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# 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*



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# 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 meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

ISO 18563-1 was prepared by the European Committee for Standardization (CEN), Technical Committee CEN/TC 138, *Non-destructive testing*, in collaboration with ISO/TC 135, *Non-destructive testing*, Subcommittee SC 3 *Ultrasonic testing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

ISO 18563 consists of the following parts, under the general title *Non-destructive testing — Characterization and verification of ultrasonic phased array equipment*:

— *Part 1: Instruments*

— *Part 3: Combined systems*

An additional part on *Probes* is planned.

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

## Part 1: Instruments

## 1 Scope

This part of ISO 18563 identifies the functional characteristics of a multichannel ultrasonic phased array instrument used for phased array probes and provides methods for their measurement and verification.

This part of ISO 18563 can partly be applicable to ultrasonic phased array instruments in automated systems, but then, other tests might 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 part of ISO 18563 gives the extent of the verification and defines acceptance criteria within a frequency range of 0,5 MHz to 10 MHz.

The evaluation of these characteristics permits a well-defined description of the ultrasonic phased array instrument and comparability of instruments.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2400, *Non-destructive testing — Ultrasonic testing — Specification for calibration block No. 1*

EN 1330-4, *Non-destructive testing — Terminology — Part 4: Terms used in ultrasonic testing*

EN 12668-1, *Non-destructive testing — Characterization and verification of ultrasonic examination equipment — Part 1: Instruments*

EN 16018, *Non-destructive testing — Terminology — Terms used in ultrasonic testing with phased arrays*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1330-4, EN 12668-1, EN 16018, and the following apply.

**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

**3.2**
**parallel phased array instrument**
phased array instrument featuring a *maximum number of channels that can be simultaneously activated* (3.1) equal to the number of channels in the instrument

EXAMPLE In a type 64/64 (or 64//), the number of channels that can be simultaneously activated is 64 and the number of channels of the instrument is 64.

**3.3**
**multiplexed phased array instrument**
phased array instrument featuring a *maximum number of channels that can be simultaneously activated* (3.1) smaller than the number of channels in the instrument and which are controlled by an internal multiplexing device

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

**3.4**
**time resolution of the phased array instrument**
inverse of the maximum digitization frequency without processing

## 4 Symbols and abbreviated terms

**Table 1 — Symbols and abbreviations**

| Symbol | 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 |
| $f_0$ | Hz | Centre frequency for each frequency range |
| $f_u$ | 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 |
| $\Delta f$ | Hz | Frequency bandwidth in each frequency range |
| $f_{RR}$ | Hz | Screen refresh rate |
| FSH | | Full screen height |
| $\Delta G$ | 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 |
| $\Delta t$ | 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 |

**Table 1** *(continued)*

| Symbol | Unit | Meaning |
|---|---|---|
| $t_r$ | s | Transmitter pulse rise time from an amplitude of 10 % to 90 % of peak amplitude |
| $t_{Target\ 0}$, $t_{Target\ i}$, $t_{Pi}$, $t_{P\ 0}$, $t_{difi}$, $t_{dif}$ | s | Transmitter or receiver time delay |
| $t_{A1}$, $t_{A2}$ | s | Temporal resolution |
| $V_A$, $V_B$ | V | Pulse voltage amplitudes |
| $V_{ein}$ | V | Receiver equivalent input noise |
| $V_{in}$ | V | Input voltage when measuring the receiver 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 |
| $V_O$ | 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 complies with this part of ISO 18563 if it fulfils all of the following requirements:

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

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

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

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

## 6 Manufacturer's technical specification for phased array 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. This table specifies the information which shall be supplied by the manufacturer in the instrument's technical specification (M = Measurement, OI = Other information). 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 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 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 ultrasonic phased array instrument performance outside of specification | OI | |
| Pulse repetition frequencies (PRFs) | M | Minimum and maximum values |
| Maximum power consumption | OI | VA (volt-amps) |
| Protection grade | OI | |
| Environment | OI | For example: restriction of hazardous substances (RoHS), explosive atmosphere (ATEX), vibration, humidity |
| Multichannel configuration | OI | Number of channels controlled simultaneously and number of available channels |
| Extension of the number of channels by interconnection of 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 delay and depth | OI | |
| List of available views | OI | |
| Screen refresh rate for A-scan presentations | M | |
| Maximum digitization frequency without processing | OI | |
| Digitization frequency with processing | OI | For example: interpolation |
| Digitizer vertical resolution | OI | In bits |
| Highest digitized frequency | M | |
| Time base error | M | |
| M Measurement. | | |
| OI Other information. | | |



 

**Table 2** *(continued)*

| Information | Type of information | Remarks |
|---|---|---|
| **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 | |
| 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, fall time and duration | M | |
| Output impedance | M | |
| Maximum time delay | OI | |
| Time delay resolution | 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 | |

M Measurement.

OI Other information.



