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Non-destructive testing — Ultrasonic testing — Reference blocks and test procedures for the characterization of contact probe sound beams

Essais non destructifs — Contrôles par ultrasons — Blocs de référence et modes opératoires des essais pour la caractérisation des faisceaux des traducteurs utilisés dans les contrôles par contact

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Foreword

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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).

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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

The committee responsible for this document is ISO/TC 135, *Non-destructive testing*, Subcommittee SC 3, *Ultrasonic testing*.

This second edition cancels and replaces the first edition (ISO 12715:1999), which has been technically revised.

Introduction

In ultrasonic non-destructive testing, pulse-echo contact tests with a straight-beam probe (also known as a normal-beam probe), an angle-beam probe (also known as an angle probe), or a dual-element probe (also known as a twin-crystal probe) are often used. To reliably detect and characterize a reflector inside a material, knowledge of the sound beam (or the beam profile) generated by the probe in contact with the test object is needed. This International Standard establishes two metal reference blocks to be adopted for various metals such as forged or rolled steel, aluminium, and titanium alloy products. The frequency range of the probes used in this International Standard range from 1 MHz to 15 MHz. Depending on the structure of the materials under evaluation, in general, 1 MHz to 5 MHz is most suitable for steel products and 5 MHz to 15 MHz is most suitable for aluminium and titanium alloys.

The two reference blocks introduced are the hemicylindrical-stepped (HS) and the side-drilled-hole (SDH) types, by which the beam profiles generated by straight-beam, focused beam, angle-beam, and dual-element probes can be measured. This International Standard establishes the techniques and procedures to be used for the characterization of probe beam profiles in metals.

In pulse-echo ultrasonic tests, the reflected pulse (echo) is used for the detection of discontinuities existing in a material. The discontinuities (such as porosity, voids, or cracks in different sizes and shapes) can be located close to the surface or deep inside, or close together and oriented at different angles. An ultrasonic pulse incident on such discontinuities can reflect or refract into longitudinal (also known as compressional) or transverse (also known as shear) waves, or both, possibly with multiple reflections and refractions. In order to accurately characterize the location, size, and shape of a discontinuity inside a material, it is necessary to know the sound beam transmitted and received by the probe and the instrument.

The sound beam inside a solid produced by a probe in contact testing depends on the type, size, and frequency bandwidth of the probe as well as other parameters such as focusing, beam angle of refraction in the test object, material properties, and characteristics of the ultrasonic instrument.

ISO 2400 establishes a steel reference block, known as calibration block No. 1. For straight-beam tests, this block is used, for example, for checking or establishing the near-field resolution, far-field resolution, and time base (or horizontal) linearity of the test equipment. For angle-beam tests, the block is used to determine the probe index point (probe index) and the angle of refraction (beam angle). This block also provides a means for determining the longitudinal (compressional) wave and transverse (shear) wave velocities of the material under test.

ISO 7963 establishes a small steel block, known as the calibration block No. 2, which is quite suitable for field use. ISO 7963 provides guidelines for material selection, preparation, and mechanical tolerances of the reference block. It also provides procedures for testing the angle of refraction and sensitivity settings of the signals.

The sound beam of a straight-beam probe (normal-beam probe) can be calculated or measured in immersion testing with the procedures given in ISO 10375.

In addition to ISO 2400 and ISO 7963, this International Standard introduces two ultrasonic reference blocks and provides a general methodology of using these blocks in order to establish the sound beams or beam profiles in contact tests.

The objectives of this International Standard are to

— determine probe axes so that consistent tests can be performed,

— establish a complete sound beam profile inside metals for probes of both types, straight-beam and angle-beam, including focused beam and dual-element probes,

— provide a method for calculating the correct angle of refraction when an angle-beam probe designed for use in steel is to be used in materials other than steel,

— provide a beam profile measurement capability for future applications, such as an electromagnetic acoustical transducer (EMAT),

— provide a capability for lateral angle-beam profile measurements,

— provide means for time base calibration with angle-beam probes to be used with ultrasonic imaging systems (see Annex A),

— provide means for time-of-flight (TOF) beam profile measurements for probes to be used with ultrasonic imaging systems (see Annex B),

— provide a technique by hand-held method and by using a mechanical scanner and UT imaging system to obtain both the amplitude and TOF beam profiles (see Figure B.1), and

— provide means for the determination of the skew (or squint) angle, far-field and near-field resolution of angle-beam probes (see Annex C).

