

JVET-J0021: Description of HDR video coding technology
proposal by Qualcomm and Technicolor

JVET-J0067: Additional information on HDR video coding
technology proposal by Qualcomm and Technicolor

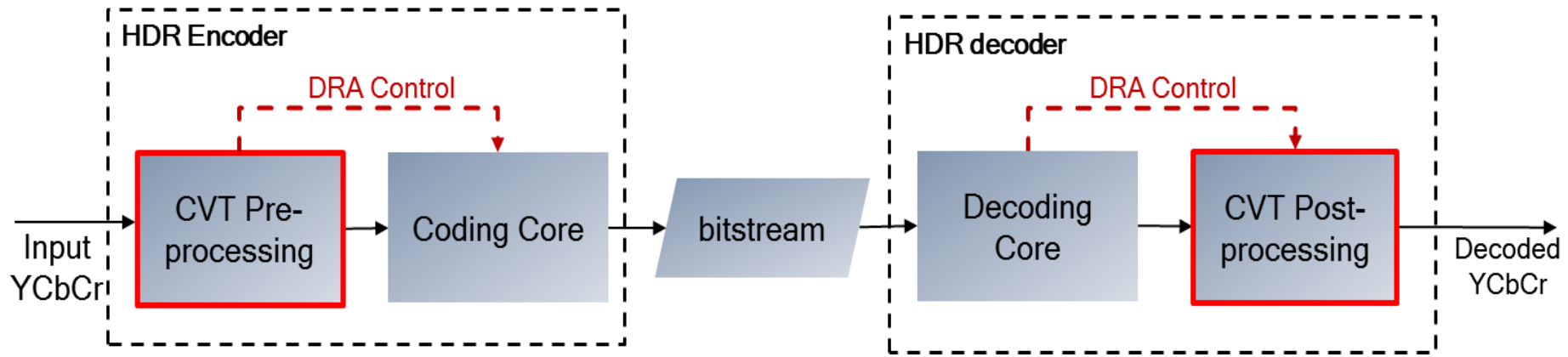
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Overview

- Proposed HDR technology:
 - Color Volume Transform:
 - Reconstruction process is outside of the coding loop
 - Used in 3 CfP response submissions:
 - High Complexity: J0021
 - Medium Complexity(*): J0022
 - Low Complexity: J0021
- Objective metrics usage
- Simulation results:
 - Results of JVET-J0021 CfP response in HDR category
 - Additional results for CVT on top of JEM7.0 and J0021 software

HDR Video Codec Design

- **Color Volume Transform (CVT):**
 - Implements Dynamic Range Adjustment (DRA) on video data
 - Applied to video data outside of coding loop
 - Encoder applies CVT prior to coding
 - Decoder applies CVT after decoding
 - Input and output of CVT is YCbCr 4:2:0, 10 bits data
 - No changes to the core design



Color Volume Transform (CVT)

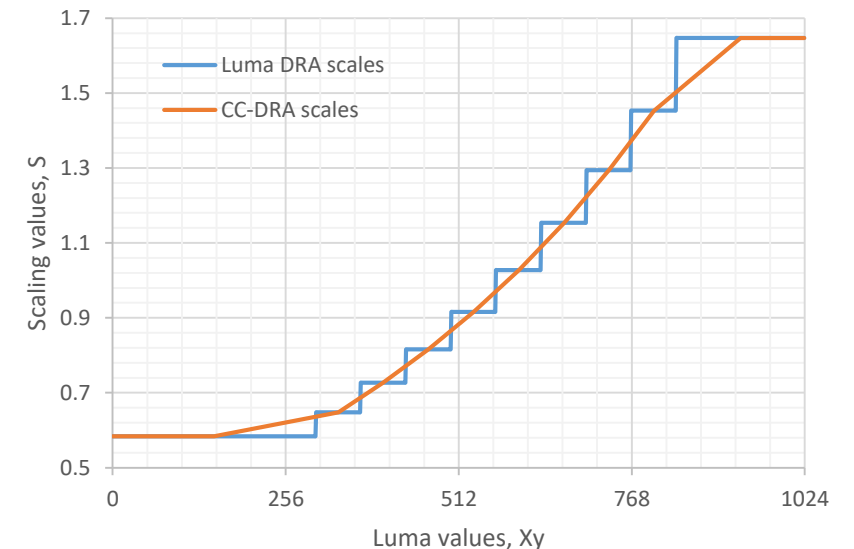
- **Dynamic Range Adaptation (DRA)** - luma and chroma samples are scaled using piecewise linear function.

