METHODS OF MEASUREMENT OF THE COLORIMETRIC FIDELITY OF TELEVISION CAMERAS

Measurement Procedures

Tech 3237 E Supplement 1 *Second edition - November 1989*

CONTENTS

Technical Centre of the European Broadcasting Union
Anclenne Route 17 A, CH-1218 Grand. Soconnex/Gonave, Sulase.

Introduction

The aim of these measurements is to obtain data that can be used to compute parameters which can give an objective assessment of camera colorimetric fidelity. The results will to a large extent depend on the accuracy of measurement and understanding of the procedures adopted. These procedures have been fully discussed in document [1].

Two methods giving similar results can be used, namely the real samples method and the spectrophotometric method. The flow chart of Fig. 1 indicates the process of successive measurement and computation. The real samples method is described in Chapter 1, the spectrophotometric method In Chapter 2, and the common calculation procedure in Chapter 3.

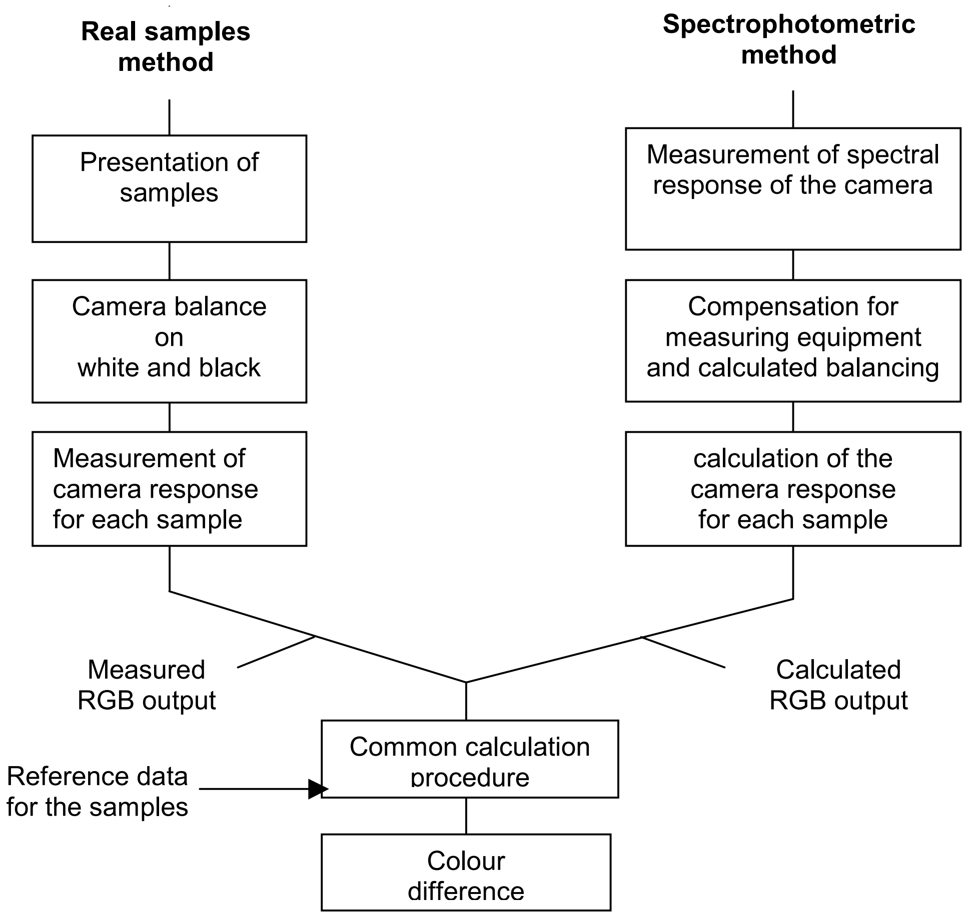


Fig. 1. - The two measurement methods with a common calculation procedure

CHAPTER 1
The real samples method

In this method, the camera is exposed to a number of coloured samples which are presented to the camera in turn. Assessment of the reproduction quality is given for each sample by the calculated value of the colour difference between the reproduced and original colours.

1.1. Equipment used

The prime requirement is a test jig or other arrangement for holding and illuminating the samples against a black background during measurement. The stability and calibration of the testing arrangement will to a large extent determine the accuracy and precision of the results.

The signal voltages from the camera R, G and B channels are measured with a differential oscilloscope or a video level meter. Accuracy should be better than + 0.5%, i.e. less than 3tV deviation for a white reference. To minimize the effects of noise, a low pass filter (about 0.5 MHz) should be inserted in the measurement chain although care must be taken to avoid introducing any appreciable phase distortion.

1.2. Colour samples

The EBU samples, EBU/CAM 1 to 159 listed in Table 1 shall be used.

Table 1.- EBU samples for television camera colorimetry

Sample	Source	EBU/CAM name	Munsell notation		
EBU/CAM 1	ColorChecker 1	Dark Skin	3	YR	3.7/3.2
EBU/CAM 2	ColorChecker 2	Light Skin	2.2	YR	6.47/4.1
EBU/CAM 3	BAM 1, Munsell	Light Greyish Red	7.5	R	6/4
EBU/CAM 4	BAM 3, Munsell	Light Yellow Green	5	GY	6/8
EBU/CAM 5	BAM 5, Munsell	Light Bluish Green	10	BG	6/4
EBU/CAM 6	BAM 7, Munsell	Light Violet	2.5	P	6/8
EBU/CAM 7	ColorChecker 4	Foliage	6.7	GY	4.2/4.1
EBU/CAM 8	Munsell	Medium Red	5	R	5/10
EBU/CAM 9	Munsell	Medium Green 1	0	GY	7/10
EBU/CAM 10	Munsell	Medium Blue	7.5	PB	5/12
EBU/CAM 11	Munsell	Dark Red	5	R	3/6
EBU/CAM 12	Munsell	Dark Green	10	GY	5/8
EBU/CAM 13	Munsell	Dark Blue	7.5	PB	3/8
EBU/CAM 14	Munsell	Medium Yellow Red	5	YR	7/10
EBU/CAM 15	Munsell	Medium Purple	5	P	5/10

*Other sets of samples conforming to the same chromaticity may be available, such as those produced by the BAN institute, Berlin (see Appendices 1, 2 and 3).

Each particular set of samples must be individually calibrated for spectral radiance factors by the supplier or by approved spectroradiometric equipment before initial use, and should occasionally be rechecked for ageing if subjected to excessive illumination and/or temperature.

For each sample the following data is required

- Tristimulus values X, Y, Z for EBU television illuminant i.e., D65'
- RGB values for the theoretical Ideal camera.
- CIE 1976 chromaticity co-ordinates u' and v'.
- CIELUV co-ordinates L*, u* and v*.

Reference data for a typical set of samples is to be found in Appendices 1, 2 and 3

1.3. White reference

A plaque of Barium Sulphate ($BaS0_4$)or a Halon bloc is recommended as the reference white.

1.4. Black reference

A black reference can be provided by a suitable cavity which should be lined internally with black velvet or similar material of low reflectance, and positioned in the place normally occupied by the samples or white reference.

Lens capping may alternatively be used to establish camera black levels.

1.5. Illumination of the samples

The samples shall be front illuminated by two calibrated low-voltage halogen lamps having a correlated colour temperature of 3100 K ± 100 K [1]. In addition, the light flux stability should be better than ± 0.5 % which can be obtained by lamp current stabilisation to ± 0.1 %.

The level of illumination depends on the sensitivity of the camera to be measured. Levels of between 1000 lx and 1500 lx are commonly used.

1.6. Lighting and viewing geometry

The Illumination and viewing conditions shall be in accordance with the CIE 45/0 specification [2].

The samples are front illuminated by two beams whose axes are at an angle of 45° ± 5° from the normal to the sample surface. The optical axis of the camera to be measured is positioned normal to the sample surface within ± 5°.

1.7. Adjustments prior to measurement

The camera to be measured should be equipped with the lens with which it is normally used, or a lens of similar type.

The camera shall be adjusted as for normal operation, but with particular attention to the following :

- Switch off the flare corrector (if possible).
- Switch off the contour corrector.

- Adjust black and white shading correctors for optimum flat field.
- Set gamma to unity (1.0), and switch off any black stretch and knee functions. Check that the camera channel transfer characteristic is effectively linear. If this cannot be done, measurements should be made with a probe at a point in the camera where the signals are linear.
- Focus the camera on the sample surface, set the aperture in the range f4 to f5.6, and set the focal length to give a central sample image of approximately 10% of the picture area, the remainder being a black background. When setting the lens focal length and aperture, take care to avoid excessive vignetting.
- Cheek that no stray light falls on the sample surface.
- Adjust the lamp current to the calibrated values which should be maintained throughout the measurement period.
- Adjust black balance and level on the black reference to obtain a nominal signal level of 35 mV (5%) in all channel outputs.
- Adjust white balance and level on the white reference to obtain a nominal signal level of 700 mV (100%) in all channel outputs, ensuring that the white clippers have no effect.
- Check that there is no significant change in white or black balance with the matrix switched in or out. The matrix should be checked if errors greater than 0.5% are observed.
- Verify the grey scale tracking.

1.8. Measurement procedure

The measurements should be made with the matrix switched in, however measurements with the matrix switched out may also be of value.

Measurement procedure is as follows :

- Place the samples in turn in front of the camera in the precise position occupied previously by the black and white references during camera balancing. The channel output signal levels, $R(A)_n$, $G(A)_n$, $B(A)_n$ in mV are recorded for each sample.
- To eliminate the effects of any possible instability in camera performance, the balance of the camera should be regularly checked on the black and white references. Checks should be made before and after the measurement of a complete set of samples.

- The camera gamma characteristic including black stretch and knee may be
- required for later computation. If measurements are not already available,
- the normal operational characteristic should be measured using procedures
- recommended in Tech. 3238. Alternatively, gamma can be measured using a
- suitable set of neutral real samples.
- Similarly, the matrix coefficients may be required for later computation, these should be found by electrical measurement.

1.9. Correction of measured values for common calculation procedure

The recorded primary signal levels for each sample $R(A)_n$ $B(A)_n$, $G(A)_n$ in mV will have been measured with respect to the blanking level of zero mV. Since the channel black levels R(b), G(b), B(b), were set above blanking level, and the white levels R(w), G(w), B(w), may not have peak values of precisely 700 mV, the recorded level for each sample must be corrected by the actual average recorded levels, for black and white. In addition the levels must be transformed to a percentage of peak white amplitude.

The corrections are performed by the following formulas:

$$
\begin{aligned}
R_n &= \frac{R(A)_n - R(b)}{R(w) - R(b)} \times 100\% \\
G_n &= \frac{G(A)_n - G(b)}{G(w) - G(b)} \times 100\% \qquad (1.\ 1) \\
B_n &= \frac{B(A)_n - B(b)}{B(w) - B(b)} \times 100\%
\end{aligned}
$$

The calculated values R_n, G_n and B_n, are the values to be used in subsequent calculations as described in Chapter 3.

CHAPTER 2
The Spectrophotometric method

In the spectrophotometric method, the spectral sensitivities of the camera R, G and B channels are measured and the reproduced colour is computed for a number of theoretical samples. The samples correspond to the real samples used in the real samples method and are defined in terms of their spectral radiance factors. Assessment of the reproduction quality is given for each sample by the calculated value of the colour difference between the computed reproduced colour and the original sample colour.

