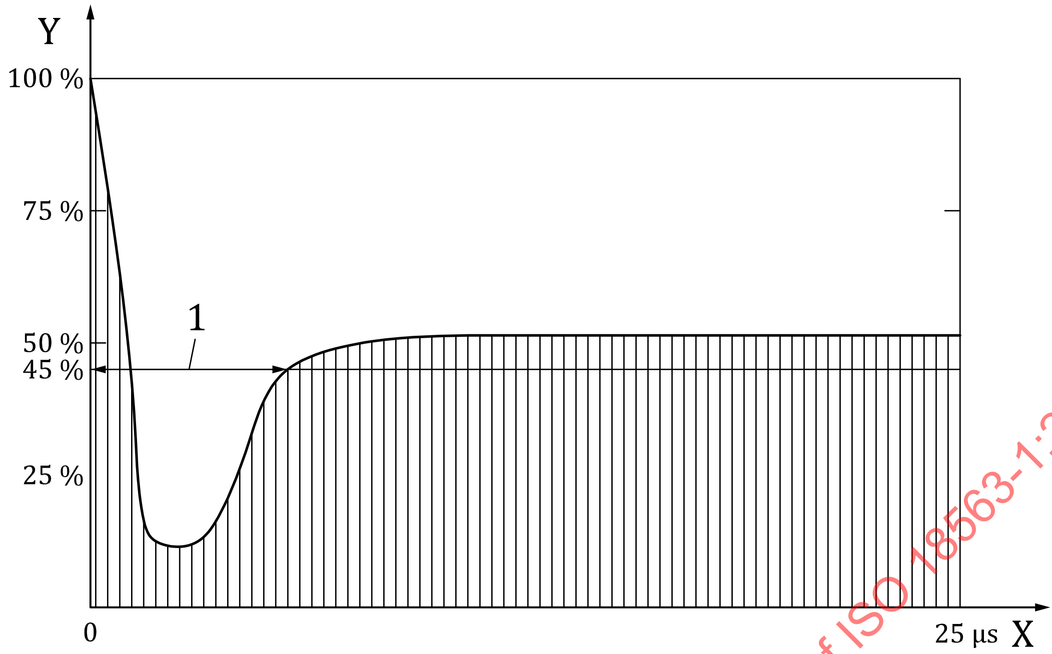
Key

1 ultrasonic phased array instrument
2 fixed attenuator
3 input
4 output
5 fixed attenuator
6 signal generator
7 RF output
8 100 MHz oscilloscope
9 input channel A
10 trigger input
11 ×10 scope probe (100 MHz)
12 transmitter output
13 receiver input

Figure 5 — Equipment setup used to measure dead time after the transmitter pulse

d) Select each frequency band setting of the ultrasonic phased array instrument in turn and adjust the signal generator output to be mid-band of the frequency band setting.

e) Using mid-gain setting of the ultrasonic phased array instrument, adjust the signal generator output level to make the signal 50 % of the FSH at the maximum range of the screen, as shown in Figure 6.



Key

X time

Y screen height

1 dead time

Figure 6 — Waveform used to measure dead time after the transmitter pulse as displayed during the test

f) Set the transmitter voltage to 50 % of the maximum value and set the pulse duration corresponding to half of the time cycle of the selected frequency, if applicable.

The dead time after the transmitter pulse t_1 is the duration from the leading edge of the transmitter pulse until the amplitude stabilizes between 45 % and 55 % of the FSH.

g) The values for pulse duration and pulse voltage used for measurement shall be recorded.

NOTE The protection circuit shown in Figure 2 is used to protect the trigger input of the oscilloscope. The fixed attenuator is used to protect the signal generator from the transmitter pulse.

8.8.3.2 Acceptance criterion

The ultrasonic phased array instruments dead time shall be less than or equal to the value stated in the manufacturer's technical specification.

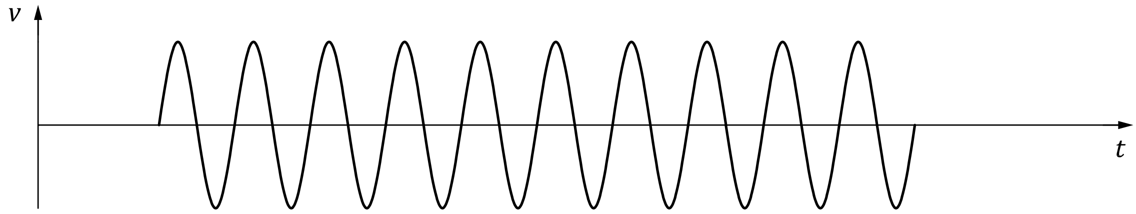
8.8.4 Dynamic range and maximum input voltage

8.8.4.1 Procedure

The procedure for the measurements of the dynamic range and the maximum input voltage shall be performed as follows:

a) The dynamic range shall be checked using the test equipment shown in Figure 4, the centre frequency, f_0, of each frequency band being as measured in 9.4.2.

b) The test signal of 10 cycles that shall be generated by this equipment is shown in Figure 7.



