EBU – TECH 3320

User requirements for Video Monitors in Television Production

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User requirements for Video Monitors in Television Production

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Scope

This document defines the technical characteristics for video broadcast monitors according to the classification of the EBU as defined in the document on 'Classification of video monitors, and their application areas in television production'. Broadcast monitors are used in a professional TV production environment for evaluation and control of the images being produced, and must provide reliable and repeatable results. The purpose of a monitor is to display the signal as it is, and it must not attempt to 'enhance' or otherwise alter the image. It is unlikely that consumer devices will be able to meet these requirements in a television production environment. Home television receiver requirements and monitor requirements for computer and data processing techniques are not covered by this document.

1. Definition of a Grade 1 monitor

Grade 1 monitors are devices for high-grade technical quality evaluation of picture capturing, post-production, transmission and storage. These monitors must possess at least the quality properties of the equipment to be controlled. It is expected that all applied technologies are state-of-the-art at this level. This means that artefacts should not be unduly masked nor should additional artefacts be introduced. As a reference device the settings of this type of monitor should be adjustable as well as lockable (mechanically or electrically), so that only authorized access is possible.

The Grade 1 monitor is a 'measuring instrument' for visual evaluation of image quality. Therefore it would be highly desirable to have the ability to reproduce the scanning mode of the signal in the native way (i.e. progressive or interlaced) or as it is intended to be viewed (e.g. 50 Hz presentation of 25p material).

Typical applications for Grade 1 monitors are for example camera control, colour grading and quality control, and possibly lighting control positions, that is areas where video technical quality parameters are evaluated, controlled, and corrected.

2. Definition of a Grade 2 monitor

A Grade 2 monitor may have wider tolerances on its specification than a Grade 1 monitor, for the benefit of a significantly lower price, or smaller size or weight. Grade 2 monitors are used in applications where tighter tolerances (for example on accuracy of colour reproduction and stability) as well as some equipment features, are not necessary.

Areas of application for Grade 2 monitors are for example preview, control walls, edit suites, and control rooms if no picture quality manipulation is carried out.

It should be possible for Grade 2 and Grade 1 monitors to be used together, for example in television production control walls.

3. Definition of a Grade 3 monitor

Grade 3 (observation or presence) monitors are devices equivalent in many respects to high end domestic/consumer displays. For television production applications, important considerations include the availability of professional interfaces, mechanical robustness (including the ability to mount in racks or stacks) and transportability, as well as electromagnetic compatibility and acoustic noise.

Application areas for Grade 3 monitors are for example audio production, dialogue dubbing, signal presence monitoring, commentator positions and displays for the audience in a studio.

4. Special application of displays

4.1 Viewfinder monitors

Monitors used as viewfinders for television cameras are similar in many respects to Grade 2 monitors. Picture quality requirements such as geometry and stability are important. A higher maximum brightness will be required, to allow for very different ambient lighting conditions. The viewfinder must provide facilities to assist in focus adjustment.

4.2 Displays used for set design

In the production area of broadcast companies the use of modern flat panel displays is more and more common, for example to produce large in-shot images as part of the set design. Unique factors for such monitors include the ability to match studio lighting (i.e. tungsten light, white balanced to 3200 K) and that they should have a particularly wide viewing angle and low delay. The issue of compatibility between studio cameras and displays that emit polarized light requires further study.

4.3 Displays used in location shooting, or on set/studio floor

These are monitors for use by the director, director of photography, or lighting cameraman, on set, both indoors and outdoors, for viewing material live from the camera. There is a potential requirement for such monitors to include the ability to simulate grading or another post-production process. The video data from the camera may for example be raw, logarithmic data, rather than matrixed and gamma-corrected data, and the director may therefore wish to preview a simulation of the intended output appearance achieved at a later stage in TV production.

4.3.1 Luminance ranges

When a luma signal of 100% white (digital level is 940 in 10-bit systems, see Note 1) is input, the display should provide an adjustable preset including the ability to produce a reference luminance level, for example of 80 cd/m^2. However, it should be adjustable so that the 100% luminance (see Notes 2&3) on the screen can be set to provide luminance levels within the ranges:

Grade 1 Monitor: 70 to at least 100 cd/m^2 (Note 4).