$$\begin{aligned}X_Y &= x_Y * S_Y(i) + O_Y(i) \\X_{Cb} &= x_{Cb} * S_{Cb}(j) + O_{Cb}(j) \\X_{Cr} &= x_{Cr} * S_{Cr}(k) + O_{Cr}(k)\end{aligned}$$

- **Cross-Component DRA** - applied to chroma to preserve luma/chroma bitrate allocation for different brightness ranges following the application of the DRA.

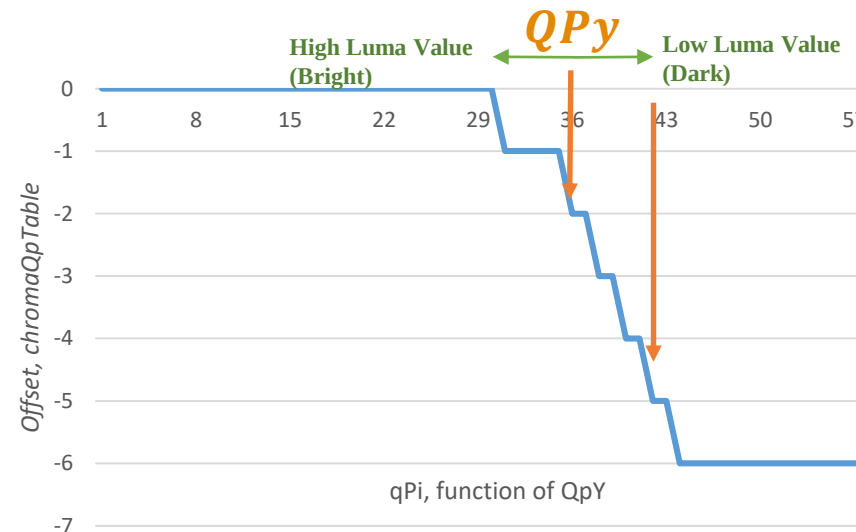
$$X2_{Cx} = (x_{Cx} - 2^{bitDepth-1}) * S2_x(Y) * S3_x(QP, x_y) + 2^{bitDepth-1}$$

- Factor $S2_{cx}(Y)$ is obtained by linear interpolation of luma DRA scales of adjacent intervals, e.g. $S_Y(i)$ and $S_Y(i + 1)$.
- Factor $S3_{cx}(QP)$ used to harmonize DRA scalars and scalar quantizer of the core codec



Color Volume Transform (CVT)

- **DRA scales and scalar quantizer harmonization** – preserve luma/chroma bitrate allocation assumed by the core coding design for a given QP setting.
 - E.g. Table 8-10 of HEVC introduces internal luma-dependent chroma offset
 - DRA scaling of luma component shifts the luma/chroma allocation



- CC-DRA scales are adjusted with a correction multiplier $S3_{cx}(QP, x_y)$ to preserve codec's allocation

$$X2_{Cx} = (x_{Cx} - 2^{bitDepth-1}) * S2_x(Y) * S3_x(QP, x_y) + 2^{bitDepth-1}$$

