# 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

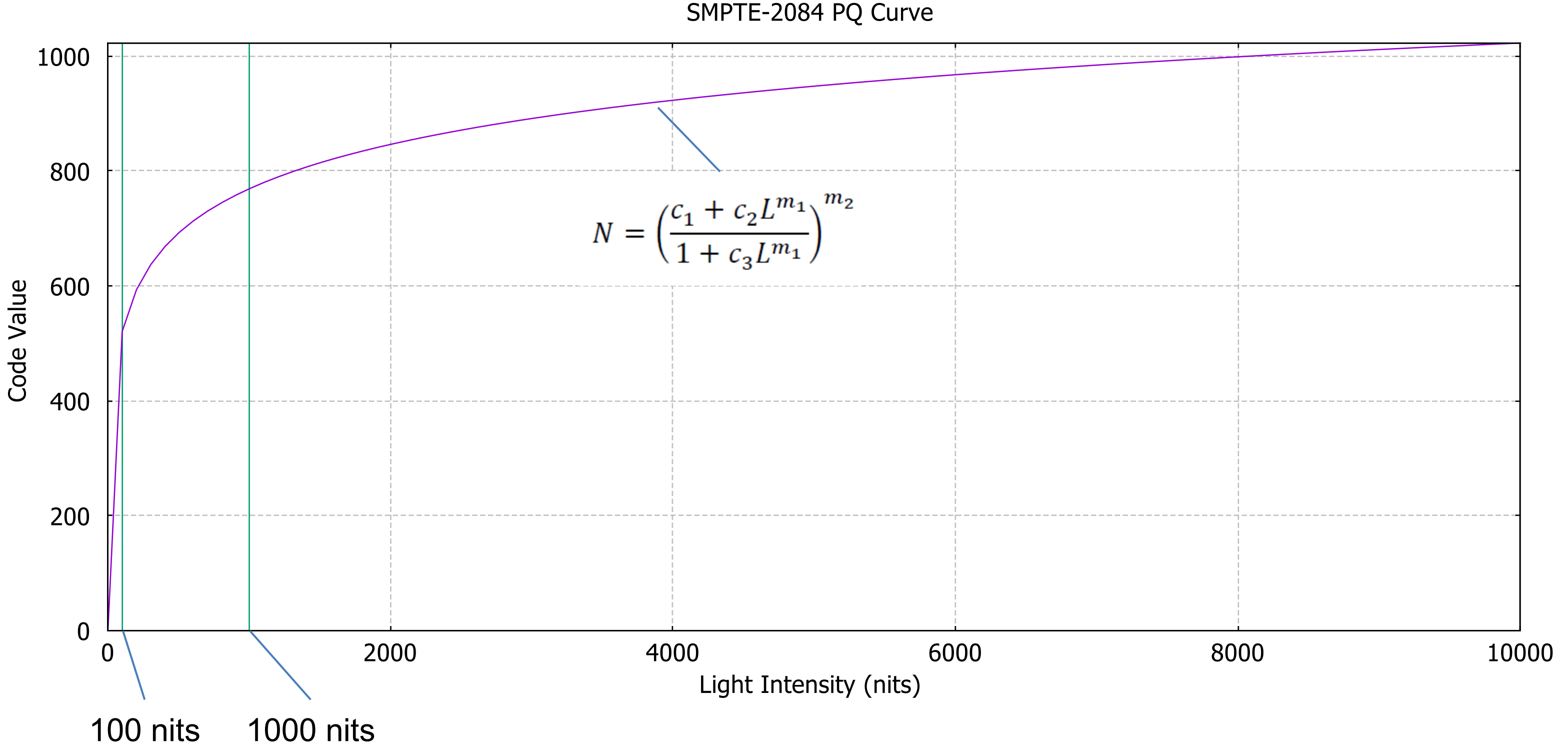
# A Quick Overview of HDR

- 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

# 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 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)

# SMPTE 2084 PQ Curve

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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
- The HDR signal can be seen as “a base signal plus instructions (metadata) to adapt it to whatever is needed”

