**Designation: ~~E2002 – 15~~ E2002 – 22**

# Standard Practice for Determining ~~Total~~ Image Unsharpness and Basic Spatial Resolution in Radiography and Radioscopy[1]

This standard is issued under the fixed designation E2002; 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 the design and basic use of a gauge used to determine the ~~total~~ image unsharpness and the basic spatial resolution of film radiographs or of digital images taken with CR imaging plates, digital detector arrays, or radioscopic systems.

1.2 This practice is applicable to radiographic and radioscopic imaging systems utilizing X-ray and gamma ray radiation sources.

1.3 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 The gauge described can be used effectively with tube voltages up to 600 kV. ~~When using source voltages in the megavolt range the results may not be completely satisfactory.~~

1.5 When using source voltages in the megavolt range, the results may not be completely satisfactory. The gauge may be used in the MV range, preferably for characterization of detectors without object.

1.6 *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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *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]

E543 Specification for Agencies Performing Nondestructive Testing

E747 Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology

E1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiography

E1316 Terminology for Nondestructive Examinations

[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.01 on Radiology (X and Gamma) 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.

E1815 Test Method for Classification of Film Systems for Industrial Radiography

2.2 *ISO Standards*[3]

ISO ~~19232–1~~9712 ~~Non-destructive Testing—Image Quality of Radiographs—Part 1: Image Quality Indicators (Wire Type)—Determination of Image Quality Value~~Non-Destructive Testing—Qualification and Certification Of NDT Personnel

~~ISO 19232–2 Non-destructive Testing—Image Quality of Radiographs—Part 2: Image Quality Indicators (Step/Hole Type)—Determination of Image Quality Value~~

ISO 19232–5 Non-destructive Testing—Image Quality of Radiographs—Part 5: Determination of Image Unsharpness Value Using Duplex Wire Type Image Quality Indicators

ISO/IEC 17050–1 Conformity Assessment—Supplier's Declaration of Conformity—Part 1: General Requirements

2.3 *CEN ~~Standard:~~Standards:*[4]

EN-462-5:1996 Nondestructive Testing—Image Quality of Radiographs—Part 5: Image Quality Indicators (Duplex Wire Type)—Determination of Total Image Unsharpness Value[5]

EN 4179 Aerospace Series — Qualification and Approval of Personnel for Non-destructive Testing

2.4 *ANSI/ASNT Standards:*[6]

ANSI/ASNT CP 189 Standard for Qualification and Certification of Nondestructive Testing Personnel

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

2.5 *AIA Standard:*[7]

NAS410 Certification & Qualification of Nondestructive Test Personnel

## 3. Terminology

3.1 *Definitions*—Definitions of terms applicable to this practice may be found in Terminology E1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *basic spatial resolution of the detector - visual ($vSR_b^{detector}$)*—determined from the smallest number of the duplex wire pair that is visually not separable in a film radiograph on a viewing station or on a monitor image with the duplex wire IQI directly on the detector with no object.

3.2.2 *basic spatial ~~image resolution (SR~~resolution of the imaging system - visual ($vSR_b^{image}$~~) value—)~~*—determined with the IQI on the object (side closest to X-ray source) or beside the object from the smallest number of the duplex wire pair, which is ~~not separable by visual inspection or from the smallest number of the duplex wire pair with less than 20% modulation depth in a linearized profile, and corresponds to~~visually not separable in a film radiograph on a viewing ~~½ · U~~station ~~$_T$. $U_T$ may be $U_T^{visual}$~~or ~~U~~on~~$_T^{20\%}$.~~ a monitor.

3.2.3 *detector unsharpness – interpolated ($iU_{detector}$)*—two times the Basic Spatial Detector Resolution - interpolated (2 x $iSR_b^{detector}$).

3.2.4 *detector unsharpness - visual ($vU_{detector}$)*—two times the Basic Spatial Detector Resolution - visual (2 x $vSR_b^{detector}$).

3.2.5 *duplex wire type image quality indicator*—duplex wire type IQI image quality indicator ~~(IQI)~~ specifically designed to assess the ~~total~~ image unsharpness and basic spatial image resolution of a radiograph or a digital image and composed of a series of pairs of wire elements made of high density metal.