Objective metrics usage

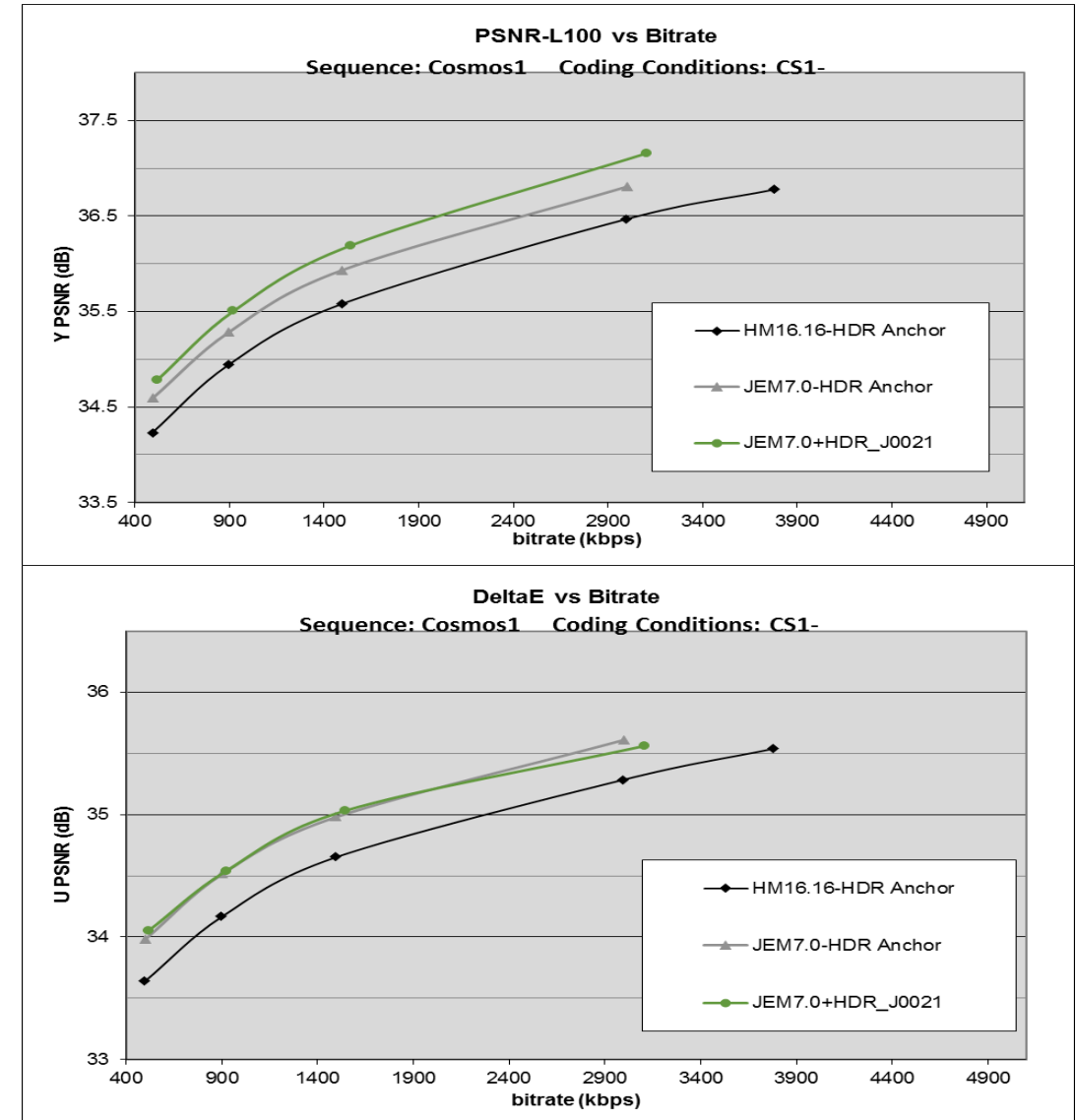
- **HDR test set of HDR Category:**
 - HLG sequences
 - PQ sequences:
 - PQ/BT.709
 - PQ/P3
- **Objective metrics of HDR Category:**
 - PSNR in YCbCr
 - Weighted PSNRY in YCbCr
 - HDR metrics: PSNR L100 and PSNR DeltaE100
- **Metrics for CfP response design and optimization:**
 - PSNR L100 and DeltaE 100 were found to be well correlated

