AHG8: On the need of luma delta QP for BT.2100 HLG content

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1 Context and objectives

Context

- At the last JVET meeting in Hobart:
  - Document F0094 proposed a new set of HDR sequences graded with the BT.2100 Hybrid Log-Gamma (HLG) characteristics
  - Proponents asked for inclusion of that material in the CfP's test set
  - During review in the BoG it was asked whether luma delta QP is also needed for HLG

- Luma delta QP:
  - Results from an extensive analysis presented in MPEG document m37439
  - Compensates for a code level redistribution when SDR content is mapped into PQ
  - Allows to use a BT.709-optimised codecs over PQ material
  - Is recommended in TR1 (JCTVC-Y1017) for coding PQ material with HEVC

- The BoG recommended further study on luma delta QP for HLG and provision of additional coding rates for the material in F0094
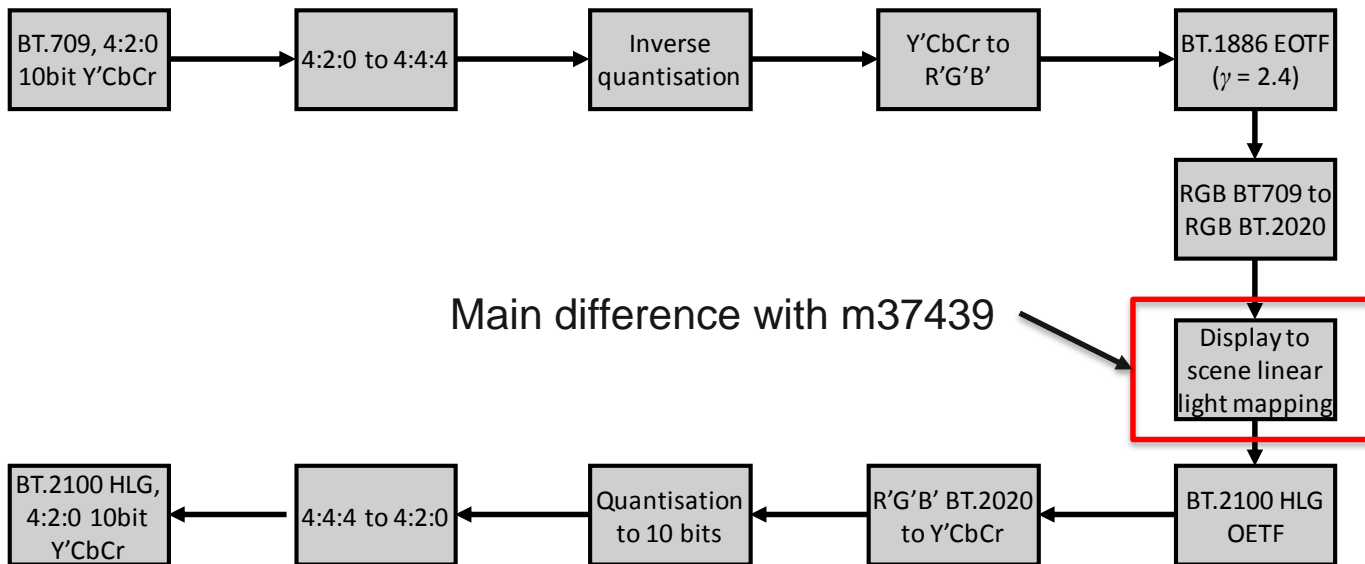
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Objective

- Study of luma delta QP for HLG is also envisaged as third mandate of the AHG

- Accordingly, the same methodology proposed in m37439 is followed to study the associated code level redistribution

- This contribution reports on the analysis made by BBC and NHK, particularly:
  - Remapping of SDR material into an HLG is considered and addressed
  - Results presented in terms of code levels distribution and coding performance
  - Conclusions are drawn accordingly on whether an ad-hoc QP adjustment is needed when HLG material is compressed with a BT.709-optimised codec

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2 Overall workflow

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Processing chain for HLG graded material

