Bit-Rate Evaluation of Compressed HDR using SL-HDR1

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Abstract

- HDR works by changing the "interpretation" of the video samples
  - "What actual luminance level is represented by a given sample"
- Video encoders and decoders are agnostic to HDR
  - The video samples are transported without interpretation
- We analyze two ways of transporting HDR over a compressed link:
  - Transport HDR natively
  - Transport HDR using SL-HDR1

A Quick Overview of HDR

- The human eye response is non-linear
  - We perceive more detail at the lower luminosities
- Assign bits to light intensity in a non-linear fashion
  - More bits to the lower intensities
  - Expand the higher intensities to less bits to express a higher range
- In the display, this is the EOTF curve: the Electrical to Optical Transfer Function
  - Make the higher bit values mean "more light"
- Fundamentally, HDR shows more detail in the bright areas

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Relative vs Absolute Luminance Levels

- The luminance encoded in SDR signals is relative
  - 100% means “give me your best shot at white”
- A basis for a number of HDR implementations is the SMPTE ST 2084 Perceptual Quantizer (PQ)
- In PQ, what is coded is the <u>absolute</u> value of the luminance
  - Light intensity is measured in candelas per square meter, a unit also known as “nit”
  - A standard TV monitor can do about 100 nits
  - HDR can code up to 10,000 nits (which no commercial monitor can do)

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What happens at the monitor?

- The monitor may get an HDR signal it cannot display
- It will need to create an image that is as close as possible to the "original" based on what it can do
- In order to help the monitor do this job, in some HDR standards, metadata is included in the stream
- Metadata content:
  - Most HDR standards: metadata **describes** what is in the signal
  - SL-HDR1: metadata contains **instructions** on how recover the HDR signal

SL-HDR1 Details

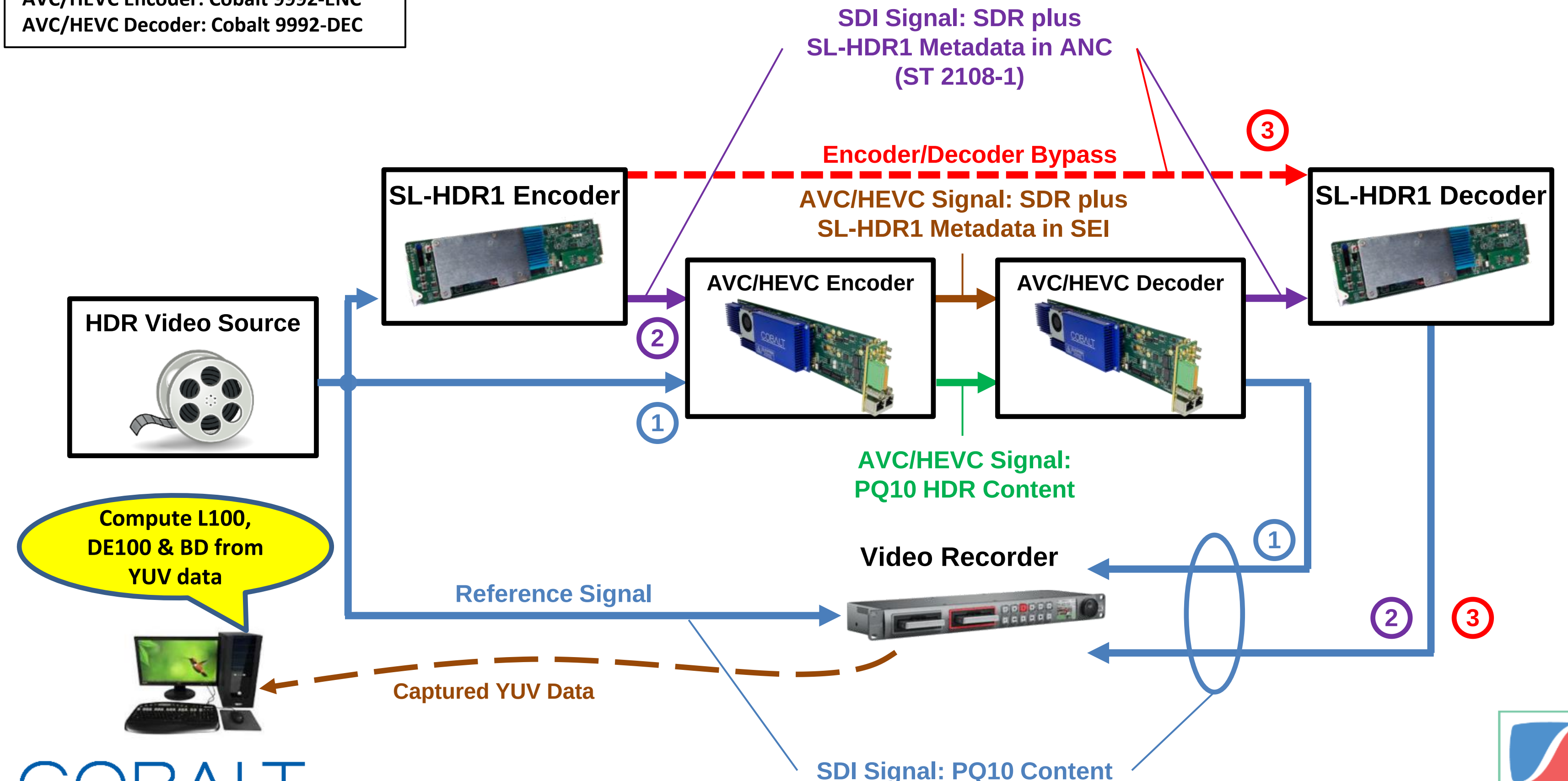
- SL-HDR1 is defined in ETSI TS 103 433-1
  - Also included in ATSC A/341
- Base layer is SDR
  - Metadata allows mapping of anything between SDR and full HDR
  - Other HDR standards have an HDR base layer
- Metadata carriage:
  - SDI: Ancillary space, defined in SMPTE ST 2108-1
  - Compressed streams: SEI messages