CVT configuration in CfP response:

- **Parameters of CVT :**

- Fixed CVT design across all sequences and rate points
- Parameters of CVT are optimized for HDR content
- CVT parameters are fixed HDR category:
 - HLG, PQ/BT.709, PQ/P3
 - Fixed across sequence and all rate points
- DRA parameters estimated with grading process:
 - Transfer characteristics
 - Color gamut, brightness characteristics of the content
- Chroma DRA parameters:
 - Follow HDR Anchor chroma QP offset settings

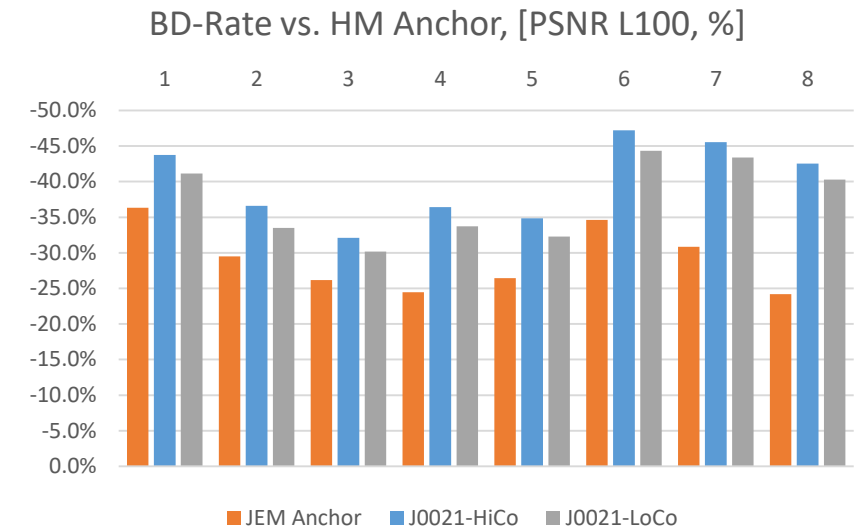
Y value:	0	301	367	434	501	567	634	701	767	834
HLG scales:	0.87	0.86	0.86	0.86	0.86	0.86	1.04	1.10	1.19	1.31
PQ/709 scales:	0.58	0.64	0.72	0.81	0.91	1.02	1.15	1.29	1.45	1.64
PQ/P3 scales:	0.52	0.85	0.87	0.97	1.09	1.13	1.23	1.26	1.37	1.50



CfP Response, HDR Results (JVET-J0021):

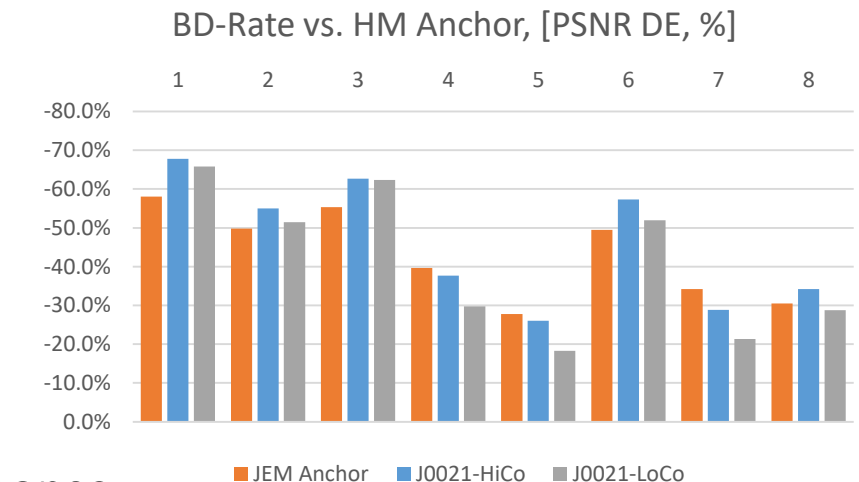
- Objective HDR metrics in design:
 - PSNR L100 for Luma and PSNR DeltaE for chroma were prioritized
 - Stable performance for different CVT initialization (DRA-function)
- Performance of CVT in High Complexity mode [BD-rate, %]:

JVET J0021-HiCo	vs. HM HDR Anchor				vs. JEM HDR Anchor			
	BD-rate, %		Time Est., %		BD-rate, %		Time Est., %	
	PSNRL100	DE100	Enc	Dec	PSNRL100	DE100	Enc	Dec
Average HDR-A	-37.50%	-61.80%	1023	515	-10.10%	-17.00%	146	62
Average HDR-B	-41.30%	-36.80%			-18.80%	-0.70%		
Average HDR	-39.90%	-46.20%			-15.60%	-6.80%		



- Performance of CVT in Low Complexity mode [BD-rate, %]:

JVET J0021-LoCo	vs. HM HDR Anchor				vs. JEM HDR Anchor			
	BD-rate, %		Time Est., %		BD-rate, %		Time Est., %	
	PSNRL100	DE100	Enc	Dec	PSNRL100	DE100	Enc	Dec
Average HDR-A	-34.90%	-59.80%	313	514	-6.40%	-12.10%	45	62
Average HDR-B	-38.80%	-30.00%			-15.20%	10.70%		
Average HDR	-37.30%	-41.20%			-11.90%	2.10%		

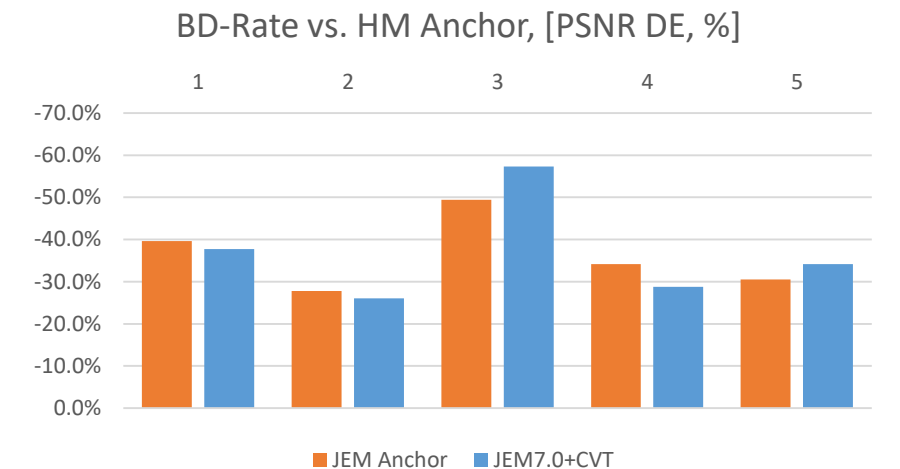
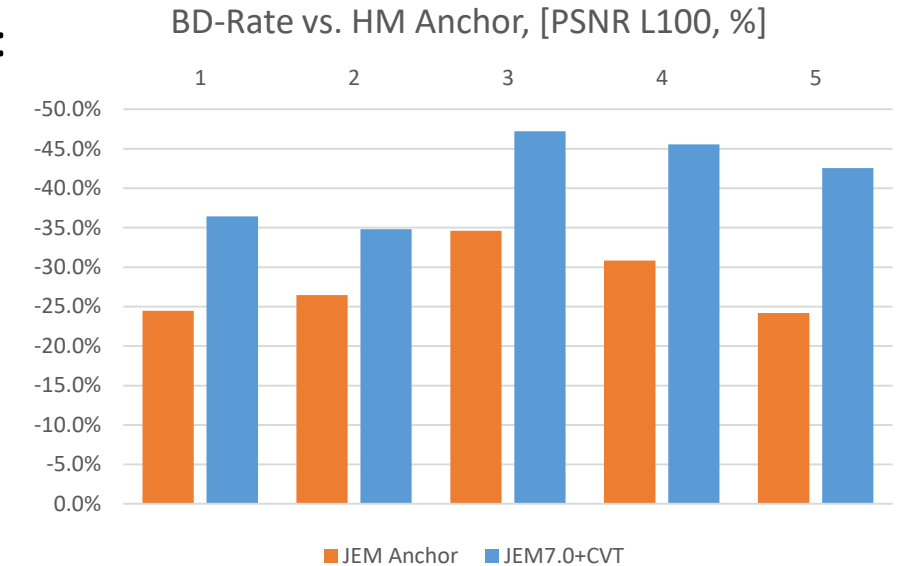