2.1. Equipment used

The prime requirement is a light source and monochromator assembly which can produce monochromatic light in the range of the visible spectrum, 380 nm to 730 nm. The stability and precision of the equipment will to a large extent determine the accuracy of the results.

The signal voltages from the camera R, G and B channels are measured with a differential oscilloscope or a video level meter. Accuracy should be better than 0.5%, i.e. less than 3 mV deviation for a white reference. To minimize the effects of noise, a low pass filter (about 0.5 MHz) should be inserted in the measurement chain although care must be taken to avoid introducing any appreciable phase distortion.

2.2. Monochromator calibration

It is essential that the monochromator assembly has been calibrated for wavelength (λ) and bandwidth. The relative spectral output power (E_λ) is also required since the data is used in subsequent computation.

The preferred method for establishing output power levels is by the use of a photocell continuously monitoring ($c_{m\lambda}$) the output of the monochromator at each selected wavelength. The cell itself must be very accurately calibrated for relative spectral sensitivity (CA), preferably by the manufacturer or by a standards laboratory.

If a monitoring cell cannot be made available, then the monochromator assembly must, before initial use, be calibrated for spectral output power (E,) by the manufacturer or by an approved standards laboratory. This calibration should not be attempted by the user unless comprehensive specialist facilities are available. The monochromator assembly will have been calibrated with a particular light source operating at a specified colour temperature and/or current. The source stability should be maintained by current stabilization to ± 0.1% to obtain repeatability in monochromator spectral output power.

To eliminate any errors due to backlash in the control mechanism, the wavelength scan during initial calibration and during the subsequent measurements must always be made in the same direction. A bandwidth of 5 nm is recommended.

Attention must be paid to avoiding stray light and spurious flux of unwanted order in the output of monochromator. Polarisation of the monochromator output light can alter the behaviour of colour camera splitting systems, and must therefore be eliminated, for example by use of a diffusing glass.

2.3. Viewing geometry

The camera to be measured shall be positioned so that its optical axle coincides with the optical axis of the monochromator assembly.

2.4. Adjustments prior to measurement

The camera to be measured should be equipped with the lens with which it is normally used, or a lens of similar type.

The camera shall be adjusted as for normal operation, but with particular attention to the following:

- Switch off the flare corrector (if possible);
- Switch off the contour corrector;
- Adjust black and white shading correctors for optimum flat fields;
- Set the gamma to unity (1.0), and switch off any black stretch and knee controls. Check that the camera channel transfer characteristic Is effectively linear. If this cannot be done, measurements should be made with a probe at a point in the camera where the signals are linear.

- Position the camera such that its optical axis is coincident with that of the monochromator assembly. The camera should be focused on the diffusing glass at the output of the monochromator, and the focal length set to give a centrally located image of the monochromator output approximately 10 % of the total picture area;
- Check that the ambient light does not affect the measurements. Fluorescent lights, monitor and VDU displays, and neon indicators are common sources of interference;
- Adjust the black level controls to introduce a lift of approximately 20 % in each of the camera channels. This lift is required to prevent crushing of the negative output signal voltages which are caused by the negative lobes of the channel spectral response curves when a camera has the matrix switched into service. Black balancing is performed by computation;
- Adjust the camera iris and channel gain controls to give reasonable maximum signal levels at the point of peak spectral response for each channel. White balancing is performed by computation.

2.5. Measurement procedure

The measurements should be made with the matrix switched in, however measurements with the matrix switched out may also be of interest.

The measurement procedure is as follows:

- Sweep the monochromator across the entire visible spectrum to verify that the negative lobes are not clipped and that the channel gains are set to give reasonable maximum signal levels in each channel. Record the channel black' levels R(b), G(b), and B(b), in mV.
- Scan the spectrum in 10 nm steps, or at 5 nm steps if greater accuracy is required for responses with large rates of change. For each step wavelength measure and record the signal levels at each channel output $R_{m\lambda}$ $G_{m\lambda}$ $B_{m\lambda}$, and also the monochromator monitoring photocell output $c_{m\lambda}$.
- The camera gamma characteristic including black stretch and knee may be required for later computation. If measurements are not already available, the normal operational characteristic should be measured using procedures recommended in Tech. 3238. Alternatively, gamma can be measured using a suitable set of neutral real samples.
- Similarly, the matrix coefficient will be required for later computation, these should be found by electrical measurement.

2.6. Theoretical samples

The samples used will be those specified for the real sample method which are listed below in Table 2.

Table 2. - EBU samples for television camera colorimetry

Samples	Source *	EBU/CAM name	Munsell notation		
EBU/CAM 1	ColorChecker 1	Dark Skin	3	YR	3.7/3.2
EBU/CAM 2	ColorChecker 2	Light Skin	2.2	YR	6.47/4.1
EBU/CAM 3	BAM 1, Munsell	Light Greyish Red	7.5	R	6/4
EBU/CAM 4	BAM 3, Munsell	Light Yellow Green	5	GY	6/8
EBU/CAM 5	BAM 5, Munsell	Light Bluish Green	10	BG	6/4
EBU/CAM 6	BAM 7, Munsell	Light Violet	2.5	P	6/8
EBU/CAM 7	ColorChecker 4	Foliage	6.7	GY	4.2/4.1
EBU/CAM 8	Mansell	Medium Red	5	R	5/10
EBU/CAM 9	Munsell	Medium Green	10	GY	7/10
EBU/CAM 10	Munsell	Medium Blue	7.5	PB	5/12
EBU/CAM 11	Munsell	Dark Red	5	R	3/6
EBU/CAM 12	Munsell	Dark Green	10	GY	5/8
EBU/CAM 13	Munsell	Dark Blue	7.5	PB	3/8
EBU/CAM 14	Munsell	Medium Yellow Red	5	YR	7/10
EBU/CAM 15	Munsell	Medium Purple	5	P	5/10

* *Other sets of samples conforming to the same chromaticity may be available, such as those produced by the BAM institute, Berlin. (see Appendices 1, 2 and 3).*

The spectral radiance factors $\beta_{m\lambda}$ for each sample are required for later computation. If the spectrophotometric method only is used, values in the Appendix for reference data for a typical sample set can be used. If both the real sample and spectrophotometric methods are used together, the values used must be those obtained by spectroradiometric calibration of the actual sample set.

2.7. Theoretical illumination of the samples

For calculation of the results, the theoretical illumination of the samples must be specified. Normally It shall be P 3100 which corresponds to standard studio lighting. The spectral distribution P_λ of, that light is given in Appendix 4.

2.8. Correction of measured values for common calculation procedure

The measured signals $R_{m\lambda}$, $G_{m\lambda}$, $B_{m\lambda}$, for the monochromatic radiations are first corrected for zero lift conditions. If the black levels at the output of the camera channels are R(b), G(b), B(b), the correction is as follows:

$$R_{l\lambda} = R_{m\lambda} - R(b)$$

$$G_{l\lambda} = G_{m\lambda} - G(b) \qquad (2.1)$$

$$B_{l\lambda} = B_{m\lambda} - B(b)$$

These values must then be corrected for the variation of power level with wavelength at the output of the monochromator. The measured data from the monitoring photocell, $c_{m\lambda}$, and its supplied calibration C_λ, or data supplied for the monochromator calibration, E_λ, is used for this purpose. The result of this correction is the relative spectral response for each of the three channels to an equi-energy source. For a monitoring photocell:

$$R(M)_\lambda = \frac{C_\lambda}{c_{m\lambda}} . R_{l\lambda}$$

$$G(M)_\lambda = \frac{C_\lambda}{c_{m\lambda}} . G_{l\lambda} \qquad (2.2)$$

$$B(M)_\lambda = \frac{C_\lambda}{c_{m\lambda}} . B_{l\lambda}$$

If a monitoring photocell is not available, then the monochromator power output calibration. E_λ should be substituted into equations 2.2 with the following identity:

$$\frac{C_\lambda}{c_{m\lambda}} = \frac{1}{E_\lambda} \qquad (2.3)$$

White balancing by computation must be performed on signals at the input to the matrix. For measurements made with matrix in service, the effect of the matrix, M. can be removed by linear algebra. Using the measured coefficients for the matrix, M, the signals before matrix are calculated as follows:

$$\begin{vmatrix} R_\lambda \\ G_\lambda \\ B_\lambda \end{vmatrix} = M^{-1} . \begin{vmatrix} R(M)_\lambda \\ G(M)_\lambda \\ B(M)_\lambda \end{vmatrix} \qquad (2.4)$$

It is then possible to calculate the overall response of each channel R_n, G_n, B_n, for a sample n having spectral radiance factors $\beta_{n\lambda}$, and illuminated by a source having a relative spectral distribution P_λ

$$\begin{vmatrix} R_n \\ G_n \\ B_n \end{vmatrix} = M . \begin{vmatrix} K_R . \sum_{380}^{730} \beta_{n\lambda}.P_\lambda.R_\lambda \\ K_G . \sum_{380}^{730} \beta_{n\lambda}.P_\lambda.G_\lambda \\ K_B . \sum_{380}^{730} \beta_{n\lambda}.P_\lambda.B_\lambda \end{vmatrix} \qquad (2.5)$$

The constants K_R , K_G , K_B , perform the computational white balancing and are calculated for the reference white, where

$$R_n = G_n = B_n = 1$$

and the spectral radiance factors $\beta_{n\lambda} = 1$.

For this particular case, equation 2.5 can be re-arranged as follows:

$$K_R . = \frac{1}{\sum_{380}^{730} P_\lambda.R_\lambda}$$

$$K_G . = \frac{1}{\sum_{380}^{730} P_\lambda.G_\lambda} \qquad (2.6)$$

$$K_B . = \frac{1}{\sum_{380}^{730} P_\lambda.B_\lambda}$$

The formulas giving R_n, G_n, and B_n correspond to adjustments of the camera channels gains to achieve unity output from each channel for the reference white. The inclusion of the matrix, M, In equation 2.5 restores the effect of the electrical matrix such that the output values R_n, G_n, B_n, are those of the matrix in service.

For measurements without matrix, the unit matrix U is substituted in equations 2.4 and 2.5, where:

$$M = U = \begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix} \qquad (2.7)$$

The spectral distribution P, is that of illuminant P3100 and is listed In Appendix 4. Typical values of the relative spectral radiance factors for the EBUICAN colour samples, $\beta_{n\lambda}$, can be found in Appendix 2.

R_n , G_n , B_n are the values to be used in the subsequent computations described In Chapter 3.

CHAPTER 3
Common calculation procedure

3.1. Camera transfer characteristic

The values R_n, G_n, B_n, as obtained by either measurement method, are for a linear camera transfer characteristic, and colour reproduction for an assumed overall linear system can be calculated from these values using the following procedures.

In a practical television system, gamma correction is introduced into the camera signal processing to compensate as far as possible for the power law characteristic of the CRT display. Additionally the overall system gamma is usually set to greater than unity to assist in correct visual appearance of grey scale and colour under normal viewing conditions.

To assess colour reproduction in terms of the visual appearance on the final CRT display, it is necessary to include the effects of the camera's gamma and other correctors. The values of R_n, G_n and B_n should be converted to the values of output that a camera switched to normal operation would have given. This can be done by reference to a look-up table constructed from measurement of the actual transfer function of the camera, as specified in document [3]. Correction for a display CRT gamma of 2.8 and an overall gamma of 1.2 [4], is included by raising the camera corrected values to a power of 2.8/1.2 = 2.3. Overall colour reproduction is then calculated from these modified values of R_n, G_n, B_n, using the following procedures.