# 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 2108
  - Compressed streams: SEI messages

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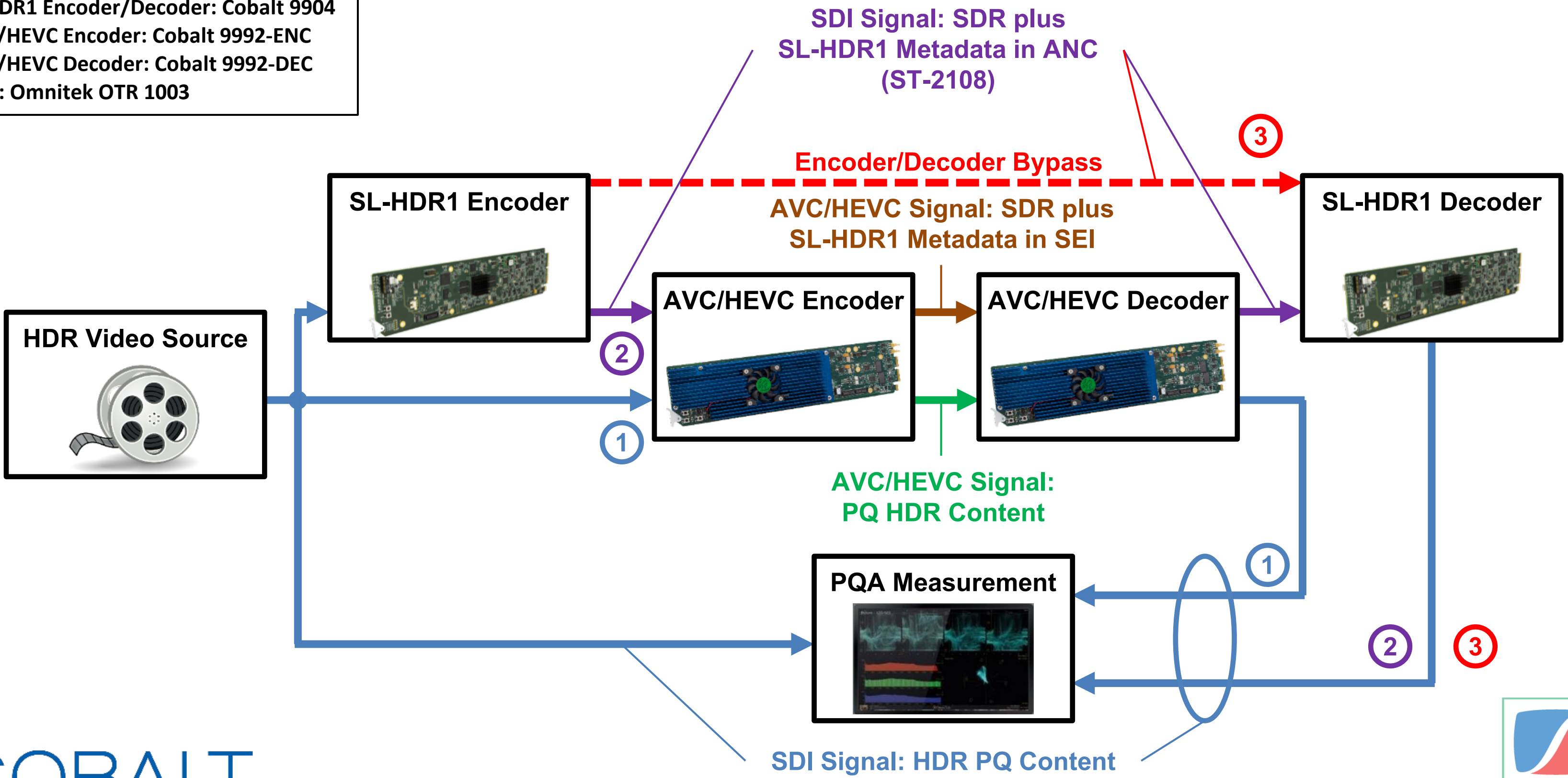
# Bit Rate Evaluation

- 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
- Adjust the bit rate of the SL-HDR1 path until the quality matches the native HDR link

# Test Setup

SL-HDR1 Encoder/Decoder: Cobalt 9904
AVC/HEVC Encoder: Cobalt 9992-ENC
AVC/HEVC Decoder: Cobalt 9992-DEC
PQA: Omnitek OTR 1003