Grade 2 Monitor: 70 to at least 200 cd/m^2.

Grade 3 Monitor: 70 to 250 cd/m^2 or to 400cd/m^2 in adverse conditions.

Note 1: 100% luminance on the screen corresponds to a luma signal of digital level 940 (in 10-bit), and the black level corresponds to a luma signal of digital level 64 (in 10-bit). The *highest value of luma signal is digital level 1019 (in 10-bit). The luma level 1019 is called 'Super-white' or '109% white', by the formula (1019 - 64)/(940 - 64) = 1.09.*

Note 2: *100% luminance on the screen is defined as the luminance of a luma signal of digital level 940, but levels 941 through 1,019 should also be correctly displayed and should track any adjustment made to the 100% luminance level.*

Note 3: *The 100% luminance is measured on a white patch occupying the central 13.13% horizontally and vertically (as described in EBU Tech3273, section 3.5 – to be revised), perpendicular to the centre of the screen.*

Note 4: *ITU-R BT.500-11 requires monitor brightness up to 200 cd/m^2 for tests simulating domestic viewing conditions.*

Note 5: *Automatic brightness limiters shall not be used for Grade 1 or Grade 2 Monitors.*

4.3.2 Black level

With a luma signal at black level (digital level 64 in 10-bit), the luminance level measured from the screen should be adjustable to be

Grade 1 Monitor: below 0.1 cd/m^2.

Grade 2 Monitor: below 0.4 cd/m^2.

Grade 3 Monitor: below 0.7 cd/m^2.

It must be possible to adjust black level with a PLUGE test signal (incl. sub-black) according to the procedure outlined in ITU-R BT.814. We expect Grade 1 and 2 monitors to be used in control rooms with subdued lighting, for example ISO 12608 'Cinematography - Room and conditions for evaluating television from telecine reproduction'.

Note 1: *Measurement must be conducted in accordance with EBU Tech on measurement guidelines (to be defined).*

4.3.3 Contrast ratio

Depending on the luminance level set for 100% white, the following full screen contrast ratio may be achieved in relation to the appropriate minimum black level.

Full screen contrast ratio shall be:

Grade 1 Monitor: above 1000 to 1

Grade 2 Monitor: above 500 to 1

Grade 3 Monitor: above 300 to 1 (142 to 1 with 100% white at 100 cd/m^2, since black may be 0.7 cd/m^2)

Simultaneous contrast ratio (with EBU box pattern) should be:

Grade 1 Monitor: above 200 to 1

Grade 2 Monitor: above 100 to 1

Grade 3 Monitor: above 100 to 1

Note 1: *'Full screen contrast' is defined as the ratio between the luminance of the screen when displaying 100% white at 100cd/m^2 and that corresponding to displaying only the black level in a completely dark room. EBU recommends the VESA FPDm^2 section 302-3 test method.*

Note 2: *'Simultaneous contrast' should be measured using the EBU test pattern defined in EBU Tech-3273, section 3.5.*

Note 3: *Measurement must be conducted in accordance with EBU Tech measurement guidelines (under revision)*

4.3.4 Gamma characteristics

1) The gamma characteristics (electro-optical transfer characteristic) of the screen should be equivalent to those of a reference CRT with the rendering intent (dim-surround) expected of a TV system, once offsets of signal level at black and residual brightness at black have been removed. We believe that a value of 2.35 is appropriate. See Annex A and the Note below.
2) The gamma characteristics of the green, red and blue components of the display should be identical.
3) The gamma characteristic shall be followed (for Grade 1 and Grade 2 Monitors) to within 0.5% of the ideal gamma curve throughout the entire signal range, and shall remain monotonic. For Grade 1 and Grade 2 Monitors, a 10-bit input signal shall result in a 10-bit presentation on the screen (always allowing that only 877 video levels are specified between black and 100% white).