Key

v voltage

t time

Figure 7 — Test waveform generated by the signal generator

c) Set the gain of the ultrasonic phased array instrument controls to minimum gain.

d) Increase the amplitude of the input signal until the signal is displayed at 100 % of the FSH or there is no discernible linear change in signal amplitude for an increase in input signal.

NOTE The receiver input voltage at FSH is the input voltage which reaches FSH for the lowest gain possible.

e) Using an oscilloscope, measure (taking due account of the standard attenuator setting) the input voltage amplitude, V_{max}, and the corresponding screen height.

f) If the maximum voltage supplied by the signal generator is not sufficient, set the ultrasonic phased array instrument gain to 20 dB above the minimum gain and carry out the necessary measurement correction.

g) Disconnect the test signal from the input of the ultrasonic phased array instrument.

h) Set the gain controls to maximum gain.

i) If the average noise level is higher than 5 % of the FSH, decrease the gain until the average noise level is 5 % of the FSH.

j) Reconnect the test signal to the input of the ultrasonic phased array instrument.

k) Adjust the amplitude of the input signal so that it is displayed at 10 % of the FSH.

l) Measure the input voltage amplitude, V_{min} (taking due account of the standard attenuator setting).

m) Repeat this measurement for each receiver channel (e.g. on a 16/64 multiplexed ultrasonic phased array instrument, the measurement shall be carried out on 16 channels).

The usable dynamic range, G_D, is given by Formula (4):

$$G_D = 20\log_{10}\left(\frac{V_{max}}{V_{min}}\right) \quad (4)$$

The dynamic range of the ultrasonic phased array instrument is characterized by the smallest dB value of the dynamic ranges measured on all the channels.

8.8.4.2 Acceptance criterion

The dynamic range of the ultrasonic phased array instrument and V_{max} of the ultrasonic phased array instrument shall be greater than or equal to the value stated in the manufacturer's technical specification.

8.8.5 Receiver input impedance

8.8.5.1 Procedure

The procedure for the measurement of the receiver input impedance shall be performed as follows:

a) Determine the real and imaginary parts of the input impedance with an impedance analyser. The transmitter pulse shall be disabled while measuring the input impedance.

b) Perform the measurements at centre frequency of the ultrasonic phased array instrument and applying mid-range gain.

c) Repeat this measurement on at least 10 % of available receiver channels (e.g. on a 16/64 multiplexed ultrasonic phased array instrument, the measurement shall be carried out on at least six channels).

8.8.5.2 Acceptance criterion

The modulus of the input impedance obtained for each channel shall be within ±20 % of the manufacturer's technical specification.

8.8.6 Time-corrected gain (TCG)

8.8.6.1 General

a) The performance of the time-corrected gain (TCG) or distance–amplitude compensation shall be verified by comparing the theoretical DAC (distance–amplitude curve) requested by the operator with the actual curve generated by the ultrasonic phased array instrument.

b) The theoretical curve shall be calculated from the information supplied by the manufacturer on the operation of the TCG controls.

c) This shall be compared to the actual curve which is measured by the change in amplitude of a test pulse (one cycle of a sine wave) at a number of n positions on the horizontal time base over which the TCG is active.

8.8.6.2 Procedure

The procedure for the measurements on time corrected gain shall be performed as follows:

a) Activate one channel.

b) Disable the transmission function of the channel being used.

c) Connect the test equipment as shown in Figure 4.

d) Set the gain of the ultrasonic phased array instrument at minimum value in order to maximize the TCG dynamic range.

e) The curve selected for this test shall contain the steepest slope possible with the ultrasonic phased array instrument enabling to record at least 11 measurement points at regular intervals.

f) Throughout this test, avoid saturating the amplifier preceding the TCG circuit.

g) With the test signal at a position on the horizontal time base just before the start of the theoretical curve, adjust the external standard attenuator so that the amplitude of the test signal is at 80 % of the FSH and call the standard attenuator setting A_0.

h) If the signal is saturated, reduce the amplitude of the test signal and note the value as the reference screen height, H_R.

i) Increase the delay of the test signal in order to move the signal along the time base by Δt, as given by Formula (5):

$$\Delta t = \frac{t_{final} - t_0}{n-1} \tag{5}$$

where

t_0 is the time at the start of the theoretical curve;

t_{final} is the time at the end of the theoretical curve;

n is the number of measurements to be taken, which shall be greater than or equal to 11.

