SMPTE ST 2122:2020

SMPTE STANDARD

Spectral Similarity Index (SSI)

Table of Contents **Page**

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Foreword

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SMPTE Engineering Documents are drafted in accordance with the rules given in its Standards Operations Manual. This SMPTE Engineering Document was prepared by Technology Committee 10E.

Intellectual Property

At the time of publication no notice had been received by SMPTE claiming patent rights essential to the implementation of this Engineering Document. However, attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. SMPTE shall not be held responsible for identifying any or all such patent rights.

Introduction

This section is entirely informative and does not form an integral part of this Engineering Document.

The Spectral Similarity Index (SSI) is a measure of the similarity of the relative spectral distribution of a test source to that of a reference source or illuminant, expressed as a single metric reported on a 100-point scale. The more similar a test-source spectral distribution is to that of a reference, the more confidence a user can have that the test source will be an acceptable replacement for the reference source or illuminant.

SSI was developed by the Academy of Motion Picture Arts and Sciences' Science and Technology Council to provide an improved measure of the predictability of colors captured with artificial lighting – in particular with LED luminaires – for motion picture photography. The Color Rendering Index (CRI) and other similar metrics are based on human vision and are not designed considering camera characteristics. There is no spectral-sensitivity standard for cinema cameras, so a metric for cinema-lighting quality cannot presume a particular set of sensitivities. SSI compares a cinema light source to a chosen known, satisfactory, reference (typically daylight or tungsten), and provides a measure of the similarity of their spectra, independent of any particular camera sensitivity characteristics or surface spectral reflectances.

Although SSI is applicable for most sources, it is primarily intended for use with "white" sources of various correlated color temperatures.

1 Scope

This standard specifies the method for calculating the Spectral Similarity Index (SSI) and the notation for the index and its reference spectral distribution. SSI can be used to evaluate how similarly one can expect two light sources to work with, or in place of, each other for motion-picture photography. It is also suitable for other lighting applications.

2 Conformance Notation

Normative text is text that describes elements of the design that are indispensable or contains the conformance language keywords: “shall”, “should”, or “may”. Informative text is text that is potentially helpful to the user, but not indispensable, and can be removed, changed, or added editorially without affecting interoperability. Informative text does not contain any conformance keywords.

All text in this document is, by default, normative, except: the Introduction, any section explicitly labeled as “Informative” or individual paragraphs that start with “Note:”

The keywords “shall” and “shall not” indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.

The keywords “should” and “should not” indicate that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.

The keywords “may” and “need not” indicate courses of action permissible within the limits of the document.

The keyword “reserved” indicates a provision that is not defined at this time, shall not be used, and may be defined in the future. The keyword “forbidden” indicates “reserved” and in addition indicates that the provision will never be defined in the future.

A conformant implementation according to this document is one that includes all mandatory provisions (“shall”) and, if implemented, all recommended provisions (“should”) as described. A conformant implementation need not implement optional provisions (“may”) and need not implement them as described.

Unless otherwise specified, the order of precedence of the types of normative information in this document shall be as follows: Normative prose shall be the authoritative definition; Tables shall be next; then formal languages; then figures; and then any other language forms.

3 Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this engineering document. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this engineering document are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below.

CIE 015:2018 Colorimetry, 4th Edition

CIE 204:2013 Methods for Re-defining CIE D Illuminants

ISO 7589:2002(E) Photography — Illuminants for sensitometry — Specifications for daylight, incandescent tungsten and printer

ISO 11664-2:2007 Colorimetry — Part 2: CIE standard illuminants

4 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

4.1 CIE illuminant

illuminant specified by the International Commission on Illumination (CIE)

4.2 correlated color temperature

CCT

$\boldsymbol{T}_{\mathrm{cp}}$

temperature of a Planckian radiator having the chromaticity nearest the chromaticity associated with the given spectral distribution on a diagram where the (CIE 1931 standard observer based) *u*′, 2/3*v*′ coordinates of the Planckian locus and the test stimulus are depicted

Unit: K

[SOURCE: CIE DIS 017/E:2016 ILV, 17-23-068]

4.3 Planckian radiator

blackbody

ideal thermal radiator that absorbs completely all incident radiation, whatever the wavelength, the direction of incidence or the polarization

[SOURCE: CIE DIS 017/E:2016 ILV, 17-24-004]

4.4 illuminant

radiation with a relative spectral distribution defined over the wavelength range that influences object color perception