Note: The electro-optical transfer characteristic of a monitor is based on the following requirements:

Whilst the camera may have a nominal opto-electrical transfer function according to ITU-R BT. Rec.709, this is in practice modified by the intention of the director in camera control or in grading.

The television system has been deliberately designed with an end-to-end system gamma of about 1.2, to provide compensation for the 'dim surround' effect [6]. Therefore the monitor gamma is not, and never has been, the inverse of the camera gamma.

The reference for archived and current programmes has been a Grade 1 CRT monitor.

The conclusion must be that any new monitor technology should retain the same electro-optical characteristic as has historically been used.

BBC R&D Report RD 1991/6, 'Methods of measuring and calculating display transfer characteristics (gamma)' by Alan Roberts, indicates a method of performing such measurements, and has yielded results which indicate that the gamma of a grade 1 CRT monitor is typically in the region of 2.3 to 2.4. See also [5]

The overall electro-optical characteristic will therefore consist of this gamma curve, sitting on top of an adjustable offset of the light-output at 'black' as set using a PLUGE test signal to meet the requirements of the viewing environment.

Annex A gives further information.

4.3.5 Grey scale reproduction

1) For Grade 2 and Grade 1 Monitors, grey scale tracking between colour channels shall be within ellipses defined:

Grade 1 Monitor:	±0.0010 Δu', ±0.0015 Δv' (CIE 1976 chromaticity differences) for luminances from 1 cd/m^2 to 100 cd/m^2 and deviation from grey should not be visible for luminances below 1 cd/m^2
Grade 2 Monitor:	±0.003 Δu', ±0.004 Δv' for luminances from 1 cd/m^2 to 200 cd/m^2 and deviation from grey should not be visible for luminances below 1 cd/m^2
Grade 3 Monitor:	±0.004 Δu', ±0.006 Δv') for luminances from 1 cd/m^2 to 250 cd/m^2 and deviation from grey should not be visible for luminances below 1 cd/m^2

2) When a luma signal of black level (digital level 64 in 10-bit systems) through 109% white (1019) is input, grey scale tracking should be maintained.

Note: *It may, for the present, be difficult both to measure, and for displays to achieve, these tolerances near black.*

4.3.6 Colour gamut

1) The intention is that colours within the relevant system gamut should be reproduced such that the human eye perceives them to be identical to the presentation on an ideal CRT monitor, that is, a metameric match should be achieved. Reproduction of the EBU test colours (EBU Tech. 3237 and its supplement) should be to the same tolerances as defined above for grey-scale tracking.
2) The display should present pictures with the colour primaries and reference white specified in the relevant video standard (ITU-R BT.1360, ITU-R BT.601, ITU-R BT.709, ITU-R BT.1700 or SMPTE 274M, 170M and 296M-2001). The displayed primaries should fall within the tolerance boxes (EBU Tech.3213 and its HD version, yet to be defined).

Note: *For displays intended for use in studio sets, some pre-distortion of the colour rendition may be desirable to achieve the required look on camera.*

4.3.7 Colour temperature

1) The monitor should present pictures with a reference white colour D65 when feeding the monitor with primary signals of equal amplitude.
2) Monitors to be used in shot in the studio (in set design) must be able to be adjusted to approximately 3200 K.

Grade 1 Monitor:	Default D65
Grade 2 Monitor:	Default D65 and optionally switchable to 3200K for use in set design
Grade 3 Monitor:	Default D65 and optionally switchable to 3200K for use in set design

Tolerances to be applied to the white point, D65, are:

Grade 1 Monitor:	±0.0010 Δu', ±0.0015 Δv' (CIE 1976 chromaticity differences)
Grade 2 Monitor:	±0.003 Δu', ±0.004 Δv'
Grade 3 Monitor:	±0.004 Δu', ±0.006 Δv'

