



JVET-N0221: Chroma Quantization Parameter Qp_C Table for HDR Signal

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Dolby Laboratories

Overview

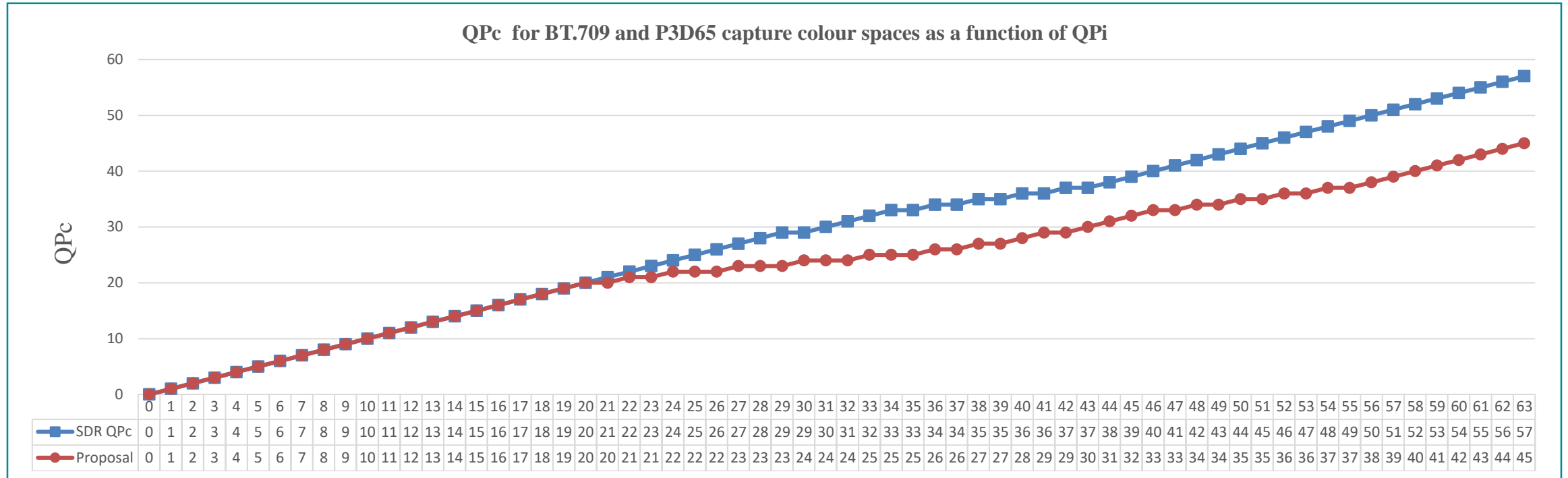
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 - Signal characteristics
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Introduction

- The chroma quantization parameter (Qp_C) table specified in VVC is insufficient for HDR
 - Designed for SDR only
 - Inherited from HEVC
- HDR PQ content requires different chroma QP offsets from SDR to prevent chroma artefacts
 - Option 1 (current default): Non-normative encoder optimization
 - Option 2 (proposed): add an HDR chroma quantization parameter Qp_C table in VVC
- Motivation
 - Unify codec design for all SDR and HDR signal types
 - Eliminate the need for different encoder optimizations for different content
 - Make coding performance more consistent for future encoder implementations

Proposal – Add Q_{pC} table and syntax for HDR

Complements existing Q_{pC} table for SDR



In SPS, add a new syntax element:

chroma_qp_table_idc. When the value of chroma_qp_table_idc is equal to 0, it refers to the original SDR Q_{pC} table in the VVC specification text. When the value of chroma_qp_table_idc is equal to 1, it refers to the new HDR Q_{pC} table proposed in this contribution.