Bit Rate Evaluation

- The objective is to transport a native HDR signal through a compressed link at a given quality (measured objectively)
- This can be done in two ways:
  - Directly encode the HDR signal, transport, and decode it
  - Use SL-HDR1 to convert the signal to SDR plus metadata, encode it, transport the signal and metadata, decode and convert back to HDR
- Figure out what bit rate to use in the SL-HDR1 path to achieve the same quality as the native HDR path

Test Setup

SL-HDR1 Encoder/Decoder: Cobalt 9904
AVC/HEVC Encoder: Cobalt 9992-ENC
AVC/HEVC Decoder: Cobalt 9992-DEC



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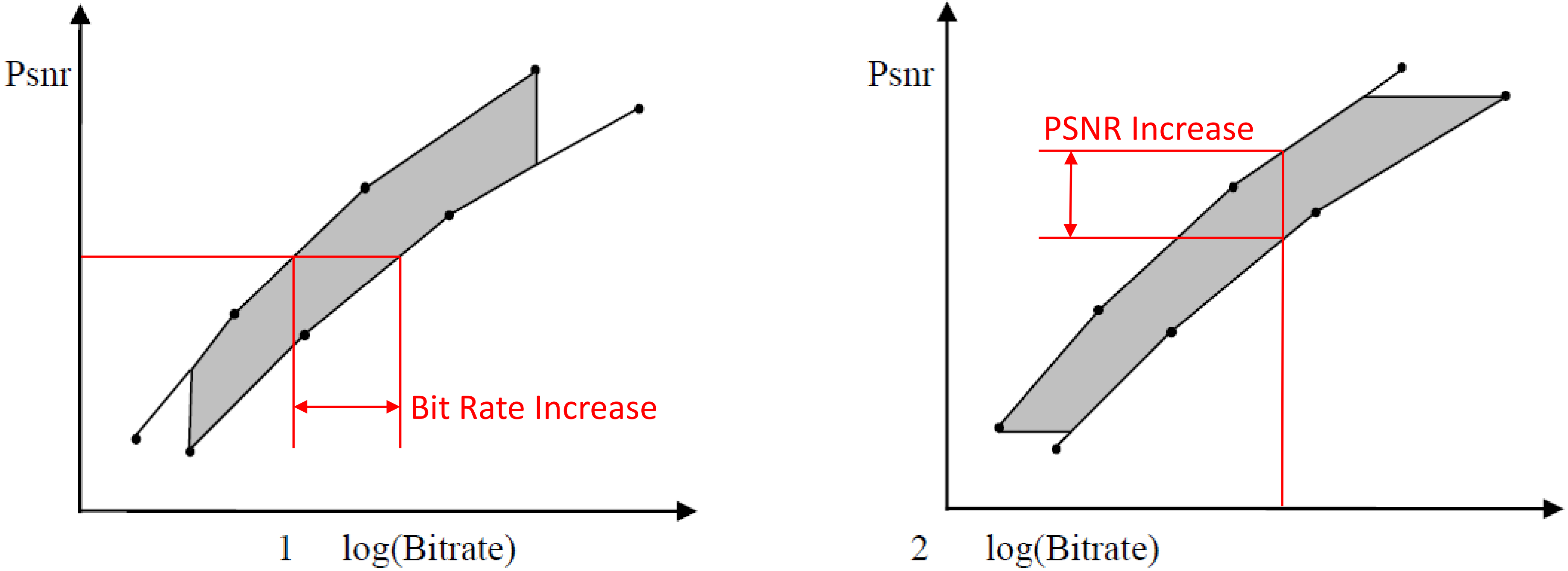
Quality Metrics