 

**Table 2** *(continued)*

| Information | Type of information | Remarks |
|---|---|---|
| Linearity of the vertical display over the extreme frequency ranges of the instrument | M | |
| Frequency response | M | |
| Dead time after transmitter pulse | M | |
| Equivalent input noise | M | $\frac{V}{\sqrt{Hz}}$ |
| Dynamic range | M | |
| Input impedance | M | |
| Maximum time delay | OI | |
| Time delay resolution | M | |
| Time-corrected gain (TCG) | M | |
| Possibility to apply different gain values on each channel | OI | |
| Cross-talk between receivers | M | |
| Linearity of time delays | M | |
| Gain linearity | M | |
| Channel gain variation | M | |
| **Data acquisition** | | |
| Transfer rate between the external storage unit and the instrument (type of link) | OI | |
| 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 warnings | OI | For example: number of sequences before an alarm |
| Linearity of monitor gate amplitude | M | |
| Time-of-flight of the monitor gate | M | |
| Impedance of analogue output | M | |
| Linearity of analogue output | M | |
| M Measurement. | | |
| OI Other information. | | |

**Table 2** *(continued)*

| Information | Type of information | Remarks |
|---|---|---|
| Influence of the measurement signal position in the analogue gate output | M | |
| Rise, fall, and hold time of analogue gate output | M | |
| **Signal processing** | | |
| Processing features | OI | For example: averaging, Fast Fourier Transform (FFT), rectification, envelope, compression, dimensional measurements |
| M Measurement. | | |
| OI Other information. | | |

## 7 Performance requirements for ultrasonic phased array instruments

In order to fulfil the requirements of this part of ISO 18563, ultrasonic phased array instruments shall be verified with the following two groups of tests:

— Group 1: Tests to be performed by the manufacturer (or his agent) on a representative sample of the ultrasonic phased array instruments. High level measurement instruments are required for these tests.

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

a) by the manufacturer (or his 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 measurement 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) are specified in ISO 18563-3. During their lifetime, these are performed at regular intervals on site.

For ultrasonic phased array instruments marketed before the introduction of this part of ISO 18563, continuing fitness for purpose shall be demonstrated by performing the group 2 (periodic) tests every 12 months.

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

Table 3 contains the 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<br>Manufacturing test | Group 2<br>Periodic and repair test |
|---|---|---|
| | Subclause | Subclause |
| Visual inspection | 9.2 | 9.2 |
| **Portable or battery operated instruments** | | |
| Operating time | 8.2.1 | |
| Stability against voltage variations | 8.2.2 | |
| **Stability** | | |
| Stability after warm-up time | 8.3.1 | |
| Stability against temperature | 8.3.2 | |
| **Display** | | |
| Time base error | 8.4.2 | |
| Highest digitized frequency | 8.4.3 | |
| Screen refresh rate for A-scan presentation | 8.4.4 | |
| **Beam forming** | | |
| Summation | 8.8 | |
| **Transmitter** | | |
| Pulse repetition frequency | 8.5.1 | |
| Output impedance | 8.5.2 | |
| Time delay resolution | 8.5.3 | |
| Transmitter voltage, rise time, and duration | 9.3.2 | 9.3.2 |
| Linearity of time delays | 9.3.3 | 9.3.3 |
| **Receiver** | | |
| Cross-talk between receivers | 8.6.1 | |
| Dead time after the transmitter pulse | 8.6.2 | |
| Dynamic range and maximum input voltage | 8.6.3 | |
| Receiver input impedance | 8.6.4 | |
| Time-corrected gain (TCG) | 8.6.5 | |
| Temporal resolution | 8.6.6 | |
| Time delay resolution | 8.6.7 | |
| Linearity of vertical display over the extreme frequency ranges of the instrument | 8.6.8 | |
| Frequency response | 9.4.2 | 9.4.2 |
| Channel gain variation | 9.4.3 | 9.4.3 |
| Equivalent input noise | 9.4.4 | 9.4.4 |
| Gain linearity | 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 monitor gate amplitude | 8.7.2 | |
| Time-of-flight of monitor gate | 8.7.3 | |
| Impedance of analogue output | 8.7.4.1 | |



 

**Table 3** *(continued)*

| Title of the test | Group 1<br>Manufacturing test | Group 2<br>Periodic and repair test |
|---|---|---|
| | Subclause | Subclause |
| Linearity of an analogue output | 8.7.4.2 | |
| Influence of the signal position within the gate | 8.7.4.3 | |
| Rise time, fall time, and hold time of analogue output | 8.7.4.4 | |



# 8 Group 1 tests

## 8.1 Equipment required for group 1 tests

The equipment utilized to obtain the required information should 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 include the following items or functions:

a) oscilloscope;

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) arbitrary waveform generator, capable of producing gated bursts of sinusoidal signals;

g) protection circuit (see Figure 2);

h) impedance analyser;

i) environmental test chamber;

j) regulated DC power supply (for testing the performances of battery operated instruments);

k) phased array probe (2 MHz to 6 MHz);

l) 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 8.3.2), 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 part of ISO 18563, it should be verified that the oscilloscope will not be damaged by the high transmitter voltage.

 

## 8.2 Battery operated phased array instruments

### 8.2.1 Operating time

#### 8.2.1.1 Procedure

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

— fully charged new battery(ies);

— ambient temperature between 20 °C and 30 °C;

— gain set to mid-gain position;

— if the instrument features a screen:

  — display A–scan and S-scan presentations;

  — brightness is set at mid-range.

When made possible by the characteristics of the instrument:

— pulse repetition frequency set to 1 kHz;

— 16 channels active simultaneously;

— 10 delay laws;

— pulse voltage set to 50 V;

— pulse width set to 100 ns;

— 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.



#### 8.2.1.2 Acceptance criterion

The duration measured shall be higher than or equal to the duration specified by the manufacturer.

### 8.2.2 Stability against voltage variations

#### 8.2.2.1 Procedure

The ultrasonic phased array instrument is powered by a regulated DC power supply. The voltage applied is in the centre of the range specified for the use of the instrument.

Apply a nil delay law simultaneously to all available channels. Display the summed A-scan presentation (e.g. using an array probe with centre frequency between 2 MHz and 6 MHz) and a test block to generate a back wall echo.

The echo amplitude shall be set to 80 % of FSH and the time base shall be set so that the displayed signal is at 50 % of the 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.