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# Quality Metrics

- **PSNR:** Peak Signal-to-Noise Ratio
  - Industry standard
  - Measures the difference between the pixels of the reference image and the test image
  - Absolute values do not directly correlate to perceived video quality
- **CSNR:** Compensated Signal-to-Noise Ratio
  - Proprietary metric for the PQA used in the testing
  - Better correlation with perceived quality
  - Captures the fact that artifacts are most visible close to object edges at mid-range brightness levels

# 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 record the quality metric for the sequence, which we will denote by $P_1$.
4. Run the **Path 2** signal and record the quality metric for the sequence, which we will denote by $P_2$.
5. Still running the **Path 2** signal, adjust the encoder bit rate until the PQA measures the same quality metric $P_1$ as in step 3 above. Record the bit rate $B_h$ at which the quality metric matches.
6. Repeat steps 2-5 for other values of $B_r$.

**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

Sequence 3

Sequence 2


Sequence Info:
- Duration: 12 sec
- Resolution: 1920x1080
- Frame Rate: 50 fps, progressive
- Color Space: BT. 2020

Encoder Settings:
- GOP Size: 60 frames
- Bit Depth: 10 bits
- Chroma Mode: 4:2:0

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# 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 PSNR | Path 3 CSNR |
|---|---|---|
| Sequence 1 | 66.00 dB | 65.90 dB |
| Sequence 2 | 60.21 dB | 68.99 dB |
| Sequence 3 | 56.54 dB | 52.63 dB |

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

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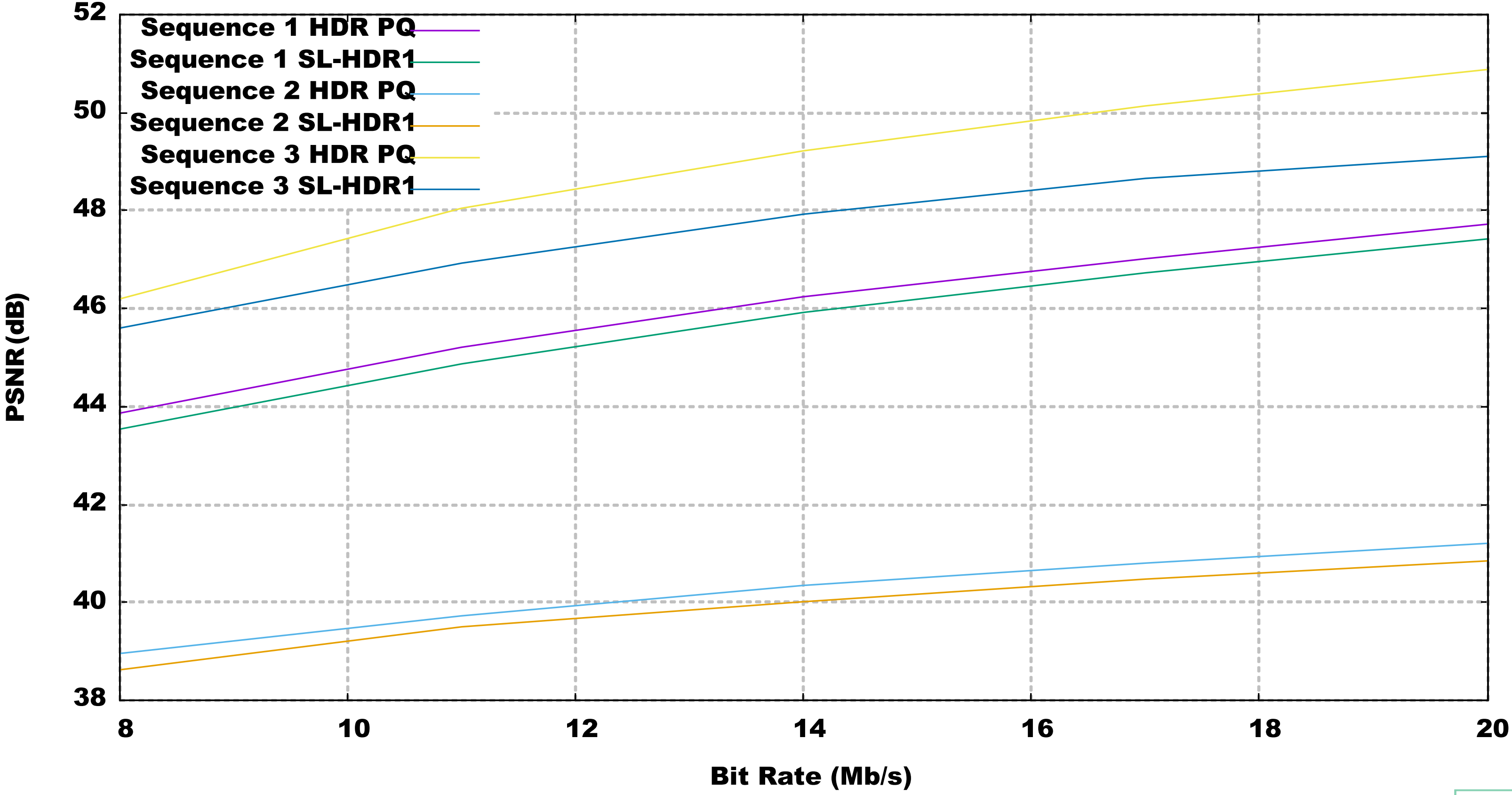
# AVC (H.264) Test Results