j) Adjust the standard attenuator to set the test signal to 80 % of the FSH (or to H_R) and record the attenuator setting, A_n.

k) Increase the time base position of the test signal by increasing the time delay a further Δt and again, record the attenuator setting, A_n, to set the test signal to 80 % of the FSH (or H_R).

l) Continue increasing the time delay and adjusting the standard attenuator until n measurements have been made.

m) After the last measurement, test the TCG for saturation by increasing the external calibrated attenuation by 6 dB and ensuring that the signal is between 38 % and 42 % of the FSH (or $H_R/2 \pm 2$ %)

n) If the signal is not within these limits, reduce the range by Δt and repeat the saturation test.

o) The dynamic range of the TCG shall be measured at the point where saturation no longer occurs.

p) Plot the actual DAC curve and the theoretical one.

q) Repeat the measurement on all receiver channels featuring a TCG (e.g. on a 16/64 multiplexed ultrasonic phased array instrument, the measurement shall be carried out on 16 channels).

8.8.6.3 Acceptance criterion

The difference between the theoretical curve requested by the operator and the actual curve shall not exceed ±2 dB.

8.8.7 Resolution of time delay

8.8.7.1 Procedure

The test shall be performed on one channel only.

a) Connect the test equipment as shown in Figure 4.

b) Synchronise the pulse generator and the signal generator by means of the ultrasonic phased array instrument synchronisation signal (by default, the transmit pulse from the first channel can be used using the protection circuit as shown in Figure 4).

c) Produce a test signal with a single-cycle sine wave by means of the signal generator.

d) Set the test signal frequency to the centre frequency of the ultrasonic phased array instrument filter with the widest band.

e) Connect the test signal to channel 2.

f) Select the widest frequency band of the ultrasonic phased array instrument.

g) With the ultrasonic phased array instrument set to mid-gain, adjust the output amplitude of the signal generator until the amplitude of the displayed signal on the ultrasonic phased array instrument screen is at 80 % of the FSH.

h) Set the ultrasonic phased array instrument time base delay to 0 µs.

i) Set the receiving delay to 0 µs for each channel.

j) Adjust the delay time of the pulse generator to display the signal in the centre of the time base.

k) Adjust the ultrasonic phased array instrument width of the time base so that all the test signals produced in the test remain displayed.

l) Increase the time delay of the ultrasonic phased array instrument by one or more increments, each equal to the resolution of time delay stated by the manufacturer, until the signal is offset on the time base.

m) Record the delay used and the corresponding position of the signal (gates may be used).

n) Continue incrementing the time delay of the ultrasonic phased array instrument to produce five signal offsets in turn.

8.8.7.2 Acceptance criterion

Resolution of time delay is acceptable if, for all these five measurements, the maximum deviation of signal positions from the values recorded is smaller than or equal to the time resolution of the ultrasonic phased array instrument stated in the manufacturer's technical specification.

8.8.8 Linearity of vertical display against frequency

8.8.8.1 Procedure

The test method for the linearity of vertical display is given in 9.4.6.1.

The tests shall be performed at the centre frequencies (f_0) of the following analogue filters (as measured in 9.4.2):

a) filter including the lowest centre frequency of the ultrasonic phased array instrument;

b) filter including the highest centre frequency of the ultrasonic phased array instrument;

c) filter with the largest bandwidth of the ultrasonic phased array instrument.

8.8.8.2 Acceptance criterion

For each frequency value, the measured amplitudes shall be within the tolerances specified in Table 7.

8.8.9 Summation

8.8.9.1 General

This test is intended to verify the ability of the ultrasonic phased array instrument to sum signals in reception.

8.8.9.2 Procedure

The procedure for the measurement shall be performed as follows:

a) Connect the test equipment as shown in Figure 4.

b) Synchronise the pulse generator and the signal generator by means of the ultrasonic phased array instrument synchronisation signal (by default, the transmit pulse from the first channel can be used using the protection circuit as shown in Figure 4).

c) Produce a test signal with a single-cycle sine wave of 5 MHz by means of the signal generator.

d) Feed the single-cycle sine wave in parallel on the first four channels only.

e) Activate the first four channels in reception with a delay of 1 µs between each, starting from channel 1 (0 µs) up to channel 4 (3 µs).

f) Set the gain at a minimum and adjust the amplitude of the first sine wave cycle of the summated signal to 80 % of the FSH, using the signal generator.

g) Measure the variation in amplitude against 80 % of the FSH for the three other signals.

h) Measure the temporal positions of the maxima of the three other signals.

i) Determine the time variation between two consecutive signals.