- M37439 studied how code levels redistribute when BT.709 content is put in a PQ container
- The same approach is followed here, adapted for HLG

```
┌──────────────┐   ┌──────────────┐   ┌──────────────┐   ┌──────────────┐   ┌──────────────┐
│ BT.709, 4:2:0│   │ 4:2:0 to 4:4:4│  │   Inverse    │   │  Y'CbCr to   │   │ BT.1886 EOTF │
│ 10bit Y'CbCr │──▶│              │──▶│ quantisation │──▶│   R'G'B'     │──▶│  (γ = 2.4)   │
└──────────────┘   └──────────────┘   └──────────────┘   └──────────────┘   └──────────────┘
                                                                                    │
                                                                                    ▼
                                                                            ┌──────────────┐
                                                                            │ RGB BT709 to │
                                                                            │  RGB BT.2020 │
                                                                            └──────────────┘
                                                                                    │
                                                                                    ▼
Main difference with m37439 ─────────────────▶                              ┌──────────────┐
                                                                            │  Display to  │
                                                                            │ scene linear │
                                                                            │ light mapping│
                                                                            └──────────────┘
                                                                                    │
                                                                                    ▼
┌──────────────┐   ┌──────────────┐   ┌──────────────┐   ┌──────────────┐   ┌──────────────┐
│ BT.2100 HLG, │   │              │   │ Quantisation │   │ R'G'B' BT.2020│  │ BT.2100 HLG  │
│ 4:2:0 10bit  │◀──│ 4:4:4 to 4:2:0│◀─│ to 10 bits   │◀──│  to Y'CbCr   │◀──│     OETF     │
│   Y'CbCr     │   │              │   │              │   │              │   │              │
└──────────────┘   └──────────────┘   └──────────────┘   └──────────────┘   └──────────────┘
```

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3 Remapping to an HLG container

Remapping to an HLG container: Preliminary remarks
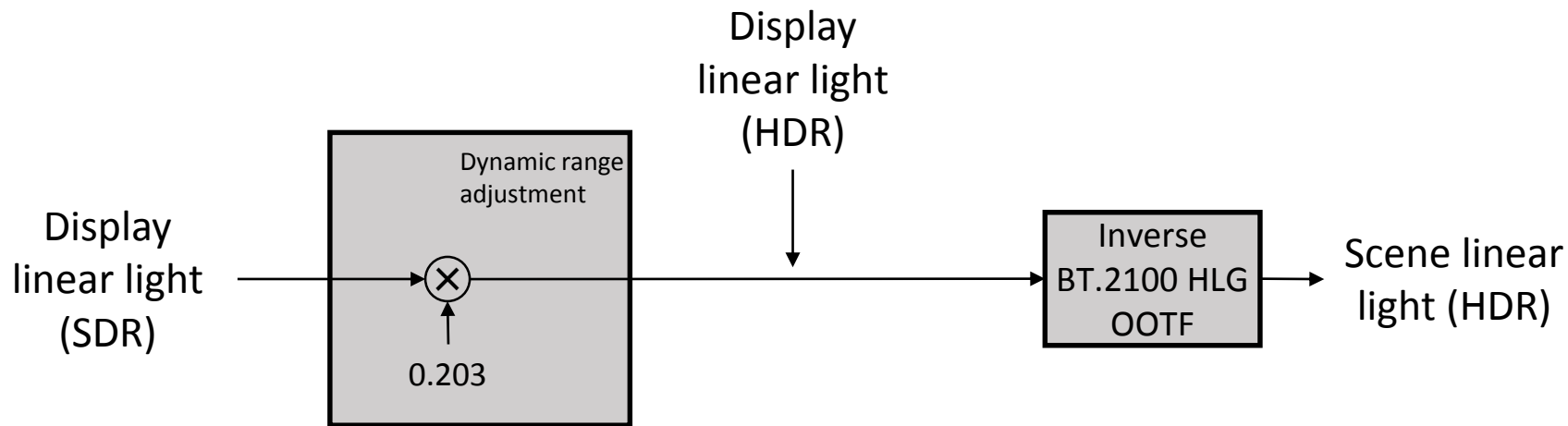
- HLG OETF applied after BT.1886 means that 100% SDR ↔ 100% HLG (very bright images)
- The Digital Production Partnership (DPP) recommends 100% SDR ↔ 75% HLG
- After scaling, resulting linear display light is converted to linear scene light

