HDR-TVに関する
ITU-R SG6会合(2016年1-2月）の結果

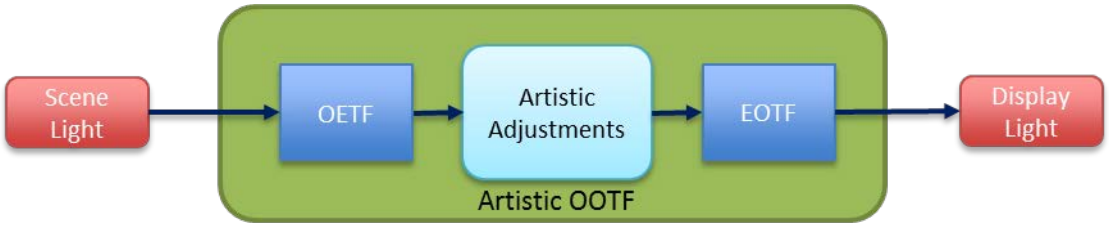
2016年2月29日

概要

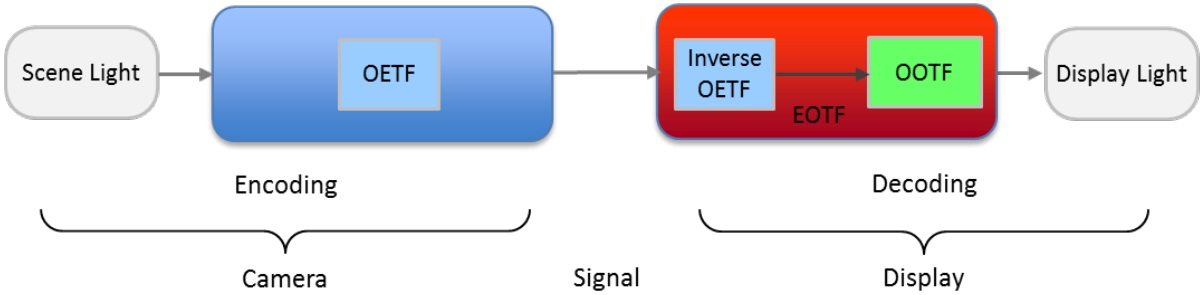
- 勧告案：HDRテレビの番組制作及び国際番組交換用の映像パラメータ
  - 空間解像度：2K, 4K, 8K、時間解像度：24～120Hz、BT.2020広色域
  - 背景輝度：5cd/m^2、ピーク輝度1000cd/m^{2}以上、黒：0.005cd/m^{2}以下
  - 伝達関数：HLGとPQの２方式のOETF、EOTF、OOTFを規定
    - HLGのOETFはARIB STD-B67と同等
    - PQのEOTFはSMPTE ST 2084と同等
  - 輝度・色差信号：$Y'C'_BC'_R$とIC_TC_Pの２通り
    - 非低輝度$Y'C'_BC'_R$はBT.2020と同等
    - 定輝度IC_TC_Pは新規定
  - デジタル表現：narrow rangeとfull rangeの整数表現及び浮動小数点表現
  - 採択・承認手続きに5ヶ月程度を要する見込み
- レポート：番組制作及び国際番組交換用のHDRテレビ
  - HDRテレビの技術的な説明
- 今後の主要な検討課題
  - IC_TC_Pの妥当性
  - PQ方式のOOTFの妥当性
  - 1000cd/m^{2}超のディスプレイ輝度に対応するHLGのシステムガンマ