4.3.8 Viewing-angle dependency

1) For Grade 1 and Grade 2 Monitors, deviations in reproduced colour on the screen should not be visible to a human observer when viewing the screen from an angle of up to ±45° horizontally or ±20° vertically in any direction from the perpendicular axis to the centre of the screen.
2) As a guide to an acceptable numerical value, Δu', Δv' (CIE 1976 chromaticity differences) should be less than 0.01 for any of the EBU test colours when measured from viewing angles in the range described above.
3) The luminance on the screen, when measured from viewing angles in a rectangle of ±30° horizontally and ±15° vertically should drop by no more than 10% of the luminance value measured along an axis perpendicular to the centre of the screen. When measured from viewing angles in a rectangle of ±45° horizontally and ±20° vertically, the luminance should drop by no more than 20%.
4) The black level, when measured from viewing angles up to ±20° in any direction horizontally and vertically, should remain within the tolerances described above. When measured from viewing angles between ±20-45° horizontally, this tolerance is relaxed to twice that value.

Note: *The tolerances in 2-4 above can be further relaxed to double the stated values for Grade 2 and Grade 3 Monitors.*

4.3.9 Motion artefacts

Motion artefacts (such as blur, and other effects on moving images) are an area of great concern and require further research. Work is required to characterise the motion portrayal of the CRT, with respect to its interaction with both camera and computer generated images, and with the human visual system. We then need to consider what is required from a flat panel display to achieve subjectively equivalent results. This is not an insignificant task, but is one that the displays industry has been investigating for some time.

Note 1: Reference document about Moving Picture Response Time (MPRT) measurements is available (under development by VESA for FPDM3). The EBU member IRT is also working on measurement techniques.

Note 2: Motion blur (both in moving edges and texture) in LCDs is caused by a combination of:

'Sample and hold' type presentation

Intrinsic response time of the panel

Signal processing such as de-interlacing

Note 3: Other technologies have other motion effects, such as colour fringing on moving edges and false contour generation.

Whilst we do not wish the display to introduce motion artefacts, on the other hand, motion artefacts which are included in the input signal by, for example, a failure to anti-alias filter moving graphics, should be represented on the display.

4.3.10 Screen resolution

The resolution required of a monitor will vary depending on screen size and application.

Grade 1 Monitor: At least as many pixels as the signal format to be displayed, with the ability to display a pixel-mapped image.

Grade 2 Monitor: At least as many pixels as signal format to be displayed.

Note 1: Large screens intended for multi-viewers may require substantially higher resolution.

Note 2: There are some advantages in having super-sampled displays, such that the pixel structure and shape no longer affect the visible image. For example, a 1920x1080 image might be displayed on a 4k (horizontal pixel) screen.

4.3.11 Image scaling, de-interlacing and overscan

1) Image scaling should be done in such a way as to avoid the introduction of artefacts, such as excessive ringing, aliases or banding, etc.
2) Monitors should offer a choice of de-interlacing modes (see section below on delay). Progressive (segmented field, or film-mode) material should be detected and not passed through a de-interlacer
3) The default mode should be to display without overscan, that is showing the full active image area right to its edges. This should be the optimal mode for scaling quality, and often may be one-to-one pixel mapping.
4) The edges of the picture must not be obscured by a bezel.
5) All monitors should be adjustable to allow overscan of around 2%.

4.3.12 Delay time

The delay time in each display mode shall be explicitly specified, and optionally indicated on the screen. The timing shall indicate the delay from the arrival of the data relating to the top line of the image to the presentation of the image on the screen.

In the case of Grade 2 and Grade 3 monitors, it is essential that models should be available that include a ‘short delay display mode’. A short delay display mode is useful when strict timing accuracy is required in cases such as video switching or editing, or when used to cue musical performers. This mode may have lower picture quality (for example, due to simpler de-interlacing) than the normal display mode. For this reason, the availability of such a mode is not demanded for Grade 1 monitors.

In the short delay display mode, pictures should preferably be displayed with a latency of no more than 10ms between the input signal and the displayed signal. The intent is to minimise the lip-synchronization errors that can occur and cause annoyance to viewers and professional production staff.