8.8.9.3 Acceptance criteria

a) The maximum amplitude variation shall be less than ±2 dB.

b) The maximum time variation shall be less than or equal to the time resolution of the ultrasonic phased array instrument.

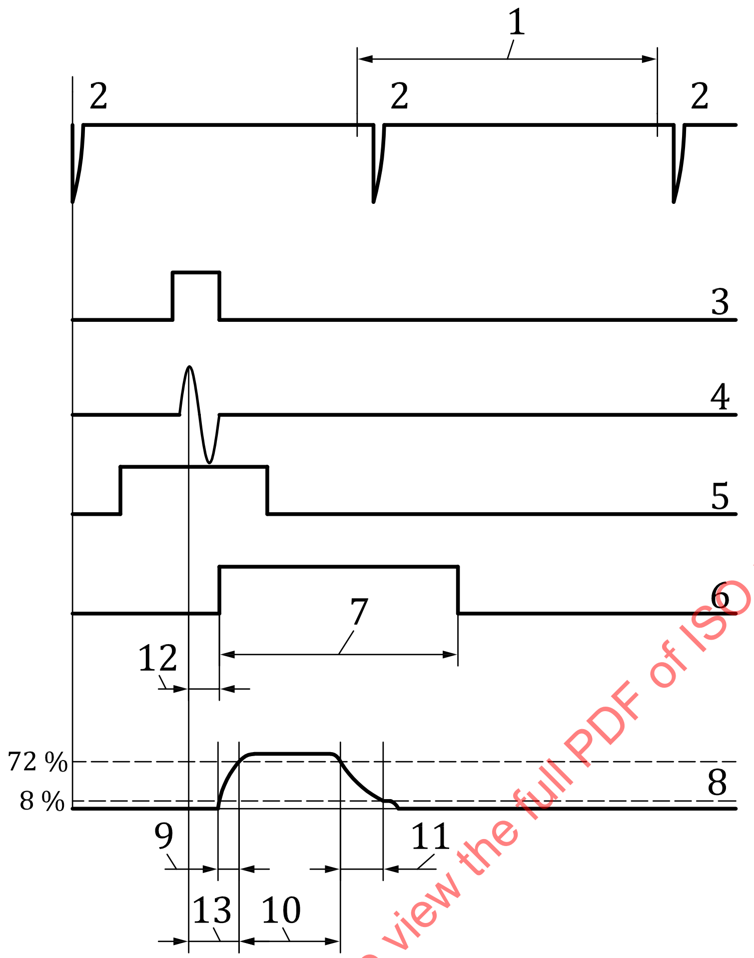
NOTE The maximum amplitude variation includes the channel variation measured in 9.4.5 increased by a tolerance of ±0,5 dB.

8.9 Gates

8.9.1 General

All the gate tests shall use the equipment setup shown in Figure 4.

The generators enable this setup to generate a test signal, as shown in Figure 8.



Key

1 screen width
2 transmitter pulses
3 test enabling signal
4 test signal
5 monitor gate
6 switched monitor gate signal
7 switched monitor gate signal hold time
8 proportional gate output
9 rise time
10 hold time
11 fall time
12 digital output delay time
13 analogue output delay time

Figure 8 — Timing diagram of signals used to test a monitor gate

8.9.2 Linearity of gate amplitude

8.9.2.1 Procedure

The procedure for the measurement of the linearity of the gate amplitude shall be performed as follows:

a) Program the ultrasonic phased array instrument with one active transmitter channel and one different active receiver channel.

b) Using the setup shown in Figure 4, generate a test pulse synchronised to the transmitter pulse.

c) Select the setting at which the gain controls are in the middle of their range and the widest band setting of the ultrasonic phased array instrument.

d) Adjust the triggering of the test signal so as to produce a signal for each transmitter pulse.

e) Adjust the amplitude of the test signal to get an indication at 80 % of the FSH from the gate of the ultrasonic phased array instrument, calling this the reference amplitude.

f) Change the amplitude of the test signal in steps according to the relative attenuation in Table 4.

g) Record the deviation of the amplitude value in the gate from the nominal value (see Table 4).

h) If the ultrasonic phased array instrument can measure signal amplitudes above 100 % of the FSH (using the gate), Table 4 shall be extended accordingly to the maximum possible measurement with a 2 dB step.

Table 4 — Expected monitor gate amplitude for specified attenuator settings

Relative attenuation dB	**Nominal value** % of FSH
1	90
0	80
−2	64
−4	50
−6	40
−8	32
−10	25
−12	20
−14	16
−16	13
−18	10

8.9.2.2 Acceptance criterion

The measurement results shall be equal to the nominal values in Table 4, within ±2 % of the FSH.