Non-destructive testing — Ultrasonic testing — Reference blocks and test procedures for the characterization of contact probe sound beams

1 Scope

This International Standard introduces two metal reference blocks, the hemicylindrical-stepped (HS) block and the side-drilled-hole (SDH) block. This International Standard establishes procedures for measuring the sound beam profiles generated by probes in contact with the test object. The probes include straight-beam, angle-beam (refracted compressional and refracted shear wave), focused beam, and dual-element probes. The side dimension of the probe has to be no greater than 25 mm.

The methodology of this International Standard provides guidelines for probes to be used for different metals including forged or rolled steel, aluminium, or titanium alloy products. The frequency range of the probes used in this International Standard extends from 1 MHz to 15 MHz, where 1 MHz to 5 MHz is best suited for steels and 5 MHz to 15 MHz is best for fine grain structured alloys such as aluminium products.

If this International Standard is to be used for materials other than steels, users should be aware of the fact that the wave velocities in these materials can be different from that of steels and the angle-beam probes are normally designed based on the steel applications. Snell's law of refraction is described in this International Standard so that correct angles of refraction in other homogeneous and fine-grained materials can be calculated. This International Standard applies to angle-beam probes of all practical angles (0° to 70°) and to focused and dual-element probes. This International Standard does not address the use of surface (Rayleigh) wave probes.

This International Standard does not address the estimation of equivalent defect sizes which requires reference blocks with flat-bottomed holes. This International Standard establishes no acceptance criteria, but does establish the technical basis for criteria that can be defined by users.

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

ISO 7963, *Non-destructive testing — Ultrasonic testing — Specification for calibration block No. 2*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577 apply.

4 Symbols and abbreviated terms

4.1 Symbols

For the purposes of this document, the following symbols apply.

Symbol	Designation	Unit
A	peak echo amplitude	dB
F_w	beam width at focal distance	mm
F_D	focal distance	mm
F_L	focal length	mm
H_i	distance along the test surface from the probe index point to the ith hole[a]	mm
L_x, L_y, L_z	axes of probe	—
R	radius of the eight side-drilled holes[b]	mm
t_1	time from hemi-step surface 1	s
t_2	time from hemi-step surface 2	s
t_d	time delay	s
v_l	longitudinal (compressional) wave velocity in the test object	mm/s
v_s	transverse (shear) wave velocity in the test object	mm/s
v_w	longitudinal (compressional) wave velocity in the wedge material	mm/s
x, y, z	axes of the reference block (plane of x-y, surface; z, perpendicular to and below the surface)	mm
y_i	distance along y-axis from the ith hole to the probe location of the peak echo amplitude[c]	mm
y_{i1}, y_{i2}	locations along y-axis of the two 6 dB drop points	—
z_i	depth of the ith hole centre to one of the side surfaces[d] of the SDH block[c]	mm
z_β	longitudinal beam axis of the angle-beam probe	—
$z_{\beta i}$	distance along the beam axis from the probe index point to the ith hole centre[c]	mm
$z_{\beta L}$	lateral beam axis of the angle-beam probe	—
α_w	incident angle (wedge angle)	°
β	angle of refraction (beam angle)	°
β_l	refracted longitudinal (compressional) wave angle in the test object	°
β_s	refracted transverse (shear) wave angle in the test object	°
γ	skew (or squint) angle[e]	°

[a] i = 1, 2, 3...

[b] Diameter is 1,5 mm.

[c] i = 2, 3...

[d] T-, B-, R-, and L-, surfaces.

[e] See ISO 10375:1997, Figure 4.

4.2 Abbreviated terms

FSH	full screen height of display graticule
HS	hemicylindrical-stepped
IP	initial pulse
P	probes
P_i	probe position on the reference block
R	receiver connector
SDH	side-drilled hole
SDH_i	*i*th side-drilled hole
B-surface	bottom surface of the SDH block
F-surface	front surface of the SDH block
L-surface	left surface of the SDH block
R-surface	right surface of the SDH block
T-surface	top surface of the SDH block
T	transmitter connector