# PSNR Comparison for AVC

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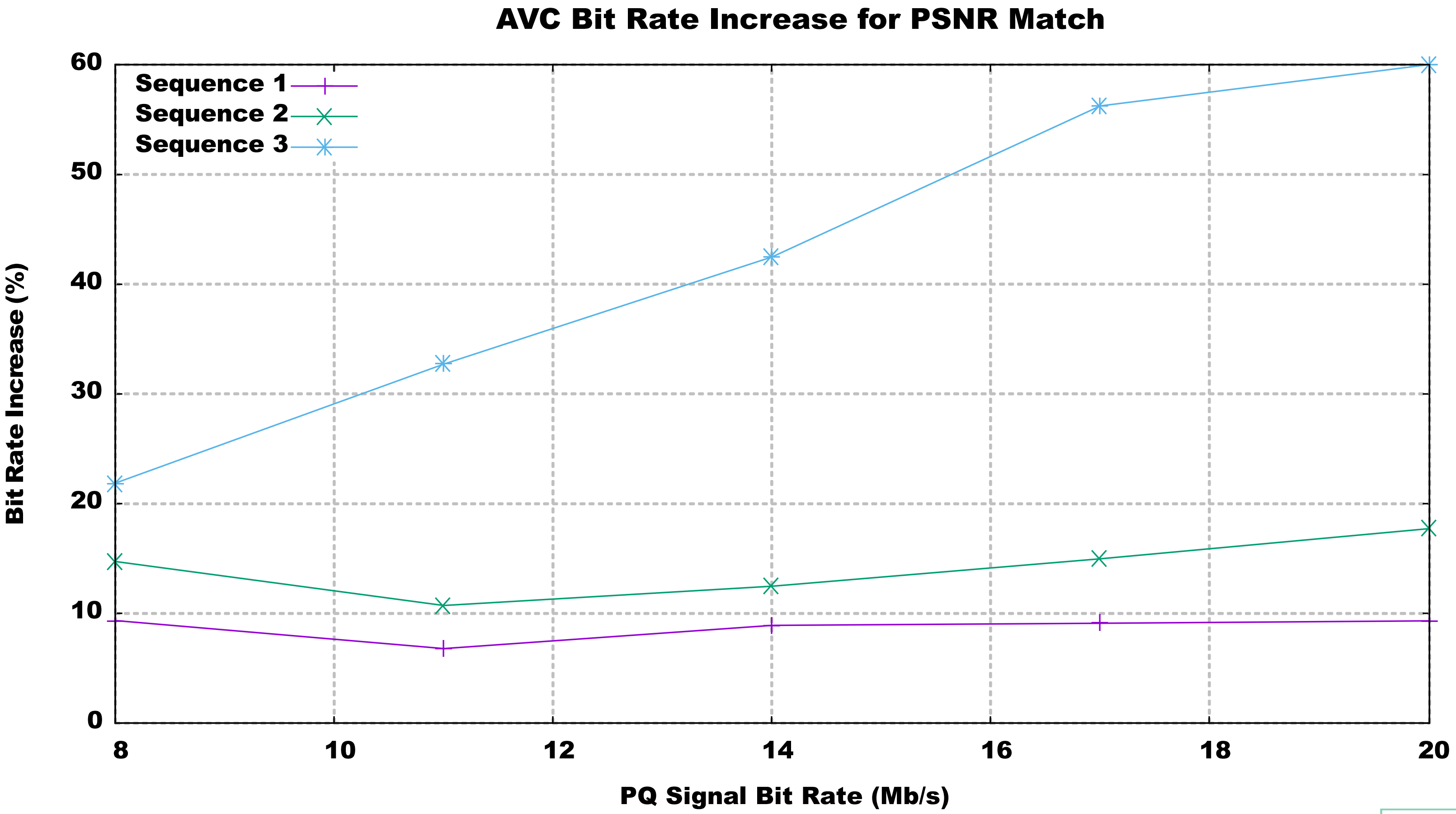