- **PSNR:** Peak Signal-to-Noise Ratio
  - Measures the difference between the pixels of the reference image and the test image
  - Absolute values do not directly correlate to perceived video quality
- **PSNR_DE100:**
  - PSNR of mean absolute deltaE2000 metric referred to 100-nit luminance
- **PSNR_L100**
  - PSNR of mean square error of L component of CIELab color space for deltaE2000, referred to 100-nit luminance
- DE100 and L100 correlate well with perceived quality

The BD-Rate Calculation

- This is an "industry-standard" method of computing either bit rate improvement (for the same PSNR) or PSNR improvement (for the same bit rate) for two competing approaches
  - Proposed by G. Bjontegaard, document VCEG-AI11
- Method:
  - Plot PSNR vs Log(Bit Rate)
  - Fit a third-order polynomial to the data set
  - Calculate the area between the curves
  - Use that to derive average PSNR or bit rate improvement

BD-Rate, Continued



Bjontegaard, G., "Improvements of the BD-PSNR model", ***ITU-T SG16/Q6 VCEG 35th meeting, Berlin, Germany, 16–18 July, 2008, Doc. VCEG-AI11***

Test Procedure

1. Take a baseline reading of the quality metric using **Path 3**. This only needs to be done once.
2. Select a target test bit rate B_r for the AVC/HEVC encoder.
3. Run the **Path 1** signal and compute the selected quality metrics.
4. Run the **Path 2** signal and compute the selected quality metrics.
5. Repeat steps 2-4 for other values of B_r.
6. Perform the BD-rate computation for both PSNR_DE100 and PSNR_L100.

Quality metrics are computed by using the original image as a reference and the path output as the comparison signal.

Path 1: Native HDR through AVC/HEVC
Path 2: SL-HDR1 through AVC/HEVC
Path 3: Direct SL-HDR1 (no AVC/HEVC)

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Test Sequences

Sequence 1 “basejump” (50fps)

Sequence 3 “zombie” (24 fps)

Sequence 2 “baseball” (59.94fps)

Sequence Info:
- Duration: 12 sec
- Resolution: 1920x1080
- Progressive Sequences
- Color Space: ITU-R BT.2020

Encoder Settings:
- GOP Size: 100 frames
- Bit Depth: 10 bits
- Chroma Mode: 4:2:0
- HEVC: Chroma Qp Offset=0