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

 

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.

#### 8.2.2.2 Acceptance criteria

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

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

## 8.3 Stability tests

### 8.3.1 Stability after warm-up time

#### 8.3.1.1 Procedure

Program the instrument with one active transmitter channel and one different active receiver channel.

Use the signal from the active transmitter channel as the trigger for the signal generator. Connect the signal generator gated output to the active receiver channel. See Figure 3.

Set the instrument range to 50 mm for a velocity of 5 920 m/s, full rectification. Set the signal generator to generate a burst of three cycles at 2 MHz to 6 MHz with a delay of 10 µs. Set the burst amplitude to 100 mV peak-to-peak. Adjust the instrument gain to set the viewed signal to 80 % of FSH.

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

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

#### 8.3.1.2 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 FSH, and

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

### 8.3.2 Stability against temperature

#### 8.3.2.1 Procedure

Program the instrument with one active transmitter channel and one different active receiver channel.

Use the signal from the active transmitter channel as the trigger for the signal generator. Connect the signal generator gated output to the active receiver channel. See Figure 3.

Set the instrument range to 50 mm for a velocity of 5 920 m/s, full rectification. Set the signal generator to generate a burst of three cycles at 2 MHz to 6 MHz with a delay of 10 µs. Set the burst amplitude to 100 mV peak-to-peak. Adjust the instrument gain to set the viewed signal to 80 % of FSH.

The ultrasonic phased array instrument is placed in a climatic chamber and subjected to varying ambient temperatures. 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.



 

#### 8.3.2.2 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 FSH and ±1 % of full screen width respectively.

## 8.4 Display

### 8.4.1 General

The tests described in the following subclauses are performed on one channel only.

### 8.4.2 Time base deviation

#### 8.4.2.1 Procedure

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

Connect the instrument as shown in Figure 4. Set the pulse generator to produce a single-cycle sine wave, with a frequency at the centre frequency, $f_0$, of the widest frequency range. Set the time base to minimum, maximum, and mid-range position in turn. At each setting, adjust the trigger delay, the gain of the ultrasonic phased array instrument, and the external calibrated attenuator to obtain a signal which is at least 80 % of FSH at the centre of the time base. This step defines the time references of the pulse generator.

Vary the trigger delay of the pulse generator in increments smaller than or equal to 5 % of the screen width.

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.

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

#### 8.4.2.2 Acceptance criterion

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

### 8.4.3 Highest digitized frequency

#### 8.4.3.1 Procedure

This test defines the highest 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 FSH.

Program the instrument with one active transmitter channel and one different active receiver channel.

Using the set-up shown in Figure 4, generate a test pulse synchronised to the transmitter pulse. Set the delay, $t$, of the signal to $t_0$, longer than the receiver dead time measured in 8.6.3. Set the frequency of the signal generator at the upper 3 dB limit, measured in 9.4.2, for the filter with the largest bandwidth, including the highest frequency. Adjust the signal generator to produce a single-cycle sine wave with an amplitude of 80 % of FSH. Using the variable time delay, increase $t$ by the following small increment as given in Formula (1):

$$\Delta t = \frac{1}{10 f_u} \quad (1)$$

where

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

At each increment $\Delta t$, measure the amplitude of the signal on the ultrasonic phased array instrument. Continue increasing the time delay and measuring the amplitude until 30 measurements have been recorded (i.e. three periods).

The signal shall not vary by more than ±5 % of FSH, from the largest to the smallest amplitude recorded. If the variation is larger, repeat the test reducing the frequency of the test signal until a variation of ±5 % of FSH is reached.

#### 8.4.3.2 Acceptance criterion

The measured frequency, $f_h$, shall be higher than or equal to the value specified by the manufacturer.

### 8.4.4 Screen refresh rate for A-scan presentations

#### 8.4.4.1 General

The displays of digital ultrasonic phased array instruments have a limited refresh rate which might not match the ultrasonic pulse repetition frequency ($f_R$). The purpose of this test is to verify the screen refresh rate ($f_{RR}$) quoted in the specification.

#### 8.4.4.2 Procedure

Using the set-up shown in Figure 4, produce a burst (test signal) after which, the signal generator will require manual re-arming before the next burst is generated. Adjust the ultrasonic phased array instrument gain to the centre value of its dynamic range and the amplitude of the test pulse to 80 % of FSH on the A-scan presentation.

The number of cycles in the burst shall be chosen so that the duration of the signal corresponds to the refresh rate mentioned in the technical specification of the instrument and the pulse repetition frequency shall be equal to this screen refresh rate.

The signal generator is armed manually 25 times at one second intervals.

#### 8.4.4.3 Acceptance criterion

The screen refresh rate is verified if, each time the signal generator is armed, the test signal (or part of it) is always displayed on the A-scan.

NOTE If the actual screen refresh rate is lower than the value quoted in the technical specification, transient signals might not be displayed.

## 8.5 Transmitter

### 8.5.1 Pulse repetition frequency

#### 8.5.1.1 Procedure

Connect an oscilloscope to one of the transmitter terminals.



 

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

#### 8.5.1.2 Acceptance criterion

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

### 8.5.2 Output impedance

#### 8.5.2.1 Procedure

Before connecting the oscilloscope, it should be checked that the input 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 instrument used shall be reported.

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). Replace this resistor with $R_B$ resistor (e.g. 75 Ω) and measure the transmitter pulse voltage, $V_B$. The measurement shall be made for a mid-range value of the pulse energy and transmitter pulse frequency.

This measurement shall be repeated at least on 10 % of available transmitter channels (e.g. on a 16/64 multiplexed instrument, the measurement shall be carried out on six channels).