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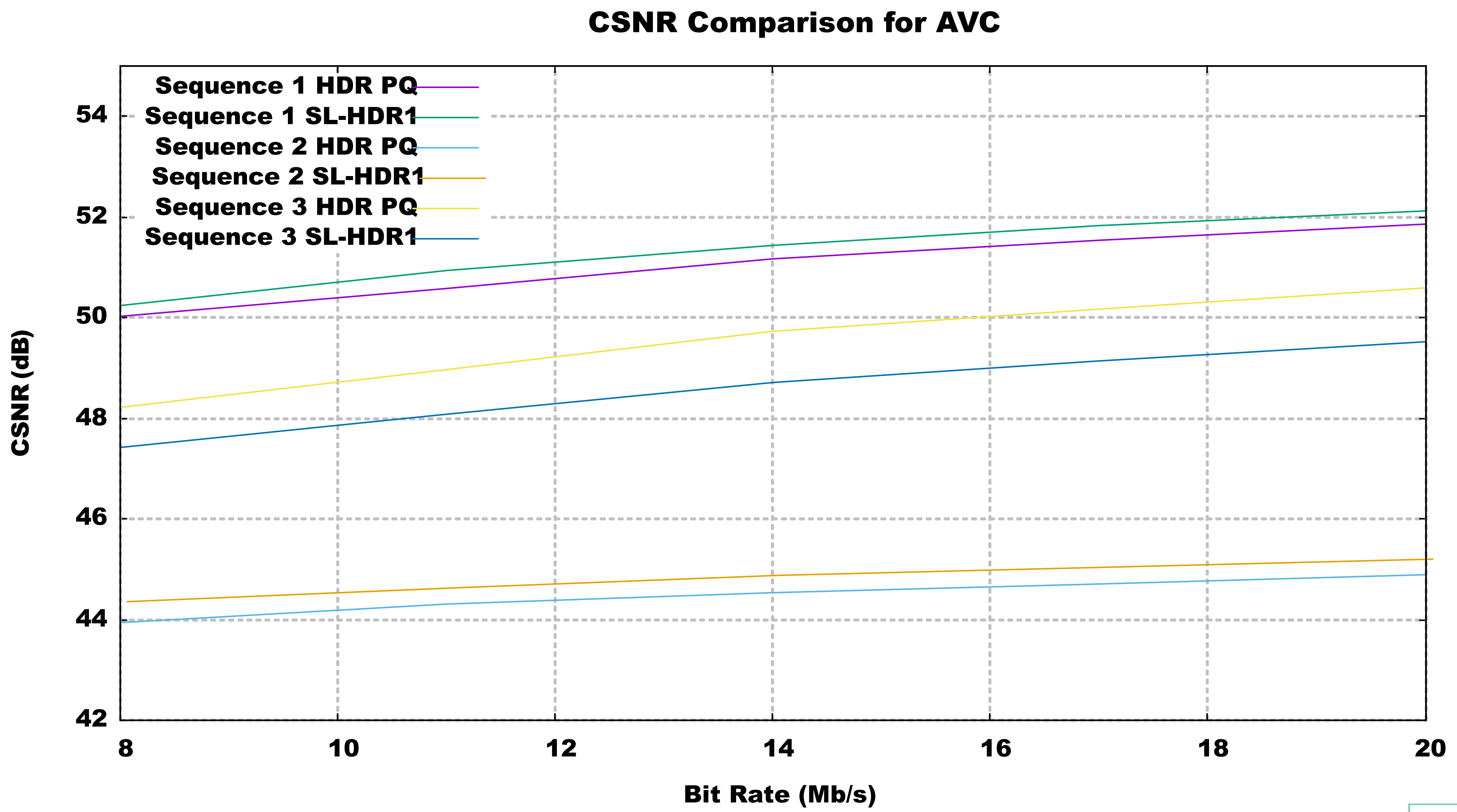
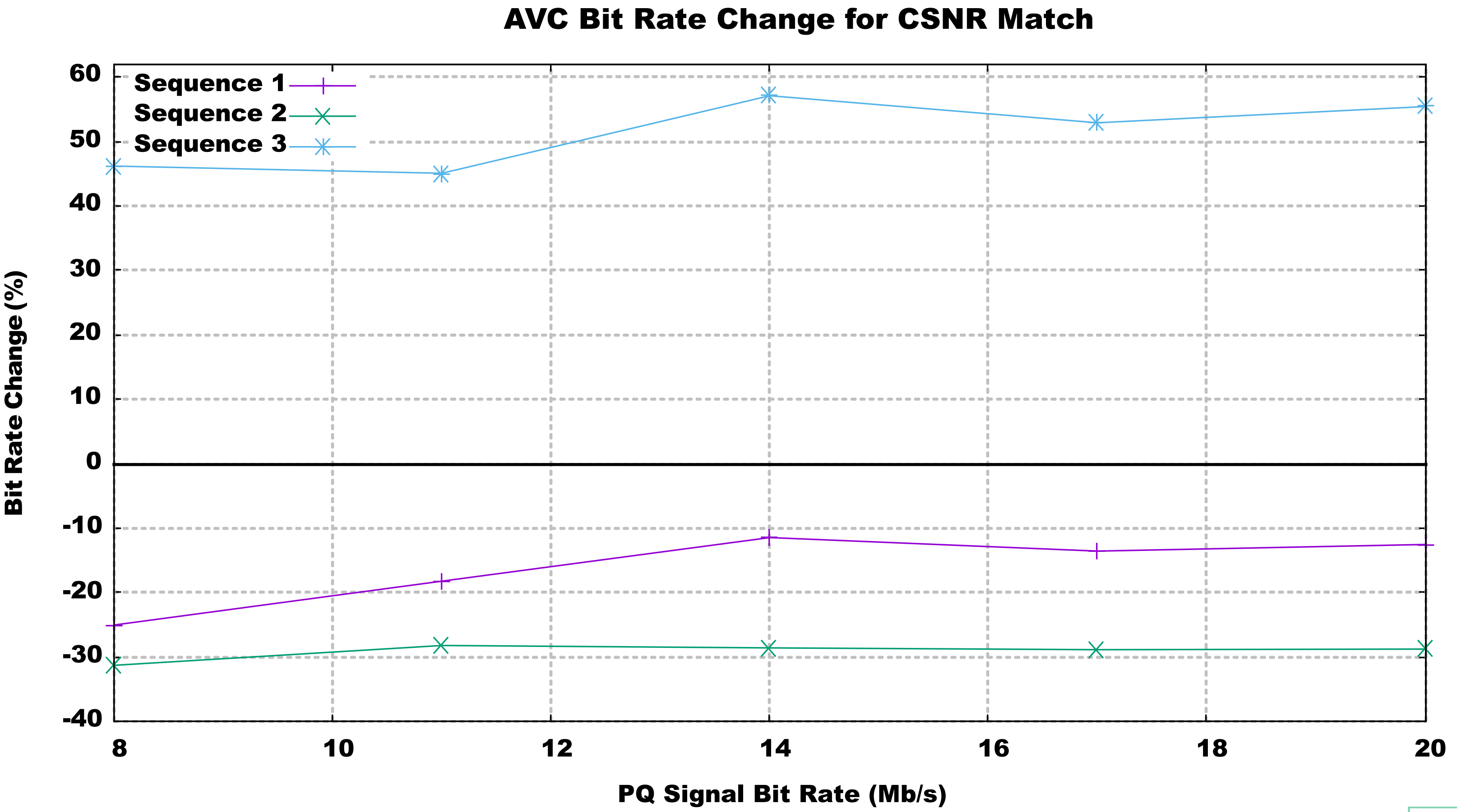