Sequence 1

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Sequence 2

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Sequence 3

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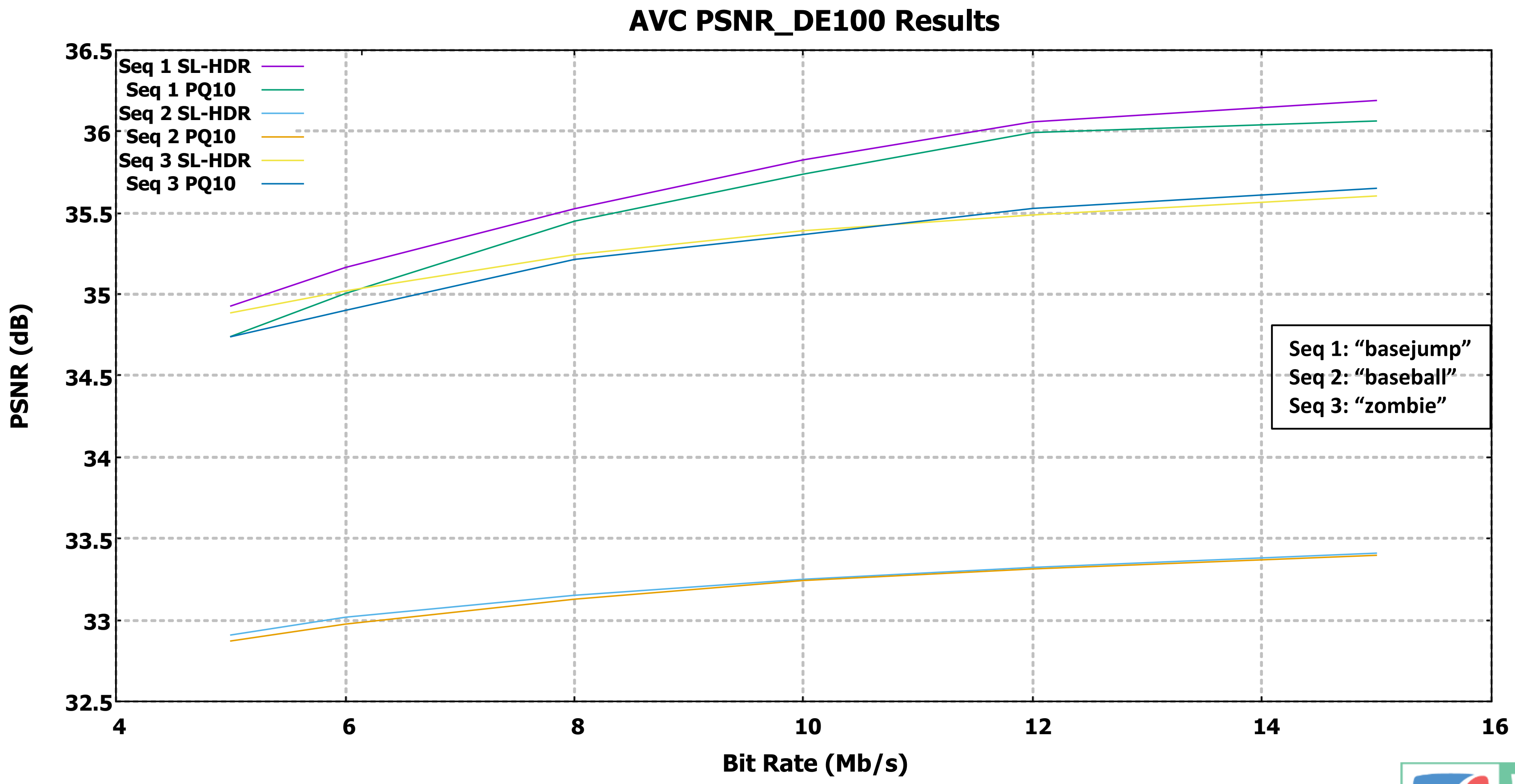
Path 3 Quality Metrics

Path 3: Direct SL-HDR1 (no AVC/HEVC encoding/decoding)

Sequence	Path 3 YUV PSNR	Path 3 DE100	Path 3 L100
Sequence 1	59.26 dB	38.54 dB	51.80 dB
Sequence 2	58.72 dB	38.16 dB	51.53 dB
Sequence 3	59.07 dB	38.32 dB	51.67 dB