8.9.3 Linearity of time-of-flight in the gate

8.9.3.1 Procedure

The procedure for the measurement of the linearity of time-of-flight in the gate shall be performed as follows.

a) The equipment setup shown in Figure 4 shall be used to generate a test signal for each transmitter pulse.

b) Select a mid-gain position and the widest band setting of the ultrasonic phased array instrument.

c) Adjust the triggering of the test signal so as to produce a signal for each transmitter pulse.

d) Adjust the amplitude of the signal with the centre frequency, f_0, so as to obtain an indication at 80 % of the FSH.

e) Adjust the time base from 0 µs to 40 µs. Adjust the monitor gate from 5 µs to 35 µs and the height at 50 % of the FSH.

f) Position the test signal in the first fifth of the screen width, read the value of the time-of-flight (t_{TOF}) from the gate of the ultrasonic phased array instrument and take this as the reference value.

g) Change the time-of-flight of the test signal in steps according to the delay in Table 5 using the pulse generator.

h) Record the deviation of the time-of-flight value t_{TOF} in the gate from the nominal t_{TOF} value, see Table 5.

Table 5 — Expected time-of-flight in monitor gate for specified positions in the screen width

Position in the screen width %	Nominal value of the time-of-flight t_{TOF} µs
20	Reference
40	Reference + 8 µs
60	Reference + 16 µs
80	Reference + 24 µs

8.9.3.2 Acceptance criterion

The measurement results shall be within ±40 ns of the values given in Table 5.

8.9.4 Monitor gates with analogue outputs

8.9.4.1 Impedance of analogue output

8.9.4.1.1 Procedure

The procedure for the measurement of the impedance of the analogue output shall be performed as follows:

a) Select the setting at which the gain controls are in the middle of their range and the widest band setting of the ultrasonic phased array instrument.

b) Adjust the trigger of the measurement signal so that a measurement signal with the carrier frequency, f_0, measured in 9.4.2 is produced with every transmitter pulse.

c) Set the amplitude of the measurement signal to produce an indication at 80 % of the FSH and measure the output voltage, V_o.

d) Terminate the analogue output with a resistor of value, R_l, which satisfies Formula (6):

$$0{,}75 I_{max} \leq \left(\frac{V_o}{R_l} \right) \leq 0{,}85 I_{max} \tag{6}$$

where I_{max} is the maximum current that can be driven by the analogue output.

e) Record the altered output voltage, V_l.

f) Calculate the resistive part of the output impedance using Formula (7):

$$\left| Z_A \right| = \left(\frac{V_o}{V_l} - 1 \right) R_l \tag{7}$$

8.9.4.1.2 Acceptance criterion

The measured output impedance shall be within the tolerance stated in the manufacturer's technical specification.

8.9.4.2 Linearity of the analogue output

8.9.4.2.1 Procedure

The procedure for the measurement of the linearity of the analogue output shall be performed as follows:

a) Select the setting at which the gain controls are in the middle of their range and the widest band setting of the ultrasonic phased array instrument.

b) Adjust the triggering of the test signal so as to produce a signal for each transmitter pulse.

c) Adjust the amplitude of the test signal to give an indication at 80 % of the FSH and measure the voltage at the analogue output, calling this the reference voltage.

d) The output voltage enabling an indication at the FSH is specified as 1,25 times the reference voltage.

e) Change the amplitude of the test signal in steps according to Table 6.

f) Record the deviation of the output voltage from the nominal value.

Table 6 — Expected output voltage for specified attenuator settings

Relative attenuation dB	**Nominal value** % of the FSH output voltage
+1	90
0	80
−2	64
−4	50
−6	40
−8	32
−10	25
−12	20
−14	16
−16	13
−18	10

8.9.4.2.2 Acceptance criterion

The measurement result shall be within the tolerance stated in the manufacturer's technical specification.

8.9.4.3 Influence of signal position within gate

8.9.4.3.1 Procedure

The procedure for the influence of the signal position within gate shall be performed as follows:

a) The equipment setup shown in Figure 4 shall be used to generate a test signal for each transmitter pulse.

b) Select a mid-gain position and the widest band setting of the ultrasonic phased array instrument.

c) Adjust the amplitude of the signal with the centre frequency, f_0, so as to obtain an indication at 80 % of the FSH.

d) Position the test signal in the first fifth, in the centre, then in the last fifth of the gate and measure the voltages of the analogue output.

8.9.4.3.2 Acceptance criterion

The measurement results shall be within the tolerance stated in the manufacturer's technical specification.

