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Geometrical product specifications (GPS) — Filtration —

Part 21: Linear profile filters: Gaussian filters

Spécification géométrique des produits (GPS) — Filtrage —

Partie 21: Filtres de profil linéaires: Filtres gaussiens

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 16610-21 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

ISO 16610-21 cancels and replaces ISO 11562:1996, which has been technically revised.

ISO 16610 consists of the following parts, under the general title *Geometrical product specifications (GPS) — Filtration*:

— *Part 1: Overview and basic concepts* [Technical Specification]

— *Part 20: Linear profile filters: Basic concepts* [Technical Specification]

— *Part 21: Linear profile filters: Gaussian filters*

— *Part 22: Linear profile filters: Spline filters* [Technical Specification]

— *Part 28: Profile filters: End effects* [Technical Specification]

— *Part 29: Linear profile filters: Spline wavelets* [Technical Specification]

— *Part 30: Robust profile filters: Basic concepts* [Technical Specification]

— *Part 31: Robust profile filters: Gaussian regression filters* [Technical Specification]

— *Part 32: Robust profile filters: Spline filters* [Technical Specification]

— *Part 40: Morphological profile filters: Basic concepts* [Technical Specification]

— *Part 41: Morphological profile filters: Disk and horizontal line-segment filters* [Technical Specification]

— *Part 49: Morphological profile filters: Scale space techniques* [Technical Specification]

The following parts are planned:

— *Part 26: Linear profile filters: Filtration on nominally orthogonal grid planar data sets*

— *Part 27: Linear profile filters: Filtration on nominally orthogonal grid cylindrical data sets*

— *Part 42: Morphological profile filters: Motif filters*

— *Part 60: Linear areal filters: Basic concepts*

— *Part 61: Linear areal filters: Gaussian filters*

— *Part 62: Linear areal filters: Spline filters*

— *Part 69: Linear areal filters: Spline wavelets*

— *Part 70: Robust areal filters: Basic concepts*

— *Part 71: Robust areal filters: Gaussian regression filters*

— *Part 72: Robust areal filters: Spline filters*

— *Part 80: Morphological areal filters: Basic concepts*

— *Part 81: Morphological areal filters: Sphere and horizontal planar segment filters*

— *Part 82: Morphological areal filters: Motif filters*

— *Part 89: Morphological areal filters: Scale space techniques*

Introduction

This part of ISO 16610 is a geometrical product specification (GPS) standard and is to be regarded as a global GPS standard (see ISO/TR 14638). It influences the chain links 3 and 5 of all chains of standards.

The ISO/GPS masterplan given in ISO/TR 14638 gives an overview of the ISO/GPS system of which this document is a part. The fundamental rules of ISO/GPS given in ISO 8015 apply to this document and the default decision rules given in ISO 14253-1 apply to specifications made in accordance with this document, unless otherwise indicated.

For more detailed information about the relation of this part of ISO 16610 to the GPS matrix model, see Annex D.

This part of ISO 16610 develops the terminology and a concept of Gaussian filters. It has the transmission for the cut-off wavelength as 50 % since the short wave and long wave portions of surface profile are separated and can be reconstructed without altering the surface profile.

Geometrical product specifications (GPS) — Filtration —

Part 21:
Linear profile filters: Gaussian filters

1 Scope

This part of ISO 16610 specifies the metrological characteristics of the Gaussian filter, for the filtration of profiles. It specifies, in particular, how to separate long and short wave components of a surface profile.

2 Normative references

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

ISO/TS 16610-1:2006, *Geometrical product specifications (GPS) — Filtration — Part 1: Overview and basic concepts*

ISO/TS 16610-20:2006, *Geometrical product specifications (GPS) — Filtration — Part 20: Linear profile filters: Basic concepts*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC Guide 99:2007, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TS 16610-1, ISO/TS 16610-20, ISO/IEC Guide 98-3 and ISO/IEC Guide 99 and the following apply.

3.1
linear profile filters
profile filter to separate profiles into long wave and short wave components

[ISO/TS 16610-20:2006]

3.1.1
open profile
finite length surface profile with two ends

[ISO/TS 16610-1:2006]

3.1.2
closed profile
connected finite length surface profile without ends

[ISO/TS 16610-1:2006]

3.1.3
cut-off wavelength
wavelength of a sinusoidal profile of which 50 % of the amplitude is transmitted by the profile filter

[ISO/TS 16610-20:2006]

4 Characteristics of Gaussian profile filter for an open profile

4.1 Gaussian weighting function for an open profile

The weighting function of an open profile filter (see Figure 1) has the equation of the Gaussian function with the cut-off wavelength λ_c, where c is cut-off. The equation is given by:

$$s(x) = \frac{1}{\alpha \times \lambda_c} \times \exp\left[-\pi \left(\frac{x}{\alpha \times \lambda_c} \right)^2 \right] \quad (1)$$

where

x is the distance from the centre (maximum) of the weighting function;

λ_c is the cut-off wavelength;

α is a constant, to provide 50 % transmission characteristic at the cut-off λ_c.