OETF（光-電気）EOTF（電気-光）, OOTF（光-光）

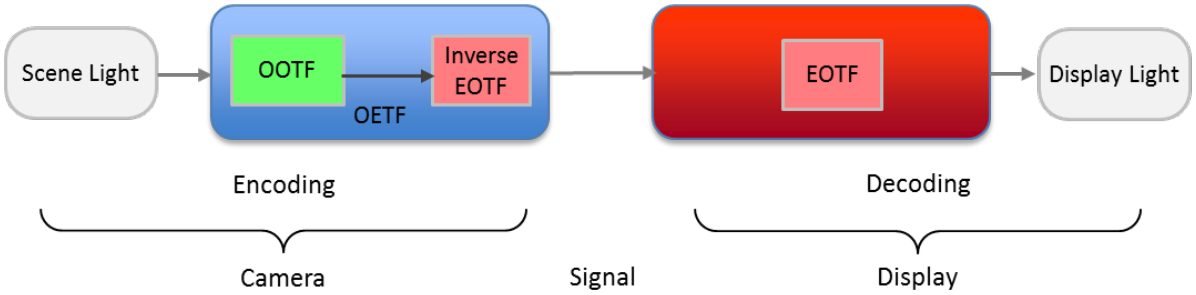
- OETF, EOTF, OOTF



- HLG

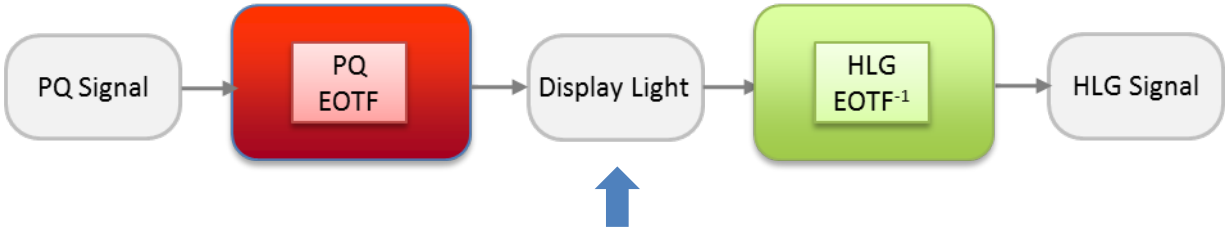


- PQ

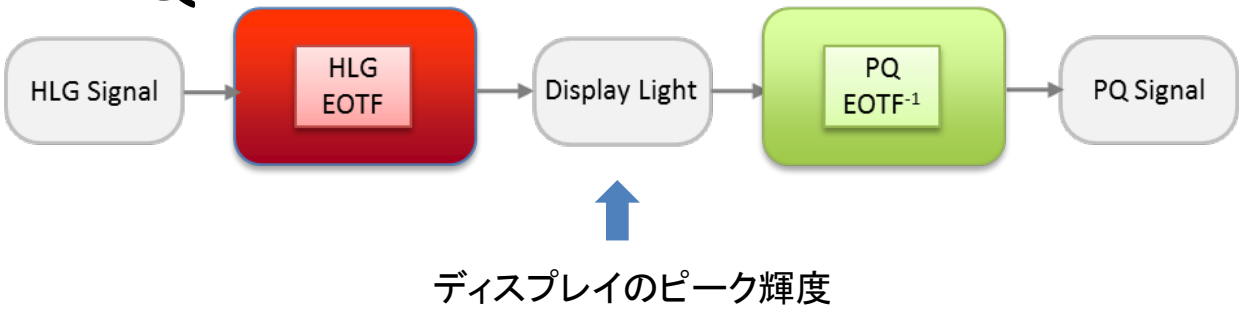


HLGとPQの相互変換

■PQ→HLG



■HLG→PQ



（Scene Lightを介した変換も可能）

TABLE 1
映像の空間･時間特性

映像形状	16:9
画素数（水平×垂直）	7 680 × 4 320 3 840 × 2 160 1 920 × 1 080
サンプル構造	Orthogonal
画素形状	1:1 (square pixels)
画素順序	Pixel ordering in each row is from left to right, and rows are ordered from top to bottom.
フレーム周波数 (Hz)	120, 120/1.001,100, 60, 60/1.001, 50, 30, 30/1.001, 25, 24, 24/1.001
走査	Progressive

TABLE 2
カラリメトリ

		Optical spectrum (informative)	**Chromaticity coordinates (CIE, 1931)**	
			x	***y***
三原色	赤 (R)	monochromatic 630 nm	0.708	0.292
	緑 (G)	monochromatic 532 nm	0.170	0.797
	青 (B)	monochromatic 467 nm	0.131	0.046
基準白色		D65 per ISO 11664-2:2007	0.3127	0.3290
等色関数		CIE 1931		