These numbers represent an upper bound of what can be expected with compression

AVC (H.264) Test Results



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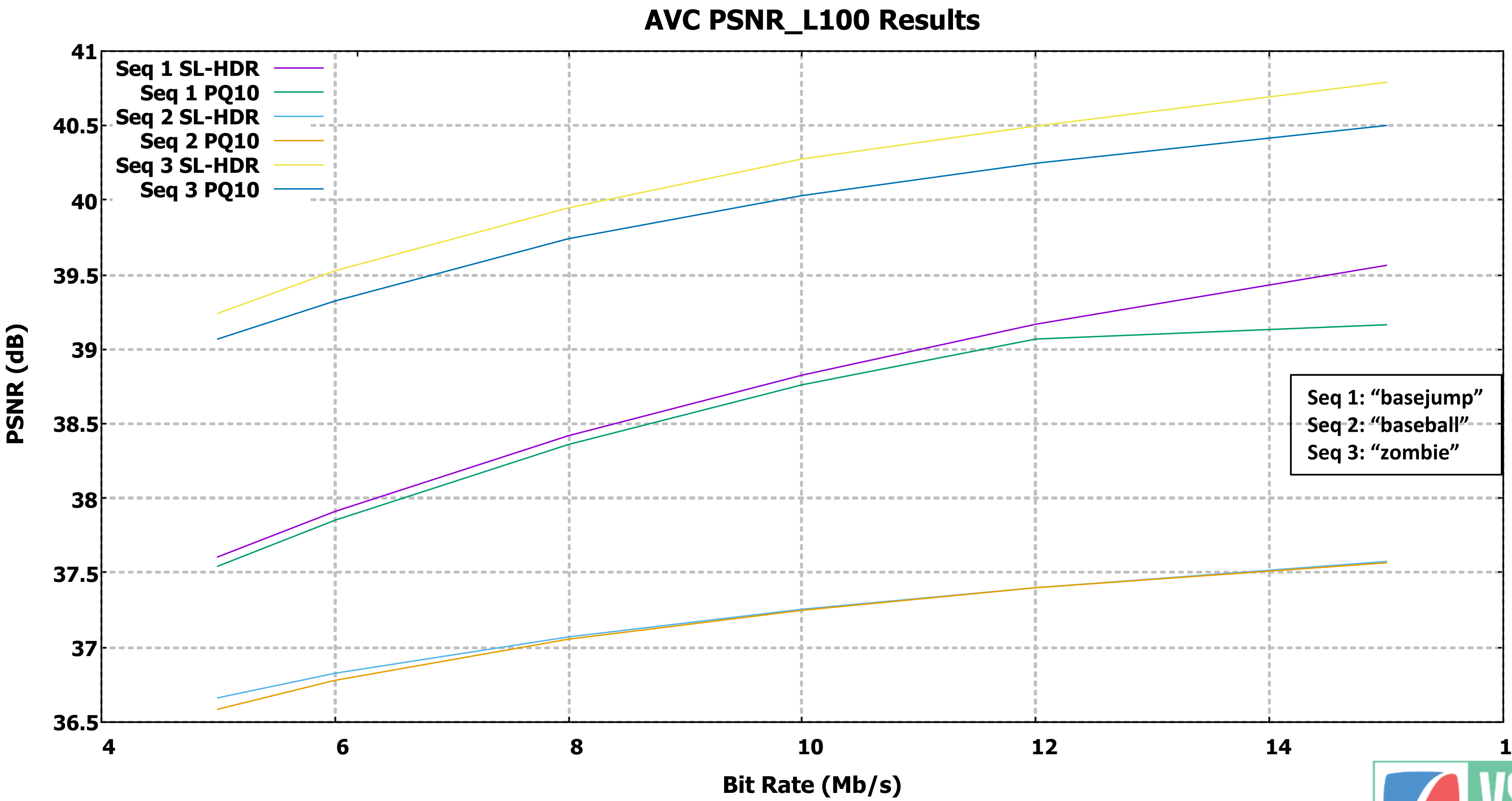