The Presentation of Results should state clearly if overall linearity has been assumed, or compensation has been included for camera and display transfer functions.

3.2. Calculation of the calorimetric parameters characterising the reproduced colour samples

The camera response values R_n, G_n, B_n are converted to CIE colour parameters by calculation.

The colour defined by the components of the camera output signal must first be converted Into values of X, Y, Z, as defined by the CIE 1931 standard observer colorimetric reference system [2!. The matrix for this conversion Is:

$$\begin{vmatrix} X_n \\ Y_n \\ Z_n \end{vmatrix} = \begin{vmatrix} 0.4306 & 0.3416 & 0.1782 \\ 0.2220 & 0.7067 & 0.0713 \\ 0.0202 & 0.1296 & 0.9392 \end{vmatrix} . \begin{vmatrix} R_n \\ G_n \\ B_n \end{vmatrix}$$

The CIE 1976 chromaticity co-ordinates u' and v' [5] are calculated:

$$u' = \frac{4X_n}{X_n + 15Y_n + 3Z_n} \qquad (3.2)$$

$$v' = \frac{9Y_n}{X_n + 15Y_n + 3Z_n}$$

Next, the CIELUV 1976 colour space parameters are calculated:

$$L^*_n = 116\,(Y_n / Y_0)^{1/3} - 16$$

$$U^*_n = 13\,L^*_n\,(u'_n - U'_0)$$

$$V^*_n = 13\,L^*_n\,(v'_n - v'_0) \qquad (3.3)$$

$$C^*n = (u^{*2}_n + V^{*2}_n)^{1/2}$$

where Y_0, u'_0 , v'_0 , are the co-ordinates for D_{65} reference white, and have the values:

Y0 = 1

u'_0 = 0.1978

v'_0 = 0.4683

The formula for L^*_n is only valid for $Y_n/Y_0 > 0.01$. This condition is satisfied for the EBU/CAM colour samples.

The parameters derived from equation 3.3 are used for colour difference calculations.

3.3. Calculation of the calorimetric parameters characterising the original colour samples

The colour of the original sample in defined for television viewing conditions (D_{65} illuminant) in the CIELUV 1976 colour space.

The tristimulus values X_{0n} , Y_{0n} , Z_{0n} ,of the original colour of ample n are given by:

$$X_{0n} = K_{\gamma} . \sum_{380}^{730} \beta_{n\lambda} . D_{\lambda} . \overline{x_{\lambda}}$$

$$Y_{0n} = K_{\gamma} . \sum_{380}^{730} \beta_{n\lambda} . D_{\lambda} . \overline{y_{\lambda}} \qquad (3.4)$$

$$Z_{0n} = K_{\gamma} . \sum_{380}^{730} \beta_{n\lambda} . D_{\lambda} . \overline{z_{\lambda}}$$

where D_{λ} is the spectral energy distribution for illuminant D_{65}, and $\overline{x_{\lambda}}$, $\overline{y_{\lambda}}$ and $\overline{z_{\lambda}}$ are the colour matching functions for the CIE 1931 standard observer. Tables for these parameters can be found in Appendices 5 and 6. The constant Kγ is defined so that Y_{0n} will have the value of 1 or 100% for the reference white.

The CIE 1976 co-ordinates are calculated from the equation 3.2, and the CIELUV colour space co-ordinates from equation 3.3. The latter co-ordinates are used for colour difference calculations.

3.4. Calculation of colour difference

The colour difference is calculated as the square root of the sum of the squares of the difference between the values of L*, u*, and v* co-ordinates for the reproduced and original colour samples:

$$\Delta E^*n = (\Delta L^*n2 + \Delta u^*n2 + \Delta v^*n2)1/2 \qquad (3.5)$$

where:

$$\Delta L^*_n = L^*_n - L^*_{0n}$$

$$\Delta u^*_n = u^*_n - u^*_{0n} \qquad (3.6)$$

$$\Delta v^*_n = v^*n - v^{*0n}$$

and also:

$$\Delta C^*_n = C^*_n - C^*_{0n} \qquad (3.\ 6a)$$

The colour difference ΔE* can also be expressed in terms of differences in lightness ΔL*, chroma ΔC*, and hue ΔH*.

$$\Delta\ E^* = (\ \Delta L^{*\prime} + \Delta C^{*\prime} + \Delta C'\ )\ 112 \qquad (3.7)$$

where ∆L* and ∆C* are an defined in equation 3.6, and equation 3.7 is itself the definition of CIE 1976 u v hue difference ∆H*.

The L*u*v* CIELUV 1976 co-ordinates are not accepted without reservations for assessing colour television reproduction. This co-ordinate system is adopted here in the absence of any other more acceptable system. However, any future dimensioning system is likely to be calculable from existing data.

CHAPTER 4
Presentation of results

The measured and calculated results should be clearly presented. The following pages show an example presentation :

Measurement method: Real sample/spectrophotometric

Operator: Date: Time:

4.1. Camera

Camera, type and serial No. :

Matrix in service : Yes/No

Matrix Coefficients :

$$\begin{vmatrix} R_{out} \\ G_{out} \\ B_{out} \end{vmatrix} = \begin{vmatrix} \quad & \quad & \quad \end{vmatrix} \cdot \begin{vmatrix} R_{in} \\ G_{in} \\ B_{in} \end{vmatrix}$$

Flare corrector in service : Yes/No

Contour corrector in service : Yes/No

Compensation for camera and display transfer functions : Yes/No

Camera lens, type and serial No. :

Camera tubes, type and serial No. :

Red :

Green :

Blue :

4.2. Test colours

Identification reference of sample set:

Sample	Source	EBU/CAM name	Munsell notation		
EBU/CAM 1		Dark Skin	3	YR	33/3.2
EBU/CAM 2		Light Skin	2.2	YR	6.47/4.1
EBU/CAM 3		Light Greyish Red	7.5	R	6/4
EBU/CAM 4		Light Yellow Green	5	GY	6/8
EBU/CAM 5		Light Bluish Green	10	BG	6/4
EBU/CAM 6		Light Violet	2.5	P	6/8
EBU/CAM 7		Foliage	6.7	GY	4.2/4.1
EBU/CAM 8		Medium Red	5	R	5/10
EBU/CAM 9		Medium Green	10	GY	7/10
EBU/CAM 10		Medium Blue	7.5	PB	5/12
EBU/CAM 11		Dark Red	5	R	3/6
EBU/CAM 12		Dark Green	10	GY	5/8
EBU/CAM 13		Dark Blue	7.5	PB	3/8
EBU/CAM 14		Medium Yellow Red	5	YR	7/10
EBU/CAM 15		Medium Purple	5	P	5/10

4.3. Original and reproduced colour data

a) Camera RGB values

	Ideal RGB values			Measured RGB values*		
	R	G	B	R	G	
	mV / %	mV / %	mV / %	mV / %	mV / %	mV / %
EBU/CAM 1						
EBU/CAM 2						
EBU/CAM 3						
EBU/CAM 4						
EBU/CAM 5						
EBUICAM 6						
EBU/CAM 7						
EBU/CAM 8						
EBU/CAM 9						
EBU/CAM 10						
EBU/CAM 11						
EBU/CAM 12						
EBU/CAM 13						
EBU/CAM 14						
EBU/CAM 15						

* If compensation for camera and display transfer functions are to be included, then the measured RGB values must be modified by the procedures described in Section 3.1.

b) CIE 1976 co-ordinates

	Original colour			Reproduced colour		
	Y	**U'**	**V'**	**Y**	**U'**	**V'**
EBU/CAM 1						
EBU/CAM 2						
EBU/CAM 3						
EBU/CAM 4						
EBU/CAM 5						
EBU/CAM 6						
EBU/CAM 7						
EBU/CAM 8						
EBU/CAM 9						
EBU/CAM 10						
EBU/CAM 11						
EBU/CAM 12						
EBU/CAM 13						
EBU/CAM 14						
EBU/CAM 15						

As an example, a plot of the u', v' co-ordinates in the CIE 1976 diagram for a given reproduction is shown in Fig. 4.1.

c) CIELUV co-ordinates

	Original colour			Reproduced colour		
	L*	**u***	**v***	**L***	**u***	**v***
EBU/CAM 1						
EBU/CAM 2						
EBU/CAM 3						
EBU/CAM 4						
EBU/CAM 5						
EBU/CAM 6						
EBU/CAM 7						
EBU/CAM 8						
EBU/CAM 9						
EBU/CAM 10						
EBU/CAM 11						
EBU/CAM 12						
EBU/CAM 13						
EBU/CAM 14						
EBU/CAM 15						

d) Colour difference data

	ΔL*	**ΔC***	**ΔH***	**ΔE***
EBU/CAM 1 EBU/CAM 2 EBU/CAM 3 EBU/CAM 4 EBU/CAM 5 EBU/CAM 6 EBU/CAM 7 EBU/CAM 8 EBU/CAM 9 EBU/CAM 10 EBU/CAM 11 EBU/CAM 12 EBU/CAM 13 EBU/CAM 14 EBU/CAM 15				

4.4. Average results

ΔE_A* for skin tones Nos. 1, 2 :

ΔE_A* for desaturated colours Nos. 3, 5, 6, 7 :

ΔE_A* for middle saturated colours Nos. 4, 9, 12, 15 :

ΔE_A* for strong saturated colours Nos. 8, 10, 11, 13, 14 :

4.5. Gamma characteristic

Input %	output %
100	100

Gamma mean index : Gamma maximum gain :

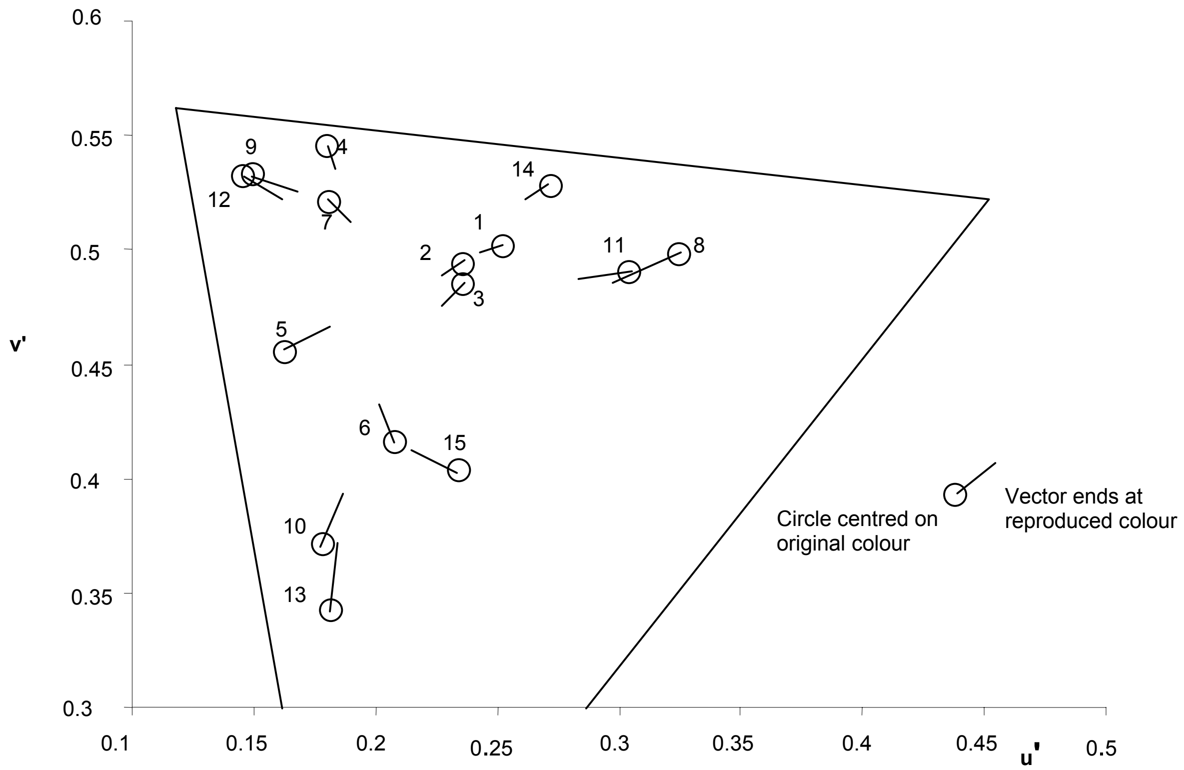
4.6. Spectral sensitivity-curves

Spectral sensitivity curves measured by the spectrophotometric method are shown in Fig. 4. 2.

