



Designation: E2491 – 23

Standard Guide for Evaluating Performance Characteristics of Phased-Array Ultrasonic Testing Instruments and Systems¹

This standard is issued under the fixed designation E2491; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This guide covers procedures for evaluating some performance characteristics of phased-array ultrasonic examination instruments and systems.

1.2 Evaluation of these characteristics is intended to be used for either comparing instruments and systems or, by periodic repetition, for detecting long-term changes in the characteristics of a given instrument or system. Significant changes may be indicative of impending failure, and, if beyond certain limits, will require corrective maintenance. Some electronic instrument characteristics in phased-array units are similar to non-phased-array units and may be measured as described in Practice [E1065](#) or Guide [E1324](#).

1.3 Ultrasonic examination systems using pulsed-wave trains and A-scan presentation (rf or video) may be evaluated.

1.4 This guide establishes no performance limits for examination systems; if such acceptance criteria are required, these shall be specified by the using parties. Where acceptance criteria are implied herein, they are for example only and are subject to more or less restrictive limits imposed by customer's and end user's controlling documents.

1.5 The specific parameters to be evaluated, conditions, frequency of test, and report data required shall be determined by the user.

1.6 This guide may be used for the evaluation of a complete examination system, including search unit, instrument, interconnections, scanner fixtures, connected alarm, and auxiliary devices. This guide is not intended to be used as a substitute for calibration or standardization of an instrument or system to inspect any given material.

1.7 Required test apparatus includes selected test blocks and position encoders in addition to the instrument or system to be evaluated.

1.8 Alternate procedures, such as examples described in this document, or others, may only be used with customer approval.

1.9 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.10 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.11 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

- [E317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Instruments and Systems without the Use of Electronic Measurement Instruments](#)
- [E494 Practice for Measuring Ultrasonic Velocity in Materials by Comparative Pulse-Echo Method](#)
- [E1065 Practice for Evaluating Characteristics of Ultrasonic Search Units](#)
- [E1316 Terminology for Nondestructive Examinations](#)
- [E1324 Guide for Measuring Some Electronic Characteristics of Ultrasonic Testing Instruments](#)

3. Terminology

3.1 Refer to Terminology [E1316](#) for definitions of terms in this guide.

4. Summary of Guide

4.1 Phased-array instruments and systems have similar individual components as traditional ultrasonic systems. These

¹ This guide is under the jurisdiction of ASTM Committee [E07](#) on Nondestructive Testing and is the direct responsibility of Subcommittee [E07.06](#) on Ultrasonic Method.

Current edition approved June 1, 2023. Published August 2023. Originally approved in 2006. Last previous edition approved in 2018 as E2491 – 13 (2018). DOI: 10.1520/E2491-23.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard

include pulsers, receivers, probes, and interconnecting cables. The most significant difference is that phased-array systems form the transmitted ultrasonic pulse by constructive phase interference from the wavelets formed off the individually pulsed elements of the phased-array probes.

4.2 Each phased-array probe consists of a series of individually wired elements that are activated separately using a programmable time delay pattern. Varying the number of elements used and the delay time between the pulses to each element allows control of the beam. Depending on the probe design, it is possible to electronically vary the angle (incident or skew), the focal distance, the beam dimensions, or a combination of the three. In the receiving mode, acoustic energy is received by the elements and the signals undergo a summation process utilizing the same type of time delay process as was used to generate the pulse.

4.3 The degree of beam steering available is dependent on several parameters including; number of elements, element pitch, element dimensions, element array shape, resonant frequency of the elements, the material into which the beam is directed, the minimum delay possible between firing of adjacent pulsers and receivers, and the pulser voltage characteristics.

4.4 Pulser and receiver parameters in phased-array systems are generally computer controlled and the received signals are typically displayed on computer monitors via computer data acquisition systems and may be stored to computer files.

4.5 Although most systems use piezo-electric materials for the elements, electro-magnetic acoustic transducer (EMAT) devices have also been designed and built using phased-array instrumentation.

4.6 Most phased array systems can use encoders for automated and semi-automated scanning.

4.7 Side Drilled Holes used as targets in this document should have diameters less than the wavelength of the pulse being assessed and long enough to avoid end effects from causing interfering signals. This will typically be accomplished when the hole diameter is between about 1.5 mm and 2.5 mm and 20 mm to 25 mm in length.

4.8 Procedures for assessment of several parameters in phased-array systems are described in [Annex A1 – Annex A7](#).

4.8.1 These include; determination of beam profile ([Annex A1](#)), beam steering capability ([Annex A2](#)), element activity ([Annex A3](#)), focusing capability ([Annex A4](#)), software calculations ([Annex A5](#)), compensation for wedge attenuation and delay ([Annex A6](#)), and receiver linearity ([Annex A7](#)).

5. Significance and Use

5.1 This guide is intended to evaluate performance assessment of combinations of phased-array probes and instruments. It is not intended to define performance and acceptance criteria, but rather to provide data from which such criteria may be established.

5.2 Recommended procedures described in this guide are intended to provide performance-related measurements that can be reproduced under the specified test conditions using simple targets and the phased-array test system itself. It is intended for phased-array flaw detection instruments operating in the nominal frequency range of 1 MHz to 20 MHz, but the procedures are applicable to measurements on instruments utilizing significantly higher frequency components.

5.3 This guide is not intended for service calibration, or maintenance of circuitry for which the manufacturer's instructions are available.

5.4 Implementation of specific assessments may require more detailed procedural instructions in a format of the using facility.

5.5 The measurement data obtained may be employed by users of this guide to specify, describe, or provide performance criteria for procurement and quality assurance, or service evaluation of the operating characteristics of phased-array systems.

5.6 Not all assessments described in this guide are applicable to all systems. All or portions of the guide may be used as determined by the user.

6. Keywords

6.1 characterization; focal point; phased-array; phased-array probe; sound beam profile; ultrasound