Results – Q_{pC} table for HDR

Complements existing Q_{pC} table for SDR

Proposed HDR Q_{pC} table provides performance similar to non-normative encoder optimization using chromaQPOffset

Average of BD-rate for HDR CTC testsets in RA configuration compared to modified HDR Anchor (disable chromaQPOffset)

Ref	Test	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV
SDR_ Q_{pC}	HDR_VTM4.0_Anchor	-42.50%	5.00%	5.80%	-50.00%	-70.40%
	HDR_ Q_{pC} _Proposal	-31.80%	4.90%	5.40%	-52.00%	-52.60%

- Subjective test shows minor or no chroma difference between the proposal and the HDR Anchor.



Design philosophy

Common signal formats for SDR and HDR

- SDR: NCL Y'CbCr in BT. 709 and BT. 2020
 - CTC: use default Qp_C table and no severe chroma artefact has been reported.
- HDR: NCL Y'CbCr/ICtCp PQ and Y'CbCr HLG in BT. 2100
 - PQ:
 - Y'CbCr (CTC): apply encoder-only chromaQPOffset to reduce chroma artefact for low bitrate.
 - ICtCp: add a positive constant value 6 to the value of chromaQPOffset used for Y'CbCr PQ.
 - HLG: use default Qp_C table

Common signal formats for SDR and HDR

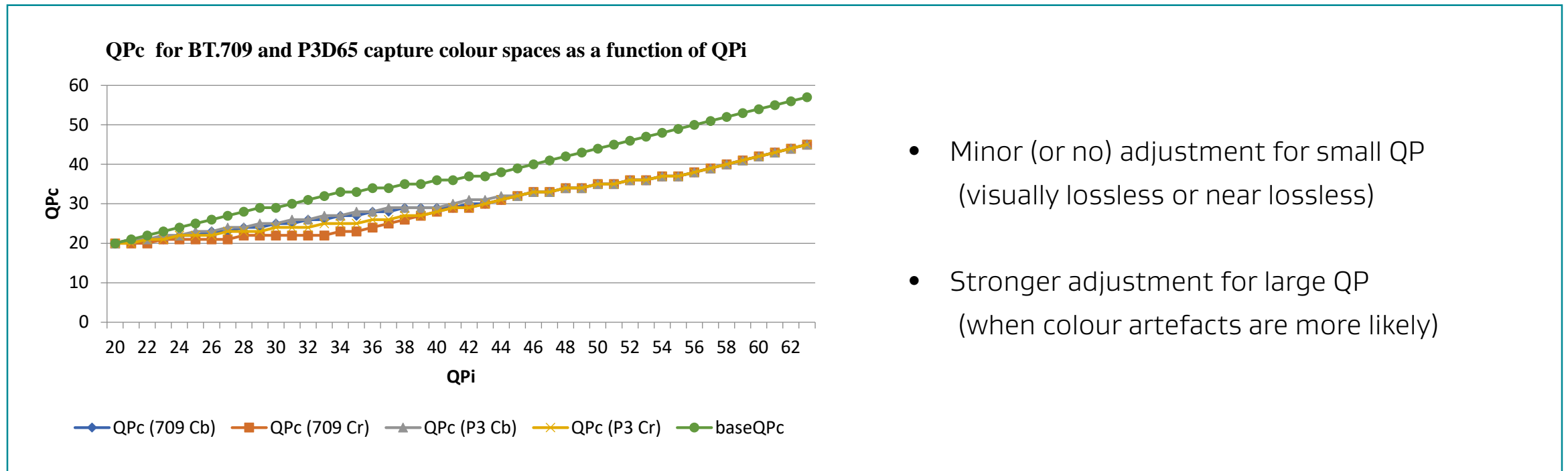
name	colour_primaries	transfer_characteristics	matrix_coeffs
SDR NCL Y'CbCr	BT.709(1)/BT. 2020(9)	gamma (1, 14, 15)	YCbCr 709 (1)/ YCbCr 2020 (9)
HDR NCL Y'CbCr PQ	BT. 2020/2100 (9)	PQ (16)	Y'CbCr 2020/2100 (9)
HDR NCL ICtCp PQ	BT. 2020/2100 (9)	PQ (16)	ICtCp (14)
HDR NCL Y'CbCr HLG	BT. 2020/2100 (9)	HLG (18)	Y'CbCr (9)

- Only a Qp_C table for HDR NCL Y'CbCr PQ content is required.