TABLE 3
厳密な観視の場合の基準観視条件

背景、周囲	Neutral grey at D65
背景輝度	5 cd/m^2
周囲輝度	≤ 5 cd/m^2
照明	Avoid light falling on the screen
視距離	For 1920x1080 format: 3.2 picture heights For 3840x2160 format: 1.6 to 3.2 picture heights For 7680x4320 format: 0.8 to 3.2 picture heights
ディスプレイピーク輝度	≥ 1 000 cd/m^2
黒レベル	≤ 0.005 cd/m^2

TABLE 4
PQ方式の基準非線形伝達関数

PQ EOTFの入力信号	Non-linear PQ encoded value. The EOTF maps the non-linear PQ signal into display light.
PQ EOTF	$F_D = \text{EOTF}[E'] = 10000\,Y$ where $Y = \left(\frac{\max[(E'^{1/m_2} - c_1), 0]}{c_2 - c_3 E'^{1/m_2}} \right)^{1/m_1}$ E' denotes a nonlinear colour value {R', G', B'} or { L', M', S'} in PQ space [0,1] F_D is the luminance of a displayed linear component {R_D, G_D, B_D} or Y_D or I_D, in cd/m^2. So that when $R'=G'=B'$, the displayed pixel is achromatic. Y denotes the normalised linear colour value, in the range [0:1] $m_1 = 2610/16384 = 0.1593017578125$ $m_2 = 2523/4096 \times 128 = 78.84375$ $c_1 = 3424/4096 = 0.8359375 = c_3 - c_2 + 1$ $c_2 = 2413/4096 \times 32 = 18.8515625$ $c_3 = 2392/4096 \times 32 = 18.6875$

TABLE 4（続き）

PQ OOTFの入力信号	Scene linear light. The OOTF maps relative scene linear light to display linear light.
PQ OOTF	F_D = OOTF[E] = G_{1886} [G_{709}[E]] where E = {*Rs*, *Gs*, *Bs*; *Ys*; or *Is*} is the signal determined by scene light and scaled by camera exposure E' is a non-linear representation of E F_D is the luminance of a displayed linear component (R_D, G_D, B_D; Y_D; or I_D) The values E, *Rs*, *Gs*, *Bs*, *Ys*, *Is* are in the range [0:1] $F_D = G_{1886}$ [$G_{709}[E]$] = G_{1886} E' $E' = G_{709}[E] = 1.099\ (59.5208\ E)^{0.45} - 0.099$ for $1 > E > 0.0003024$ $= 267.84\ E$ for $0.0003024 \geq E \geq 0$ $F_D = G_{1886}[E'] = 100\ E'^{2.4}$

TABLE 4（続き）

PQ OETFの入力信号	Scene linear light. The OETF maps relative scene linear light into the non-linear PQ signal value.
PQ OETF	where $E' = \mathrm{OETF}[E] = \mathrm{EOTF}^{-1}[\mathrm{OOTF}[E]] = \mathrm{EOTF}^{-1}[F_D]$ $\mathrm{EOTF}^{-1}[F_D] = \left(\frac{c_1 + c_2 Y^{m_1}}{1 + c_3 Y^{m_1}} \right)^{m_2}$ $Y = F_D / 10000$ E' is the resulting non-linear signal (*R’,G’,B’*) in the range [0:1] F_D, E, are as specified in the opto-optical transfer function m_1, m_2, c_1, c_2, c_3 are as specified in the electro-optical transfer function

TABLE 5
HLG方式の基準非線形伝達関数

HLG OETFの入力信号	Scene linear light. The OETF maps relative scene linear light into the non-linear signal value.
HLG OETF	$$E' = \mathrm{OETF}\left[E\right] = \begin{cases} \sqrt{E}/2 & 0 \le E \le 1 \\ a \cdot \ln\left(E - b\right) + c & 1 < E \end{cases}$$ where: *E* is the signal for each colour component {*Rs, Gs, Bs*} proportional to scene linear light and scaled by camera exposure, normalised to the range [0:12][5b]. E' is the resulting non-linear signal {*R', G', B'*} in the range [0:1]. *a* = 0.17883277, *b* = 0.28466892, *c* = 0.55991073

