Designation: E2904 – 22

Standard Practice for Characterization and Verification of Linear Phased Array Ultrasonic Probes[1]

This standard is issued under the fixed designation E2904; 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 practice covers measurement procedures for evaluating certain characteristics of phased-array ultrasonic probes that are used with phased-array ultrasonic examination instrumentation.

1.2 This practice describes means for obtaining performance data that may be used to define the acoustic and electric responses of phased-array ultrasonic probes including contact (with or without a wedge) and immersion linear phased-array probes used for ultrasonic nondestructive testing with central frequencies ranging from 0.5 MHz to 10 MHz. Frequencies outside of this range may use the same methods but the testing equipment may vary.

1.3 When ultrasonic values dependent on material are specified in this practice, they are based on carbon steel with an ultrasonic wave propagation speed of 5920 m/s (±50 m/s) for longitudinal wave modes and 3255 m/s (±30 m/s) for transverse or shear wave modes.

1.4 This practice describes some of the characterization and verification procedures that can be carried out at the end stage of the manufacturing process of linear phased array probes. This practice does not describe the methods or acceptance criteria used to verify the performance of the combined phased array ultrasonic instrument and probe system.

1.5 While this practice is intended to provide standardized procedures for evaluating linear phased-array ultrasonic probes, it may, with suitable modifications, be used for evaluation of configurations other than linear; for example, 1.5D or 2D matrix array probes.

1.6 *Units*—The values stated in SI units are to be regarded as the standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.7 *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.*

1.8 *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]

E1065 Practice for Evaluating Characteristics of Ultrasonic Search Units

E1316 Terminology for Nondestructive Examinations

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, see Terminology E1316.

3.1.2 *Technical Specification of the Phased Array Probes:*

3.1.2.1 *certification, n*—defined as measured performance of an individual probe. This is the document that reports the measured performance of a specific probe (specific to a serial number).

3.1.2.2 *datasheet, n*—defined as specification. This is the document that defines the general geometry and expected performance of a specific model or part number.

3.1.2.3 *probe shape and size, n*—probe form and dimensions.

3.1.2.4 *probe type, n*—contact or immersion.

3.1.3 *Terminology for Array Probes:*

3.1.3.1 *active aperture, n*—pitch times the number of elements.

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

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[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

3.1.3.2 *element length, n—in a rectangular element*, the acoustic element's long dimension. See *passive aperture* (also called element elevation) and Fig. 3.

3.1.3.3 *element pitch (or pitch), n*—the distance between the centers of two adjacent array elements.

3.1.3.4 *element width, n—in a rectangular element*, the acoustic element's short dimension.

3.1.3.5 *passive aperture, n*—the dimension of an array element's length.

3.1.3.6 *saw cut, n*—also called "kerf," space or gap. The space between adjacent elements.

4. Summary of Practice

4.1 The physical, acoustic and electrical characteristics which can be described from the data obtained by procedures outlined in this guide are described as follows.

4.2 *Physical Aspects*—Identification and physical dimension aspects of the probe should be noted. Details to be noted are described in 7.1.

4.3 *Center Frequency, Bandwidth And Time Response*—Section 7.2 describes procedures for determining center frequency, bandwidth, and time response of the individual elements of the linear array probe.

4.4 *Sensitivity Range Of Elements*—Section 7.3 describes a procedure to determine variation of sensitivity from one element to the next based on a fixed input voltage.

4.5 *Probe Sensitivity*—The overall sensitivity performance of all the elements in the array is assessed in the procedure described in 7.4.

4.6 *Element Crosstalk*—A procedure for assessment of damping between elements to eliminate crosstalk is provided in 7.5.