8.9.4.4 Rise, fall, delay and hold time of analogue output

8.9.4.4.1 Procedure

The procedure for the measurements shall be performed as follows:

a) The equipment setup shown in Figure 4 shall be used to set the triggering of the test signal so as to produce a signal for each transmitter pulse.

b) Also use a mid-gain position, the widest band setting of the ultrasonic phased array instrument, and a test signal with the carrier frequency, f_0, measured in 9.4.2.

c) Adjust the test signal so as to produce a voltage at the analogue output equal to 80 % of the output voltage for the FSH.

d) Change the trigger of the test signal so that at the analogue output, the minimal output voltage can be observed between two consecutive pulses (e.g. a transmitter pulse producing a test signal is followed by approximately one thousand pulses for which no signal is produced).

e) The rise time, fall time, delay time and hold time shall be measured as follows and recorded:

   1) the rise time is specified as the time interval during which the output voltage increases from 8 % to 72 % of the output voltage at the FSH (see Figure 8); these values are equivalent to 10 % and 90 % of the output signal produced by the test signal;

   2) the fall time is specified as the time interval during which the output voltage decreases from 72 % to 8 % of the FSH output voltage (see Figure 8);

   3) the delay time is specified as the time interval from the peak of the test signal till the output voltage is above 72 % (see Figure 8);

   4) the hold time is specified as the time interval during which the output voltage is above 72 % of the FSH output voltage, following the end of the test signal (see Figure 8).

8.9.4.4.2 Acceptance criterion

The measurement results shall be within the tolerance stated in the manufacturer's technical specification.

8.10 Highest digitized frequency

8.10.1 Procedures

8.10.1.1 General

This test defines the highest digitized frequency (f_h) in the ultrasonic phased array instrument bandwidth at which the signal is independent from its position on the time base. f_h is the highest frequency at which the variation is lower than ±5 % of the FSH.

Choose one of the methods specified in 8.10.1.2 and 8.10.1.3.

8.10.1.2 Method A

The procedure for the measurement shall be performed as follows:

a) Program the ultrasonic phased array instrument with one active transmitter channel and one different active receiver channel.

b) Using the setup shown in Figure 4, generate a test pulse synchronised to the transmitter pulse.

c) Set the delay, t, of the signal to t_0, longer than the receiver dead time measured in 8.8.3.

d) Set the frequency of the signal generator at the upper 3 dB limit, f_u, measured in 9.4.2, for the filter with the largest bandwidth, including the highest frequency.

e) Adjust the signal generator to produce a single-cycle sine wave with an amplitude of 80 % of the FSH.

f) Using the variable time delay, increase t by the following small increment as given in Formula (8):

$$\Delta t = \frac{1}{10 f_u} \tag{8}$$

where f_u is the upper frequency limit at –3 dB for the filter, as measured in 9.4.2.

g) At each increment Δt, measure the amplitude of the signal on the ultrasonic phased array instrument.

h) Continue increasing the time delay and measuring the amplitude until 30 measurements have been recorded (i.e. three periods).

i) The signal shall not vary by more than ±5 % of the FSH, from the largest to the smallest amplitude recorded.

j) If the variation is larger, repeat the test reducing the frequency of the test signal until a variation of ±5 % of the FSH is reached.

8.10.1.3 Method B

The procedure for the measurement shall be performed as follows:

a) Set the ultrasonic phased array instrument for separate transmitter-receiver mode using the setup shown in Figure 4.

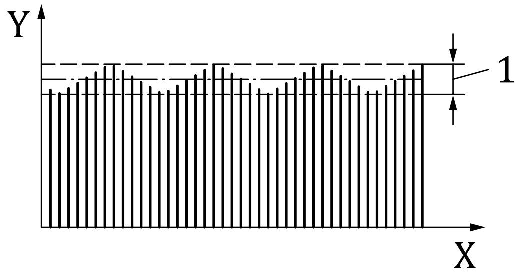
b) Calibrate the ultrasonic phased array instrument screen width from 0 µs to 25 µs at full scale.

c) Then adjust the zero offset so that the zero screen division starts well after the dead time as determined in 8.8.3.

d) Set the frequency of the signal generator to f_u, as determined in 9.4.2, for the selected filter setting of the ultrasonic phased array instrument.

e) Adjust the signal generator to produce a continuous sine wave with an average amplitude of 80 % of the FSH.

f) Record the minimum and maximum signal amplitudes displayed on the screen of the ultrasonic phased array instrument as shown in Figure 9.



Key

X time

Y screen height

1 digitisation sampling error

Figure 9 — Waveform used with method B to measure the digitisation sampling error

g) For this measurement it is important that the frequency generated by the signal generator is not synchronous to the sampling clock of the ultrasonic phased array instrument.