4.3.13 Screen size

The screen size of the display is at the discretion of users, but may need to be larger (because of the target viewing distance of 3 times picture height) for adequate monitoring of HD. Production spaces are still designed for the same size monitors previously used, because there are often constraints which make moving to larger screen sizes difficult. This may have an impact on the ability to adequately monitor HD quality. Multi-view (tiled) large screen monitors are increasingly used for source monitoring, so are included in the Grade 3 monitor category, but might also be classified as Grade 2 monitors.

4.3.14 Uniformity

Large area uniformity

The minimum uniformity in large area white level (that is, a smooth drop-off in brightness towards the edges of the screen) that is acceptable is 80% for a CRT, but we should be moving towards a goal of 95% in the flat panel environment.

Note 1: Current procedure is described in EBU Tech 3273.

Note 2: VESA FPDm[2] section 306 defines uniformity/non-uniformity across the area of the screen, measured for each of white, black, colours and dark grey.

Small area uniformity

The use of a few fixed measurement positions can result in missing a periodic uniformity error that matches the pitch of the measurements.

A specification and measurement technique will be developed.

In the extreme, fixed pattern noise is a type of non-uniformity, and if necessary should be counteracted by pre-correction in the display.

4.3.15 Mura (imperfections in LCD panels)

Mura should not be visually detected on the screen regardless of reproduced luminance levels or colour saturation.

We do not expect Mura to be a problem in practice, but for completeness we include it here.

Note 1: ‘Mura’ is a defect that looks like a small-scale crack with very small changes in luminance or colour. ‘Mura’ is likely to be noticeable in the flat portions of images even if the size of the mura is very small.

Note 2: VESA FPDm[2] section 301-3D defines a possible test procedure.

4.3.16 Streaking (also known as overspill or shadowing)

The effect, as shown in figure 1, is the result of horizontal or vertical crosstalk between the signal in different parts of the line or column in the display.

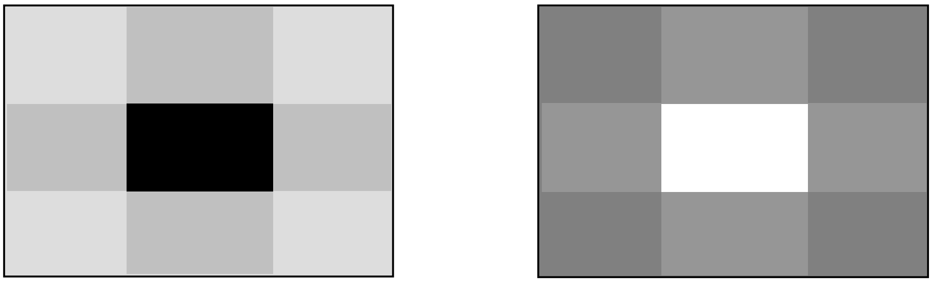

Figure 1. Examples of shadowing (in this case both horizontal and vertical)

When the input signal is a rectangle of 100% white near the centre, surrounded by a grey area, the difference in luminance between the horizontal and vertical belt-like portions and the other grey portions shown in Figure 1 should not be greater than 0.5% for Grade 1 monitors, 1% for Grade 2 monitors, and 2% for Grade 3 monitors. The same should apply to a black rectangle on a grey surround.

4.3.17 Stability

1) A 30-minute warm-up period from a 'cold' start should be allowed before any observations or measurements are taken.
2) After this warm-up time, the measurements shall remain within the specifications given for 12 hours.

4.3.18 Pixel defects

Defects are classified according to the severity of their visual impact. ISO 13406-2 provides more information and a classification of different types of pixel defects.

1) Grade 1 and Grade 2 monitors shall have no visible pixel defects (defined as pixel defect category I in ISO 13406-2).
2) Grade 3 monitors shall have no visible pixel defects in the central area covering 50% of the display area, and fulfil pixel defect category II outside this area.
3) There should never be coupled pixel defects (defined as pixel cluster defect category I in ISO 13406-2).