3.2.6 ~~*interpolated basic spatial image resolution (iSR*~~*image unsharpness -~~$_b^{image}$~~) value—* interpolated ($iU_{Im}$)*~~—determined from the modulation values of different neighbored duplex wire pairs by interpolation,~~two times the Basic Spatial Resolution of the imaging system - interpolated (2 x ~~*which corresponds to iSR½ · iU$_{Tb}^{20\%}$*~~*image*~~.~~).

3.2.7 ~~*interpolated total image unsharpness (iU$_T$ = iU*~~*visual ($vU_{Im}^{20\%}$)*~~—value determined from a profile function in a digital image by interpolation – is~~two times the Basic Spatial Resolution of the imaging system - visual (2 x ~~*determined vSR$_b^{image}$*~~ ~~from a linearized profile function and obtained by interpolation to 20% modulation depth from neighbored element modulations.~~).

[3] Available from International Organization for Standardization (ISO), ISO Central Secretariat Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

[4] Available from British Standards Institute (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., http://www.bsi-global.com.

[5] Not an active standard, but still used as a reference in companies' procedures.

[6] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

[7] Available from Aerospace Industries Association (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209, http://www.aia-aerospace.org.

3.2.8 *linearized profile*—a graph, generated by an image processing software, which shows the pixel values, which are proportional to the radiation dose versus a spatial position as, for example, duplex wire IQI length.

3.2.9 *linepair per mm (lp/mm) value*—determined from the duplex wire pair values ~~or the interpolated values,~~ and corresponds to $1/U_{~~Ilm~~}$. ~~U~~(IQI$_T$ ~~may be U~~on the object$_T^{visual}$, ~~U~~ or$_T^{20\%}$, ~~or iU~~ beside the$_T^{20\%}$. object) or $1/U_{detector}$ (IQI on the detector).

3.2.9.1 *Discussion*—

The corresponding values are given in Table 1.

~~3.2.6 *total image unsharpness ($U_T = U_T^{visual}$)*—determined visually—is determined from the smallest number of the duplex wire pair, which is visually not separable in a film radiograph on a viewing station or on a monitor image.~~

~~NOTE 1—The corresponding unsharpness values are given in Table 1.~~

~~3.2.7 *total image unsharpness ($U_T = U_T^{20\%}$)*—value, determined from a profile function in a digital image – is determined from the smallest number of the duplex wire pair, which is separable by a profile function with less than 20% modulation depth in a linearized profile.~~

## 4. Summary of Practice

4.1 When it is determined necessary to evaluate and measure the ~~total~~ image or detector unsharpness or the basic spatial resolution of an imaging system or a detector separately and apart from contrast sensitivity measurements, a tool or gauge as described in this practice can be used. Conventional IQIs as described in Practices E747 ~~and~~or E1025~~, or ISO 19232-1 and ISO 19232-2.~~ ~~Combine~~ combine the contrast sensitivity and resolution measurements into an overall figure of merit. Such figures of merit may not be adequate to detect subtle changes in the imaging system's performance. For example, in a high-contrast image, unsharpness can increase with almost no noticeable effect upon the overall image contrast, but the contrast sensitivity for fine details will be reduced. Similarly, in an application in which the imaging system provides a very sharp image, contrast can fade with little noticeable effect upon the overall image contrast. These situations often develop and may go undetected until the system performance deteriorates below acceptable image quality limits.



**TABLE 1 Duplex Wire Number, Corresponding ~~Total~~Image Unsharpness, Basic Spatial ~~Resolution,~~ Resolution of the Imaging System, Linepair Readings, and Wire Diameters and ~~their~~Its Tolerances**[A]