4.7. Colour difference diagram

A diagram showing the spread of colour difference ΔE* errors for the colour samples grouped into skin tones, desaturated colours, and saturated colours is shown in Fig. 4.3.

N.B. This form of presentation is valuable for comparison between cameras, and may also be used for comparison against users' specification limits.



4. 1 - Example of colour reproduction in the CIE 1976 digram

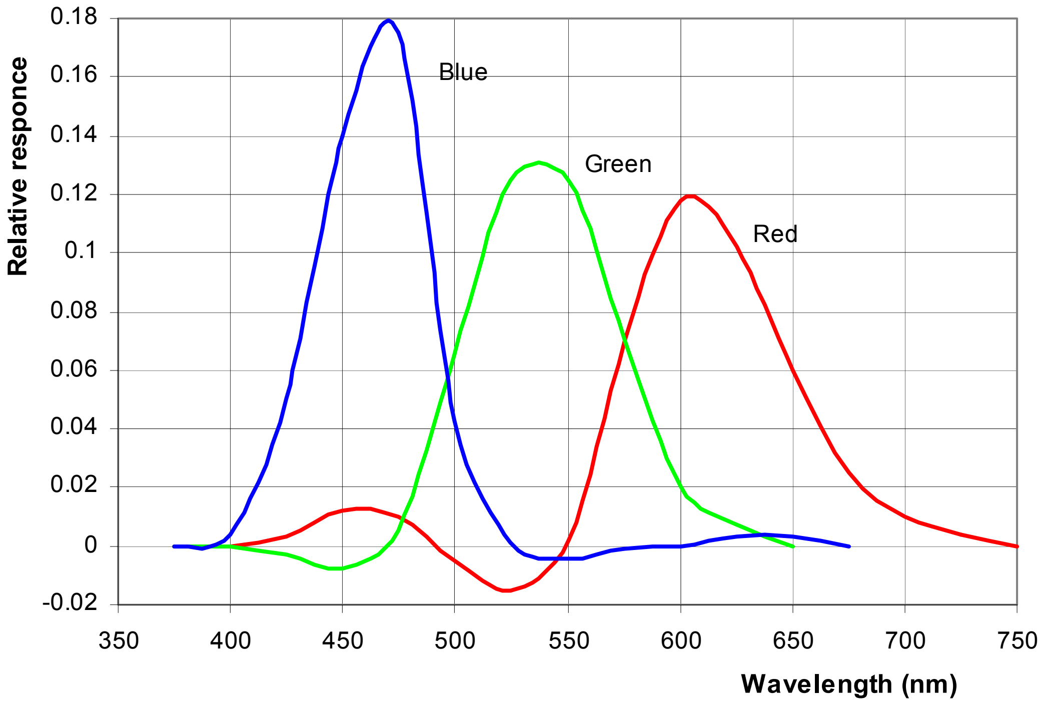


Fig. 4.2. - Example of camera response balanced for white P 3100

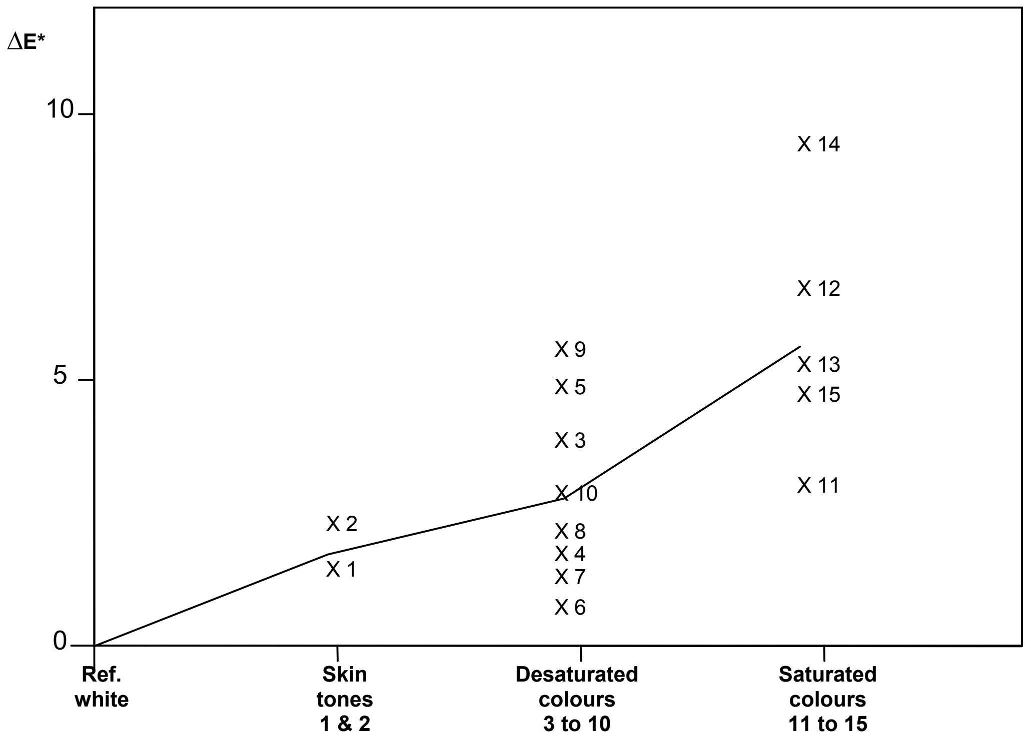


Fig. 4.3. - Example of distribution of colour differences within the set of samples

APPENDICES

The sample reference data presented in Appendices 1, 2 and 3 is that for a particular set of recommended EBU/CAM samples [6,7].

For the spectrophotometric method this data may be used as the original ample data.

For the real sample method however, the actual samples used must be calibrated to obtain the original data values since small variations may exist between samples of different batch manufacture.

Note: The use of sets with different characteristics will not lead to Incompatible results provided the differences are small. The two methods specified for measuring colorimetric fidelity are aimed at determining the colour difference between the sample and its reproduction, and not the absolute colour obtained. Camera performance would generally be the same for all colours having nearly the same spectral characteristics. All samples of the same colour do not therefore have to be absolutely identical in various sets.

Appendix 1
Typical sample reference data - colorimetric co-ordinates

Sample	X	Y	Z	u'	v'	R%	G%	B%	L*	u*	v*
EBU/CAM 1	10.9	9.6	5.8	0.2530	0.5015	17.25	7.69	4.74	37.11	26.65	13.93
EBU/CAM 2	40.7	37.7	27.3	0.2366	0.4931	59.16	32.41	23.32	67.80	34.17	20.68
EBU/CAM 3	32.7	29.8	24.5	0.2364	0.4848	46.99	25.23	21.59	61.48	30.87	12.31
EBU/CAM 4	22.3	29.9	7.6	0.1807	0.5452	23.03	34.79	2.80	61.57	-13.69	56.15
EBU/CAM 5	24.0	29.8	39.4	0.1629	0.4552	13.26	34.28	36.94	61.48	-27.88	-10.26
EBU/CAM 6	34.0	30.1	55.4	0.2087	0.4157	35. 87	25.81	54.65	61.74	8.27	-38.64
EBU/CAM 7	10.5	13.4	6.7	0.1813	0.5207	19.31	15.24	4.81	43.36	-9.29	29.12
EBU/CAM 8	28.5	19.4	10.5	0.3248	0.4974	55.27	9.21	8.72	51.15	84.43	16.79
EBU/CAM 9	27.7	43.6	18.2	0.1505	0.5329	15.44	55.70	11.36	71.96	-44.28	62.85
EBU/CAM 10	18.7	17.2	47.0	0.1791	0.3706	10.97	16.09	47.59	48.51	-11.82	-67.73
EBU/CAM 11	9.1	6.5	4.3	0.3046	0.4895	16.77	3.55	3.73	30.64	42.53	6.95
EBU/CAM 12	12.3	19.9	8.6	0.1462	0.5321	5.86	25.77	5.48	51.72	-34.74	45.63
EBU/CAM 13	7.2	6.0	20.2	0.1825	0.3422	4.09	5.12	20.71	29.41	-5.85	-47.04
EBUICAN 14	50.6	43.5	13.1	0.2726	0.5273	88.15	33.11	7.48	71.89	69.92	54.30
EBU/CAM 15	26.2	20.0	40.0	0.2349	0.4034	33.37	13.79	39.97	51.84	24.97	-48.17