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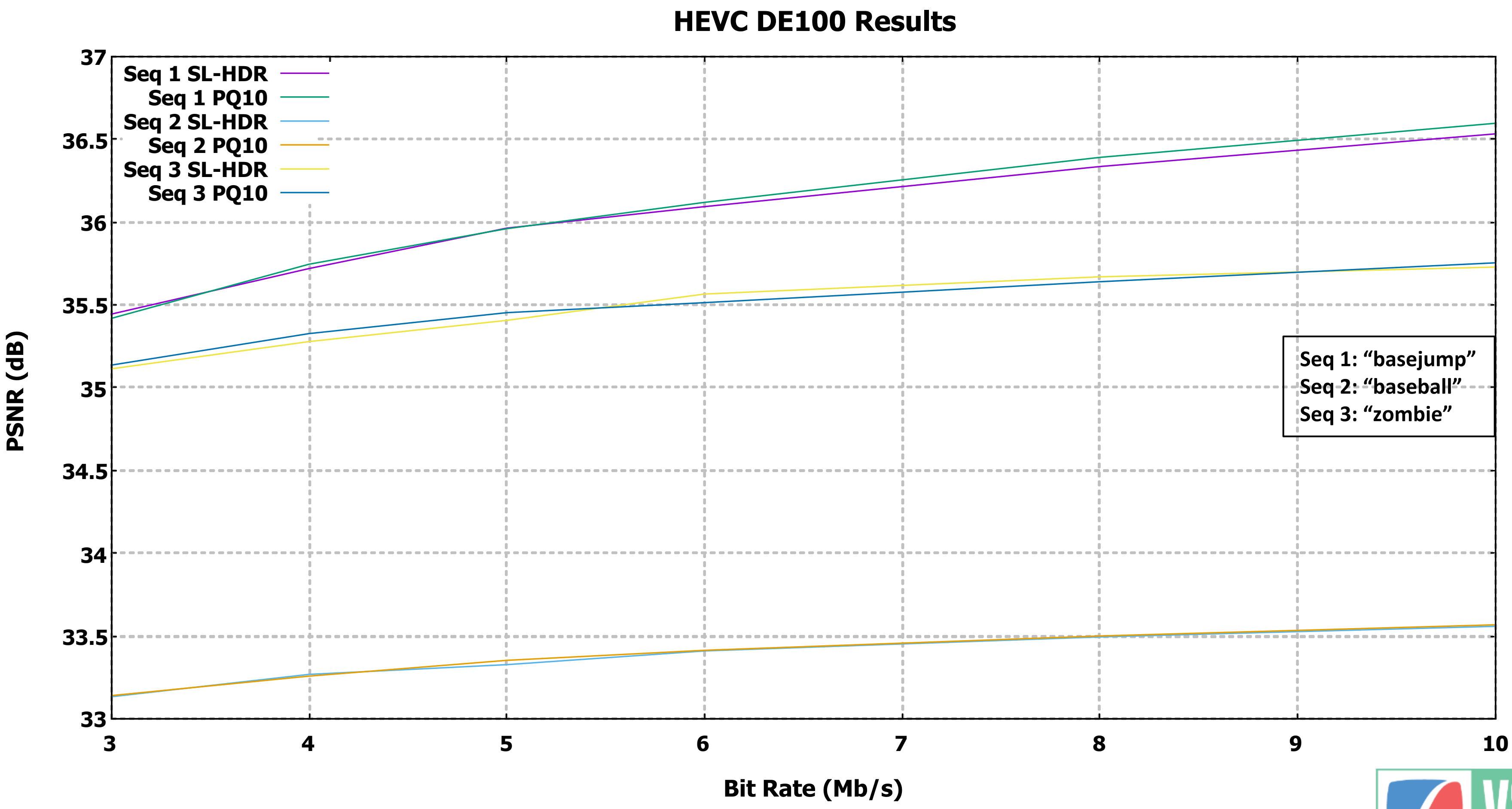
HEVC (H.265) Test Results