- Average execution time estimates are very close to SDR CfP response

Additional HDR Results (JVET-J0067):

- JEM7.0+CVT bitrate reduction [BD-rate, %] over CfP HDR Anchors:
 - JEM7.0 code base
 - HDR-B class only (HD, PQ/BT.2020)
 - Around -8.3% of BD-Rate, PSNR L100

JEM7.0+CVT	BD-rate, %		Time Est., %		BD-rate, %		Time Est., %	
vs. HDR Anchors	PSNRL100	DE100	Enc	Dec	PSNRL100	DE100	Enc	Dec
Market	-29.5%	-38.7%	687%	647%	-6.9%	1.9%	91%	82%
ShowGirl2	-29.6%	-31.8%			-4.1%	-3.0%		
Hurdles	-39.0%	-51.0%			-7.1%	-0.8%		
Starting	-36.3%	-34.8%			-8.2%	-1.8%		
Cosmos1	-35.5%	-30.7%			-15.2%	-0.2%		
Average HDR-B	-34.0%	-37.4%			-8.3%	-0.8%		



Additional HDR Results in JVET-J0021:

- CVT bitrate reduction over SDR configuration:
 - High Complexity mode only
 - HDR-B class only (HD, PQ/BT.2020)
 - Around -14.04% of BD-Rate, PSNR L100

JVET-J021-HiCo	BD-rate, %		Time Est., %	
HDR vs. SDR	PSNRL100	DE100	Enc	Dec
Market	-18.9%	-46.6%	99%	100%
ShowGirl2	-6.5%	-15.8%		
Hurdles	-9.0%	-63.6%		
Starting	-12.3%	-40.2%		
Cosmos1	-23.5%	-19.0%		
Average HDR-B	-14.0%	-37.0%		

Conclusion

- CVT is proposed as HDR response
 - Pixel-level CVT seems to outperform delta QP based approach
 - Mandatory reconstruction process outside of coding loop
- HDR metrics PSNR L100 and PSNR DeltaE100 are used for optimization
 - Visual results seems to confirm good performance
- JVET-J0021 results (HiCo mode, PSNR L100):
 - 39.9% of BD rate reduction over HM HDR Anchor
 - 15.6% of BD rate reduction of JEM HDR Anchor
- JVET-J0021 results (LoCo mode, PSNR L100):
 - 37.3% of BD rate reduction over HM HDR Anchor
 - 11.9% of BD rate reduction of JEM HDR Anchor

Additional results:

- CVT on top of JEM7.0 (HDR-B class, PSNR L100):
 - Around 37% of BD rate reduction over HM HDR Anchor
 - Around 8.3% of BD-rate reduction over JEM HDR Anchor
- CVT on top of JVET-J0021 (HDR-B class , PSNR L100):
 - Around 14% of BD rate reduction

JVET-J0021-HDR over HM (High Complexity)