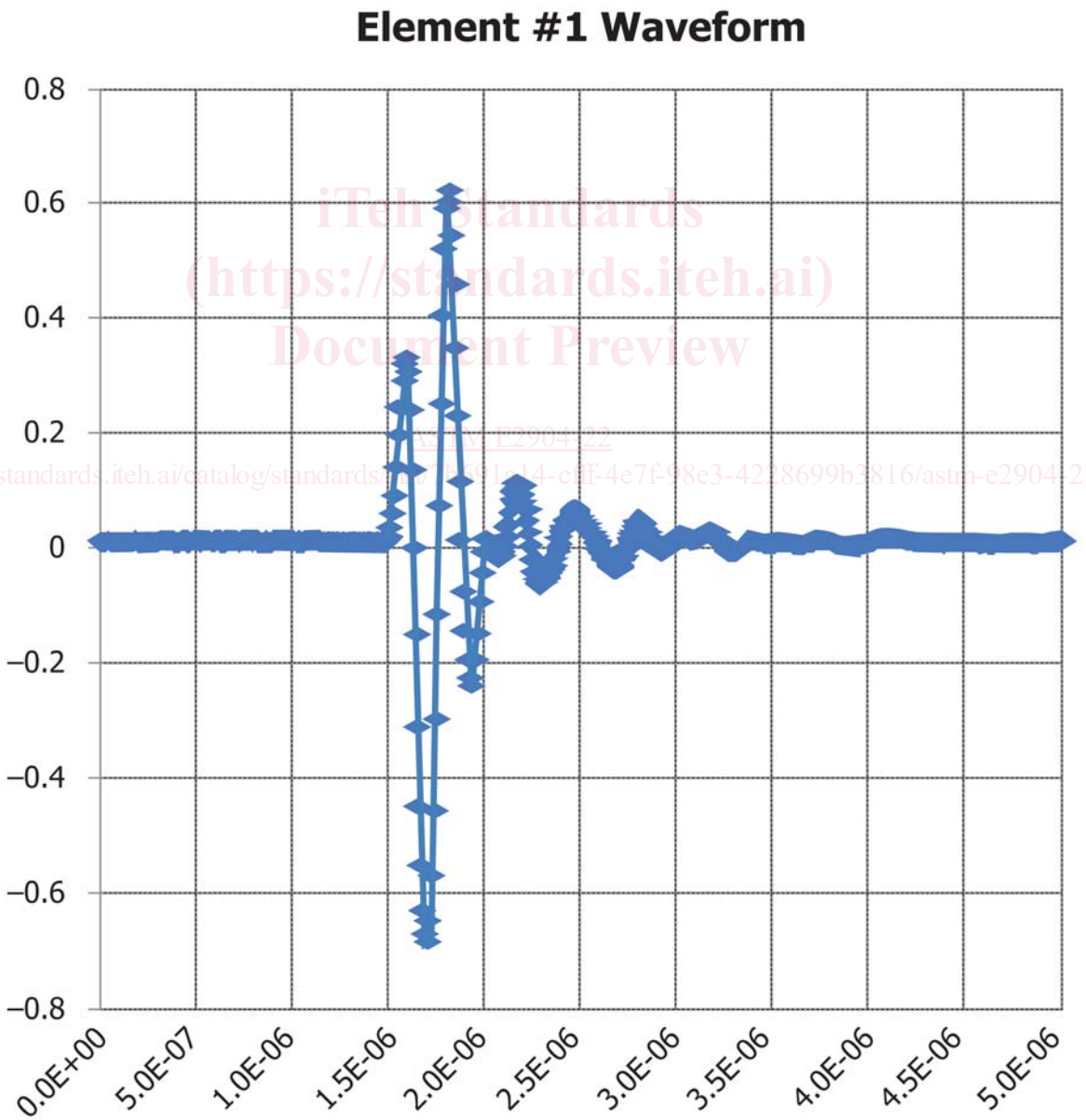


FIG. 1 Schematic Showing Digitization Rate

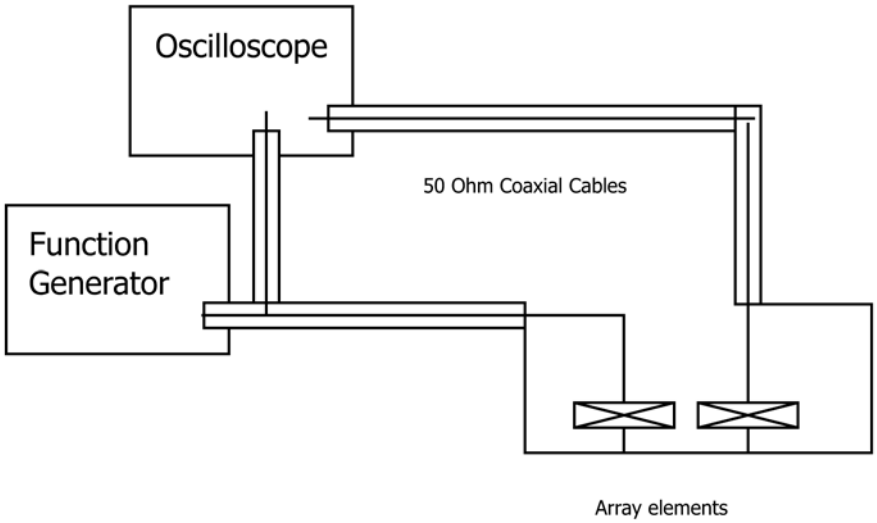
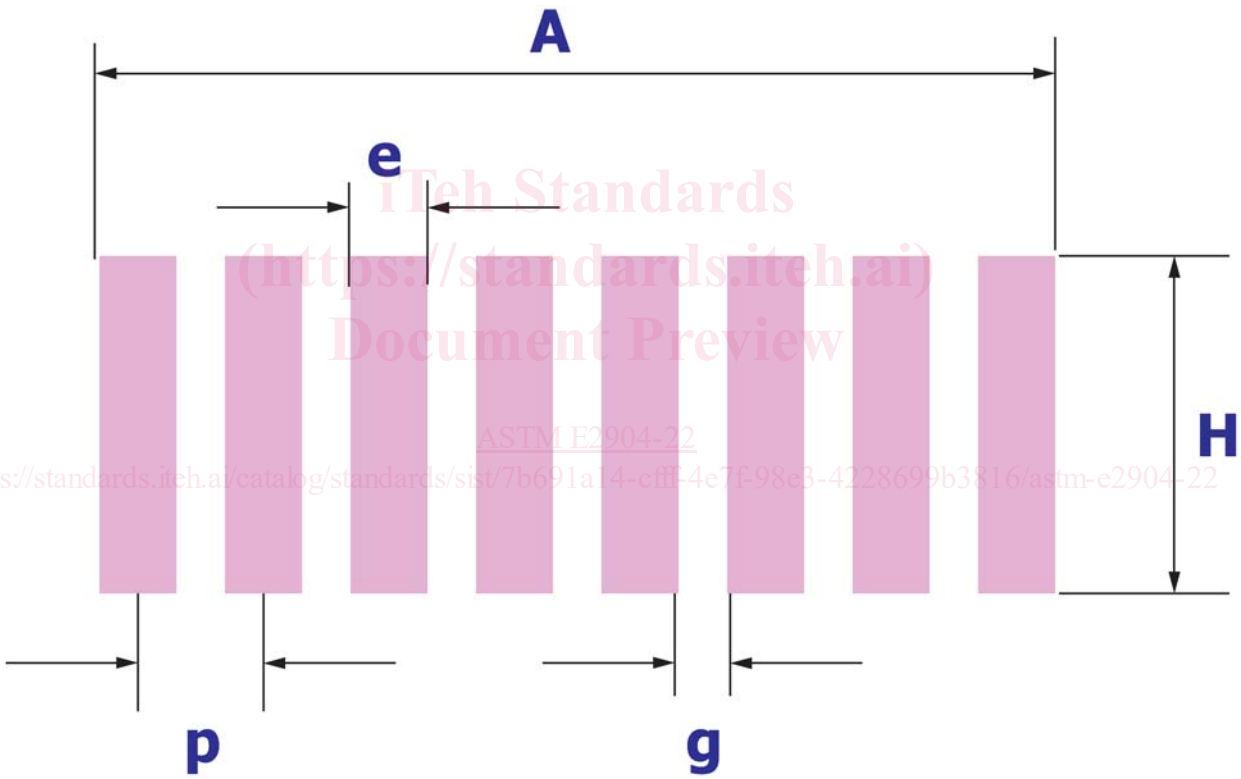


FIG. 2 Two-Channel Schematic Showing Measurement Technique for Crosstalk



Legend:
A = active aperture (number of active elements x element pitch)
H = passive aperture
e = element width
p = element pitch
g = saw cut between elements (also called kerf or gap)

FIG. 3 Schematic of Key Parameters for Linear Arrays

5. Significance and Use

5.1 This practice is intended to provide standardized procedures for evaluating linear phased-array ultrasonic probes. It is not intended to define performance and acceptance criteria, but rather to provide data from which such criteria may be established.