Qp_C table derivation

- Derive Qp_C table for HDR PQ signal based on the chromaQPOffset design in HDR PQ CTC Anchor

Step 1: Assign Cb and Cr QP offsets based on luma QP and a factor related to capture colour spaces



Qp_C table derivation

- Derive Qp_C table for HDR PQ signal based on the chromaQPOffset design in HDR PQ CTC Anchor

Step 2: Calculate candidate Qp_C tables for different components and capture colour spaces

Colour-space dependent parameters

colour space		parameter	
capture	representation	c_cb	c_cr
BT. 2020/BT.2100		1	1
P3D65	BT. 2020/BT.2100	1.04	1.39
BT. 709		1.14	1.78

$$CbQpOffset = Clip3(-12, 0, round(c_cb*(k*QP+1)))$$

$$CrQpOffset = Clip3(-12, 0, round(c_cr*(k*QP+1)))$$

where $k = -0.46, l = 9.26$

Qp_C table derivation

- Derive Qp_C table for HDR PQ signal based on the chromaQPOffset design in HDR PQ CTC Anchor

Step 3: Choose the best trade-off Qp_C table based on subjective testing and average of BD-Rate

– Prefer a single Qp_C table rather than multiple tables

- Final default Qp_C table:

$$QPc = f(QPc_Cb_709, QPc_Cr_709, QPc_Cb_P3, QPc_Cr_P3)$$

where $f(.)$ could be any one of the following:

select one (e.g., p3); average; or minimum of candidates.

Subjective evaluation for HDR PQ Qp_C table

- None of the colour-space specific Qp_C tables can reproduce HDR PQ CTC results
 - ChromaQPOffset has different values for Cb, Cr and for different capture colour spaces.
 - ChromaQPOffset based on the input QP may be different from the actual coding QP for each slice.
 - In RA CTC, there is QP modulation (JCTVC-X0038) based on hierarchical structure.
 - HDR CTC applies lumaDQP, which applies adaptive QP values for each TU based on averaging luma.
- Relied on subjective evaluation along with BD-Rate to choose the proposed Qp_C table.

qPi	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
$Qp_C(709Cb)$	21	22	22	23	23	24	24	25	25	26	26	27	27	28	28	29	29	29	29	30	30
$Qp_C(709Cr)$	21	21	21	21	21	22	22	22	22	22	22	23	23	24	25	26	27	28	29	29	30
$Qp_C(P3Cb)$	22	22	23	23	24	24	25	25	26	26	27	27	28	28	29	29	29	29	30	31	31
$Qp_C(P3Cr)$	21	22	22	22	23	23	23	24	24	24	25	25	25	26	26	27	27	28	29	29	30

Subjective evaluation setting

- Comparing proposal with HDR PQ CTC Anchor on a Pulsar display in RA case

	LumaLevelToDeltaQPMode	WCGPPSEnable	Qp _C table
HDR PQ CTC Anchor	1	1	SDR Qp _C
HDR PQ Proposal	1	0	PQ Qp _C

- Test candidates

Test	HDR_QPc function
HDR_Qp _C _avg	AVERAGE(Qp _C _709_Cb, Qp _C _709_Cr, Qp _C _P3_Cb, Qp _C _P3_Cr)
HDR_Qp _C _709avg	AVERAGE(Qp _C _709_Cb, Qp _C _709_Cr)
HDR_Qp _C _P3avg	AVERAGE(Qp _C _P3_Cb, Qp _C _P3_Cr)
HDR_Qp _C _avgmin	MIN(Qp _C _709_Cb, Qp _C _709_Cr, Qp _C _P3_Cb, Qp _C _P3_Cr)
HDR_Qp _C _709min	MIN(Qp _C _709_Cb, Qp _C _709_Cr)
HDR_Qp _C _P3min	MIN(Qp _C _P3_Cb, Qp _C _P3_Cr)

Subjective evaluation and BD-Rate

- Bd-Rate: compared with HDR PQ CTC setting with chromaQPOffset disabled
 - Referene: SDR Qp_C table without further encoder chromaQPOffset optimization
- Observation:
 - if BDRate of DE100 gain is greater than 30%, minor color difference will be observed.
 - The proposed Qp_C table is an acceptable alternative for encoder optimization.