For implementation, the weighting function equation is as follows:

$$s(x) = \begin{cases} \dfrac{1}{\alpha \times \lambda_c} \times \exp\left[-\pi \left(\dfrac{x}{\alpha \times \lambda_c} \right)^2 \right] & \text{for } -L_c \times \lambda_c \leqslant x \leqslant L_c \times \lambda_c \\ 0 & \text{Otherwise} \end{cases} \quad (2)$$

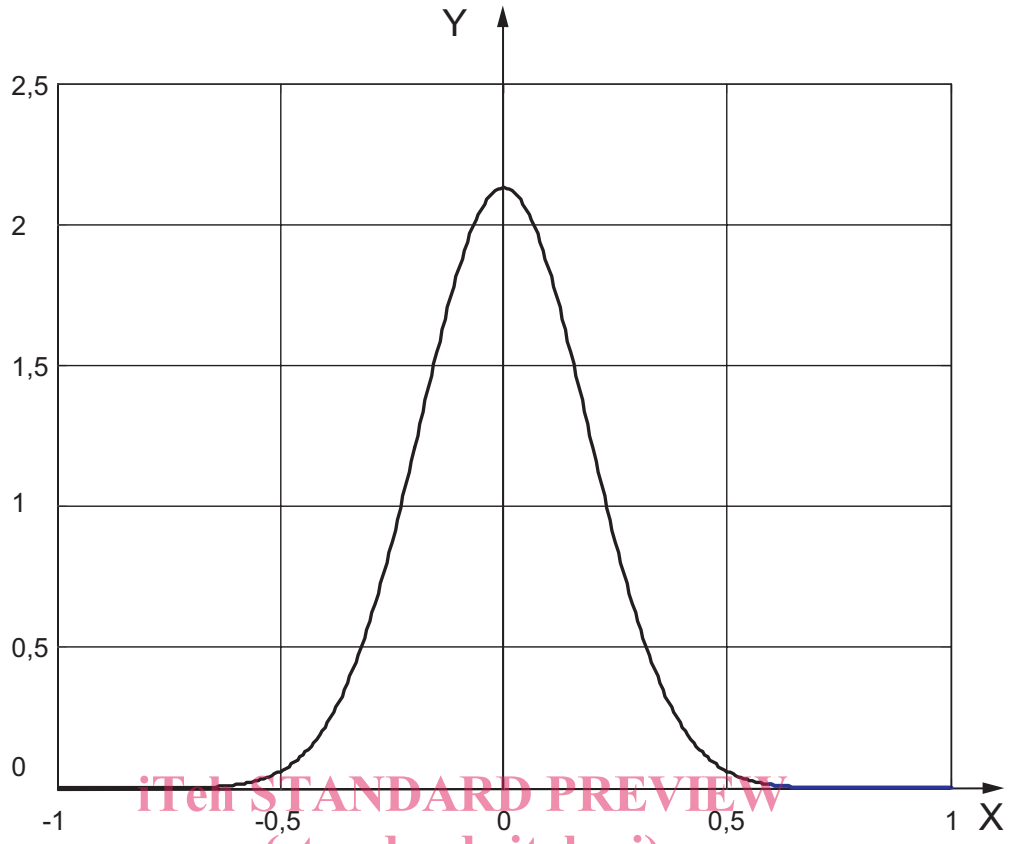
where

L_c is a truncation constant of the weighting function (see Annex A for recommended values);

α is given by:

$$\alpha = \sqrt{\frac{\ln 2}{\pi}} \approx 0{,}469\,7 \quad (3)$$

The graph of the weighting function is shown in Figure 1.