5 Descriptions of the reference blocks

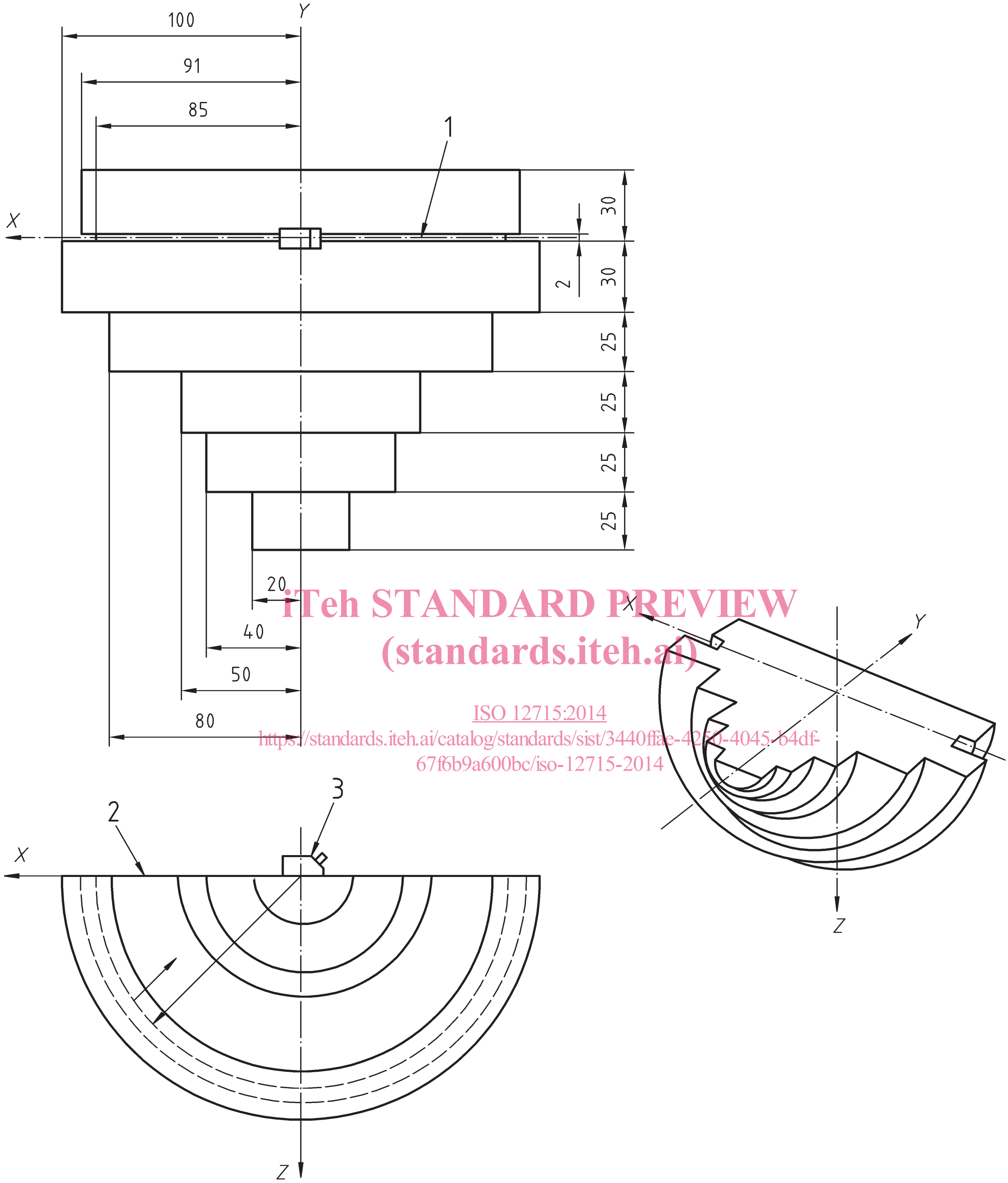
5.1 General

The two reference blocks in this International Standard are made of metal. The reference blocks shall be fabricated using a material with acoustical properties similar or equivalent to that of the test object. The general requirements for the mechanical tolerances of the blocks, surface roughness, and engraved scale should be the same as stated in ISO 7963. The geometry and dimensions of the two blocks are specified in 5.2 and 5.3.