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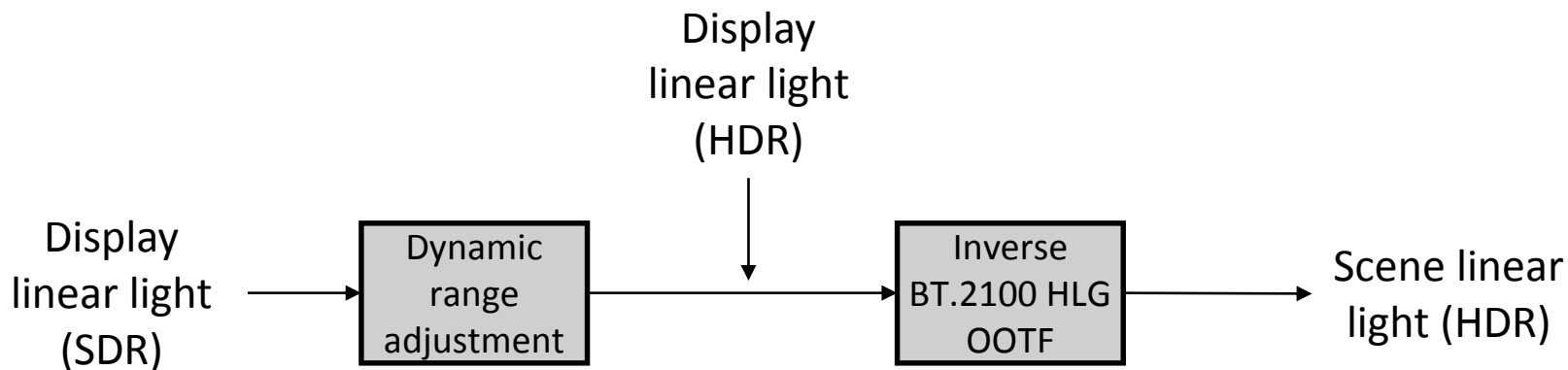
Remapping to an HLG container: Details

- Assuming a peak luminance of 1000 nits, the system gamma for the HLG OOTF is 1.2
- The scaling factor for dynamic range adjustment is given by:

$$M = \frac{EOTF_{HLG}(0.75)}{EOTF_{BT.709}(1.0)} = \frac{OOTF_{HLG}(OETF_{HLG}^{-1}(0.75))}{OOTF_{BT.709}(OETF_{BT.709}^{-1}(1.0))} = \frac{0.265^{\gamma}}{1.0^{2.4}} \xrightarrow{\gamma=1.2} 0.203$$

Display
linear light
(HDR)

Display
linear light
(SDR)

Dynamic range
adjustment

$\times$

0.203

Inverse
BT.2100 HLG
OOTF

Scene linear
light (HDR)

Remapping to an HLG container: Simplified scheme

- Mapping to 75% HLG can also be done assuming a peak luminance of 392 nits
- Resulting gamma is 1.03 (close to unity), avoiding to invert the gamma on luma
- In the experiments a system gamma of 1.04 was used instead

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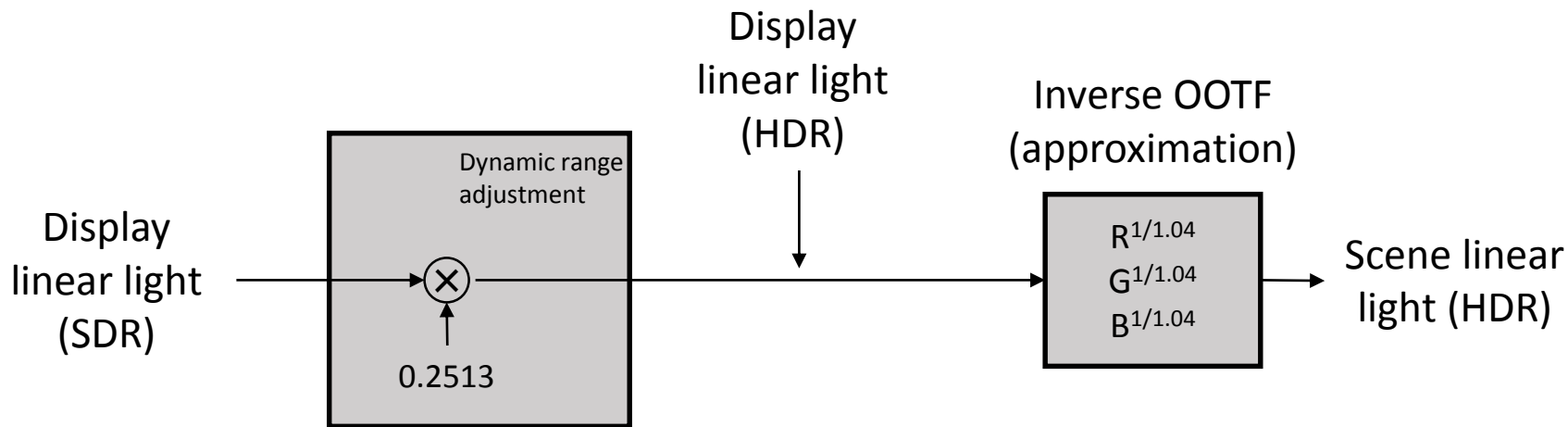
4 Results analysis