| ~~Wire Material~~ | ~~Duplex Wire Number~~ | ~~Corresponding Unsharpness Value ($U_T$) (mm)~~ | ~~Corresponding Basic Spatial Resolution $SR_b$ Value (mm)~~[D] | ~~Corresponding Linepair Value (lp/mm)~~ | ~~Wire Diameter and Spacing, $d$ (mm)~~ | ~~Tolerance of Wire Diameter and Wire Spacing (mm)~~ | |
|---|---|---|---|---|---|---|---|
| Wire Material | Duplex Wire Number | Corresponding Unsharpness Value $U_{Im}$ (mm) | Corresponding Basic Spatial Resolution $SR_b^{image}$ Value (mm)[D] | Corresponding Linepair Value (lp/mm) | Wire Diameter and Spacing, $d$ (mm) | Tolerance of Wire Diameter and Wire Spacing (mm) | |
| ~~Pt~~[B] | ~~D13~~ | ~~0.10~~ | ~~0.050~~ | ~~10.0~~ | ~~0.05~~ | | |
| Pt[B] | D13 | 0.10 | 0.050 | 10.0 | 0.050 | | |
| Pt | D12 | 0.13 | 0.063 | 7.94 | 0.063 | ~~±0.005~~ | |
| Pt | D11 | 0.16 | 0.080 | 6.25 | 0.08 | | ±0.005 |
| Pt | D10 | 0.20 | 0.100 | 5.00 | 0.10 | | |
| Pt | D9 | 0.26 | 0.130 | 3.85 | 0.13 | | |
| Pt | D8 | 0.32 | 0.160 | 3.13 | 0.16 | | |
| Pt | D7 | 0.40 | 0.200 | 2.50 | 0.20 | | |
| Pt | D6 | 0.50 | 0.250 | 2.00 | 0.25 | ±0.01 | |
| Pt | D5 | 0.64 | 0.320 | 1.56 | 0.32 | | |
| Pt | D4 | 0.80 | 0.400 | 1.25 | 0.40 | | |
| W[C] | D3 | 1.00 | 0.500 | 1.00 | 0.50 | | |
| W | D2 | 1.26 | 0.630 | 0.79 | 0.63 | ±0.02 | |
| W | D1 | 1.60 | 0.800 | 0.63 | 0.80 | | |

[A] This table is based on data provided in ISO 19232-5:2013. All unsharpness values are rounded to two ~~decimal places.~~ digits after the dot.
[B] Pt = Platinum.
[C] W = Tungsten.
[D] ~~For~~ For conversion of the $SR_b$-values to µm, multiply values which are given in mm by 1000.

## 5. Significance and Use

5.1 The gauge is intended to provide a means for measuring ~~total~~ image or detector unsharpness and basic spatial ~~image resolution~~ resolution of the image or detector as independently as practicable from the imaging system and contrast sensitivity limitations. ~~A similar description of the gauge's construction may be found in ISO 19232-5.~~ When the duplex gauge is positioned directly on the film or the digital detector ~~without any test object between them, the total image unsharpness or basic spatial image resolution is equivalent~~ and not on the test object, then the determined unsharpness corresponds to the inherent film or detector unsharpness (~~U~~($U_{idetector}$) and the determined basic spatial resolution corresponds to the basic spatial detector resolution ~~(SR~~$SR_b^{detector}$~~).~~ .~~Alternatively, line pair gauges with constant bar thickness of high attenuating material can be used to determine total image unsharpness and basic spatial resolution of radiologic imaging systems. They may produce different results up to one wire pair as compared to duplex wire measurements as described in this standard.~~

NOTE 1—The gauge, described in ISO 19232-5, is equivalent to this standard in the dimensions and the evaluation procedure.

5.2 *Basis of Application*

5.2.1 The following items are subject to contractual agreement between the parties using or referencing this practice.

5.2.1.1 *Personnel Qualification*—Personnel performing examinations to this practice shall be qualified in accordance with NAS410, EN 4179, ANSI/ASNT CP 189, ISO 9712, or SNT-TC-1A and certified by the employer or certifying agency as applicable. Other equivalent qualification documents may be used when specified on the contract or purchase order. The applicable revision shall be the latest unless otherwise specified in the contractual agreement between parties.

5.2.1.2 If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Specification E543. The applicable edition of Specification E543 shall be specified in the contract.

## 6. Gauge Construction

6.1 The standard[8] duplex wire IQI shall be fabricated in accordance with Fig. 1, using the measures and tolerances given in Table 1. ~~This gauge is identical to that described in ISO 19232-5: 2013, and if necessary, ISO 19232-5: 2013 may be reviewed for additional information.~~

NOTE 2—This gauge is identical to that described in ISO 19232-5 and if necessary, ISO 19232-5 may be reviewed for further information.