For each transmitter, calculate the output impedance, $Z_0$, using Formula (2):

$$Z_0 = R_A \times R_B \times \frac{(V_B - V_A)}{(R_B V_A - R_A V_B)} \qquad (2)$$

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).

#### 8.5.2.2 Acceptance criterion

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

### 8.5.3 Time delay resolution

#### 8.5.3.1 Procedure

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

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

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

Set the transmitting delays to zero for each channel.

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

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

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



 

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

This measurement shall be repeated on each transmitter channel (e.g. on a 16/64 multiplexed instrument, the measurement shall be carried out on 16 channels).

#### 8.5.3.2 Acceptance criterion

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

## 8.6 Receiver

### 8.6.1 Cross-talk between receivers

#### 8.6.1.1 Procedure

Measurement conditions shall be as follows:

— one single active channel;

— all measurements are carried out in a 50 Ω environment;

— all transmitters disabled.

On channel 1, set the gain ($G_1$) of the instrument to its minimum value and then increase it by 10 dB. Using an external generator, apply on channel 1 a continuous sine wave signal with a frequency of 5 MHz (see Figure 4). Set the amplitude so that the peak amplitude of the signal on channel 1 reaches 60 % FSH. If needed, increase the gain ($G_1$) to reach 60 % FSH.

Change the active channel to channel 2 and increase the gain ($G_2$) of the instrument so that the peak amplitude of the signal of channel 2 reaches 60 % FSH.

The cross-talk between channel 1 and channel 2 is defined in dB by Formula (3):

$$CT_{2,1} = G_2 - G_1 \tag{3}$$

Repeat the measurement by changing successively the active channel and gain to the other channels of the instrument. The cross-talk between channel 1 and channel *i* is defined by Formula (4):

$$CT_{i,1} = G_i - G_1 \tag{4}$$

The cross-talk of the instrument is the smallest value recorded.

#### 8.6.1.2 Acceptance criterion

The cross-talk of the instrument shall be greater than the value in the technical specification.

### 8.6.2 Dead time after the transmitter pulse

#### 8.6.2.1 Procedure

Measurement conditions shall be as follows:

— channel 1 active with transmitter and receiver connected;

— all measurements are carried out in a 50 Ω environment;

— the A-scan presentation shows full wave rectified signals.



 

Set the full screen width of the ultrasonic phased array instrument to 10 µs. Adjust the delay time so that the leading edge of the transmitter pulse coincides with the zero screen division.

Connect the circuit shown in Figure 5 with the ultrasonic phased array instrument set to operate with channel one.

NOTE The circuit shown in Figure 2 is used to protect the function generator from the transmitter peak voltage.

If applicable, set the pulse duration to 100 ns. If 5 MHz is not available, then set the pulse duration according to the centre frequency of the widest bandwidth of the ultrasonic phased array instrument.

Set the transmitter voltage to 50 % of the maximum value.

Using the signal generator, a continuous sine wave of 5 MHz (or if 5 MHz is not available, a frequency equal to the centre frequency of the widest bandwidth of the ultrasonic phased array instrument) with an amplitude equal to 5 % of the maximum input voltage (see 8.6.4) is fed into the protection circuit (see Figure 2).

Adjust the gain to make the stabilized signal amplitude reach 50 % of FSH (see Figure 6). Check that the ultrasonic phased array instrument amplifier is not saturated.

For the measured channel, the dead time after transmitter pulse $t_1$ is the duration from the leading edge of the transmitter pulse until the amplitude stabilizes between 45 % and 55 % of FSH.

The test is carried out on one channel only.

#### 8.6.2.2 Acceptance criterion

The instrument dead time shall be less than or equal to the value quoted in the manufacturer's technical specification.

### 8.6.3 Dynamic range and maximum input voltage

#### 8.6.3.1 Procedure

The dynamic range is 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. The test signal of 10 cycles that shall be generated by this equipment is shown in Figure 7. Set the ultrasonic phased array instrument gain controls to minimum gain. Increase the amplitude of the input signal until saturation (measured on the screen or with the gates). Using an oscilloscope, measure (taking due account of the standard attenuator setting) the input voltage amplitude, $V_{max}$, and the corresponding screen height.

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.

Set the gain controls to maximum gain.

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

Adjust the amplitude of the input signal so that it is displayed at 10 % of FSH. Measure (taking due account of the standard attenuator setting) the input voltage amplitude, $V_{min}$.

This measurement shall be repeated for each receiver channel (e.g. on a 16/64 multiplexed instrument, the measurement shall be carried out on 16 channels).



 

The usable dynamic range, $G_D$, is given by Formula (5):

$$G_D = 20\log_{10}\left(\frac{V_{max}}{V_{min}}\right) \quad (5)$$

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

#### 8.6.3.2 Acceptance criterion

The dynamic range of the instrument and $V_{max}$ of the instrument shall be greater than the value quoted in the manufacturer's technical specification.

### 8.6.4 Receiver input impedance

#### 8.6.4.1 Procedure

Real and imaginary parts of the input impedance are determined with an impedance analyser. The transmitter pulse should be disabled while measuring the input impedance. Measurements are to be carried out at the ultrasonic phased array instrument centre frequency and applying mid-range gain.

This measurement shall be repeated on at least 10 % of available receiver channels (e.g. on a 16/64 multiplexed instrument, the measurement shall be carried out on at least six channels).