Note: *A useful explanation is given at:*
http://www.maxdata.com/repository_com/downloads/Pixel_monitors.pdf

4.3.19 Ringing and handling of under- and over-shoots

Ringing or overshoots should not be introduced by any processing in the display if the input signal is suitably conditioned (i.e. is within Nyquist limits). See also below.

Grade 1 and Grade 2 monitors should not have a 'sharpness' control and should not introduce any other image 'enhancements'.

Monitors should not cut off under- and over-shoots, or sub-black and super-white levels.

4.3.20 Treatment of illegal signals

Signals which contain significant frequency components outside the Nyquist limit (i.e. have not been anti-alias filtered) should be displayed in such a way that any ringing or aliasing inherent in such signals DOES become visible.

Monitors must have the ability to expose 'field dominance' problems, which occur when the fields of an interlaced signal are presented in the wrong order.

4.3.21 Image sticking (long-term afterimage)

The characteristics for image sticking (long-term afterimage) on the screen should be comparable to or better than that of the CRT monitor.

Broadcasters should bear in mind that fixed service idents on multi-viewer screens may cause problems on some displays. In general guidelines for avoiding image sticking should be adhered to, although such guidelines tend to be national or informal.

4.3.22 Supported Standards, and signal interfaces

The monitors should handle the signal formats listed below. It is not necessary for a monitor to support all formats (but see EBU D97-2005). The manufacturer must state which of the formats are supported by each available interface.

Format	Relevant standard
480i 30 (29.97)	ITU-R Rec. BT.601-5
576i 25	ITU-R Rec. BT.601-5
720p 50	SMPTE 296M-2001
720p 60 (59.94)	SMPTE 296M-2001 ITU-R Rec. BT.1543
1080i 25	SMPTE 274M-2005 ITU-R Rec. BT. 709-5
1080i 30 (29.97)	SMPTE 274, ITU 709

Format	Relevant standard
1080p 24 (23.98)	SMPTE 274, ITU 709
1080psf 24 (23.98)	SMPTE 274, ITU 709
1080p 25	SMPTE 274, ITU 709
1080psf 25	SMPTE 274, ITU 709
1080p 30 (29.97)	SMPTE 274, ITU 709
1080psf 30 (29.97)	SMPTE 274, ITU 709
1080p 50	SMPTE 274, ITU 709
1080p 60 (59.94)	SMPTE 274, ITU 709

Some signal formats are available in 4:4:4 in addition to 4:2:2, and these formats shall also be supported where applicable.

The monitors should have the following interfaces:

	Grade 1	Grade 2	Grade 3	Set design	Relevant standard
SDI *	A, at least 2	A, at least 2	A	A	SMPTE 259M,
ITU-R Rec. BT.656-4					
HD-SDI *	A, at least 2	A, at least 2	A	A	SMPTE 292M-1998
Dual HD-SDI **					
or 3Gb/s	B	B	B		SMPTE 372M-2002 **
SMPTE 424M, 425M					
HDMI 1.3 ***	B	B	B	B	High-Definition Multimedia Interface Version 1.3 (www.hdmi.org)
DVI 1.0 ***	B	B	B	B	www.ddwg.org
Component RGB, Y C_rC_b	B	B	B	B	
CVBS (PAL, SECAM & NTSC)	B	B	B	B	?
RF (Analogue)			C	C	
RF (DTT)			C		DVB-T

A=mandatory, B=available as an option, C=should be available at least as an external module

* Should be auto-sensing SDI/HD-SDI, with indication of standard detected.