NOTE 3—ISO 19232-5 describes an equivalent IQI which is compatible to the requirements of Fig. 1.

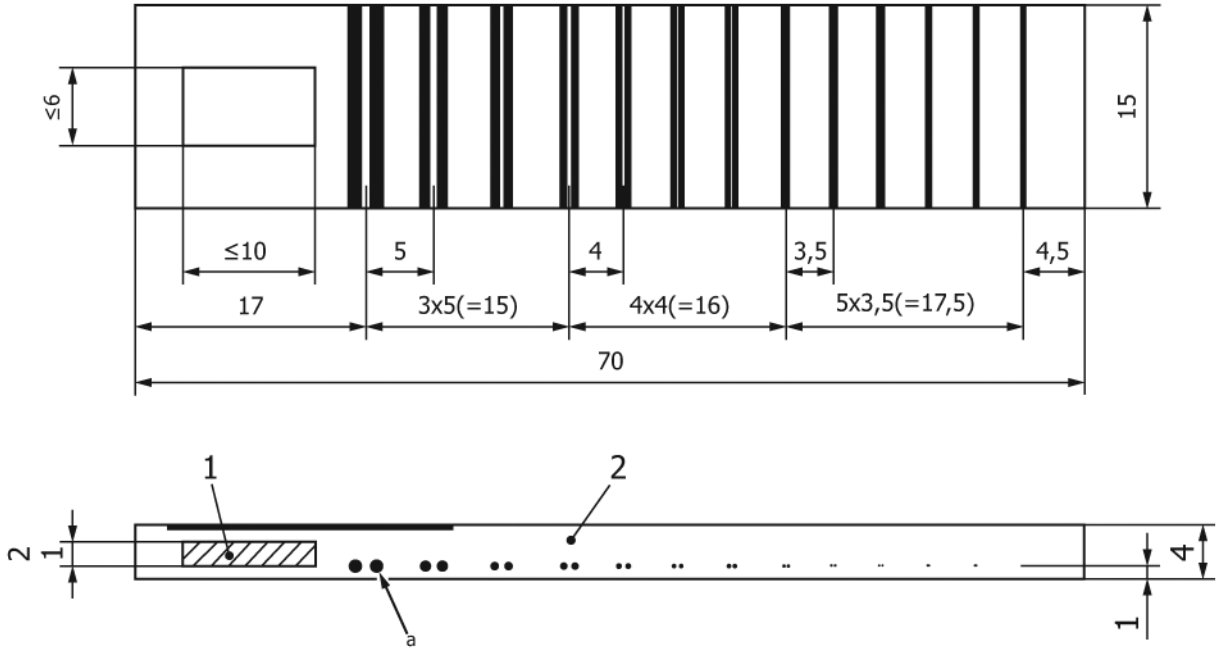
NOTE 4—If the IQI is located on the detector without object, the determined $SR_b^{image}$ value is identical with the $SR_b^{detector}$ value and the image unsharpness $U_{Im}$ corresponds to the inherent detector unsharpness $U_{detector}$.

6.2 The gauge shall consist of 13 elements. Each element shall consist of a pair of wires with circular cross-section. Elements 1 through 3 are of tungsten material and elements 4 through 13 are of platinum material. The 13 elements are mounted in a rigid plastic holder. Gauges with more elements than 13 can be used (see ~~Section~~8). ~~8).~~ These shall be used if unsharpness values lower than 0.1 mm or basic spatial resolution values lower than 0.05 mm need to be determined (see ~~Sections~~also 7 and ~~8).~~8).

6.3 The gauge shall be identified by marking "ISO D (or ISO ~~19232-5~~19232-5) or ASTM ~~E2002)~~E2002 and a serial number." Marking shall be performed by any suitable means. IQIs with the letters "EN D (or EN 462-5)" are considered to be identical to IQIs with the letters ~~"ISO"~~ISO or ~~"ASTM."~~ASTM.