Key

X x/λ_c

Y $\lambda_c \times s(x)$

Figure 1 — Weighting function of a Gaussian profile filter for an open profile

4.2 Transmission characteristics of an open profile

4.2.1 Transmission characteristic of the long wave component for an open profile

The transmission characteristic (see Figure 2) is determined from the weighting function by means of the Fourier transformation. The transmission characteristic of the long wave component (mean line) is given by:

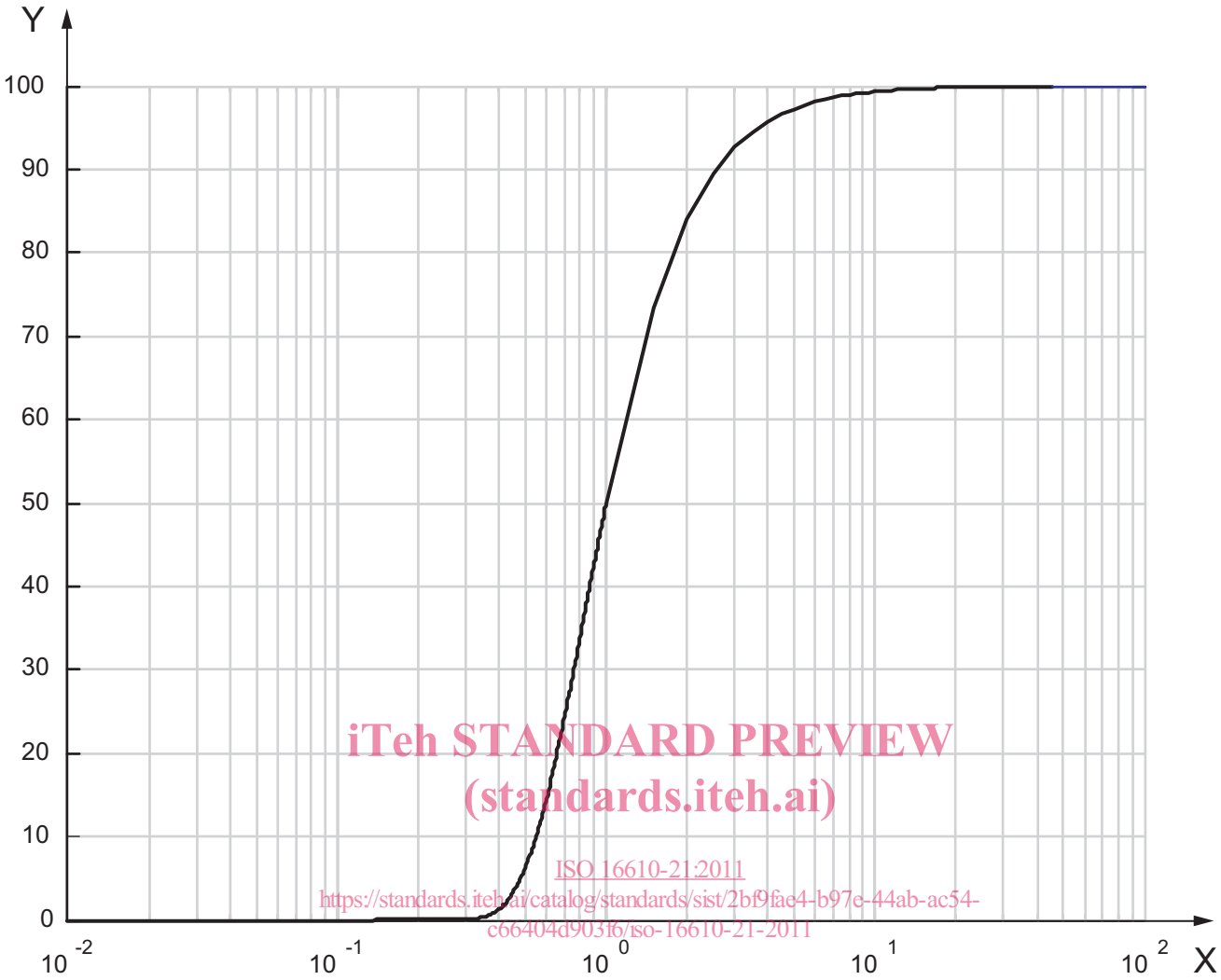
$$\frac{a_1}{a_0} = \exp\left[-\pi\left(\frac{\alpha \times \lambda_c}{\lambda}\right)^2\right] \tag{4}$$

where

a_0 is the amplitude of a sinusoidal wave profile before filtering;

a_1 is the amplitude of this sinusoidal profile in the mean line;

λ is the wavelength of this sinusoidal profile.