#### 8.6.4.2 Acceptance criterion

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

### 8.6.5 Time-corrected gain

#### 8.6.5.1 General

The performance of the time-corrected gain or distance–amplitude correction (DAC) is verified by comparing the theoretical DAC curve with the actual curve generated by the ultrasonic phased array instrument. The theoretical curve is plotted from the information supplied by the manufacturer on the operation of the DAC controls. This is compared to the actual curve which is measured by the amplitude variation of a test pulse (one cycle of a sine wave) at a number of positions of the time base over which the DAC is active.

#### 8.6.5.2 Procedure

Activate one channel.

The channel being used shall be disabled in transmission and connected to an external generator. Connect the test equipment as shown in Figure 4. Set the gain of the ultrasonic phased array instrument at minimum value in order to maximize the DAC dynamic range.

The DAC curve activated for this test shall feature the steepest slope enabling to record at least 11 measurement points at regular intervals.

Throughout this test, avoid saturating the amplifier preceding the DAC circuit.

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

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

Increase the delay of the test signal in order to move the signal along the time base by $\Delta t$, as given in Formula (6):

$$\Delta t = \frac{t_{\text{final}} - t_0}{n} \qquad (6)$$

where

$t_0$ is the time at the start of the DAC curve;

$t_{\text{final}}$ is the time at the end of the DAC curve;

$n$ is the number of measurements to be taken.

$n$ shall be greater than or equal to 11.

Adjust the standard attenuator to bring the test signal to 80 % of FSH (or to $H_R$) and record the attenuator setting. Increase the time base position of the test signal by increasing the time delay a further $\Delta t$ and again, record the attenuator setting to bring the test signal to 80 % of FSH (or $H_R$). Continue increasing the time delay and adjusting the standard attenuator until $n$ measurements have been made.

After the last measurement, test the DAC for saturation by increasing the external calibrated attenuation by 6 dB and ensuring that the signal is between 38 % and 42 % of FSH (or $H_R/2 \pm 2$ %). If the signal is not within these limits, reduce the range by $\Delta t$ and repeat the saturation test. The dynamic range of the DAC is measured at the point where saturation no longer occurs.

Plot the actual DAC curve and the theoretical one.

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

### 8.6.5.3 Acceptance criterion

The difference between the theoretical DAC curve and the actual DAC curve shall not exceed ±2 dB.

## 8.6.6 Temporal resolution

### 8.6.6.1 Procedure

The widest frequency band setting of the instrument is selected. Set up the equipment as shown in Figure 4 to generate two single cycle measurement pulses at 5 MHz (or a frequency equal to the centre frequency of the widest bandwidth of the ultrasonic phased array instrument if 5 MHz is not available). These two pulses should follow each other at a distance so that they do not influence each other. The indications are adjusted to 80 % of FSH. The equipment should be arranged so that the amplitude of the two pulses can be varied independently over a 20 dB range.

Using the ultrasonic phased array instrument in full wave rectified signal mode, measure the temporal resolutions ($t_{A1}$ and $t_{A2}$) using the following methods:

a) measurement of the temporal resolution, $t_{A1}$

Decrease the distance between the two measurement pulses until the dip between them is 6 dB. In doing this, both pulses shall not vary by more than 10 % of FSH. The distance from the start edge of the first measurement pulse to the start of the second measurement pulse (measured at the pulse generator) is the temporal resolution $t_{A1}$;

b) measurement of the temporal resolution, $t_{A2}$

Increase the amplitude of the first measurement pulse by 20 dB, while maintaining the amplitude of the second pulse at 80 % of FSH. Decrease the distance between the two measurement pulses until the dip between them is 6 dB (relative to the smaller signal). The distance from the start of the first measurement pulse to the start of the second measurement pulse (measured at the pulse generator) is the temporal resolution $t_{A2}$.

The indication of the smaller measurement pulse shall not vary by more than 10 % of FSH.

The test is carried out on one channel only.

#### 8.6.6.2 Acceptance criterion

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

### 8.6.7 Time delay resolution

#### 8.6.7.1 Procedure

The test is performed on one channel only.

Synchronise the signal generator by means of the ultrasonic phased array instrument synchronisation signal (by default, the pulse from the first channel can be used). Produce a test signal (single-cycle sine wave) by means of the generator. Set the test signal frequency to the centre frequency of the ultrasonic phased array instrument filter with the widest band. Connect the test signal to channel 2.

Select the widest frequency band of the instrument.

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

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

Set the receiving delay to 0 µs for each channel.

Adjust the generator to display the signal in the centre of the time base.

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

Increase the time delay of the instrument by one or more increments, each equal to the time delay resolution quoted by the manufacturer, until the signal is offset on the time base. Record the delay used and the corresponding position of the signal (gates may be used).

Continue incrementing the time delay of the instrument to produce five signal offsets in turn.

#### 8.6.7.2 Acceptance criterion

Time delay resolution 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 quoted by the manufacturer.

### 8.6.8 Linearity of vertical display over the extreme frequency ranges of the instrument

#### 8.6.8.1 Procedure

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

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

— filter including the lowest centre frequency of the instrument;

— filter including the highest centre frequency of the instrument;



 

— filter with the largest bandwidth of the instrument.

#### 8.6.8.2 Acceptance criterion

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

## 8.7 Monitor gate

### 8.7.1 General

All the monitor gate tests use the equipment set-up shown in Figure 4. The generator enables this set-up to generate a test signal, as shown in Figure 8.

### 8.7.2 Linearity of monitor gate amplitude

#### 8.7.2.1 Procedure

Program the instrument with one active transmitter channel and one different active receiver channel.

Using the set-up shown in Figure 4, generate a test pulse synchronised to the transmitter pulse. 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.

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

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

The amplitude of the test signal is changed in steps according to the relative attenuation in Table 4.