5.2 Hemicylindrical-stepped block

Figure 1 shows the dimensions of the HS block. It shall be machined from a solid cylinder. After it is machined into cylindrical step shape, it is cut along the longitudinal axis and machined to the required surface finish. The radii of the hemicylindrical steps are 20 mm, 40 mm, 50 mm, 80 mm, 100 mm, and a slot of 85 mm and 91 mm. The width of the 20 mm to 80 mm radial steps is 25 mm; the width of the 100 mm step is 30 mm; the width of the 85 mm slot is 2 mm and the width of the 91 mm radius step is 28 mm. A line along the centre section of the slot (the *x*-axis), a centre line dividing the HS block in symmetry (the *y*-axis), and boundary lines between adjacent steps, on the flat surface, shall be engraved. When in use, the block should rest on an appropriate support. The support frame shall cause neither mechanical damage to the block nor any acoustical damping effect due to the support.

Dimensions in millimetres



Key

1 centre line of slot

2 front surface

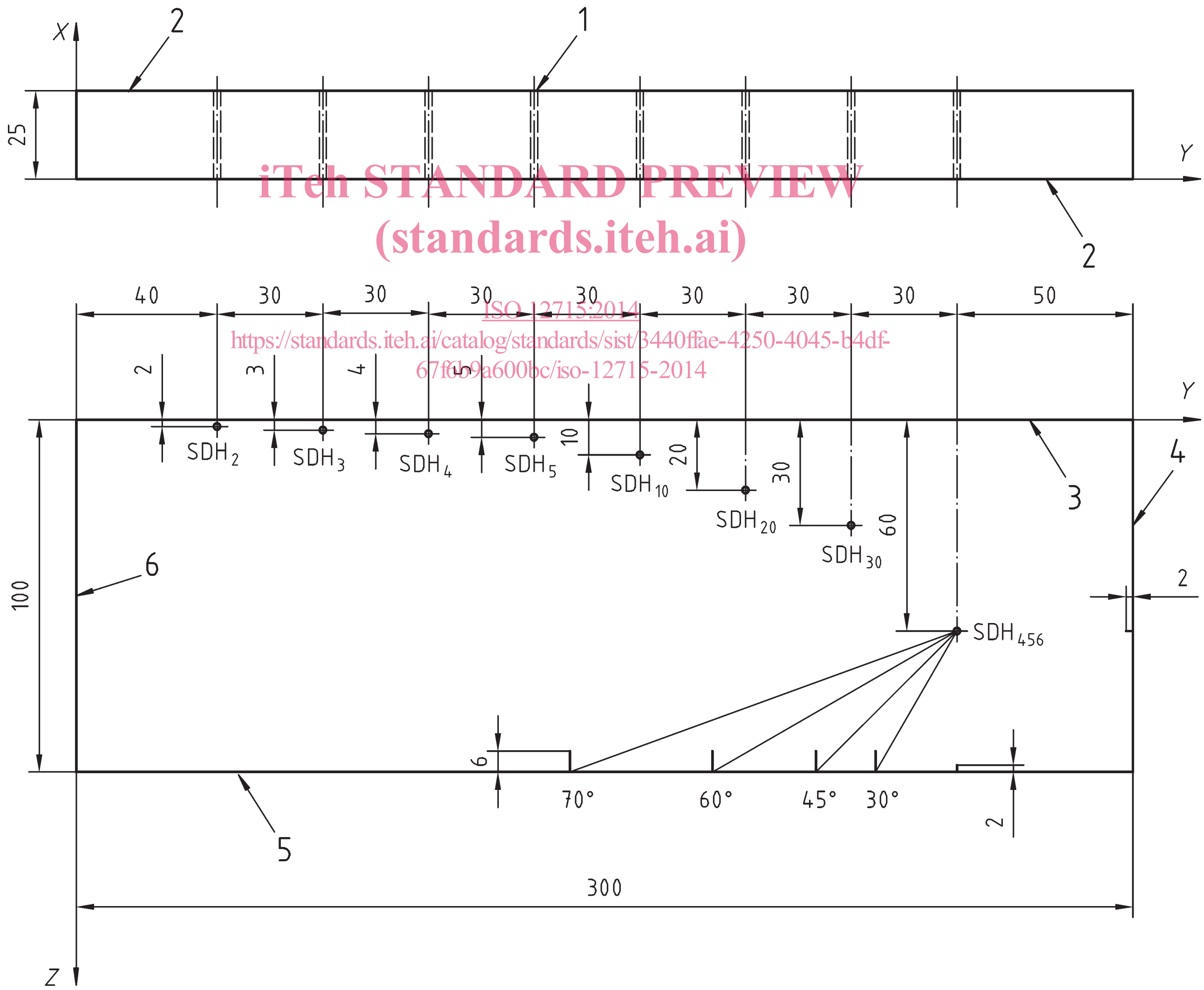
3 angle-beam probe

Figure 1 — Hemicylindrical-stepped (HS) block

5.3 Side-drilled-hole block

Figure 2 shows the dimensions of the SDH block. It is 300 mm long by 25 mm wide by 100 mm high with eight identical side-drilled holes 1,5 mm in diameter. They are identified as SDH$_2$, SDH$_3$, SDH$_4$, SDH$_5$, SDH$_{10}$, SDH$_{20}$, SDH$_{30}$, and SDH$_{456}$. The longitudinal axis of the holes shall be parallel to the top and bottom surfaces of the block. The surfaces of the block are identified as the T- (top), B- (bottom), R- (right) and L- (left), and F- (front) surface, which refers to either side of the large surfaces. The location of the hole is measured from the centre of the hole to the top, bottom, or end surface of the block. Short lines on the edge of the F- and T-surfaces are engraved indicating the locations of the SDH centre lines. The location of the SDH$_{456}$ is engraved on all the T-, B-, R-, and F-surfaces. Except for the SDH$_{456}$ hole, the number affixed to the SDH indicates the distance of the hole centre to the T-surface. For example, the distance from the SDH$_2$ hole centre to the T-surface is 2 mm. The distances from the SDH$_{456}$ centre to the B-, R-, and T-surfaces are 40 mm, 50 mm, and 60 mm, respectively. The first hole, the SDH$_2$, is 40 mm from the L-surface, and the distance between the adjacent holes is 30 mm. Angles of refraction (0° to 70°) are indicated by short lines engraved on the F-surfaces at the edge between the F- and the B-surfaces. The nominal longitudinal and transverse wave velocities of the material, determined empirically after the block has been machined, can be engraved on one of the F-surfaces of the SDH block.