Results analysis: Test material and experimental conditions

- JCT-VC sequences (Class A-E) with 10 bit upscaling by simple bit shifting
- Coding of this material according to CTC (L1100):
  - Main10 profile
  - Random Access
  - Low Delay
- Distribution of code levels is analysed by scatter plots inspection (luma and chroma)
- Least square regression is applied to quantify the code level variation

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Results analysis: Code levels distribution for luma and BQSquare

- Scatter plots for luma codewords are reported for both remapping schemes

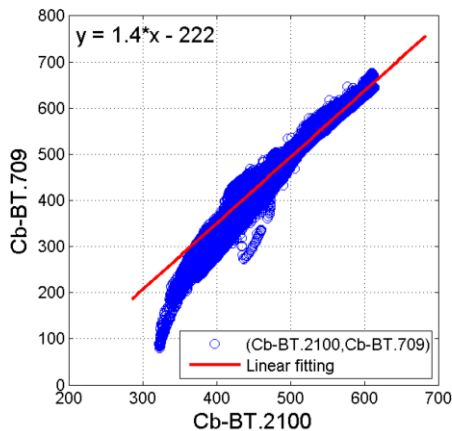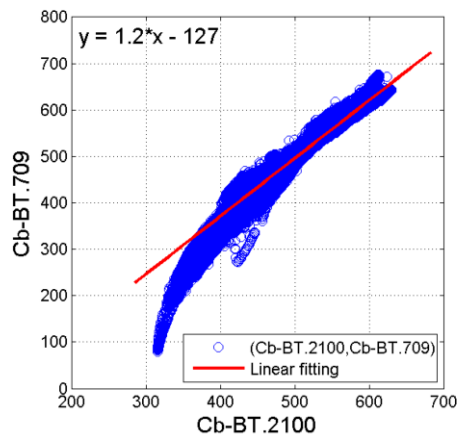## Full conversion

$y = 1.5 \cdot x - 167$

Simplified conversion

$y = 1.2 \cdot x - 70$

- Content spans same range of levels
- Linear relationship exists
- $QP_{709} - QP_{2100}$ independent on luma level

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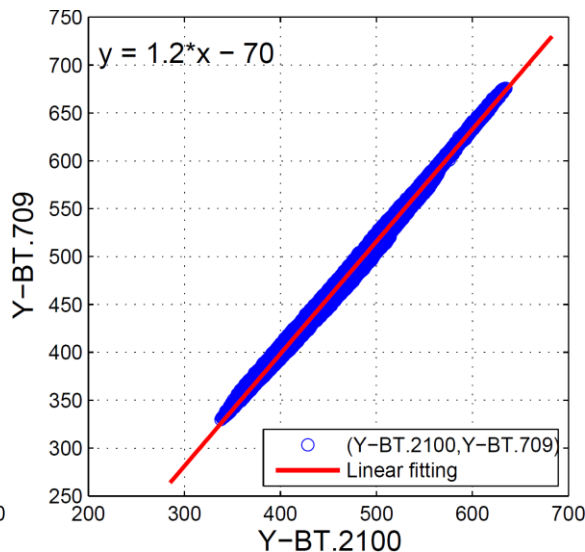
Results analysis: Code levels distribution for luma and all content