		BD-rate							
		DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV	psnrY	psnrU	psnrV
HDR-A	DayStreet	-67.7%	-43.8%	-41.7%	-63.0%	-79.1%	-40.3%	-61.0%	-76.6%
	PeopleInShoppingCenter	-55.0%	-36.6%	-35.4%	-61.4%	-58.0%	-34.9%	-59.4%	-57.7%
	SunsetBeach	-62.7%	-32.1%	-29.8%	-80.8%	-87.3%	-26.9%	-74.3%	-86.0%
HDR-B	Market	-37.7%	-36.4%	-35.3%	-21.5%	22.2%	-29.6%	1.9%	44.7%
	ShowGirl2	-26.0%	-34.8%	-31.8%	-34.7%	43.5%	-26.5%	-18.6%	4.9%
	Hurdles	-57.3%	-47.2%	-45.1%	-61.5%	-56.1%	-41.5%	-48.0%	-35.6%
	Starting	-28.8%	-45.6%	-42.7%	-27.0%	45.9%	-39.5%	-18.1%	79.7%
	Cosmos1	-34.2%	-42.5%	-20.7%	47.2%	2017.1%	-12.1%	1195.2%	153.4%
Average HDR-A		-61.8%	-37.5%	-35.6%	-68.4%	-74.8%	-34.0%	-64.9%	-73.4%
Average HDR-B		-36.8%	-41.3%	-35.1%	-19.5%	414.5%	-29.8%	222.5%	49.4%
Average HDR		-46.2%	-39.9%	-35.3%	-37.8%	231.0%	-31.4%	114.7%	3.3%
Enc Time[%]		1023%							
Dec Time[%]		515%							
Max Delta Rate[%]		-0.1%							
Min Delta Rate[%]		-3.0%							
Max Delta PSNR		1.22	1.65	3.45	2.46	3.23	3.01	2.30	2.50
Min Delta PNSR		0.05	0.34	0.52	-1.14	-1.00	0.23	-1.30	-1.15

JVET-J0021-HDR over JEM (High Complexity)

	BD-rate							
	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV	psnrY	psnrU	psnrV
DayStreet	-21.2%	-12.1%	-10.6%	-15.2%	-25.0%	-9.8%	-14.0%	-20.7%
PeopleInShoppingCenter	-11.8%	-10.0%	-9.7%	-13.8%	-12.5%	-9.3%	-12.9%	-12.8%
SunsetBeach	-18.0%	-8.3%	-11.4%	1.4%	-37.4%	-6.3%	7.3%	-29.6%
Market	4.5%	-16.2%	-13.9%	49.8%	170.8%	-8.2%	83.1%	224.4%
ShowGirl2	3.6%	-11.6%	-5.9%	105.3%	100.0%	-1.0%	175.3%	100.0%
Hurdles	-13.5%	-20.1%	-18.0%	2.4%	19.8%	-15.8%	20.2%	43.4%
Starting	7.3%	-21.7%	-18.1%	14.8%	184.1%	-15.4%	26.4%	100.0%
Cosmos1	-5.2%	-24.5%	4.8%	100.0%	100.0%	14.3%	100.0%	100.0%
Average HDR-A	-17.0%	-10.1%	-10.6%	-9.2%	-25.0%	-8.5%	-6.5%	-21.0%
Average HDR-B	-0.7%	-18.8%	-10.2%	54.5%	114.9%	-5.2%	81.0%	113.6%
Average HDR	-6.8%	-15.6%	-10.4%	30.6%	62.5%	-6.4%	48.2%	63.1%
Enc Time[%]	146%							
Dec Time[%]	62%							
Max Delta Rate[%]	-0.1%							
Min Delta Rate[%]	-3.0%							
Max Delta PSNR	0.27	0.67	1.27	0.52	0.55	1.07	0.52	0.57
Min Delta PSNR	-0.18	0.06	-0.15	-2.11	-1.92	-0.39	-2.28	-2.11