This can be verified by setting the frequency of the signal generator to a frequency of f_u – 0,1 MHz.

h) Again observe the minimum and maximum signal amplitudes displayed on the screen of the ultrasonic phased array instrument.

i) The observed values should not change due to this small frequency variation.

j) Record the lowest minimum amplitude, the largest maximum amplitude and the signal frequency used.

8.10.2 Acceptance criterion

The measured frequency, f_h, shall be higher than or equal to the value stated in the manufacturer's technical specification.

8.11 Response time of ultrasonic phased array instrument

8.11.1 General

The displays have a limited refresh rate; and this may not match the ultrasonic pulse repetition frequency f_R. Hence transient echoes which are only detected for a short period of time may not be displayed on the screen at their full amplitude.

The purpose of this test is to measure the time for which a transient echo shall be detected before it is displayed on the screen of the ultrasonic phased array instrument, at 90 % of its full amplitude.

8.11.2 Procedure

The test is performed with one channel operation.

a) Use the setup shown in Figure 4 to produce a single-cycle sinusoidal test signal with a frequency, f_u, measured in 9.4.2 for the filter with the largest bandwidth including the highest frequency.

b) Adjust the ultrasonic phased array instrument gain to the middle of its dynamic range and the amplitude of the test pulse to 80 % of the FSH.

c) Set the pulse repetition frequency to mid-range.

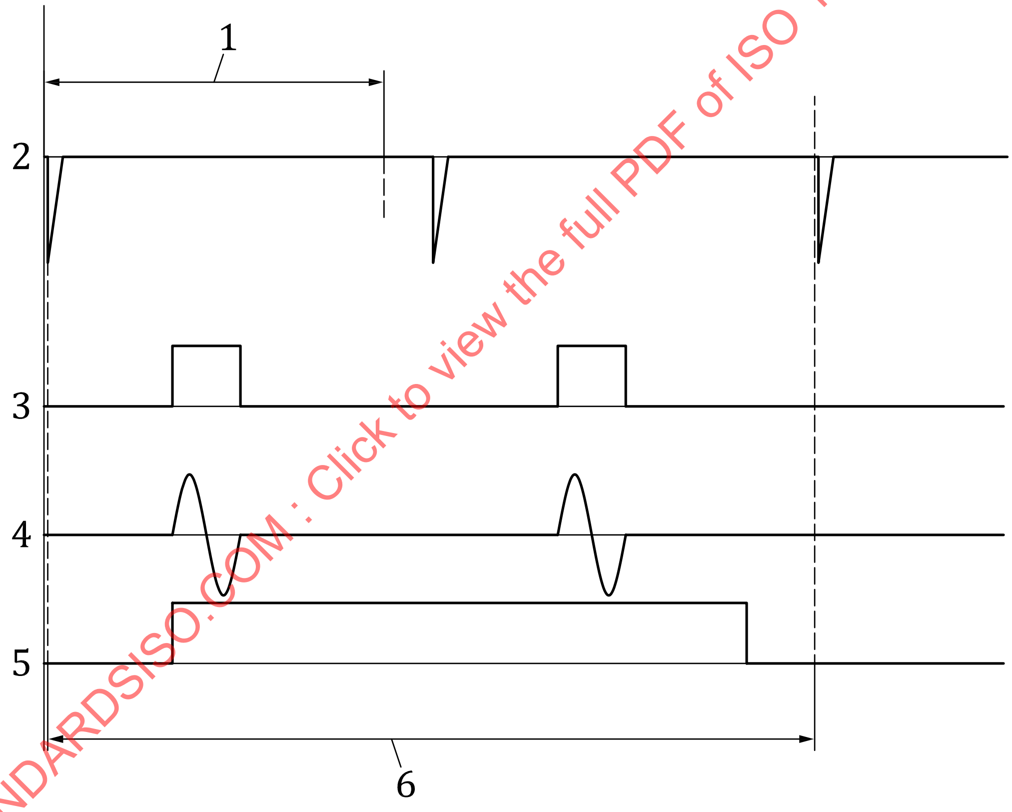
d) Set the pulse generator to produce a single-shot pulse, after which the pulse generator will require rearming before the next pulse (to trigger the signal generator) is generated.

After arming the test signal, an indication should appear on the ultrasonic phased array instrument screen at 80 % of the FSH.

e) If no echo appears or the amplitude is not between 75 % and 85 % of the FSH, increase the number of shots (by increasing the width of the test signal gate used to enable the signal generator as shown in Figure 10 or by setting the pulse generator to multi-cycle mode) until the signal is between 75 % and 85 % of the FSH.

f) Measure the response time (t_{RT}) of the ultrasonic phased array instrument by measuring the time from the start of the transmitter pulse triggering the test signal gate to the start of the transmitter pulse following the end of the test signal gate, as shown in Figure 10.

g) Repeat this test for each setting for the relevant settings which influences the response time of the ultrasonic phased array instrument, such as maximum range or maximum pulse repetition frequency setting.