** Dual link ancilliary data packet for channel identification according to SMPTE 372M.

*** HDCP must be available on the input, so that the picture is always shown.

Note: *At present there are a number of additional candidate interface technologies to carry the highest data rate signals, in compressed and uncompressed forms. The adoption of these interfaces in the professional broadcasting environment is still open. Examples include 10 Gbyte Ethernet and forms of intermediate (quasi-lossless) compression.*

4.3.23 Other facilities

The following switchable features are also necessary:

Features	Grade 1	Grade 2	Grade 3	Set design
4 : 3 and 16 : 9 aspect ratio mode	M	M	M	M
safe title and aspect ratio markers	M	M		
tally lamp (red, green, yellow)	M	M	*	
RS 232 and/or GPI remote control	M	M		
over scan / full screen / 1 to 1 pixel-map modes	M	M		
H/V delay	M	M		
blue only mode	M	M		
mono mode	M	M		
ext. sync in	M	M		
Stereo loudspeaker			*	

M=Mandatory

* required in some applications

5. References

[1] EBU Tech 3273: Methods of Measurement of the Colorimetric Performance of Studio Monitors (1993 – UNDER REVISION)

[2] ITU-R Rec.BT.709: Basic Parameter Values for the HDTV Standard for the Studio and for International Programme Exchange (1990)

[3] CIE (Commission Internationale de l'Eclairage) Standard S 014-2/E (2006): Colorimetry - Part 2: CIE Standard Illuminants

[4] Roberts, A.: Methods of measuring and calculating display transfer characteristics (Gamma)
BBC Research Department Report RD 1991/6.

[5] Roberts, A.: Measurements of display transfer characteristics using test pictures. BBC Research Department Report RD 1992/13.

[6] Hunt, R.W.G: "Corresponding colour reproduction" in *The reproduction of colour*, ed. 6, pp. 173, Wiley & Son, 2004.

6. Bibliography:

- Video Electronics Standards Association (VESA) Flat Panel Display Measurements Task Group - FLAT PANEL DISPLAY MEASUREMENTS STANDARD Version 2.0 (FPDm^2)
- Tolerances on 'Illegal' colours in television, EBU Technical Text R103-2000 (http://www.ebu.ch/CMSimages/en/tec_text_r103-2000_tcm6-4677.pdf)

Annex A

Television has evolved to give pleasing results in a viewing environment described by colour scientists as “dim surround”[6].

This outcome includes three invariant components:

- the requirement to match luminance level coding (whether analogue or digital) to the approximately logarithmic characteristic of the human vision system by means of an appropriate nonlinear coding or “perceptual” coding of level. Such a characteristic has the effect of equalizing the visibility over the tone scale of quantizing in a digital signal, or noise in an analogue one. A linear or other non-perceptual based characteristic would require greater dynamic range (bandwidth or bit rate) for the same perceptual quality, with adverse economic consequences;
- the immovable legacy effect of the CRT gamma characteristic on which the entire television system was empirically founded. This legacy consists of both archived content and world-wide consumer display populations;
- gamma is also the characteristic which coding schemes such as MPEG-2 and MPEG-4 AVC are designed to match, and any other characteristic will be less than ideal in terms of artefact and noise visibility, to the extent that much of the impairment seen these days on transmitted television material, when viewed on flat screen displays, is caused by the failure of the display to adhere closely to a gamma characteristic, particularly near black.

It has been found that the end-to-end or “system” gamma for consumer viewing environment is approximately 1.2, i.e. definitely not linear.

The system gamma can be expressed as:

System gamma = camera encoding gamma (OETF*) x display gamma (EOTF)

It has been found from measurement techniques, progressively refined over several decades, that a correctly designed CRT display has an EOTF gamma of approximately 2.35. This is part of the “immovable legacy effect” of the CRT.

Therefore our system gamma equation is rewritten as

System gamma = 1.2 = OETF gamma x 2.35

Therefore OETF (camera) gamma = 0.51.

Since a pure gamma curve would require infinite gain to be applied to camera signals near black, resulting in unacceptable noise; in practice this curve is modified to consist of a small linear region near black in combination with a reduced gamma curve of 0.45 [2]. Note however, that a “best fit” single power law curve for this characteristic comes out as 0.51, the same as the calculation above.

From the above, since the consumer viewing environment is not changing, and the OETF gamma cannot change (for compatibility reasons and for the continuation of an optimal perceptual coding characteristic), the EOTF gamma must also remain at 2.35, regardless of which new physical display device is used to implement it.

* Opto-electrical transfer function