- Scatter plots for luma codewords are reported for both remapping schemes
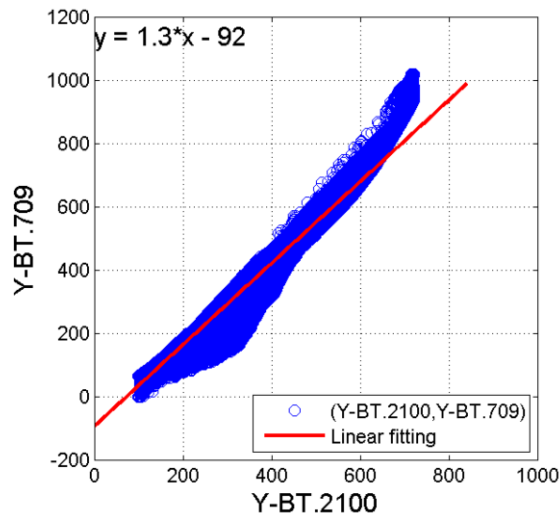
Full conversion

Simplified conversion
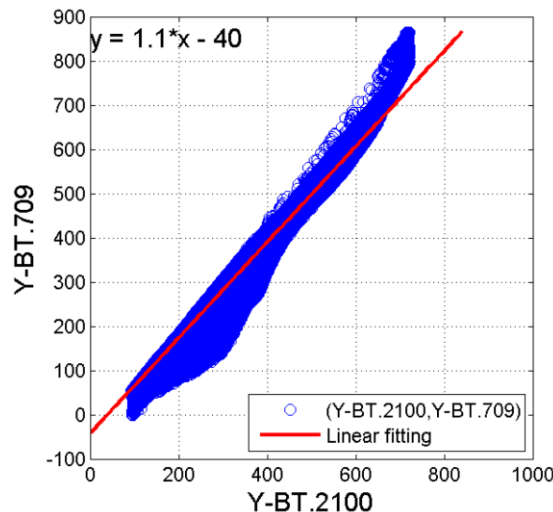
- Content spans same range of levels
- Linear relationship exists
- $QP_{709} - QP_{2100}$ independent on luma level

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Results analysis: Code levels distribution for Cb and Cr and all content
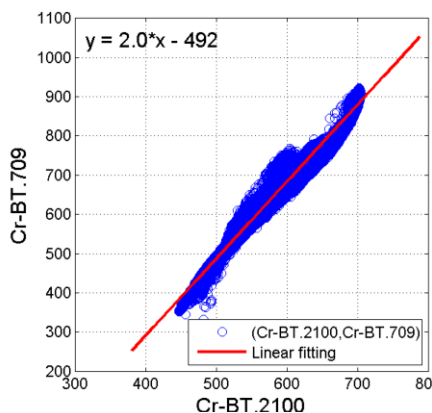

Cb — Full conversion / Simplified conversion

Cr — Full conversion / Simplified conversion
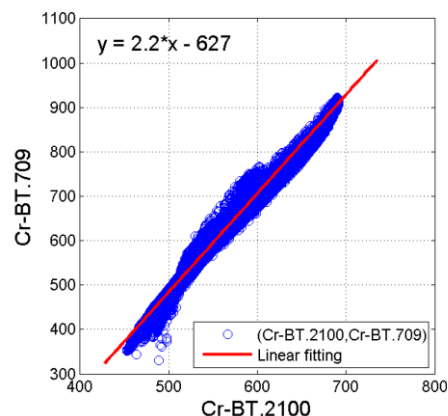
- Differently from m37439 the relationship is not piecewise linear (i.e. not luma dependent)
- The slope of the linear model is not close to unity which would suggest a static QP offset is needed
- Results suggest a QP offset of -3 and -7 for Cb and Cr, respectively

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Results analysis: Coding performance measurement

- BD-rates are computed as follows:

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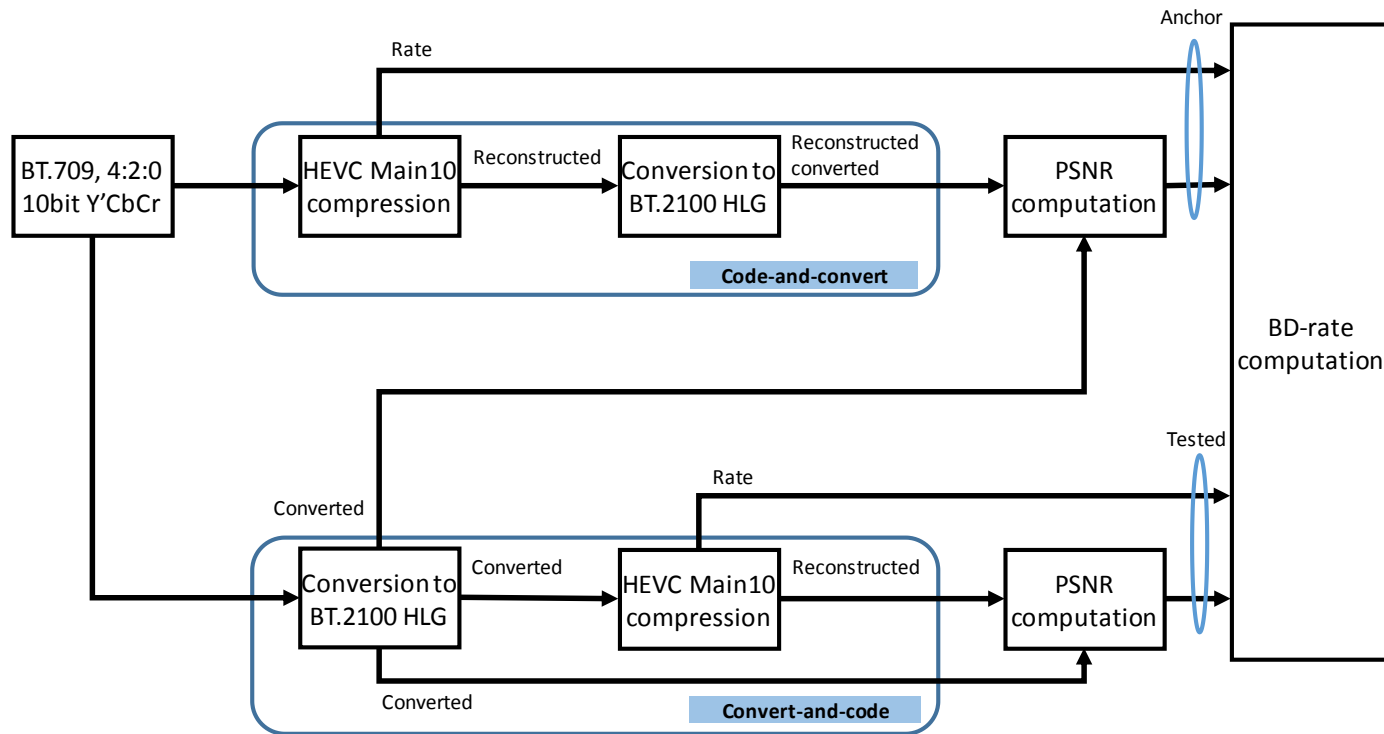
Results analysis: Coding performance results

	Random Access Main10			Low delay B Main10		
	Y	U	V	Y	U	V
Class A	3.6%	11.5%	33.2%	3.4%	15.2%	28.9%
Class B	3.4%	10.2%	-6.6%	2.8%	11.0%	-4.5%
Class C	2.4%	21.1%	7.7%	2.3%	21.2%	8.7%
Class D	5.7%	14.5%	7.3%	4.9%	14.4%	9.6%
Class E	5.9%	2.5%	3.7%	7.2%	7.8%	15.4%
Overall	4.1%	12.3%	8.6%	3.8%	12.6%	6.0%

- BD-rate losses due to joint effects or conversion process and use of QP offset
- Losses on the chroma components inline with the findings of m37439
- Losses not noticeable during visual inspection of the coded material

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5 Conclusions and recommendations

What we've learned

- Remapping SDR material to an HLG container to study how code levels are distributed:
  - Linear relationship between luma and chroma codewords over a large set of test material
  - For luma slopes of linear models close to unity
  - Hence a code level perturbation in the BT.709 space translates in the same amount in the HLG one
  - Chroma components have slopes different from unity, so a static QP offset might be used

- Recommendation:
  - No particular ad-hoc luma delta QP seems to be needed for HLG graded material
  - Chroma can be addressed with static/adaptive offsets or some ad-hoc RDO technique

- Very important caveat:
  - Is not suggested that HLG would not benefit from luminance adaptive quantisation
  - Is only suggested that no particular bitrate redistribution between the highlights and lowlights should be expected and addressed

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