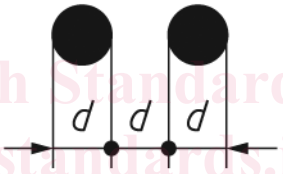
6.4 The gauge manufacturer shall provide a certificate of conformance with each gauge. Each IQI should be delivered with a declaration of conformity according to ISO/IEC ~~1750-1.~~17050-1. For identification, the IQI should be numbered and marked by the producer.

[8] The sole source of supply of the IQI shown in 8, Fig. 4, known to the committee at this time, is KOWOTEST GmbH, Solinger Strasse 186, 40764 Langenfeld, fax: +49 2173-22335, eMail: info@kowotest.de. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.










~~NOTE 1—Not to Scale.~~

~~1 space for identification marking~~
~~2 rigid plastic mounting~~
~~wire diameter (d) equals spacing between the wires~~

KEY:
1 - space for identification marking
2 - rigid plastic mounting
a - wire pair
NOTE: wire diameter (d) of wires (a) is equal to spacing between the wires

**FIG. 1 ~~Total Image~~ Unsharpness Gauge ~~(see ISO 19232-5: 2013)~~**



## 7. Application

7.1 A radiograph shall be made or an image displayed on a monitor with the duplex wire placed on the source side of the item being examined, or the gauge may be placed on a block representing the material and total thickness of the item being examined. The duplex wire IQI should be aligned, as closely as possible, normal to the axis of the radiation beam.

~~NOTE 2—If the IQI is placed directly on the detector, the inherent detector unsharpness and $SR_b^{detector}$ is measured.~~

NOTE 5—If the IQI is placed directly on the detector, the inherent detector unsharpness $U_{detector}$ and the basic spatial resolution of the detector $SR_b^{detector}$ is measured.

7.2 The evaluation of the duplex wire pair images ~~are~~is based on a visual evaluation by an operator of films on a viewing station or images on a ~~monitor,~~monitor or by measurement with a profile function if digital images are available. The ~~total~~ image unsharpness ~~$U_T$ is given as $2d$,~~ $U_{im}$ ~~where~~ or detector unsharpness ~~$d$~~$U_{detector}$ is given by 2d, where d is the corresponding diameter of the duplex wires and is also the wire spacing distance (see Fig. 1). The value of d is considered as the basic spatial resolution of the ~~image. The term 1/(2~~image or detector depending on the IQI location (this means: IQI is located on the object, beside the object or on the detector). The term 1/(2d)~~d)~~ is considered as linepair/mm value.

7.2.1 *Visual Evaluation*—~~The~~ If the image of the duplex wire IQI is evaluated visually, it shall be examined using magnification up to 4 ~~×~~times on film or on a monitor. For evaluation of D12 and higher on ~~films,~~films a magnification lens > 2 ~~×~~times shall be used. The element with ~~smallest wire number, (that is pair of wires), of~~ the first duplex wire number (smallest number) of which the image has just merged into single form without an identifiable space between the images of the two ~~wires, is~~ wires (that is pair of wires), is taken as the limit of visual discernibility for film radiography and analog radioscopy.

~~NOTE 3—Visual determination of the first unresolved wire pair may depend on the contrast-to-noise ratio (CNR) and signal-to-noise ratio (SNR) for digital systems or radioscopic systems, or may depend on the film system class and tube kV. Therefore, the visual evaluation of reference images should be performed at CNR or SNR values (for digital systems) or using the film system class and kV values typically used for the production radiographs.~~

NOTE 6—The visual determination of the first unresolved wire pair may depend on the signal-to-noise ratio (SNR) of analog radioscopic systems, or may depend on the film system class and tube kV or used gamma source, respectively.

7.2.1.1 The resulting visual basic spatial resolution value shall be documented as *visual* $SR_b^{image}$ *or visual* $SR_b^{detector}$ *-value* or $vSR_b^{image}$ *or*$vSR_b^{detector}$. The resulting visual unsharpness value shall be documented as "visual $U_{Im}$-value or visual $U_{detecor}$-value" or $vU_{Im}$ *or*$vU_{detector}$.