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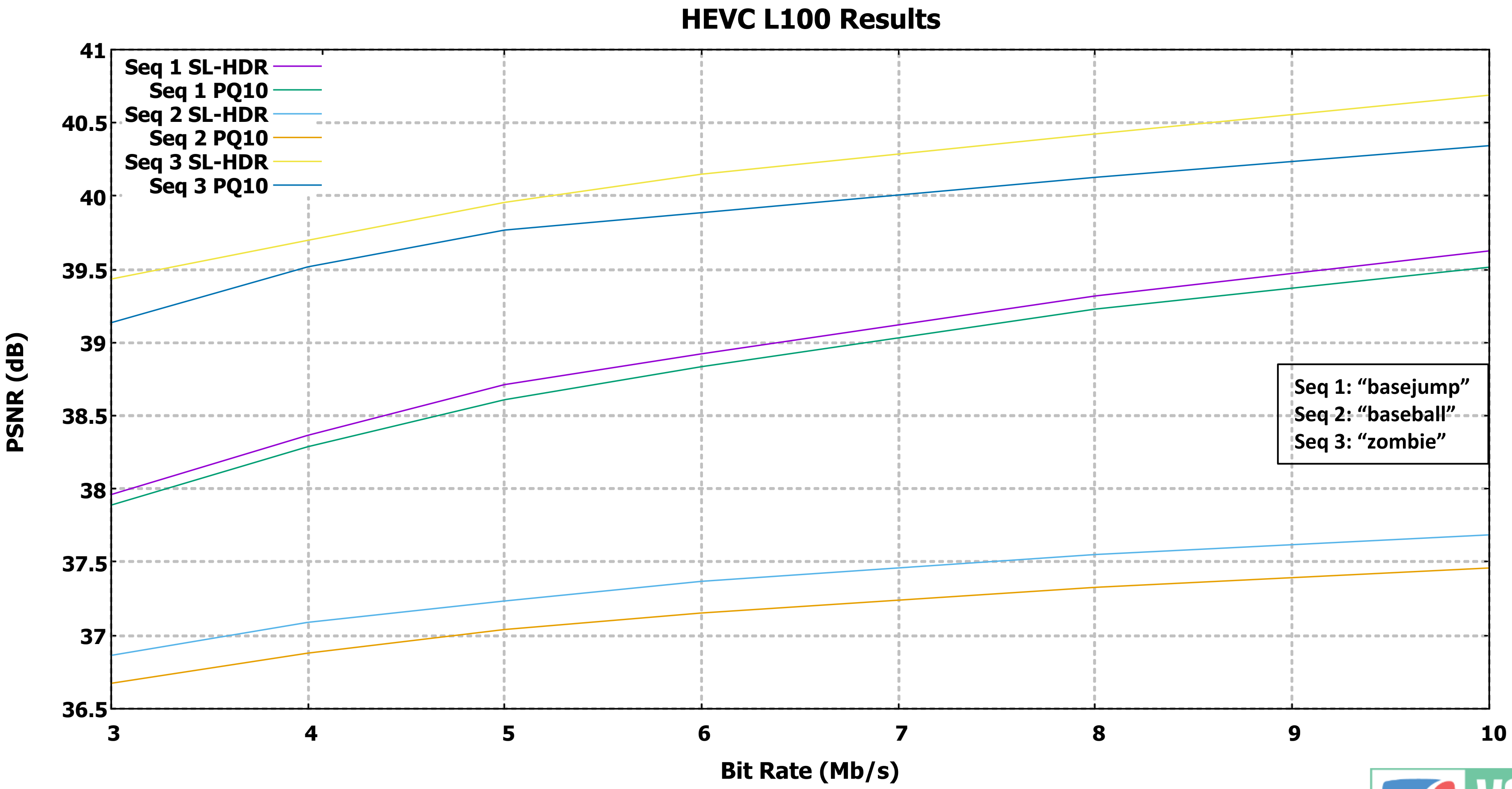

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BD-Rate Values

Sequence	HEVC		AVC	
	DE100	L100	DE100	L100
Sequence 1	0.90%	-6.92%	-6.07%	-3.65%
Sequence 2	5.61%	-25.90%	-5.84%	-2.42%
Sequence 3	7.27%	-20.25%	-2.58%	-13.07%

- Table shows average bit rate change of SL-HDR1 compared with PQ10 for the same perceived picture quality
- Positive value: SL-HDR1 requires **higher** bit rate than HDR
- Negative value: SL-HDR1 requires **lower** bit rate than HDR

A Note on Metadata Bit Rate

- The maximum size of the metadata SEI message per frame is 61 bytes.
- Based on that, an upper bound on metadata bit rate is:
  - 50 fps progressive content: 24.4 kb/s
  - 60 fps progressive content: 29.3 kb/s
- This rate increase is negligible
  - Encoder does a minor adjustment on NULL packet rate to compensate

Conclusions

- The impact of SL-HDR1 on bit rate depends on:
  - Content
  - Quality metric
- There is some indication that, when using metrics aligned with perceived quality, for some content, lower bit rate can be used
- For the encoder tested, the improvements in AVC are more marked than in HEVC
- Touze and Kerkhof (2017) reported similar results with different metrics and equipment

Comparison with VidTrans 2020 Results

- At VidTrans 2020 we had a similar presentation
- Differences:
  - Use of more advanced objective video quality measures that better correlate with perceived quality
  - Use of BD-rate to obtain an average rather than trying to match quality measures
  - One of the test sequences was unsuitable (frame-rate converted), and the SL-HDR1 encoder was misconfigured for it.
- However, qualitative results are still the same

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Q&A

- Questions?
- Thanks!

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"Wingman" (to keep the authors honest):

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