Note 5b: If *E* is normalised to the range [0:1] then the equivalent equation for the OETF is:

$$E' = \mathrm{OETF}\left[E\right] = \begin{cases} \sqrt{3E} & 0 \le E \le 1/12 \\ a \cdot \ln\left(E - b\right) + c & 1/12 < E \end{cases}$$

where a= 0.17883277, b= 0.02372241, c= 1.00429347

TABLE 5（続き）

HLG EOTFの入力信号	Non-linear HLG encoded value. The EOTF maps the non-linear HLG signal into display light.
HLG EOTF	$$F_D = \mathrm{OOTF}[E] = \mathrm{OOTF}\left[\mathrm{OETF}^{-1}[E']\right]$$ Thus, $$R_D = \alpha Y_S^{\gamma-1} R_S + \beta$$ $$G_D = \alpha Y_S^{\gamma-1} G_S + \beta$$ $$B_D = \alpha Y_S^{\gamma-1} B_S + \beta$$ where: R_s, G_s, B_s are the scene linear light signals, E, for each colour component normalised in the range [0:12][5c]. $$E = \mathrm{OETF}^{-1}[E'] = \begin{cases} 4E'^2 & 0 \le E' \le \frac{1}{2} \\ \exp\left((E'-c)/a\right)+b & \frac{1}{2} < E' \end{cases}$$ $$Y_S = 0.2627R_S + 0.6780G_S + 0.0593B_S$$ $$\alpha = \left(L_W - L_B\right)/12^{\gamma}$$ $$\beta = L_B$$ F_D is the luminance of a displayed linear component {R_D, G_D, *or* B_D}, in cd/m^2.

Note 5c: If E is normalised to the range [0:1] then the equivalent equation for the E is:

$$E = \mathrm{OETF}^{-1}[E'] = \begin{cases} E'^2/3 & 0 \le E' \le \frac{1}{2} \\ \exp\left((E'-c)/a\right)+b & \frac{1}{2} < E' \end{cases}$$

where a, b, and c are as defined in Note 5b.

TABLE 5（続き）

HLG EOTF（続き）	E' is the non-linear signal {*R'*,*G'*,*B'*} as defined for the OETF. R_D, G_D, B_D are the displayed light for each colour component[5d], in cd/m^2. The values of parameters *a*, *b*, and *c* are as defined for the OETF. The OOTF is defined below. γ = 1.2 at the nominal display peak luminance of 1000 cd/m^2. [5e, 5f] L_W is nominal peak luminance of the display in cd/m^2. L_B is the display luminance for black in cd/m^2. The nominal signal range of *E*, *Rs*, *Gs*, *Bs*, and Y_S is [0:12]. [5g] The reference display shall not display values greater than E' = 1.0. Such values should be clipped to 1.0 prior to display[5h].

Note 5d: This EOTF applies gamma to the luminance component of the signal, whereas some legacy displays may apply gamma separately to colour components. Such legacy displays approximate this reference OOTF.

Note 5e: For displays with nominal peak luminance (L_W) greater than 1000 cd/m^2, or where the effective nominal peak luminance is reduced through the use of a contrast control, the system gamma value should be adjusted according to the formula below, and may be rounded to three significant digits: $\gamma = 1.2 + 0.42 \log_{10}(L_W/1000)$

Note 5f: The system gamma value may be decreased for brighter background and surround conditions.

Note 5g: When *E* is normalised to the range [0:1] then the equation for α is: $\alpha = (L_W - L_B)$

Note 5h: Values exceeding 1.0 should not be shown on reference displays. Values below 0.0 should not be clipped in reference displays (even though they represent “negative” light) to allow the black level of the signal (L_B) to be properly set using test signals known as “PLUGE” see Recommendation ITU-R BT.814.

TABLE 5（続き）

HLG OOTFの入力信号	Scene linear light. The OOTF maps relative scene linear light to display linear light.
HLG OOTF	$$F_D = \mathrm{OOTF}[E] = \alpha Y_S^{\gamma-1} E + \beta$$ $$R_D = \alpha Y_S^{\gamma-1} R_S + \beta$$ $$G_D = \alpha Y_S^{\gamma-1} G_S + \beta$$ $$B_D = \alpha Y_S^{\gamma-1} B_S + \beta$$ $$Y_s = 0.2627 R_S + 0.6780 G_S + 0.0593 B_S$$ where: F_D is the luminance of a displayed linear component {R_D, G_D, or B_D}, in cd/m^2. E is the signal for each colour component {*Rs*, *Gs*, *Bs*} proportional to scene linear light and scaled by camera exposure, normalised to the range [0:12]. Y_S is the normalised linear scene luminance. α, β, and γ are as defined for the EOTF.