Key

X λ/λ_c

Y amplitude transmission a_1/a_0, in percent

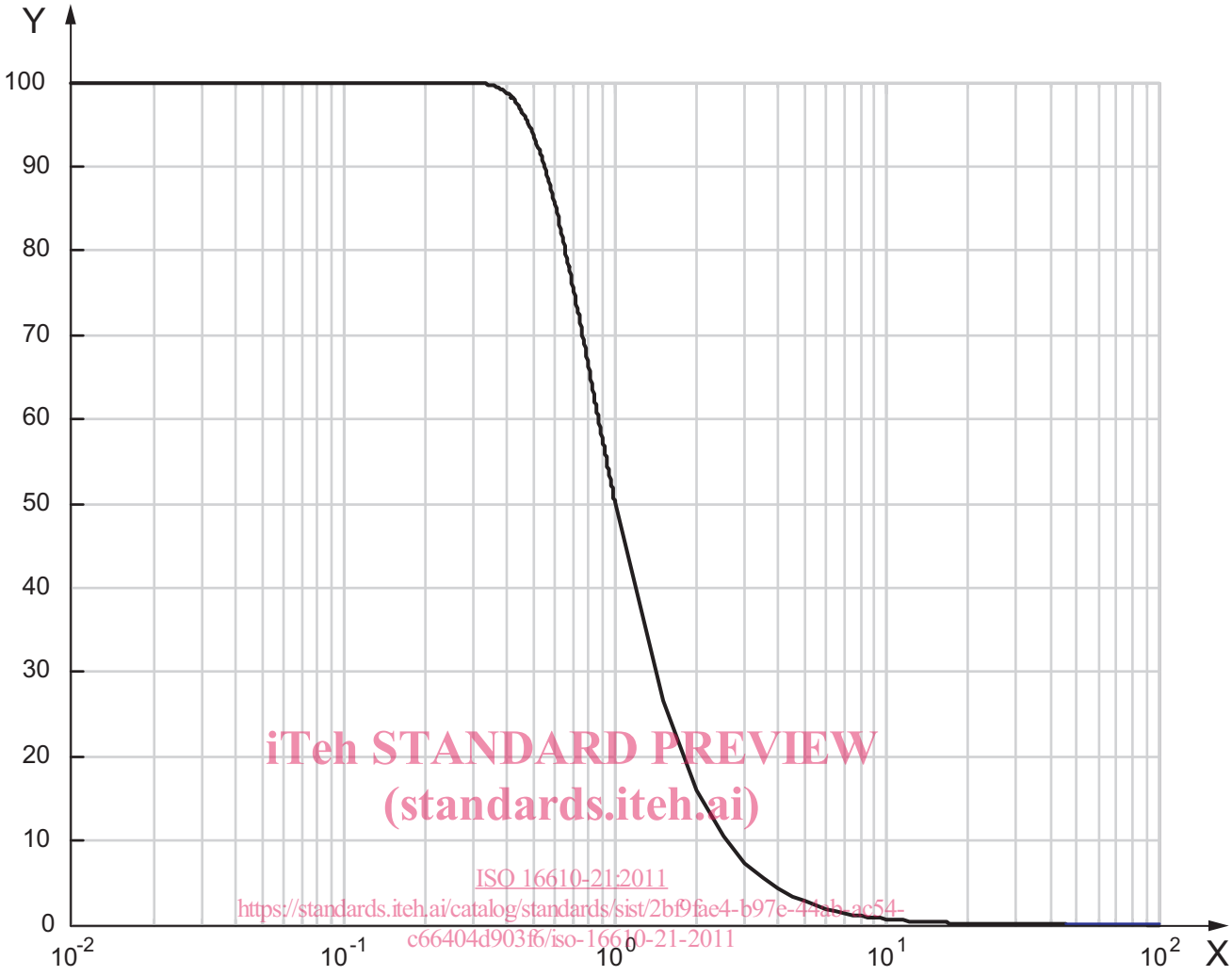
Figure 2 — Long wave transmission function of the Gaussian filter for an open profile

4.2.2 Transmission characteristic of the short wave component for an open profile

The transmission characteristic (see Figure 3) is determined from the weighting function by means of the Fourier transformation and is complementary to the transmission characteristic of the long wave profile component. The transmission characteristic of the short wave component is given by:

$$\frac{a_2}{a_0} = 1 - \exp\left[-\pi\left(\frac{\alpha \times \lambda_c}{\lambda}\right)^2\right] \qquad \frac{a_2}{a_0} = 1 - \frac{a_1}{a_0} \tag{5}$$

where a_2 is the amplitude of the short wave component of a sinusoidal wave profile.