JVET-J0021-HDR over HM (HM Complexity)

	BD-rate							
	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV	psnrY	psnrU	psnrV
DayStreet	-65.8%	-41.1%	-38.7%	-59.5%	-77.6%	-37.3%	-57.1%	-74.3%
PeopleInShoppingCenter	-51.4%	-33.5%	-32.1%	-58.0%	-53.9%	-31.5%	-55.9%	-53.5%
SunsetBeach	-62.3%	-30.2%	-27.7%	-81.3%	-86.4%	-24.5%	-74.6%	-85.7%
Market	-29.8%	-33.7%	-32.4%	-4.2%	37.6%	-26.3%	24.8%	67.5%
ShowGirl2	-18.3%	-32.3%	-29.0%	-25.3%	137.4%	-23.5%	-7.1%	226.8%
Hurdles	-51.9%	-44.3%	-41.9%	-55.3%	-50.7%	-38.0%	-41.6%	-30.0%
Starting	-21.4%	-43.4%	-40.3%	-18.5%	72.2%	-37.0%	-7.7%	105.6%
Cosmos1	-28.8%	-40.3%	-17.2%	368.4%	100.0%	-7.9%	261.1%	100.0%
Average HDR-A	-59.8%	-34.9%	-32.8%	-66.3%	-72.6%	-31.1%	-62.5%	-71.2%
Average HDR-B	-30.0%	-38.8%	-32.1%	53.0%	59.3%	-26.5%	45.9%	94.0%
Average HDR	-41.2%	-37.3%	-32.4%	8.3%	9.8%	-28.3%	5.2%	32.0%
Enc Time[%]	313%							
Dec Time[%]	514%							
Max Delta Rate[%]	0.0%							
Min Delta Rate[%]	-1.2%							
Max Delta PSNR	1.11	1.54	3.18	2.24	3.07	2.75	2.08	2.37
Min Delta PSNR	0.00	0.32	0.43	-1.33	-1.37	0.15	-1.50	-1.54

JVET-J0021-HDR over JEM (Low Complexity)

	BD-rate							
	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV	psnrY	psnrU	psnrV
DayStreet	-16.0%	-7.9%	-6.0%	-7.2%	-16.2%	-5.2%	-5.6%	-11.6%
PeopleInShoppingCenter	-4.3%	-5.7%	-5.1%	-3.3%	-1.8%	-4.6%	-3.0%	-1.8%
SunsetBeach	-16.1%	-5.7%	-8.7%	-2.0%	-32.5%	-3.2%	6.9%	-26.8%
Market	17.6%	-12.5%	-10.0%	99.3%	191.7%	-3.8%	146.0%	100.0%
ShowGirl2	16.3%	-8.1%	-2.0%	158.1%	100.0%	3.0%	100.0%	100.0%
Hurdles	-3.0%	-15.5%	-13.0%	17.4%	32.2%	-10.6%	35.3%	51.2%
Starting	19.9%	-18.5%	-14.6%	32.4%	100.0%	-11.9%	46.7%	100.0%
Cosmos1	2.7%	-21.5%	9.6%	100.0%	100.0%	19.9%	100.0%	100.0%
Average HDR-A	-12.1%	-6.4%	-6.6%	-4.2%	-16.8%	-4.3%	-0.6%	-13.4%
Average HDR-B	10.7%	-15.2%	-6.0%	81.5%	104.8%	-0.7%	85.6%	90.2%
Average HDR	2.1%	-11.9%	-6.2%	49.3%	59.2%	-2.1%	53.3%	51.4%
Enc Time[%]	45%							
Dec Time[%]	62%							
Max Delta Rate[%]	0.0%							
Min Delta Rate[%]	-1.2%							
Max Delta PSNR	0.20	0.56	1.01	0.30	0.37	0.83	0.30	0.37
Min Delta PSNR	-0.26	0.03	-0.25	-2.29	-2.29	-0.47	-2.48	-2.49