5.2 Implementation may require more detailed procedural instructions in a format of the using facility.

5.3 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 linear phased-array ultrasonic probes. All or portions of the standard practice may be used as determined by the user.

5.4 The measurements are made primarily under pulse-echo conditions. To determine the relative performance of a probe element as either a transmitter or a receiver may require additional tests.

5.5 While these procedures relate to many of the significant parameters, others that may be important in specific applications may not be treated. These might include power handling capability, breakdown voltage, wear properties of contact units, radio-frequency interference, and the like.

5.6 Care must be taken to ensure that comparable measurements are made and that users of the standard practice follow similar procedures. The conditions specified or selected (if optional) may affect the test results and lead to apparent differences.

5.7 Interpretation of some test results, such as the shape of the frequency response curve, may be subjective. Small irregularities may be significant. Interpretation of the test results is beyond the scope of this practice.

5.8 Certain results obtained using the procedures outlined may differ from measurements made with phased-array ultrasonic test instruments. These differences may be attributed to differences in the nature of the experiment or the electrical characteristics of the instrumentation.

5.9 The pulse generator used to obtain the frequency response and time response of the probe must have a rise time, duration, and spectral content sufficient to excite the probe over its full bandwidth, otherwise time distortion and erroneous results may result.

6. Instrumentation

6.1 *Electronic Instruments:*

6.1.1 The type of instrument(s) used for the tests specified in Section 7 shall be the same as that indicated on the Certification report and Table 2. They shall also be compliant with the applicable verification standard for the inspection unit.

6.1.2 The following equipment is required in order to evaluate the probes in compliance with this practice:

6.1.2.1 A pulser/receiver with a minimum bandwidth of 20 MHz, digitizing to 100 MHz, or better, and an oscilloscope (or equivalent) with a minimum bandwidth of 100 MHz. A phased-array instrument which contains the equivalent combination may be used.

6.1.2.2 Digitizing should be able to get 10 samples in maximum slope of waveform, as illustrated in Fig. 1.

6.1.2.3 A frequency spectrum analyzer with a minimum bandwidth of 100 MHz or a digital oscilloscope/converter capable of performing fast Fourier transforms (FFT), or waveform capture and digital analysis, or a combination thereof.

6.1.2.4 An impedance analyzer.

6.1.2.5 A waveform generator with burst-mode capability for a sine wave at the nominal frequency of the probe.

6.1.3 The following additional equipment is optional:

6.1.3.1 A hydrophone with an active diameter two times smaller than the central ultrasonic wavelength of the probe being tested, but no less than 0.5 mm.

6.2 *Test Blocks and Other Equipment:*

6.2.1 *For Contact Arrays with Integral Wedges:*

6.2.1.1 Blocks made of the same material as the wedge (acrylic, polystyrene, etc.) in shapes complementary to the wedge, allowing sound paths to be equalized.

TABLE 1 List of Variables for Probe Manufacture and Testing

Information Needed	Information Type (C, I, M)[A]	Optional or Required	Observations
Name of Manufacturer	I	Required	
Probe type	I	Required	
Instruments and settings used in the test process	I	Required	See Table 2
Test conditions	I	Required	Coupling medium, sound path, target, fixturing See Table 2
Probe Dimensions or shape	M or I	Optional	Casing dimensions
Element shape and size (active and passive apertures)	I	Optional	Arrangement of the array(s) Dimensions and geometry of the array(s)
Relative position of array in housing	I	Optional	Location of first or last element in relation to the housing
Pitch, gap between elements, element width, length and dimensions	I	Required	Pitch, gap between elements (saw cut), and element dimensions (length and width)
Connector type	I	Required	
Dimensions and material of integrated wedge	I	Optional	Applicable to contact probes Dimensions and geometry of integrated wedge(s)
Wiring	I	Optional	Cable length and external diameter
Center frequency, bandwidth, and time response	M	Required	
Relative Sensitivity Range of the Elements	M or C in dB	Required	Basic voltage indication of each element
Probe sensitivity	M	Required	
Probe crosstalk	I or C in dB	Optional	Must state medium if crosstalk reported

[A] Legend:
C = Calculations
I = Information
M = Measurement