BD-rate data in RA compared to modified HDR Anchor (disable chromaQPOffset)

Ref	Test	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV
SDR_ Qp_C	HDR_VTM4.0_Anchor	-42.5%	5.0%	5.8%	-50.0%	-70.4%
	HDR_ Qp_C _avg	-30.8%	4.2%	4.7%	-50.3%	-50.8%
	HDR_ Qp_C _709avg	-32.4%	4.8%	5.4%	-52.6%	-53.5%
	HDR_ Qp_C _P3avg	-26.7%	3.4%	3.9%	-44.1%	-44.4%
	HDR_ Qp_C _avgmin	-33.6%	5.8%	6.4%	-54.8%	-55.9%
	HDR_ Qp_C _709min	-38.4%	7.8%	8.4%	-62.4%	-63.6%
	HDR_ Qp_C _P3min	-31.8%	4.9%	5.4%	-52.0%	-52.6%

Decision: HDR_Qp_C_P3min

- Selection criteria:
 - BDRate of DE100 gain greater than 30%;
 - PSNRL100 and wPSNRY loss smaller or equal to the values of the HDR Anchor.
- Selected candidates: HDR_Qp_C_avg, HDR_Qp_C_709avg, and HDR_Qp_C_P3min.
- Recommend to use HDR_Qp_C_P3min
 - HDR PQ content typically expected to be created in P3 colour space

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SDR_Qp _C	HDR_VTM4.0_Anchor	-42.5%	5.0%	5.8%	-50.0%	-70.4%
	HDR_Qp _C _avg	-30.8%	4.2%	4.7%	-50.3%	-50.8%
	HDR_Qp _C _709avg	-32.4%	4.8%	5.4%	-52.6%	-53.5%
	HDR_Qp _C _P3avg	-26.7%	3.4%	3.9%	-44.1%	-44.4%
	HDR_Qp _C _avgmin	-33.6%	5.8%	6.4%	-54.8%	-55.9%
	HDR_Qp _C _709min	-38.4%	7.8%	8.4%	-62.4%	-63.6%
	HDR_Qp _C _P3min	-31.8%	4.9%	5.4%	-52.0%	-52.6%

Syntax in SPS

- `chroma_qp_table_idc` is an indication of an index to the array of Qp_C as a function of `qPi` for `ChromaArrayType` equal to 1.
- The value of `chroma_qp_table_idc` shall be in the range of 0 to 1, inclusive.
 - `chroma_qp_table_idc` = 0, refers to the original SDR Qp_C table in the VVC specification text.
 - `chroma_qp_table_idc` = 1, refers to the new HDR Qp_C table proposed in this contribution.

Specification of Qp_C as a function of `qPi` for `ChromaArrayType` equal to 1 when `chroma_qp_table_idc` = 1

qPi	< 21	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Qp_C	= qPi	20	21	21	22	22	22	23	23	23	24	24	24	25	25	25	26	26	27

qPi	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	> 54
Qp_C	27	28	29	29	30	31	32	33	33	34	34	35	35	36	36	37	= qPi - 18

Conclusion

- We propose that an HDR chroma quantization parameter Qp_c table be adopted in VVC.
 - Complements the existing SDR chroma quantization parameter Qp_c table
 - Unifies codec design for SDR and HDR for different signal types, including:
 - Y'CbCr gamma, Y'CbCr PQ, ICTcP PQ, and Y'CbCr HLG
 - Eliminates the need for different encoder optimizations for different content types
 - Makes coding performance more consistent for future encoder implementations

Acknowledgement

- We would like to thank Technicolor for crosschecking the test results (JVET-N0793).



Thanks for attention!