7.2.2 *Evaluation of Digital Images ~~with~~With Profile Function*—If digital images are evaluated with a profile function, the element with ~~smallest wire number,~~ the first duplex wire number (smallest number), of the duplex wire pair, which is separable by a profile function with less than ~~20%~~20 % modulation depth, is taken as the limit of discernibility for digital radiography. See Fig. 2. The profile function shall be evaluated from linearized pixel profiles.

7.2.2.1 The duplex wire IQI shall be positioned at an angle of approximately 2° to 5° towards the pixel line or column orientation as shown in Fig. 2a in order to reduce aliasing effects in the digital images.

7.2.2.2 The ~~total~~ unsharpness or the basic spatial resolution of digital images or detectors is based on the determination of the first duplex wire ~~pair~~number (smallest number) with less than ~~20%~~20 % modulation depth (dip).

7.2.2.3 The measurement shall be done with a profile function of an image processing software across the middle area of the IQI image, integrating along the wires of about ~~30-60%~~ 30 - 60 % of the duplex ~~wires'~~wires length in order to obtain a robust repeatable value, but shall use a minimum of an 11 pixel width line profile (or the average of 11 single width line profiles) to avoid variability along the length of the wires (Fig. 2~~b).~~ b, c).

7.2.2.4 The resulting basic spatial resolution value shall be documented as "$SR_b^{image}$" or "$SR_b^{detector}$"-value. The resulting unsharpness value shall be documented as $U_{Im}$ or $U_{detector}$. The image unsharpness ($U_{Im}$) is calculated from $SR_b^{image}$ by:

$$U_{Im} = 2 \cdot SR_b^{image} \tag{1}$$

The detector unsharpness ($U_{detector}$) is calculated from $SR_b^{detector}$ by:

$$U_{detector} = 2 \cdot SR_b^{detector} \tag{2}$$

7.2.3 *Evaluation of Digital Images ~~with~~With Profile Function by Interpolation*—For more accurate measurement of the ~~total~~ unsharpness ~~(iU~~($iU_{Im}$ *or* $iU_{detector}$) or the basic spatial resolution ~~of~~($iSR_b^{image}$ ~~*digital images (iSR*~~*or* $iSR_b^{detector}$) the measurement of the ~~20%~~20 % modulation depth should be performed by interpolation or approximation. This may be required for manufacturer qualification or if specified by contracting parties. See Fig. 3. The profile function shall be evaluated from linearized pixel profiles.

7.2.3.1 The duplex wire IQI shall be positioned at an angle of approximately ~~2°~~2 to 5° towards the pixel line or column orientation as shown in Fig. 2a in order to reduce aliasing effects in the digital images.

7.2.3.2 The measurement shall be done with a profile function of an image processing software across the middle area of the IQI image integrating along the wires of about 30 ~~to~~- 60 % of the duplex ~~wires'~~wires length in order to obtain a robust repeatable value, but shall use a minimum of an ~~11 pixel~~ 11pixel width line profile (or the average of 11 single width line profiles) to avoid variability along the length of the wires (Fig. 3~~a-b).~~a-c).

7.2.3.3 For improved accuracy in the measurement of the $iU_{Im}$ or $iU_{detector}$ and the $iSR_b^{image}$ *ori*$SR_b^{detector}$ value, the 20 % modulation depth (dip) value shall be approximated from the modulation depth (dip) values of the neighbor duplex wire modulations. Fig. 3 visualizes the corresponding procedure.