The deviation of the amplitude value in the gate from the nominal value (see Table 4) is recorded.

**Table 4 — Expected monitor gate amplitude for specified attenuator settings**

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

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

#### 8.7.2.2 Acceptance criterion

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



 

### 8.7.3 Linearity of monitor gate time-of-flight

#### 8.7.3.1 Procedure

The equipment set-up shown in Figure 4 is used to generate a test signal for each transmitter pulse. Select a mid-gain position and the widest band setting of the ultrasonic phased array instrument. Adjust the triggering of the test signal so as to produce a signal for each transmitter pulse.

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

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

The TOF of the test signal is changed in steps according to the delay in Table 5 using the external generator.

The deviation of the TOF value in the gate from the nominal TOF value (see Table 5) is recorded.

**Table 5 — Expected monitor gate TOF for specified positions in the screen width**

| Position in the screen width<br>% | Nominal time-of-flight value<br>µs |
|---|---|
| 20 | Reference |
| 40 | Reference + 8 µs |
| 60 | Reference + 16 µs |
| 80 | Reference + 24 µs |

#### 8.7.3.2 Acceptance criterion

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

### 8.7.4 Monitor gates with analogue outputs

#### 8.7.4.1 Impedance of analogue output

##### 8.7.4.1.1 Procedure

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.

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.

Set the amplitude of the measurement signal to produce an indication at 80 % of FSH and measure the output voltage, $V_o$. Terminate the analogue output with a resistor of value, $R_l$, which satisfies Formula (7):

$$0{,}75 I_{max} \leq \left( \frac{V_o}{R_l} \right) \leq 0{,}85 I_{max} \quad (7)$$

where:

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

Record the altered output voltage, $V_l$. The (resistive part) of the output impedance is calculated using Formula (8):

$$|Z_A| = \left(\frac{V_o}{V_l} - 1\right) R_l \tag{8}$$

#### 8.7.4.1.2 Acceptance criterion

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

### 8.7.4.2 Linearity of analogue output

#### 8.7.4.2.1 Procedure

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.

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

Adjust the amplitude of the test signal to give an indication at 80 % of FSH and measure the voltage at the analogue output, calling this the reference voltage. The output voltage enabling an indication at FSH is equal to 1,25 times the reference voltage.

The amplitude of the test signal is changed in steps according to Table 6.

The deviation of the output voltage from the nominal value shall be recorded.

**Table 6 — Expected output voltage for specified attenuator settings**

| **Relative attenuation**<br>dB | **Nominal value**<br>% of 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 |

#### 8.7.4.2.2 Acceptance criterion

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



 

#### 8.7.4.3 Influence of signal position within gate

##### 8.7.4.3.1 Procedure

The equipment set-up shown in Figure 4 is used to generate a test signal for each transmitter pulse. Select a mid-gain position and the widest band setting of the ultrasonic phased array instrument. Adjust the amplitude of the signal with the centre frequency, $f_0$, so as to obtain an indication at 80 % of FSH. 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.

##### 8.7.4.3.2 Acceptance criterion

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

#### 8.7.4.4 Rise time, fall time, and hold time of analogue output

##### 8.7.4.4.1 Procedure

The equipment set-up shown in Figure 4 is used to set the triggering of the test signal so as to produce a signal for each transmitter pulse. 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.

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

The rise time is the time interval during which the output voltage increases from 8 % to 72 % of the output voltage at full screen height (see Figure 8). These values are equivalent to 10 % and 90 % of the output signal produced by the test signal.

The fall time is the time interval during which the output voltage decreases from 72 % to 8 % of FSH output voltage (see Figure 8).

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

##### 8.7.4.4.2 Acceptance criterion

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

## 8.8 Summation

### 8.8.1 General

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

### 8.8.2 Procedure

A single-cycle sine wave at 5 MHz (if available) is fed in parallel on the first four channels only.

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

Gain is set at a minimum and the amplitude of the first sine wave cycle of the summated signal is adjusted to 80 % of FSH, using the generator.

Measure the amplitude and the temporal position of the maximum of the four signals.

The variation in amplitude is measured against 80 % of FSH for the three other signals.

The time variation is calculated between two consecutive signals and compared against 1 µs.

### 8.8.3 Acceptance criteria

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

The maximum time variation shall be less than or equal to the time resolution of the instrument.

NOTE The maximum amplitude variation includes the channel variation measured in 9.4.3 increased by a tolerance of ±0,5 dB.



# 9 Group 2 tests

## 9.1 Equipment required for group 2 tests

The equipment necessary to the performance of group 2 tests on ultrasonic phased array instruments include the following:

a) oscilloscope;

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) arbitrary waveform generator, capable of producing gated bursts of sinusoidal signals.

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 Visual inspection

### 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 pulse parameters

### 9.3.1 General

The following subclauses contain tests for transmitter pulse shape and time delays.

### 9.3.2 Transmitter voltage, rise time, and duration

#### 9.3.2.1 Procedure

Before connecting the oscilloscope, it should be checked that the input 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 instrument used shall be reported.

Connect a non-reactive 50 Ω resistor across the transmitter output socket. Using the oscilloscope, measure

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

— pulse duration at 50 % of amplitude, and

— transmitter pulse voltage.

The measurements carried out on the transmitter signal are illustrated in Figure 9.

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

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 instrument, the measurement shall be carried out on 16 channels).