Dimensions in millimetres



Key

1 side-drilled hole of diameter 1,5 mm
2 F-surface
3 T-surface
4 R-surface
5 B-surface
6 L-surface

Figure 2 — Side-drilled-hole (SDH) block

6 Techniques and procedures

6.1 Straight-beam probes (normal-beam probes)

6.1.1 Amplitude beam profile of straight-beam probe

Place the probe on the T-surface, on top of the first SDH as shown in Figure 3. If the echo signal on the screen of the instrument is within the dead zone of the probe, ignore this hole and proceed testing with the next hole until the echo signal is able to be resolved. Move the probe such that the signal reflected from the hole is at its maximum. Adjust the gain such that the signal amplitude is about 80 % of full screen height (FSH) of the instrument display graticule. The signal shall be at least 20 dB greater than the background noise level. Move the probe along the y-axis to and from the peak amplitude position such that the signal amplitude drops 6 dB from the peak amplitude. Record the gain for the peak echo amplitude (A), the probe location (y_i) of the peak amplitude, the two 6 dB drop (−6 dB) points (y_{i1}, y_{i2}), and the depth (z_i) of the hole in the test.

Repeat the above tests for all of the holes of interest on the SDH block. The depth (z_i) of the SDH$_i$ is measured from the centre of the hole and the wave is reflected from the top surface of the hole. For engineering accuracy, no radius corrections are needed, since the error caused by this difference is relatively small compared to other uncertainties in ultrasonic tests. Figure 4 shows the beam profile in the test object produced by a straight-beam probe.

It should be noted that the amplitude varies in the near field due to diffraction from the transducer edges. Beyond the near field is the far field where the amplitude decreases with increasing distance. The calculation of the near-field length is given in ISO 10375.

6.1.2 Amplitude beam profile of focused straight-beam probe

Repeat the procedures specified in 6.1.1. The result is plotted in Figure 5.

a) The line joining the peak amplitude at each depth is the sound beam axis.

b) The location of the signal at maximum amplitude is the focal point.

c) The distance from the test surface to the focal point is the focal distance(F_D).

d) The distance between the two 6 dB drop points along the beam axis is the focal length (F_L).

e) At the focal point, the distance between the two 6 dB drop points in a plane perpendicular to the beam axis is the focal beam width (F_w).