Appendix 2
Typical sample reference data - spectral radiance factors

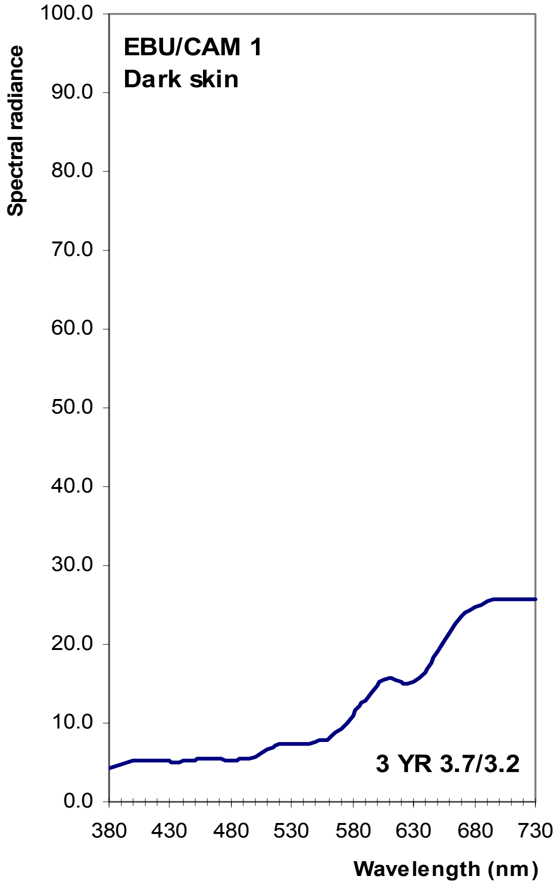
Wavelength (nm)	Spectral radiance factors							
	1	2	3	4	5	6	7	8
380	4.3	9.4	10.9	5.0	11.2	12.9	4.0	7.3
385	4.6	11.6	13.6	5.4	15.2	17.8	4.6	8.5
390	4.8	14.3	17.3	5.6	19.1	24.3	5.3	9.5
395	5.0	17.4	20.5	5.8	23.6	33.4	6.6	10.2
400	5.2	19.8	22.5	5.9	27.7	42.8	8.0	10.6
405	5.2	21.2	23.4	5.9	30.4	49.4	9.2	10.7
410	5.2	21.6	23.6	5.9	31.3	53.9	8.9	10.7
415	5.2	21.8	23.5	5.9	31.8	55.5	7.2	10.4
420	5.2	21.9	23.2	5.9	32.2	56.4	7.8	10.5
425	5.2	22.0	22.9	5.9	32.7	56.9	7.2	10.4
430	5.2	22.0	22.7	6.0	33.1	56.8	6.6	10.3
435	5.1	22.2	22.6	6.1	33.6	56.6	6.1	10.2
440	5.2	22.4	22.6	6.2	34.2	56.0	5.7	10.1
445	5.2	22.8	22.6	6.3	34.7	55.2	5.5	9.9
450	5.3	23.3	22.5	6.4	35.4	54.2	5.4	9.8
455	5.4	24.0	22.4	6.5	36.0	52.9	5.3	9.7
460	5.4	24.6	22.5	6.5	36.8	51.5	5.3	9.6
465	5.4	25.7	22.7	6.6	37.8	50.0	5.4	9.5
470	5.4	26.8	22.8	6.7	38.7	48.4	5.5	9.3
475	5.3	28.1	22.7	6.7	39.6	46.3	5.6	9.1
480	5.3	29.4	22.4	6.8	40.1	44.2	5.8	9.0
485	5.3	31.0	22.1	6.9	40.5	41.8	6.2	8.8
490	5.4	32.2	21.6	7.2	40.7	39.4	6.6	8.7
495	5.5	33.3	21.3	7.8	40.6	37.2	7.2	8.6
500	5.7	34.1	21.1	9.0	40.5	35.3	8.0	8.5
505	6.1	34.3	21.0	11.3	40.3	33.8	9.2	8.4
510	6.6	34.1	20.9	15.1	39.9	31.9	10.9	8.3
515	7.0	33.6	20.7	20.9	39.3	29.9	13.4	8.2
520	7.3	33.1	20.4	26.5	38.7	28.3	15.6	8.0
525	7.4	32.7	19.9	32.0	37.8	26.8	17.8	7.9
530	7.4	32.5	19.5	37.2	37.1	26.1	19.2	7.8
535	7.4	32.3	19.4	40.7	36.1	25.7	19.8	7.9
540	7.4	31.9	19.9	42.6	34.9	25.6	19.5	8.1
545	7.5	31.6	21.2	43.3	33.6	25.6	18.5	8.5
550	7.6	31.1	23.0	43.2	32.0	25.6	17.3	9.1
555	7.8	30.5	26.2	42.4	31.2	25.3	15.8	9.9
560	8.2	30.1	29.5	41.3	28.9	25.0	14.5	11.2
565	8.7	29.8	32.5	39.7	27.5	25.1	13.3	12.6
570	9.3	30.6	35.4	37.9	26.2	25.5	12.1	14.7
575	10.1	32.3	38.7	35.5	25.1	26.5	11.2	17.3

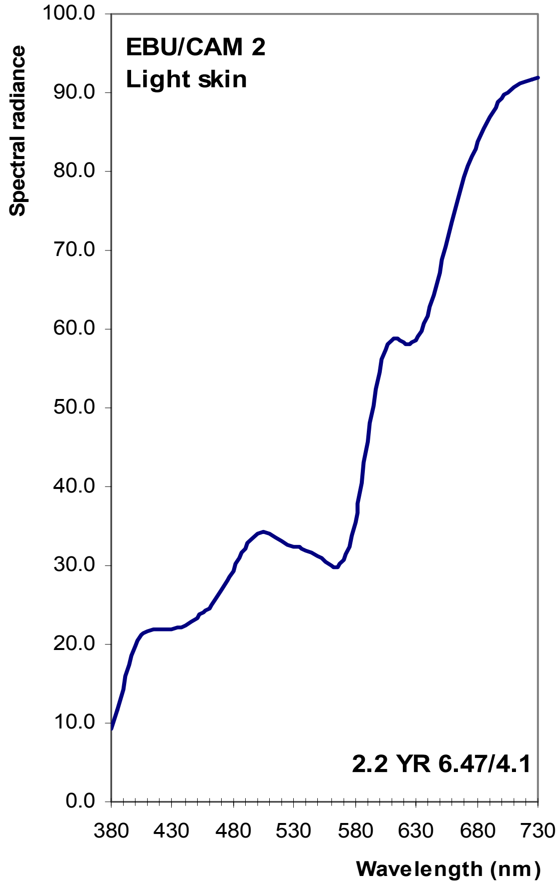
Wavelength (nm)	Spectral radiance factors							
	1	2	3	4	5	6	7	8
580	11.0	35.4	41.8	33.1	24.2	28.	10.	21.2
585	12.1	40.5	44.8	30.5	23.2	30.	10.	26.0
590	12.9	45.6	47.2	27.9	22.3	31.	10.	31.3
595	13.9	50.2	47.6	25.4	21.4	33.	10.0	36.3
600	14.8	54.5	45.8	23.1	20.5	34.	10.0	41.7
605	15.5	57.3	43.4	21.2	19.7	35.	10.1	46.3
610	15.7	58.6	41.4	19.7	18.9	34.	10.2	50.0
615	15.5	58.8	39.6	18.7	18.2	33.8	10.4	53.1
620	15.2	58.3	38.2	17.8	17.7	33.1	10.6	55.3
625	15.0	58.2	37.1	17.2	17.4	32.7	10.9	57.1
630	15.2	58.6	36.1	16.7	17.1	33.2	11.4	58.2
635	15.7	59.7	35.2	16.2	16.8	34.5	12.0	59.2
640	16.5	61.6	34.4	15.8	16.5	36.4	12.6	59.6
645	17.7	64.4	33.6	15.4	16.3	39.2	13.5	60.0
650	19.0	67.2	33.0	15.2	16.2	42.4	14.4	60.2
655	20.3	70.4	32.5	15.0	16.2	46.0	15.4	60.3
660	21.5	73.6	32.4	15.0	16.2	49.4	16.5	60.4
665	22.6	76.4	32.6	15.2	16.2	52.8	17.6	60.5
670	23.6	79.3	32.8	15.5	16.3	55.8	18.7	60.5
675	24.2	81.8	33.2	15.8	16.4	58.5	19.7	60.5
680	24.7	83.7	33.9	16.1	16.4	60.6	20.6	60.4
685	25.1	85.5	34.7	16.6	16.5	62.7	21.6	60.4
690	25.4	86.9	35.5	17.2	16.4	64.1	22.5	60.4
695	25.6	88.2	36.4	17.7	16.3	64.2	23.5	60.3
700	25.7	89.2	37.1	18.1	16.2	66.4	24.5	60.3
705	25.7	89.9	37.7	18.4	16.0	67.2	25.6	60.3
710	25.7	90.6	37.9	18.3	15.9	67.6	26.7	60.2
715	25.7	91.1	37.8	18.1	16.0	67.9	28.2	60.2
720	25.7	91.4	37.5	17.8	16.1	68.2	29.7	60.1
725	25.6	91.6	37.1	17.3	16.2	68.3	31.1	60.1
730	25.6	91.8	36.6	16.7	16.3	68.4	32.2	60.0

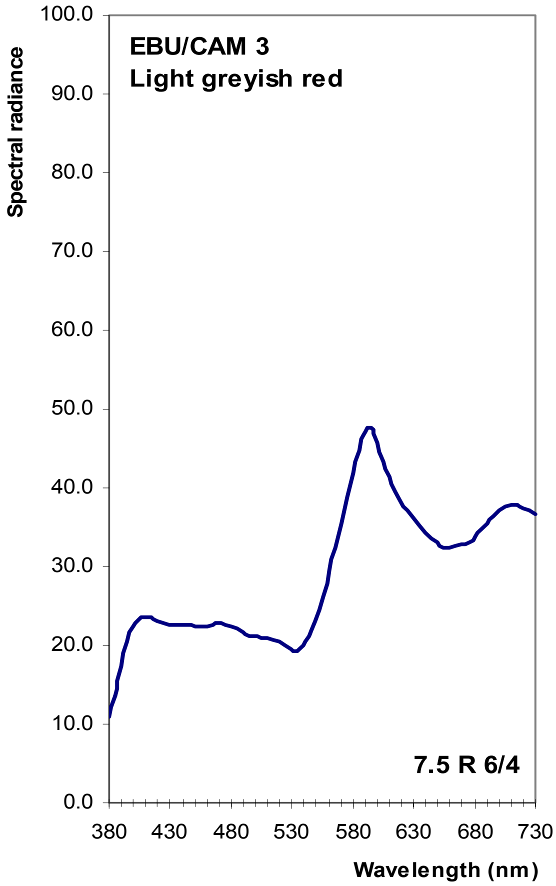
Wavelength (nm)	Spectral radiance factors						
	9	10	11	12	13	14	15
380	7.0	11.0	4.1	4.2	6.7	7.8	12.2
385	8.1	14.31	4.2	4.4	8.7	9.0	15.7
390	8.9	19.8	4.2	4.5	10.8	10.0	22.3
395	9.6	26.0	4.3	4.6	13.3	10.8	30.4
400	10.1	32.7	4.3	4.7	15.5	11.3	37.3
405	10.3	38.2	4.3	4.7	17.4	11.5	42.3
410	10.4	40.9	4.2	4.7	18.4	11.4	44.6
415	10.5	42.5	4.2	4.8	19.1	11.3	45.7
420	10.5	43.9	4.1	4.9	19.7	11.3	46.1
425	10.7	45.4	4.1	5.0	20.3	11.3	45.9
430	10.8	46.3	4.1	5.0	21.0	11.4	45.1
435	11.2	47.3	4.0	5.1	21.9	11.4	44.0
440	11.5	48.0	4.0	5.2	22.3	11.5	42.7
445	11.8	48.2	4.0	5.4	22.0	11.6	41.0
450	12.4	47.7	4.0	5.6	21.2	11.7	39.4
455	13.3	46.8	4.0	6.1	20.3	11.8	37.7
460	14.3	45.4	3.9	6.6	19.3	11.9	35.9
465	15.8	43.9	3.9	7.4	18.3	12.0	34.3
470	17.5	42.0	3.8	8.2	16.9	12.0	32.4
475	19.9	39.7	3.7	9.4	15.5	12.0	30.6
480	22.9	37.2	3.6	11.1	14.1	12.0	28.5
485	26.8	34.4	3.6	13.5	12.5	12.1	26.5
490	31.6	31.9	3.7	15.7	11.2	12.2	24.6
495	37.6	29.5	3.7	19.1	10.1	12.7	23.0
500	43.4	27.5	3.8	21.7	9.2	13.7	21.7
505	49.8	25.6	4.1	24.9	8.5	15.6	20.5
510	55.2	23.9	4.2	27.0	7.8	18.2	19.2
515	59.8	22.2	4.2	28.5	7.2	20.7	17.7
520	62.3	20.5	4.1	28.7	6.6	23.0	16.3
525	63.2	19.2	4.0	28.3	6.2	24.2	15.3
530	62.8	18.0	3.9	27.5	5.8	24.9	14.4
535	61.4	17.2	3.9	26.7	5.5	25.5	14.1
540	59.3	16.5	3.9	25.9	5.4	26.2	14.0
545	56.6	15.8	3.9	25.3	5.3	27.8	14.1
550	53.7	15.1	3.9	24.8	5.2	31.1	14.2
555	50.7	14.4	3.9	24.2	5.0	35.3	14.0
560	47.7	13.5	3.9	23.5	4.9	43.2	13.9
565	44.8	12.9	4.0	22.3	4.8	50.0	14.0
570	42.2	12.7	4.1	20.4	4.6	57.6	14.7
575	39.5	12.7	4.6	18.5	4.6	62.9	16.3