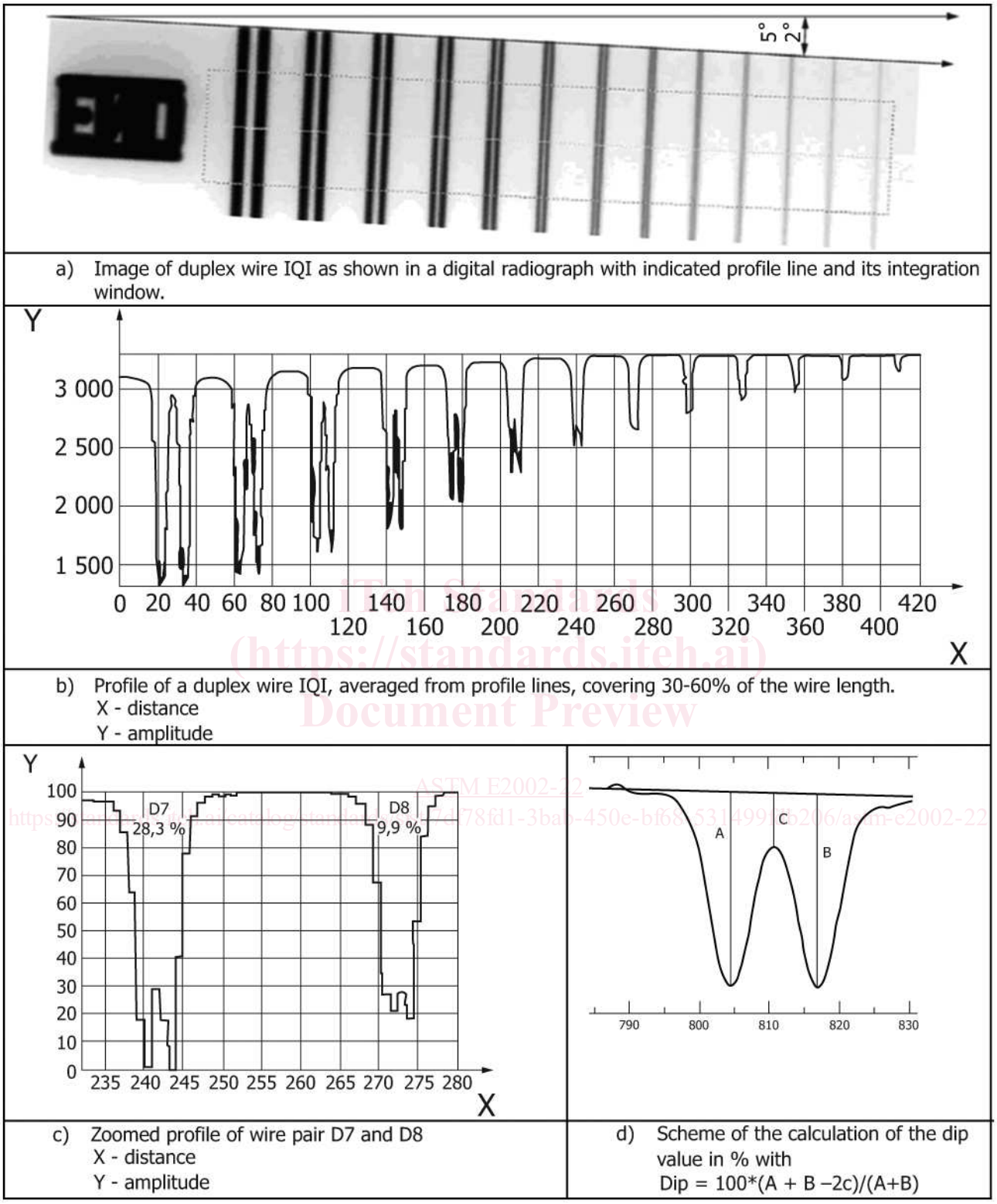





**FIG. 2 Wire-pair Image Analysis for Calculation of Basic Spatial Resolution (~~SR~~($SR_b^{image}$) and ~~Total~~ Unsharpness (~~U~~($U_{Flm}$) of Digital ~~Images. The lowest wire pair value shall be determined which has a modulation depth (dip) < 20%. The modulation depth is determined in the profile function as shown in Fig. 2c-d. The first "unsharp" wire pair~~Images; The Lowest Wire Pair Value Shall be Determined Which has A Modulation Depth (Dip) < 20 %; The Modulation Depth Is Determined In The Profile Function As Sown in Fig. 2c-d; The First "Unsharp" Wire Pair in Fig. 2c is ~~D8. The resulting values are corresponding~~D8; The Resulting Values Are Corresponding to Table 1~~Table 1~~: $SR_b^{image}$ = 0.16 mm and $U_{Flm}$ = 0.32 mm.**

**~~(a) Image of Duplex Wire IQI as Shown in a Digital Radiograph with Indicated Profile Line and its Integration Window~~**

~~NOTE 1—Digitized films and CR images are typically presented and acquired in negative presentation. These images and their line profile plots will~~