4.5 reference relative spectral distribution

reference SPD

illuminant, or relative spectral distribution of the radiant power of a source, to which a relative spectral distribution is compared

4.6 relative spectral distribution

SPD

ratio of the spectral distribution, $X_\lambda(\lambda)$, of the quantity $X(\lambda)$ to a fixed reference value, R, which can be an average value, a maximum value or an arbitrarily chosen value of this distribution

Unit: 1

[SOURCE: IEC 60050-845:1987 International Electrotechnical Vocabulary (IEV) - Part 845: Lighting, 845-01-18]

4.7 source

object that produces light or other radiant flux

[SOURCE: CIE DIS 017/E:2016 ILV, 17-21-032]

4.8 spectral distribution

density of a radiant or luminous or photon quantity, $X(\lambda)$, with respect to wavelength, λ, at the wavelength λ

Unit: $W \cdot nm^{-1}$, $lm \cdot nm^{-1}$, nm^{-1}

[SOURCE: CIE DIS 017/E:2016 ILV, 17-21-029]

4.9 test relative spectral distribution

test SPD

relative spectral distribution of the radiant power of a source being compared to a reference relative spectral distribution

5 Procedure for Calculating SSI

5.1 Specify the Test and Reference SPDs

$T(\lambda)$ shall be the test SPD.

$R(\lambda)$ shall be the reference SPD.

$T(\lambda)$ and $R(\lambda)$ shall be specified at intervals not exceeding 5 nm.

Values outside the range for which $T(\lambda)$ or $R(\lambda)$ are defined shall be zero.

5.2 Interpolate the SPDs at 1 nm Intervals

$T_I(\lambda)$ and $R_I(\lambda)$ shall be $T(\lambda)$ and $R(\lambda)$ interpolated linearly at 1 nm integer intervals over the range of $T(\lambda)$ and $R(\lambda)$, respectively, without extrapolation.

Values outside the range 375 nm to 675 nm shall then be excluded.

NOTE The result of this step is two 301-element vectors, where the first element of each is the value of the relative spectral distribution at 375 nm and the last element of each is the value of the relative spectral distribution at 675 nm.

5.3 Resample the SPDs at 10 nm Intervals

$T_R(\lambda)$ and $R_R(\lambda)$ shall be $T_I(\lambda)$ and $R_I(\lambda)$, respectively, resampled at 10 nm intervals using Equation 1.

For n = 380, 390, … , 670 (1)

$$T_R[n] = 0.5T_I[n-5] + T_I[n-4] + T_I[n-3] + T_I[n-2] + T_I[n-1] + T_I[n] + T_I[n+1] + T_I[n+2] + T_I[n+3] + T_I[n+4] + 0.5T_I[n+5]$$

$$R_R[n] = 0.5R_I[n-5] + R_I[n-4] + R_I[n-3] + R_I[n-2] + R_I[n-1] + R_I[n] + R_I[n+1] + R_I[n+2] + R_I[n+3] + R_I[n+4] + 0.5R_I[n+5]$$

where $T_I[\lambda]$, $T_R[\lambda]$, $R_I[\lambda]$, and $R_R[\lambda]$ are each the value of the respective relative spectral distribution at the wavelength λ in nanometers.

NOTE The result of this step is two 30-element vectors, where the first element of each is the value of the relative spectral distribution at 380 nm and the last element of each is the value of the relative spectral distribution at 670 nm.

5.4 Normalize the SPDs

$T_N(\lambda)$ shall be $T_R(\lambda)$ divided by the sum of all the elements of $T_R(\lambda)$.

$R_N(\lambda)$ shall be $R_R(\lambda)$ divided by the sum of all the elements of $R_R(\lambda)$.

NOTE The result of this step is two 30-element vectors, each with the sum of its elements equal to 1.

5.5 Compute a Difference Vector

D shall be calculated using Equation 2.

$$D = (T_N(\lambda) - R_N(\lambda)\ ) \,/\, (R_N(\lambda) + 1/30) \qquad (2)$$

NOTE The result of this step is a 30-element vector.

5.6 Apply Weights

W shall be calculated by multiplying the vectors D and V element-by-element where

V = [4/15, 22/45, 32/45, 8/9, 44/45, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 11/15, 3/15]

NOTE The result of this step is a 30-element vector.

5.7 Extend the Vector With a Zero at Each End

Z shall be calculated by prepending a zero and appending a zero to W.