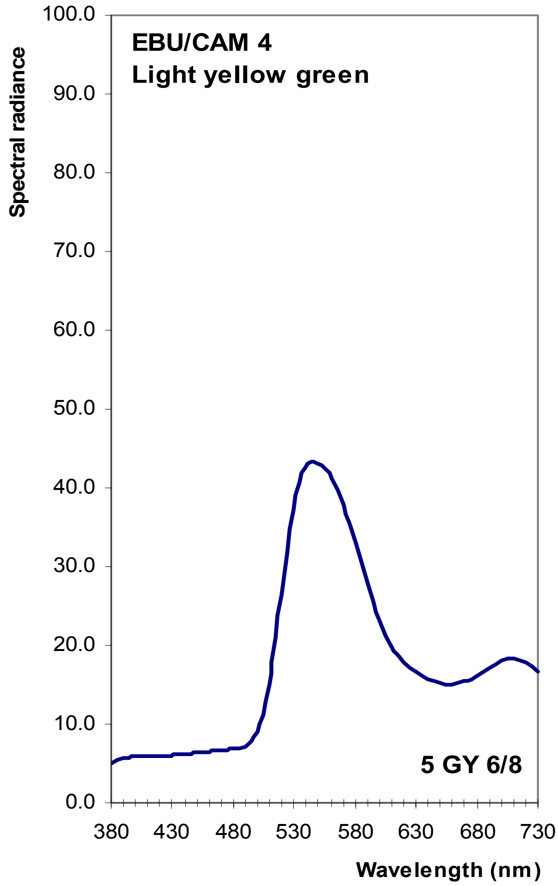
Wavelength (nm)	Spectral radiance factors						
	9	10	11	12	13	14	15
580	37.3	12.7	5.4	16.6	4.6	66.8	18.1
585	34.5	12.9	6.6	14.9	4.7	69.2	21.0
590	32.2	13.0	8.1	13.2	4.7	70.8	23.9
595	29.4	13.1	9.9	11.8	4.7	71.8	27.0
600	27.1	13.1	11.9	10.7	4.6	72.6	29.1
605	24.7	13.0	13.8	10.0	4.5	73.0	30.5
610	22.9	12.9	15.6	9.2	4.4	73.3	31.0
615	21.6	12.8	17.0	8.8	4.3	73.4	30.8
620	20.5	12.8	18.1	8.5	4.3	73.4	30.3
625	19.7	13.0	18.9	8.3	4.3	73.5	30.0
630	18.9	13.3	19.4	8.1	4.3	73.5	30.5
635	18.2	14.0	19.8	8.0	4.4	73.5	31.7
640	17.7	14.8	20.0	7.9	4.4	73.5	33.9
645	17.2	15.8	20.1	7.9	4.6	73.6	36.7
650	16.8	16.7	20.2	7.7	4.9	73.6	40.3
655	16.6	17.5	20.2	7.7	5.1	73.5	44.5
660	16.5	18.4	20.1	7.7	5.2	73.5	48.8
665	16.6	18.8	20.0	8.0	5.3	73.5	53.0
670	16.7	19.0	19.9	8.1	5.3	73.5	57.3
675	16.9	18.7	19.8	8.3	5.3	73.4	61.4
680	17.4	18.4	19.7	8.4	5.2	73.4	65.0
685	17.9	17.9	19.6	8.7	5.1	73.4	68.8
690	18.3	17.8	19.5	8.9	5.0	73.5	71.7
695	18.8	17.9	19.4	9.1	4.9	73.5	74.8
700	19.3	18.0	19.3	9.2	4.8	73.5	77.2
705	19.5	18.5	19.3	9.2	4.7	73.5	79.2
710	19.6	19.1	19.2	9.0	4.7	73.5	81.1
715	19.6	19.9	19.2	8.8	4.8	73.5	82.5
720	19.5	20.8	19.1	8.7	5.0	73.5	84.0
725	19.4	21.7	19.1	8.6	5.2	73.5	85.4
730	19.3	22.3	19.0	8.5	5.3	73.5	86.2

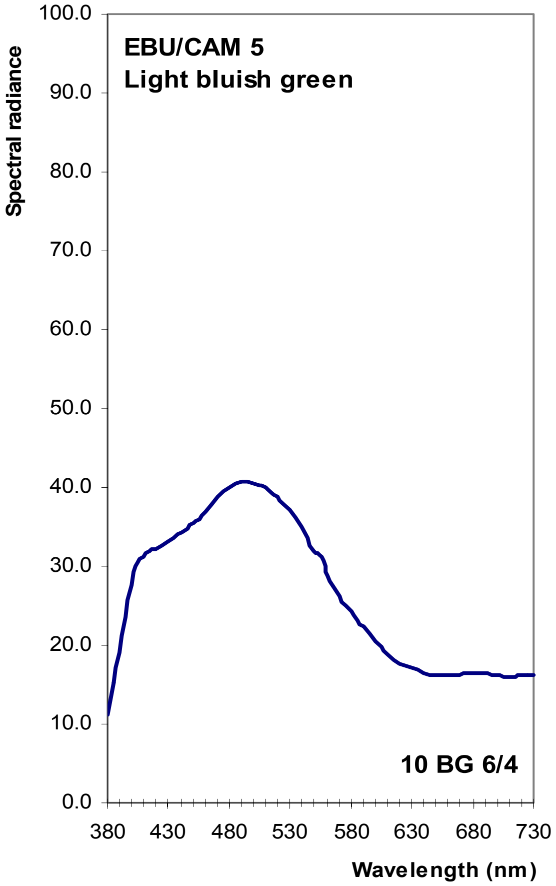
Appendix 3
Typical sample reference data - spectral radiance plots

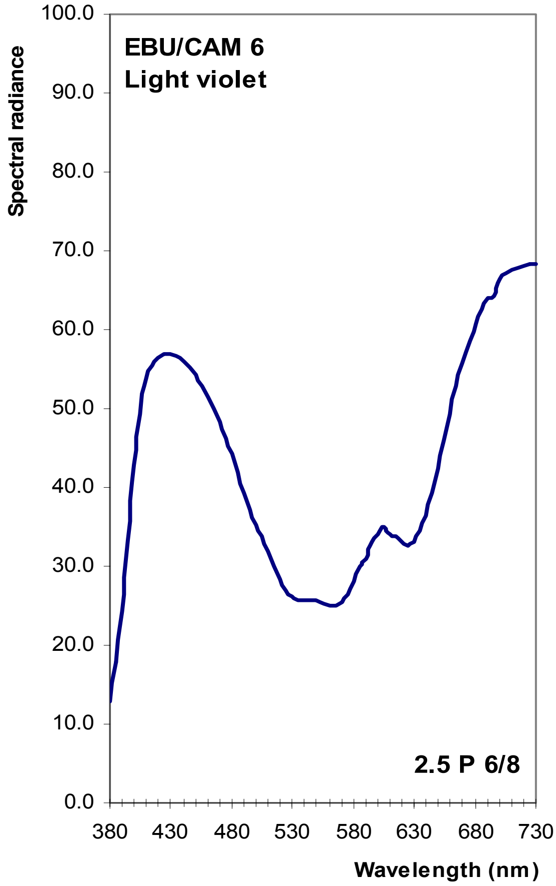

EBU/CAM 1
Dark skin
3 YR 3.7/3.2
Spectral radiance
Wavelength (nm)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
380
430
480
530
580
630
680
730

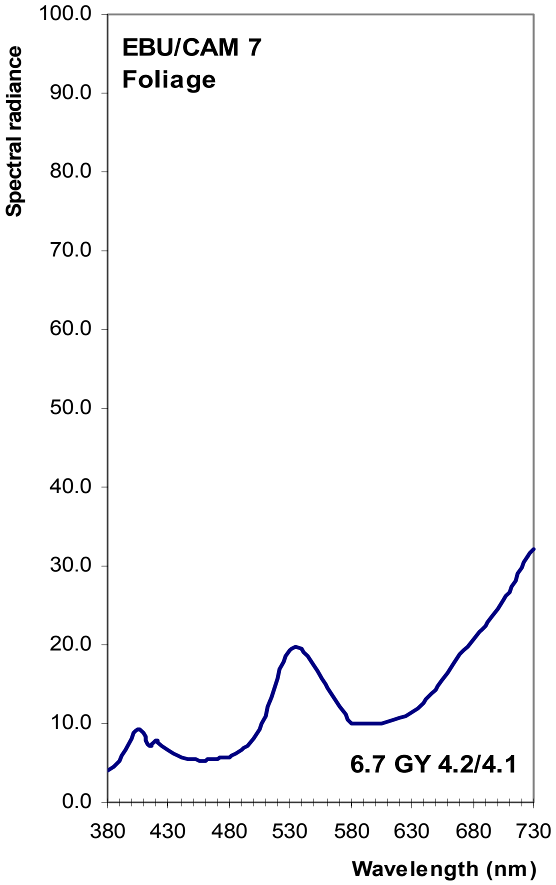

EBU/CAM 2
Light skin
2.2 YR 6.47/4.1
Spectral radiance
Wavelength (nm)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
380
430
480
530
580
630
680
730

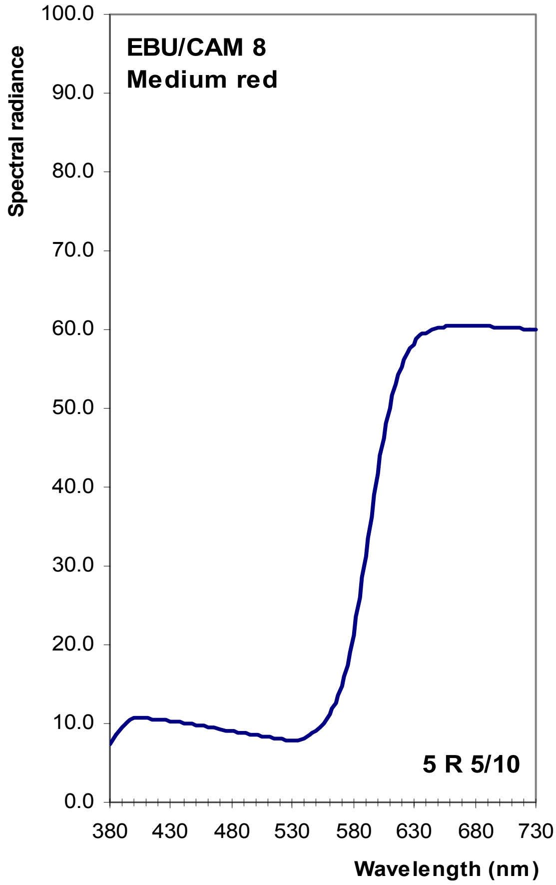

EBU/CAM 3
Light greyish red
7.5 R 6/4
Spectral radiance
Wavelength (nm)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
380
430
480
530
580
630
680
730