Key

1 screen width

2 transmitter pulses

3 test enabling signals

4 test signal

5 test signal gate

6 response time

Figure 10 — Timing diagram showing how to measure the response time of digital ultrasonic instruments

8.11.3 Acceptance criterion

The measured response time shall be within the tolerance stated in the manufacturer's specification.

9 Group 2 tests

9.1 Equipment required for group 2 tests

The equipment required for the group 2 tests on ultrasonic phased array instruments includes the following items or functions:

a) oscilloscope with a minimum bandwidth of 100 MHz;

b) (50 ± 0,5) Ω non-reactive resistor;

c) standard 50 Ω attenuator, with 1 dB steps and a total range of 100 dB. The attenuator shall have a cumulative error of less than 0,3 dB in any 10 dB span for signals with a frequency less than or equal to 15 MHz;

d) pulse generator, capable of producing a trigger pulse with or without a defined delay;

e) signal generator, capable of producing a defined sinusoidal signal or a sinusoidal burst signal.

NOTE An arbitrary waveform generator can be used to replace one or both of the above listed generators due to its multifunctional design.

All group 2 tests use electronic means for generating the required signals.

The characteristics and the stability of the equipment employed shall be adequate for the purpose of the tests.

9.2 Physical state and external aspects

9.2.1 Procedure

Visually inspect the outside of the ultrasonic phased array instrument for physical damage which can influence its current operation or future reliability.

9.2.2 Acceptance criteria

The equipment shall be considered acceptable if no physical damage is noted.

9.3 Transmitter

9.3.1 General

9.3.2 and 9.3.3 contain tests for transmitter pulse shape and time delays.

9.3.2 Transmitter pulse voltage, rise time and duration

9.3.2.1 Procedure

The procedure for the measurements shall be performed as follows:

a) Before connecting the oscilloscope, check that the input will not be damaged by the high transmitter voltage.

b) Carry out the measurements at a typical pulse voltage and pulse width and maximum pulse repetition frequency. These typical values shall be specified by the manufacturer.

c) Report the parameters displayed on the ultrasonic phased array instrument used.

d) For measurements on individual channels connect a non-reactive 50 Ω resistor across the transmitter output socket.

e) For measurements with simultaneously activated channels only the internal termination resistors shall be used.

f) Using the oscilloscope, measure

1) pulse rise time from 10 % to 90 % of the amplitude,

2) pulse duration at 50 % of amplitude, and

3) transmitter pulse voltage.

NOTE The measured rise time includes the inherent rise times of the oscilloscope and probe if used.

g) The actual rise time t_r of the ultrasonic phased array instrumentation is given by Formula (9):

$$t_r^2 = t_m^2 - t_s^2 \quad (9)$$

where

t_m is the measured rise time in nanoseconds;

t_s is the oscilloscope rise time in nanoseconds.

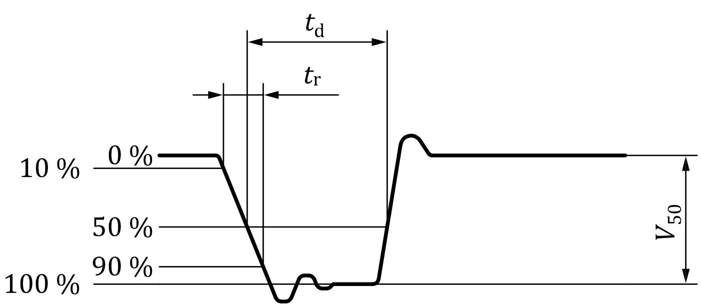
h) The measurements to be carried out on the transmitter signal are illustrated in Figure 11.

i) Repeat the transmitter pulse voltage measurement on all the individual transmitter channels (e.g. on a 16/64 multiplexed ultrasonic phased array instrument, the measurement shall be carried out on 64 channels).

j) Repeat the transmitter pulse voltage measurement when activating all the transmitter channels that can be simultaneously activated (e.g. on a 16/64 multiplexed ultrasonic phased array instrument, the measurement shall be carried out on a group of 16 channels activated).

k) Repeat the measurement of pulse rise time and duration on the transmitter channels which can be simultaneously activated (e.g. on a 16/64 multiplexed ultrasonic phased array instrument, the measurement shall be carried out on 16 channels).

l) The variation of the transmitter pulse amplitudes is given by the transmitter voltage measurements for each channel.



a) Square pulse