NOTE The result of this step is a 32-element vector.

5.8 Smooth the Vector

F shall be calculated according to Equation 3.

$$\text{For each element } F_i \text{ of } F\ (i = 1,\ldots,30):\ \ F_i = 0.22Z_i + 0.56Z_{i+1} + 0.22Z_{i+2} \qquad (3)$$

NOTE 1 This is the convolution of the 32-element vector Z with the kernel [0.22, 0.56, 0.22].

NOTE 2 The result of this step is a 30-element vector.

5.9 Calculate the Magnitude of the Vector

e shall be calculated by taking the square root of the sum of the squares of the elements of F.

NOTE The result of this step is a real number.

5.10 Calculate SSI

The SSI value s shall be calculated using Equation 4.

$$s = \mathrm{round}(100 - 32e) \tag{4}$$

where round(x) returns the largest integer value less than or equal to x + 0.5.

6 Reporting Notation

6.1 Reporting format

The computed SSI value s shall be reported as:

SSI[spd_r] s

where spd_r denotes the reference SPD as defined in sections 6.2 through 6.8.

6.2 Blackbody illuminant

If the reference SPD is the relative spectral distribution of a Planckian radiator, the reference SPD shall be denoted as “P” followed by the temperature of the Planckian radiator in kelvins truncated to an integer value.

EXAMPLE 1 SSI[P3225] 95

6.3 CIE illuminant (tabulated)

If the reference SPD is a CIE illuminant specified in ISO 11664-2, a CIE illuminant specified within a table in CIE 015, or a smoothed CIE illuminant specified within a table in CIE 204, the reference SPD shall be indicated as “CIE” followed by a space character followed by the name of the CIE illuminant.

EXAMPLE 1 SSI[CIE A] 87

EXAMPLE 2 SSI[CIE D55] 93

EXAMPLE 3 SSI[CIE C] 90

EXAMPLE 4 SSI[CIE FL3.15] 73

EXAMPLE 5 SSI[CIE sID50] 92

EXAMPLE 6 SSI[CIE LED-B1] 91

EXAMPLE 7 SSI[CIE sD50] 86

6.4 CIE D illuminant (calculated)

If the reference SPD is either:

(a) a CIE D illuminant not specified in a table in CIE 015, but calculated according to the method specified in CIE 015 or calculated according to the method specified in CIE 204 using the eigenvectors specified in Table 1 therein, or

(b) a CIE D illuminant not specified in a table in CIE 204, but calculated according to the method specified in CIE 204 using the eigenvectors specified in Table 3 therein,

then the reference SPD shall be indicated as "CIE" followed by a space character followed by "D" or "sD", respectively, followed by the correlated color temperature of the CIE D illuminant in kelvins truncated to an integer value.

EXAMPLE 1 SSI[CIE D5025] 92

EXAMPLE 2 SSI[CIE sD5025] 91

6.5 CIE illuminant E

If the reference SPD is CIE illuminant E as specified in CIE 015, the reference SPD shall be indicated as "CIE" followed by a space character followed by "E".

EXAMPLE 1 SSI[CIE E] 71

6.6 CIE source

If the reference SPD is the relative spectral distribution of a CIE source specified in ISO 11664-2 or CIE 015, the reference SPD shall be indicated as "CIE" followed by a space character followed by the name of the CIE source.

EXAMPLE 1 SSI[CIE Source A] 94

EXAMPLE 2 SSI[CIE Source B] 88

6.7 ISO 7589 illuminant (tabulated)

If the reference SPD is an illuminant specified within a table in ISO 7589, the reference SPD shall be indicated as "ISO 7589" followed by a space character followed by the name of the ISO illuminant. When the number of characters of the notation is limited (e.g. on a small display) the notation may be truncated by eliminating "7589" and "sensitometric" from the label.

EXAMPLE 1 SSI[ISO 7589 sensitometric daylight] 91

EXAMPLE 2 SSI[ISO studio tungsten] 83

6.8 User-specified reference SPD

If the reference SPD is a relative spectral distribution not considered in Sections 6.2 through 6.7, the user shall assign the relative spectral distribution a name and the reference SPD shall be indicated by that name followed by an asterisk.

EXAMPLE 1 SSI[Illuminant 1*] 86

EXAMPLE 2 SSI[Xenon*] 80

EXAMPLE 3 SSI[Source 1*] 92