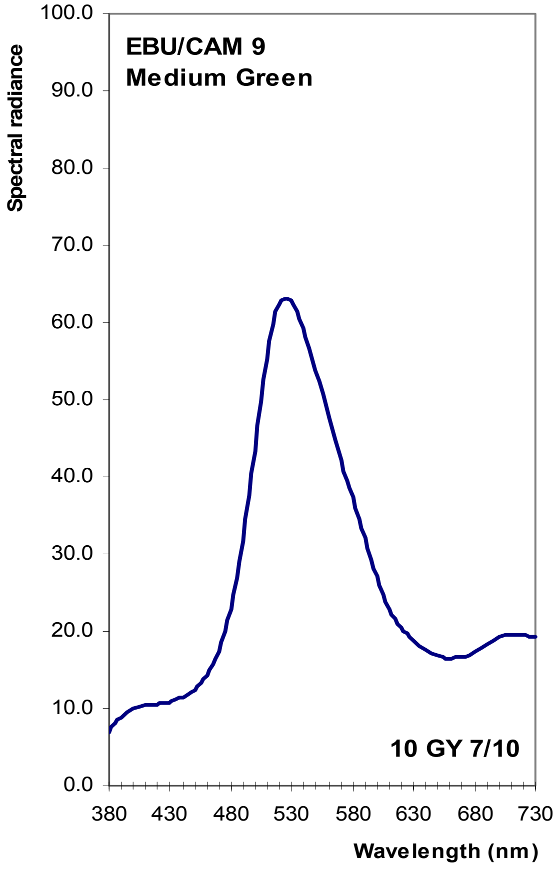

EBU/CAM 4
Light yellow green
5 GY 6/8
Spectral radiance
Wavelength (nm)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
380
430
480
530
580
630
680
730


EBU/CAM 5
Light bluish green
10 BG 6/4
Spectral radiance
Wavelength (nm)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
380 430 480 530 580 630 680 730

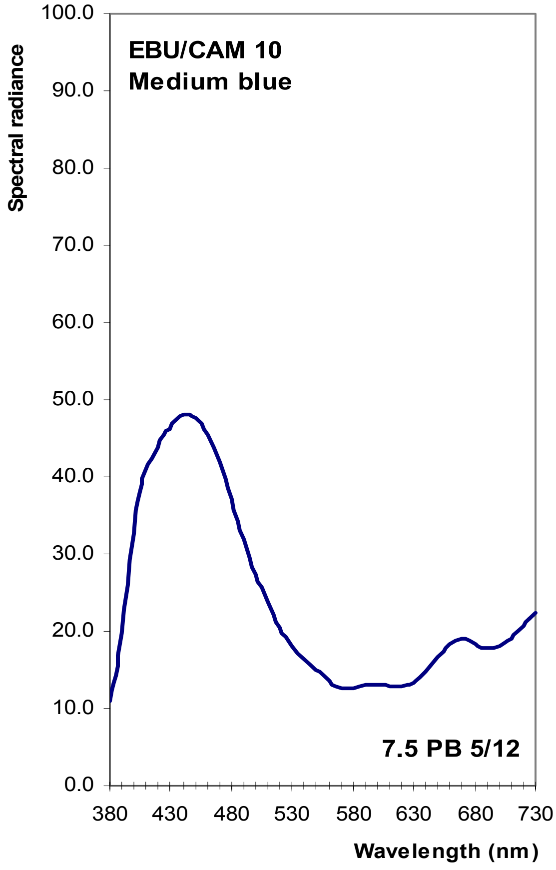

EBU/CAM 6
Light violet
2.5 P 6/8
Spectral radiance
Wavelength (nm)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
380 430 480 530 580 630 680 730


EBU/CAM 7
Foliage
6.7 GY 4.2/4.1
Spectral radiance
Wavelength (nm)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
380 430 480 530 580 630 680 730

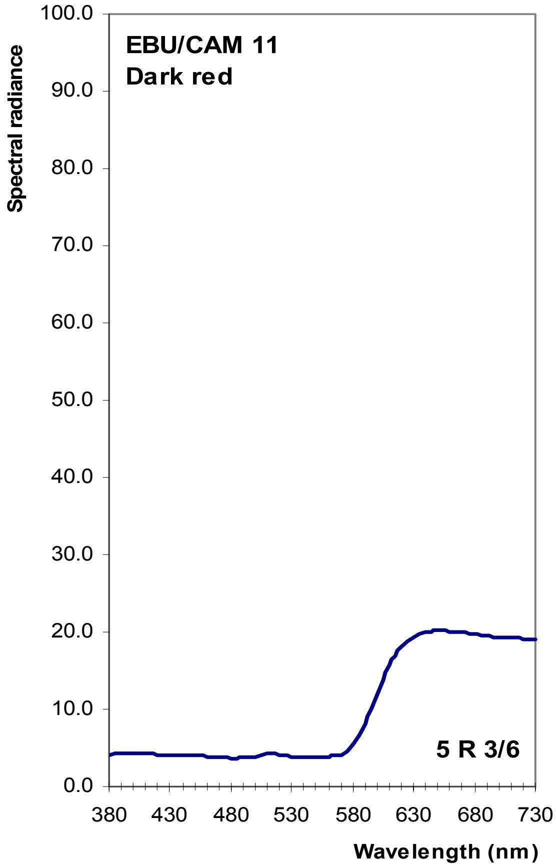

EBU/CAM 8
Medium red
5 R 5/10
Spectral radiance
Wavelength (nm)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
380 430 480 530 580 630 680 730



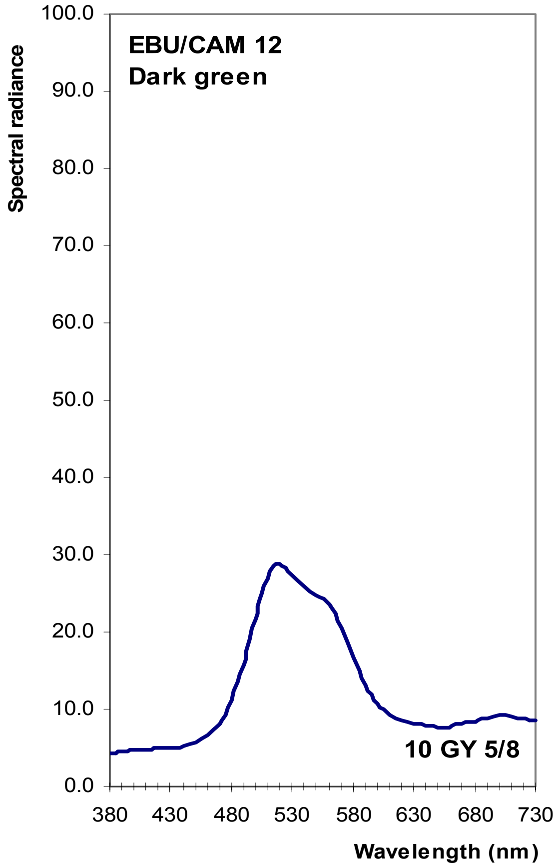
EBU/CAM 9
Medium Green
10 GY 7/10
Spectral radiance
Wavelength (nm)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
380
430
480
530
580
630
680
730



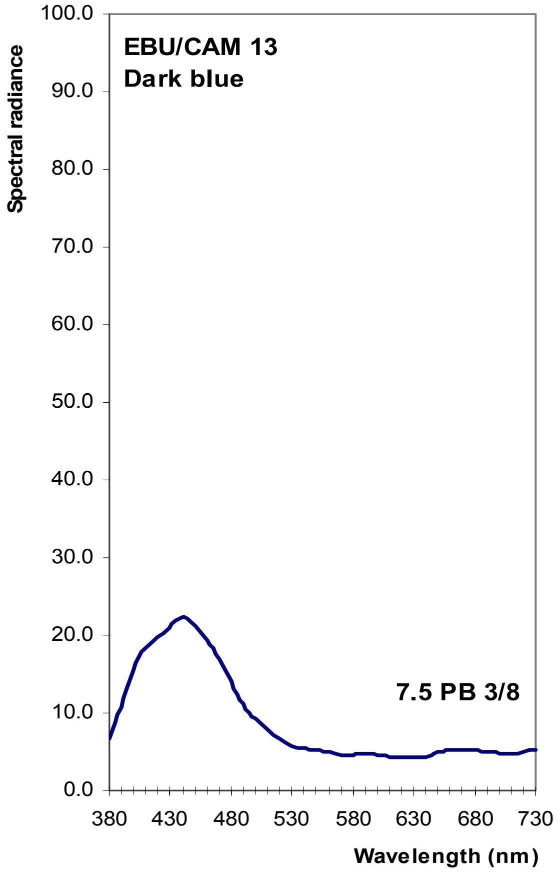
EBU/CAM 10
Medium blue
7.5 PB 5/12
Spectral radiance
Wavelength (nm)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
380
430
480
530
580
630
680
730

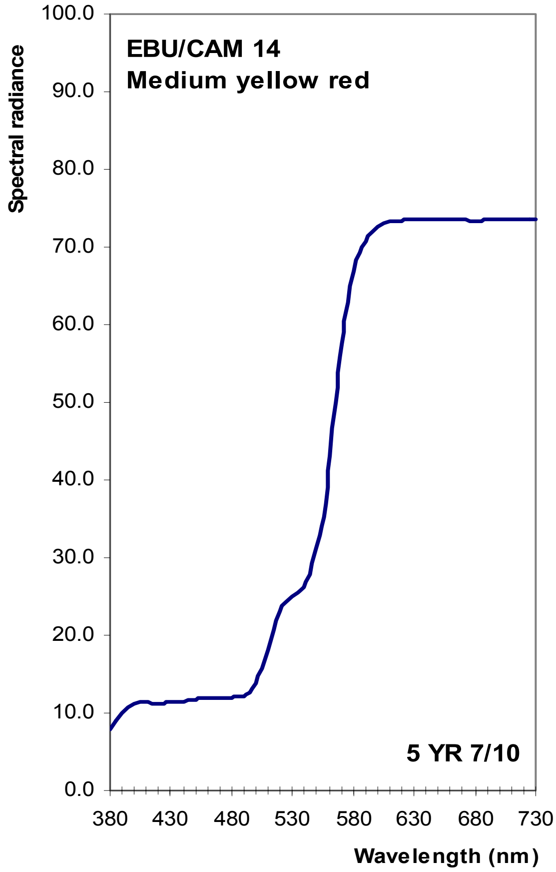


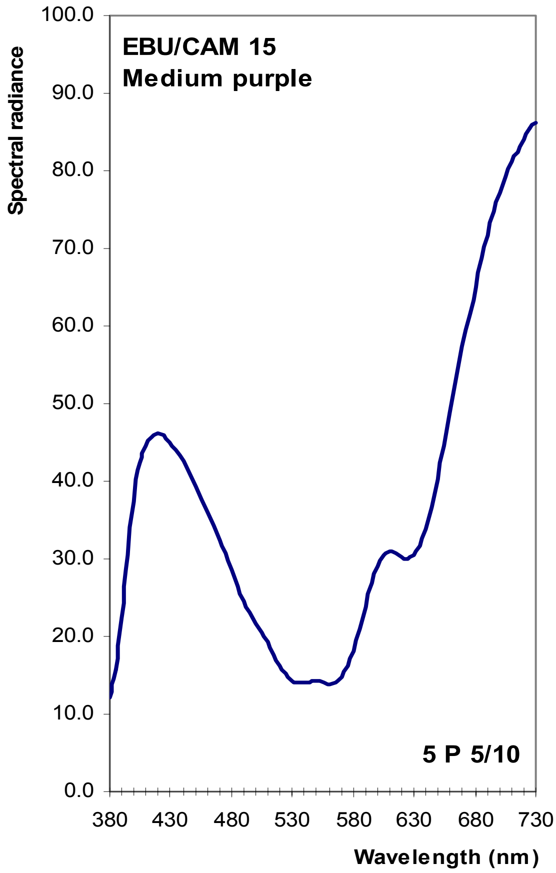
EBU/CAM 11
Dark red
5 R 3/6
Spectral radiance
Wavelength (nm)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
380
430
480
530
580
630
680
730



