SMPTE RECOMMENDED PRACTICE

RP 176-1997
Revision of RP 176-1993

Derivation of Reference Signals for Television Camera Color Evaluation

1 Scope

This practice is intended to define the numerical procedure for deriving reference video signals for television camera evaluation. A standard reflection test pattern is assumed and the signal levels computed by this procedure are the signals to be expected from an ideal camera as defined by the television system color specifications.

2 Normative references

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

ASTM E308-96, Practice for Computing the Colors of Objects by Using the CIE System

CIE Publication 15.2 (1986), Colorimetry

SMPTE RP 177-1993 (R1997), Derivation of Basic Television Color Equations

3 Definitions

The color reproduction objective of television systems is to reproduce all colors as though they were illuminated by CIE illuminant D_{65}. Thus, the ideal or reference camera used in this practice always uses a D_{65} illuminant. This practice utilizes CIE tristimulus values (XYZ) as given in CIE 15.2 to specify color samples, and the normalized primary matrix (NPM) as given in SMPTE RP 177 to derive the ideal camera linear video signal levels (RGB).

4 Input data

4.1 The required data are first the CIE tristimulus values XYZ, computed using CIE illuminant D_{65}, for each of the color patches on the test pattern to be used. One of the patches should be a reference white that will be used for the white balance of the reference camera. If the tristimulus values for the test pattern are not available, they should be computed from the spectral reflectances of the patches using the weighting tables and procedures from CIE 15.2 or ASTM E308. The reflectance data should ideally be measured using 45/0 measuring geometry as specified in CIE 15.2 and be made against an absolute white reflectance reference.

4.2 The second input data required is the normalized primary matrix, NPM, of the television standard for which the camera is being evaluated. This NPM matrix should be derived from the system reference primary chromaticities using the procedure given in SMPTE RP 177. The NPM should be accurate to at least four significant digits and ideally all 10 digits carried in its derivation should be used. The reference system NPM uses a D_{65} white reference by definition.

4.3 The final input data are the equations for the opto-electronic transfer function (gamma correction) for the television standard.

5 General procedure

5.1 The NPM defines the relationship between the normalized linear RGB video levels and CIE tristimulus values XYZ:

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$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} X_R & X_G & X_B \\ Y_R & Y_G & Y_B \\ Z_R & Z_G & Z_B \end{pmatrix} \bullet \begin{pmatrix} R \\ G \\ B \end{pmatrix} = NPM \bullet \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

5.2 The inverse of the NPM predicts linear RGB from XYZ. Since the XYZ values for the "N" test colors are the starting data, the ideal RGB values can be computed by premultiplying these XYZ values by the inverse of the NPM:

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix}_N = NPM^{-1} \bullet \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_N$$

5.3 The reference white on the pattern may not be a perfect white; therefore, the reference camera must be white balanced on the white chip of the pattern. This is accomplished by normalizing the R signals, the G signals, and the B signals individually to make the signal value 1.0000 for the white chip.

5.4 These normalized linear RGB values are then transformed to the nonlinear R′G′B′ relative video levels using the opto-electronic transfer function.

Annex A (informative)
Example calculation

A.1 Given the set of CIE XYZ tristimulus values for six colors and a white as listed below:

Color patch		X	Y	Z
01	White	0.94641	1.00000	1.07574
02	Blue	0.09590	0.07012	0.34480
03	Green	0.16624	0.26731	0.11089
04	Red	0.22485	0.13250	0.06340
05	Yellow	0.62417	0.66075	0.10465
06	Magenta	0.33516	0.22135	0.36493
07	Cyan	0.16710	0.23008	0.45425

and a normalized primary matrix:

$$NPM = \begin{pmatrix} 0.4123907993 & 0.3575843394 & 0.1804807884 \\ 0.2126390059 & 0.7151686788 & 0.0721923154 \\ 0.0193308187 & 0.1191947798 & 0.9505321522 \end{pmatrix}$$

and an opto-electronic transfer function:

$$V' = 1.099 \bullet V^{0.45} - 0.099 \quad \text{for } 1 \geq V \geq 0.018$$

$$V' = 4.500 \bullet V \quad \text{for } 0.018 > V > 0$$

A.2 The following set of ideal RGB signal values for this test pattern to this set of reference primaries is computed. Two sets of RGB data are given: the first three columns (unprimed RGB) are the linear RGB signals, and the last three columns (headed by R′G′B′) are the nonlinear RGB video levels. In this example, the white patch is not a perfect white so the linear RGB values must be normalized to 1.0 (or white balanced) as indicated in 5.3:

	R	G	B	R′	G′	B′
01	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
02	0.03129	0.05274	0.36063	0.13217	0.19340	0.59551
03	0.07300	0.34379	0.07297	0.23945	0.58072	0.23939
04	0.49663	0.03315	0.05326	0.70307	0.13827	0.19467
05	0.96113	0.63678	0.01071	0.98057	0.79800	0.04820
06	0.56766	0.10520	0.36443	0.75280	0.29994	0.59879
07	–0.03890	0.28757	0.44891	0.00000	0.52824	0.66743