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

#### 9.3.2.2 Acceptance criteria

The following criteria shall be fulfilled.

a) The transmitter pulse voltage (loaded, i.e. $V_{50}$) of each channel shall be within ±10 % of the voltage quoted in the manufacturer's specification.

b) The pulse rise time, $t_r$, shall be shorter than the maximum value quoted in the manufacturer's technical specification.

c) For rectangular and bipolar pulse shapes, the pulse duration, $t_d$, shall be within ±10 % of the value quoted in the manufacturer's technical specification. For spike pulse shapes, the pulse duration, $t_d$, shall be smaller than 1,5 times the expected value and the variation between channels shall be within a ±20 % tolerance.

### 9.3.3 Linearity of time delays

#### 9.3.3.1 Procedure

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

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

Set the transmitting delays to zero for each channel.

Synchronise the oscilloscope using the synchronisation signal of the ultrasonic phased array instrument

NOTE By default, the pulse from the first channel can be used.

Measure on the oscilloscope the time $t_{P0}$ between the synchronisation signal and the pulse from the channel being verified.

Nine transmitting delays shall be applied to the verified channel with an increment equal to 10 % of the maximum transmitting delay from the specification. These nine transmitting delays correspond to the nine target time delays.

For each target time delay ($t_{\text{Target i}}$), measure on the oscilloscope the time ($t_{\text{Pi}}$) between the synchronisation signal and the pulse and calculate the difference, $t_{\text{dif}}$, using Formula (9):

$$t_{\text{dif}} = t_{\text{P i}} - t_{\text{P 0}} - t_{\text{Target i}} \tag{9}$$

Repeat the measurements to determine the time differences ($t_{\text{dif}}$) on all the transmitter channels which can be simultaneously activated (e.g. on a 16/64 multiplexed instrument, the measurement shall be carried out on 16 channels).

#### 9.3.3.2 Acceptance criterion

The maximum difference ($t_{\text{dif}}$) shall be less than 1 % of the value of the maximum time delay quoted in the manufacturer's technical specification.

## 9.4 Receiver

### 9.4.1 General

This subclause gives tests to measure the frequency response, channel gain variation, equivalent input noise, gain linearity, linearity of vertical display, and linearity of time delays.

### 9.4.2 Frequency response

#### 9.4.2.1 Procedure

The measurement conditions shall be as follows:

— one single active channel;

— all measurements carried out in a 50 Ω environment;

— all transmitters disabled.

Using the circuit in Figure 4, a sinusoidal voltage is connected to the first channel by means of an external generator. Set the sinusoidal voltage at the input of the ultrasonic phased array instrument to 100 mV peak-to-peak and adjust the gain to produce a signal at 80 % of FSH.

Select, in turn, each frequency band defined by analogue filters. For each band, vary the frequency of the input signal over the operating range of the instrument and note the frequency ($f_{\text{max}}$), giving the maximum signal amplitude displayed on the screen of the ultrasonic phased array instrument, as well as the height of this level ($A_{\text{max}}$).

NOTE Digital filters are considered as stable; therefore, they do not need to be tested.

It shall be verified that the amplifier is not overloaded and that the input amplitude as displayed on the oscilloscope remains constant.

In turn, increase and decrease the frequency, from $f_{\text{max}}$, in small increments not exceeding 5 % of the nominal bandwidth and note the upper ($f_{\text{u}}$) and lower ($f_{\text{l}}$) frequencies (–3 dB limits) at which the displayed height on the screen of the ultrasonic phased array instrument is 3 dB below the maximum height, $A_{\text{max}}$. Again, make sure that the input signal to the calibrated external attenuator is constant.



 

The centre frequency ($f_0$) for each frequency band is given by Formula (10):

$$f_0 = \frac{f_u + f_l}{2} \tag{10}$$

The bandwidth $\Delta f$ (between −3 dB limits) of each frequency range is defined by Formula (11):

$$\Delta f = f_u - f_l \tag{11}$$

Repeat this measurement on the channel which can be simultaneously active (e.g. for a type 16/64 multiplexed instrument, the measurement shall be carried out on 16 channels).

#### 9.4.2.2 Acceptance criteria

The centre frequency ($f_0$) for each frequency range shall be within ±10 % of the value stated in the manufacturer's technical specification.

The upper ($f_u$) and lower ($f_l$) frequencies for each frequency range shall be within ±10 % of the values stated in the manufacturer's technical specification.

### 9.4.3 Channel gain variation

#### 9.4.3.1 Procedure

Measurement conditions shall be as follows:

— one single active channel;

— all measurements are carried out in a 50 Ω environment;

— all transmitters disabled.

Use the circuit in Figure 4.

Enable channel 1 and using an external generator, connect a sinusoidal voltage with a frequency ($f_0$) which corresponds to the centre frequency of the widest band.

Adjust the voltage and the gain from the generator so that the peak amplitude of the signal from channel 1 is at 80 % of FSH.

Measure the amplitude of the sine curve on the A-scan presentation.

Repeat this measurement on all the channels (e.g. for a type 16/64 multiplexed instrument, the measurement shall be carried out on 64 channels).

$A_{max}$ and $A_{min}$ correspond to the maximum and minimum recorded amplitudes respectively.

The channel gain variation of the instrument is defined by Formula (12):

$$\Delta G = 20 \lg \left( A_{max} / A_{min} \right) \tag{12}$$

#### 9.4.3.2 Acceptance criterion

The value of channel gain variation of the ultrasonic phased array instrument shall be less than 3 dB.

### 9.4.4 Equivalent input noise

#### 9.4.4.1 Procedure

The measurement conditions shall be as follows:

— one single active channel;

— all measurements carried out in a 50 Ω environment;

— all transmitters disabled.

Use the circuit shown in Figure 4. Carry out the measurements of equivalent input noise as follows for the largest bandwidth, using a signal at the centre frequency, $f_0$, of the band.