EBU/CAM 12
Dark green
10 GY 5/8
Spectral radiance
Wavelength (nm)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
380
430
480
530
580
630
680
730


EBU/CAM 13
Dark blue
7.5 PB 3/8
Spectral radiance
Wavelength (nm)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
380
430
480
530
580
630
680
730


EBU/CAM 14
Medium yellow red
5 YR 7/10
Spectral radiance
Wavelength (nm)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
380
430
480
530
580
630
680
730


EBU/CAM 15
Medium purple
5 P 5/10
Spectral radiance
Wavelength (nm)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
380
430
480
530
580
630
680
730

Appendix 4
Spectral distribution P_λ for illuminant P 3100

λ (nm)	P_λ
380	0.13706
385	0.15045
390	0.16463
395	0.17959
400	0.19532
405	0.21183
410	0.22911
415	0.24714
420	0.26593
425	0.28545
430	0.30569
435	0.32664
440	0.34826
445	0.37055
450	0.39347
455	0.41701
460	0.44113
465	0.46581
470	0.49103
475	0.51674
480	0.54293
485	0.56955
490	0.59659
495	0.62400
500	0.65176
505	0.67982
510	0.70817
515	0.73677
520	0.76558
525	0.79457
530	0.82371
535	0.85297
540	0.88232
545	0.91173
550	0.94116
555	0.97059
560	1.00000
565	1.02934
570	1.05859
575	1.08774

λ (nm)	P_λ
580	1.11674
585	1.14559
590	1.17424
595	1.20269
600	1.23091
605	1.25887
610	1.28656
615	1.31397
620	1.34106
625	1.36782
630	1.39424
635	1.42031
640	1.44600
645	1.47130
650	1.49620
'655	1.52070
660	1.54477
665	1.56841
670	1.59160
675	1.61435
680	1.63664
685	1.65846
690	1.67981
695	1.70069
700	1.72108
705	1.74099
710	1.76041
715	1.77933
720	1.79776
725	1.81570
730	1.83314

Appendix 5
Spectral distribution Dλ for illuminant D_{65}

λ (nm)	D_λ
380	0.49976
385	0.52312
390	0.54648
395	0.68702
400	0.82755
405	0.87120
410	0.91486
415	0.92459
420	0.93432
425	0.90057
430	0.86682
435	0.95774
440	1.04865
445	1.10936
450	1.17008
455	1.17410
460	1.17812
465	1.16337
470	1.14861
475	1.15392
480	1.15923
485	1.12367
490	1.08811
495	1.09083
500	1.09354
505	1.08578
510	1.07802
515	1.06296
520	1.04790
525	1.06240
530	1.07689
535	1.06047
540	1.04405
545	1.04226
550	1.04046
555	1.02023
560	1.00000
565	0.98167
570	0.96334
575	0.96061

λ (nm)	D_λ
580	0.95788
585	0.92237
590	0.88686
595	0.89346
600	0.90006
605	0.89803
610	0.89599
615	0.88649
620	0.87699
625	0.85494
630	0.83289
635	0.83494
640	0.83699
645	0.81863
650	0.80027
655	0.80121
660	0.80215
665	0.81246
670	0.82278
675	0.80281
680	0.78284
685	0.74003
690	0.69721
695	6.70665
700	0.71609
705	0.72979
710	0.74349
715	0.67977
720	0.61604
725	0.65745
730	0.69886

Appendix 6
CIE 1931 standard observer colour matching functions

λ (nm)	$\bar{x}(\lambda)$	$\bar{y}(\lambda)$	$\bar{z}(\lambda)$
380	0.0014	0.0000	0.0065
385	0.0022	0.0001	0.0105
390	0.0042	0.0001	0.0201
395	0.0076	0.0002	0.0362
400	0.0143	0.0004	0.0679
405	0.0232	0.0006	0.1102
410	0.0435	0.0012	0.2074
415	0.0776	0.0022	0.3713
420	0.1344	0.0040	0.6456
425	0.2148	0.0073	1.0391
430	0.2839	0.0116	1.3856
435	0.3285	0.0168	1.6230
440	0.3483	0.0230	1.7471
445	0.3481	0.0298	1.7825
450	0.3362	0.0380	1.7721
455	0.3187	0.0480	1.7441
460	0.2908	0.0600	1.6692
465	0.2511	0.0739	1.5281
470	0.1954	0.0910	1.2876
475	0.1421	0.1126	1.0419
480	0.0956	0.1390	0.8130
485	0.0580	0.1693	0.6162
490	0.0320	0.2080	0.4652
495	0.0147	0.2586	0.3533
500	0.0049	0.3230	0.2720
505	0.0024	0.4073	0.2123
510	0.0093	0.5030	0.1582
515	0.0291	0.6082	0.1117
520	0.0633	0.7100	0.0782
525	0.1096	0.7932	0.0573
530	0.1655	0.8620	0.0422
535	0.2257	0.9149	0.0298
540	0.2904	0.9540	0.0203
545	0.3597	0.9803	0.0134
550	0.4334	0.9950	0.0087
555	0.5121	1.0000	0.0057
560	0.5945	0.9950	0.0039
565	0.6784	0.9786	0.0027
570	0.7621	0.9520	0.0021
575	6.842-5	0.9154	0.0018

λ (nm)	$\bar{x}(\lambda)$	$\bar{y}(\lambda)$	$\bar{z}(\lambda)$
580	0.9163	0.8700	0.0017
585	0.9786	0.8163	0.0014
590	1.0263	0.7570	0.0011
595	1.0567	0.6949	0.0010
600	1.0622	0.6310	0.0008
605	1.0456	0.5668	0.0006
610	1.0026	0.5030	0.0003
615	0.9384	0.4412	0.0002
620	0.8544	0.3810	0.0002
625	0.7514	0.3210	0.0001
630	0.6424	0.2650	0.0000
635	0.5419	0.2170	0.0000
640	0.4479	0.1750	0.0000
645	0.3608	0.1382	0.0000
650	0.2834	0.1070	0.0000
655	0.2187	0.0816	0.0000
660	0.1649	0.0610	0.0000
665	0.1212	0.0446	0.0000
670	0.0874	0.0320	0.0000
675	0.0636	0.0232	0.0000
680	0.0468	0.0170	0.0000
685	0.0329	0.0119	0.0000
690	0.0227	0.0082	0.0000
695	0.0158	0.0057	0.0000
700	0.0114	0.0041	0.0000
705	0.0081	0.0029	0.0000
710	0.0058	0.0021	0.0000
715	0.0041	0.0015	0.0000
720	0.0029	0.0010	0.0000
725	0.0020	0.0007	0.0000
730	0.0014	0.0005	0.0000

SYMBOLS

1. Measurement and calibration symbols

$R(A)_n$, $G(A)_n$, $B(A)_n$	Measured channel output levels, mV, with respect to blanking level for sample n, in real samples method.
R(b), G(b), B(b)	Measured channel black levels, mV.
R(w), G(w), B(w),	Measured channel white levels, mV.
R_n, G_n, B_n	Computed channel signal levels, Z, for sample n corrected for black level - 0 and white level 100%.
λ	Wavelength, nm.
E_λ	Monochromator absolute or sensitivity relative spectral
C_λ	Monitoring photocell absolute or relative spectral sensitivity.
$R_{m\lambda}$, $G_{m\lambda}$, $B_{m\lambda}$	Measured channel spectral response. mV, at wavelength λ with respect to blanking level for spectrophotometric method.
$C_{m\lambda}$	Measured monitoring photocell spectral response, mV, at wavelength λ.
$R_{i\lambda}$, $G_{i\lambda}$. $B_{i\lambda}$	Measured channel spectral response# av, at wavelength X corrected for zero lift, spectrophotometric method.
$R(M)_\lambda$, $G(M)_\lambda$, $B(M)_\lambda$	Measured channel spectral response. MV, at wavelength X corrected for monochromator relative spectral power output, i.e. spectral response to an equi-energy source, spectrophotometric method.
M	Algebraic matrix representation for measured camera electrical matrix coefficients.

U	Algebraic unit matrix.
R_λ, G_λ, B_λ	Channel spectral response . to an equi-energy source with effects of matrix removed, i.e. response before matrix, spectrophotometric method.
$\beta_{n\lambda}$	Spectral radiance factors for sample n.
P_λ	Spectral distribution for Illuminant P3100.
D_λ	Spectral distribution for illuminant D65.
K_R, K_G, K_B	Correction constants used for computational balance of computed channel signal levels.
K_γ	Correction constant used for normalising theoretical sample response for reference white.
γ	Camera transfer function, gamma.

2. Chromaticity symbols

Chromaticity symbols may be used with suffices as follows

- n - reproduced sample values.
- 0n - original sample values.
- 0 - values for D reference white

X, Y, Z	Tristimulus values for CIE 1931 colour system.
U', v'	Chromaticity co-ordinates for CIE 1976 chromaticity diagram
L*, u*, v*, C*	Chromaticity co-ordinates for CIELUV 1976 colour space.
$\bar{x}_\lambda$, $\bar{y}_\lambda$, $\bar{z}_\lambda$	CIE colour matching functions for 2° field and equi-energy illuminant.
ΔL*	Vector magnitude in CIELUV 1976 colour space for luminance difference.
Δu*, Δv*	Vector magnitudes in CIELUV 1976 colour space for chromaticity difference.
ΔH*, ΔC*	Vector magnitudes in CIELUV 1976 colour space for hue and chroma differences.
ΔE*	Root mean square vector magnitude in CIELUV colour space for total colour difference.
ΔE_A*	Mean value of ΔE* for a group of samples

Bibliographical references

[1] Methods of measurement of the colorimetric fidelity of television cameras.
EBU Document Tech. 3237, May 1983.

[2] Colorimetry - Official recommendations of the international commission on illuminant.
CIE Publication No. 15, Paris 1971.

[3] Methods of measuring the main characteristics of television cameras.
EBU Document Tech. 3238, March 1983.

[4] Recommendations on uniform colour space - Colour difference equations Psychometric colour terms.
Supplement No. 2 to CIE Publication No. 15, Paris 1978.

[5] CCIR Report No. 624-2. Table 1.
International Telecommunications Union, Geneva.

[6] C. Dalton and J.J. Peters: Real sample sets for camera colour-rendering measurement.
EBU Review - Technical No. 227 (February 1988).

[7] P. Otto and G. Döring: Production and properties of EBU/CAM surface test colour samples for the measurement of the colorimetric fidelity of television cameras.
EBU Review - Technical No. 227 (February 1988).

Editeur responsable : G.T. Waters, Anclenne Route 17 A, CH-1218 Grand. Soconnex/Gonave, Sulase.