Key

X λ/λ_c

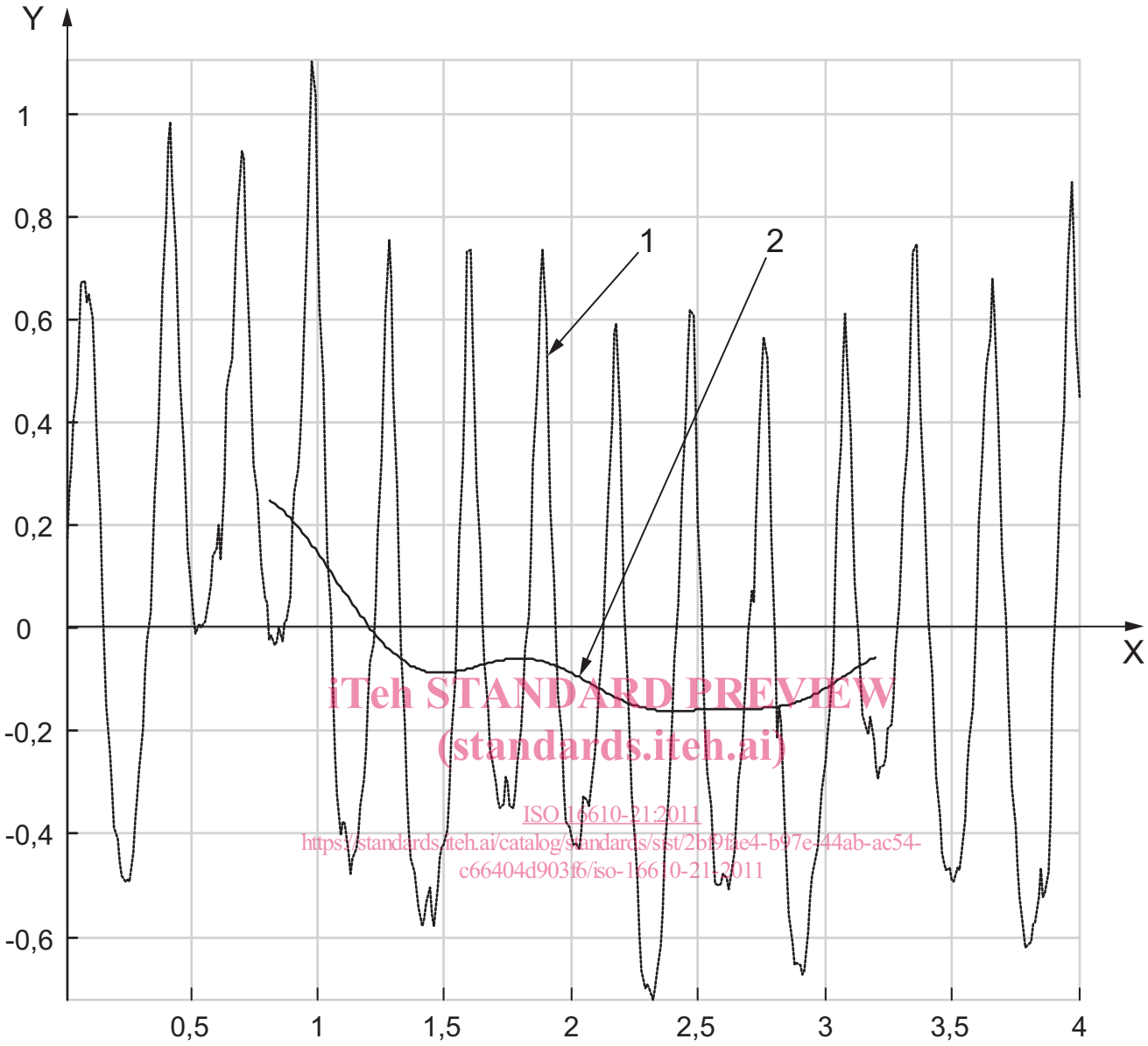
Y amplitude transmission a_1/a_0, in percent

Figure 3 — Short wave transmission function of the Gaussian filter for an open profile

4.3 End effects

Since open profiles are only defined for a finite length; the convolution of the Gaussian filter with the open profile will cause unintentional changes in the filtration response in the end portions of the profile. The end portion of an open profile where end effects are significant are called the *end effect regions*.

One strategy to reduce these end effects is to take a longer profile and remove the end effect regions to leave a filtration response with insignificant end effects (see Figure 4).



Key

1 unfiltered profile
2 filtered profile
X length, mm
Y height, µm

Figure 4 — Example of Gaussian filtration (λ_c = 0,8 mm) **with the removal of the end effect regions**

Alternative strategies to reduce end effects are to apply the techniques used in ISO/TS 16610-28. For an illustrative example, see Figure 5.