Set the ultrasonic phased array instrument to maximum gain. Disconnect the input signal and note the noise level on the ultrasonic phased array instrument.

Reduce the gain by 40 dB and reconnect the input signal. Adjust the calibrated external attenuator and/or the input signal level until the RF pulses appear at the same level as the previous noise level. Measure the input signal, $V_{in}$, in volts peak-to-peak from the oscilloscope and the attenuation of the calibrated external attenuator ($S$, dB). The equivalent input noise, $V_{ein}$, (in volts), is calculated using Formula (13):

$$V_{ein} = \frac{V_{in}}{10^{\left(\frac{S+40}{20}\right)}} \tag{13}$$

And the noise per root bandwidth is given by Formula (14):

$$N_{in} = \frac{V_{ein}}{\sqrt{f_u - f_l}} \tag{14}$$

where

$f_u$ and $f_l$ are the frequencies measured in 9.4.2.

Repeat this measurement on the channels which can be simultaneously active (e.g. for a type 16/64 multiplexed instrument, the measurement shall be carried out on 16 channels).

#### 9.4.4.2 Acceptance criterion

The measured values shall be smaller than the value stated in the manufacturer's technical specification.

### 9.4.5 Gain linearity

#### 9.4.5.1 Procedure

The measurement conditions shall be as follows:

— one single channel active;

— all measurements carried out in a 50 Ω environment;

— all transmitters disabled.

Using the circuit shown in Figure 4, connect the first channel to a sinusoidal voltage from an external generator at the centre frequency ($f_0$) of the largest bandwidth, as measured in 9.4.2.

Set the ultrasonic phased array instrument gain to minimum and adjust the reference signal produced by the signal generator to display it without saturation.



 

Increase the gain of the ultrasonic phased array instrument by adequate increments over the complete range of variation. For each value of gain, adjust the calibrated external attenuator to maintain the signal at constant height.

For each increment, note the deviation (in dB) between the value of the gain and that of the external attenuator.

Repeat this measurement on the channels which can be simultaneously active (e.g. for a type 16/64 multiplexed instrument, the measurement shall be carried out on 16 channels) and for each frequency band defined by analogue filters.

As noise might occur at high levels of gain, the measurements shall be performed over the range of gain indicated in the manufacturer's specification.

#### 9.4.5.2 Acceptance criteria

The following criteria shall be fulfilled:

a) deviation of gain shall not exceed ±1 dB in any successive 20 dB span covering the whole range of the instrument;

b) deviation of gain shall not exceed ±0,5 dB in any successive 1 dB span covering the whole range of the instrument;

c) the deviation of gain shall not exceed ±2 dB in the range of gain quoted in the manufacturer's technical specification.

### 9.4.6 Linearity of vertical display

#### 9.4.6.1 Procedure

The measurement conditions shall be as follows:

— one single channel active;

— all measurements carried out in a 50 Ω environment;

— all transmitters disabled.

Using the circuit shown in Figure 4, connect the first channel to a sinusoidal voltage with the centre frequency ($f_0$) included in the widest bandwidth of the available filters (as measured in 9.4.2), by means of an external generator.

Set the external calibrated attenuator to 2 dB and adjust the input signal and the ultrasonic phased array instrument gain to show a signal at 80 % of FSH. Report the related gain setting.

Without changing the gain of the ultrasonic phased array instrument, set the calibrated external attenuator to the values given in Table 7.

For each setting, measure the amplitude of the signal on the screen of the ultrasonic phased array instrument.



 

**Table 7 — Acceptance levels for vertical display linearity**

| External attenuator setting<br>dB | Target amplitude on screen<br>% of FSH | Acceptable amplitude<br>% of FSH |
|---|---|---|
| 0 | 100 | > 98 |
| 1 | 90 | 88 to 92 |
| 2 | 80 | Reference line |
| 4 | 64 | 62 to 66 |
| 6 | 50 | 48 to 52 |
| 8 | 40 | 38 to 42 |
| 12 | 25 | 23 to 27 |
| 14 | 20 | 18 to 22 |
| 20 | 10 | 8 to 12 |
| 26 | 5 | 3 to 7 |

If the instrument can measure signal amplitudes above 100 % of FSH (using the gate), Table 7 should be extended accordingly to the maximum possible measurement.

Repeat this measurement on the channels which can be simultaneously active (e.g. for a type 16/64 multiplexed instrument, the measurement shall be carried out on 16 channels).

#### 9.4.6.2 Acceptance criterion

For each setting, the measured amplitude shall be within the tolerances specified in Table 7.

### 9.4.7 Linearity of time delays

#### 9.4.7.1 Procedure

Synchronise the signal generator by means of the ultrasonic phased array instrument synchronisation signal (by default, the pulse from the first channel can be used). Produce a test signal (single-cycle sine wave) by means of the generator. Set the test signal frequency to the centre frequency of the ultrasonic phased array instrument filter with the widest band.

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

Set the ultrasonic phased array instrument time base delay to 0 µs and connect the test signal to the instrument.

Program the receiving delay to 20 % of the maximum receiving delay, $t_{\text{Target 0}}$.

Adjust the width of the ultrasonic phased array instrument time base to enable the display of the signal for the maximum delay.

Measure the reference time, $t_{\text{P 0}}$, of the test signal (e.g. with the gate) corresponding to the target time delay, $t_{\text{Target 0}}$.

Four successive receiving delays shall be applied with an increment equal to 20 % of the maximum receiving delay from the specification. These four receiving delays shall correspond to the four target time delays, $t_{\text{Target i}}$.