TABLE 6
非定輝度Y′C′$_B$C′$_R$信号形式

	PQ	**HLG**
R', G', B'	$\{R', G', B'\}$=EOTF^{-1}(F_D) where F_D = {R_D, G_D, B_D}	$\{R', G', B'\}$=OETF(E) where E = {R_S, G_S, B_S}
輝度信号	Y' = 0.2627R' + 0.6780G' + 0.0593B'	
色差信号	$C'_B = \frac{B' - Y'}{1.8814}$ $C'_R = \frac{R' - Y'}{1.4746}$	

TABLE 7
定輝度IC_TC_P信号形式

	PQ	HLG
L, M, S色空間	$L = (1688R + 2146G + 262B)/4096$ $M = (683R + 2951G + 462B)/4096$ $S = (99R + 309G + 3688B)/4096$	
L', *M'*, *S*	$\{L', M', S'\}=\text{EOTF}^{-1}(F_D)$ where $F_D = \{L_D, M_D, S_D\}$	$\{L', M', S'\}=\text{OETF}(E)$ where $E = \{L_S, M_S, S_S\}$
I'	$I = 0.5L'+0.5M'$	
色差信号	$C_T = (6610L'-13613M'+7003S')/4096$ $C_P = (17933L'-17390M'-543S')/4096$	

Y′C′$_B$C′$_R$信号の使用がdefault。IC_TC_P信号の使用は関係者の合意が条件。

TABLE 8
信号サンプリング

信号	*R', G', B' or Y', C'_B, C'_R, , or I, C_T, C_P*		
サンプリング構造 *R', G', B', Y', I*	Orthogonal, line and picture repetitive co-sited		
サンプリング構造 C'_B, C'_R, C_T, C_P	Orthogonal, line and picture repetitive co-sited with each other. The first (top-left) sample is co-sited with the first *Y'* or *I* samples.		
	4:4:4 system	4:2:2 system	4:2:0 system
	Each has the same number of horizontal samples as the *Y'* or *I* component.	Horizontally subsampled by a factor of two with respect to the *Y' or I* component.	Horizontally and vertically subsampled by a factor of two with respect to the *Y' or I* component.

TABLE 9
10-bit、12-bit整数表現

信号	R', G', B' or Y', C'_B, C'_R, or I, C_T, C_P			
ビット数	n = 10, 12 per component			
R', G', B', Y', I の量子化	Narrow range		Full range	
	$D = INT[(219 \times E' + 16) \times 2^{n-8}]$		$D = INT[E' \times 2^n]$	
C'_B, C'_R, C_T, C_P の量子化	$D = INT[(224 \times E' + 128) \times 2^{n-8}]$		$D = INT[(E' + 0.5) \times 2^n]$	
量子化レベル	10-bit coding	12-bit coding	10-bit coding	12-bit coding
黒($R' = G' = B' = Y' = I = 0$) DR', DG', DB', DY', DI	64	256	0	0
無彩色($C'_B = C'_R = 0$) DC'_B, DC'_R, DC_T, DC_P	512	2048	512	2048
Nominalピーク ($R' = G' = B' = Y' = I = 1$) DR', DG', DB', DY', DI	940	3760	1023	4092
Nominalピーク ($C'_B = C'_R = \pm 0.5$) DC'_B, DC'_R, DC_T, DC_P	960	3840	1023	4092
映像データ	4 through 1019	16 through 4079	0 through 1023	0 through 4092

Narrow rangeの使用がdefault。Full rangeの使用は関係者の合意が条件。

TABLE 10
浮動小数点表現

信号	Linear R, G, B.
信号表現	16-bit floating point per IEEE standard 754-2008.
PQの正規化	A value of 1.0 for each of R, G, B yields 1.0 cd/m^2 on the reference display.
HLGの正規化	A value of 1.0 represents nominal peak white of the signal.