CSNR Comparison for AVC
Sequence 1 HDR PQ
Sequence 1 SL-HDR1
Sequence 2 HDR PQ
Sequence 2 SL-HDR1
Sequence 3 HDR PQ
Sequence 3 SL-HDR1
CSNR (dB)
54
52
50
48
46
44
42
8
10
12
14
16
18
20
Bit Rate (Mb/s)

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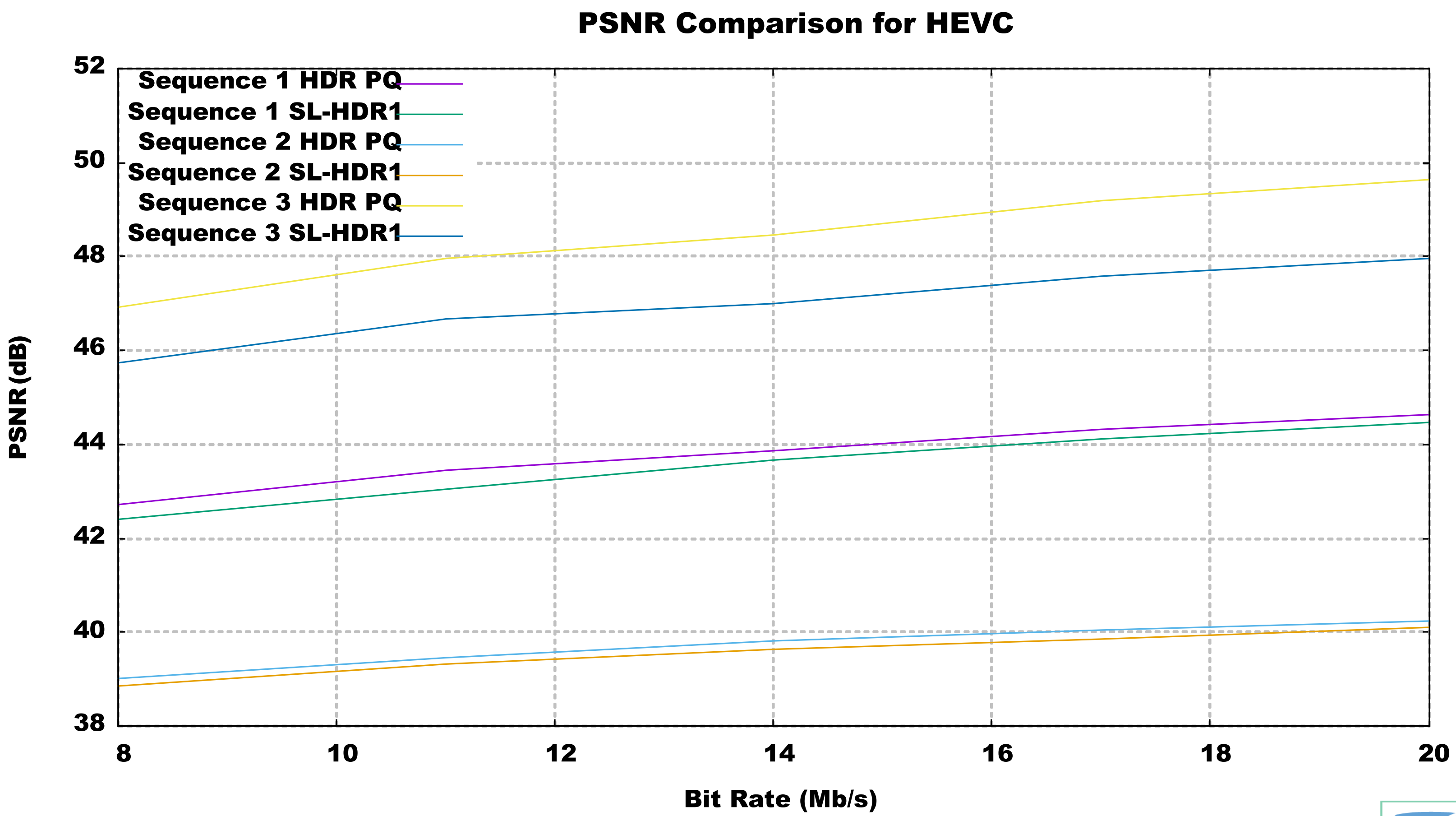
# HEVC (H.265) Test Results

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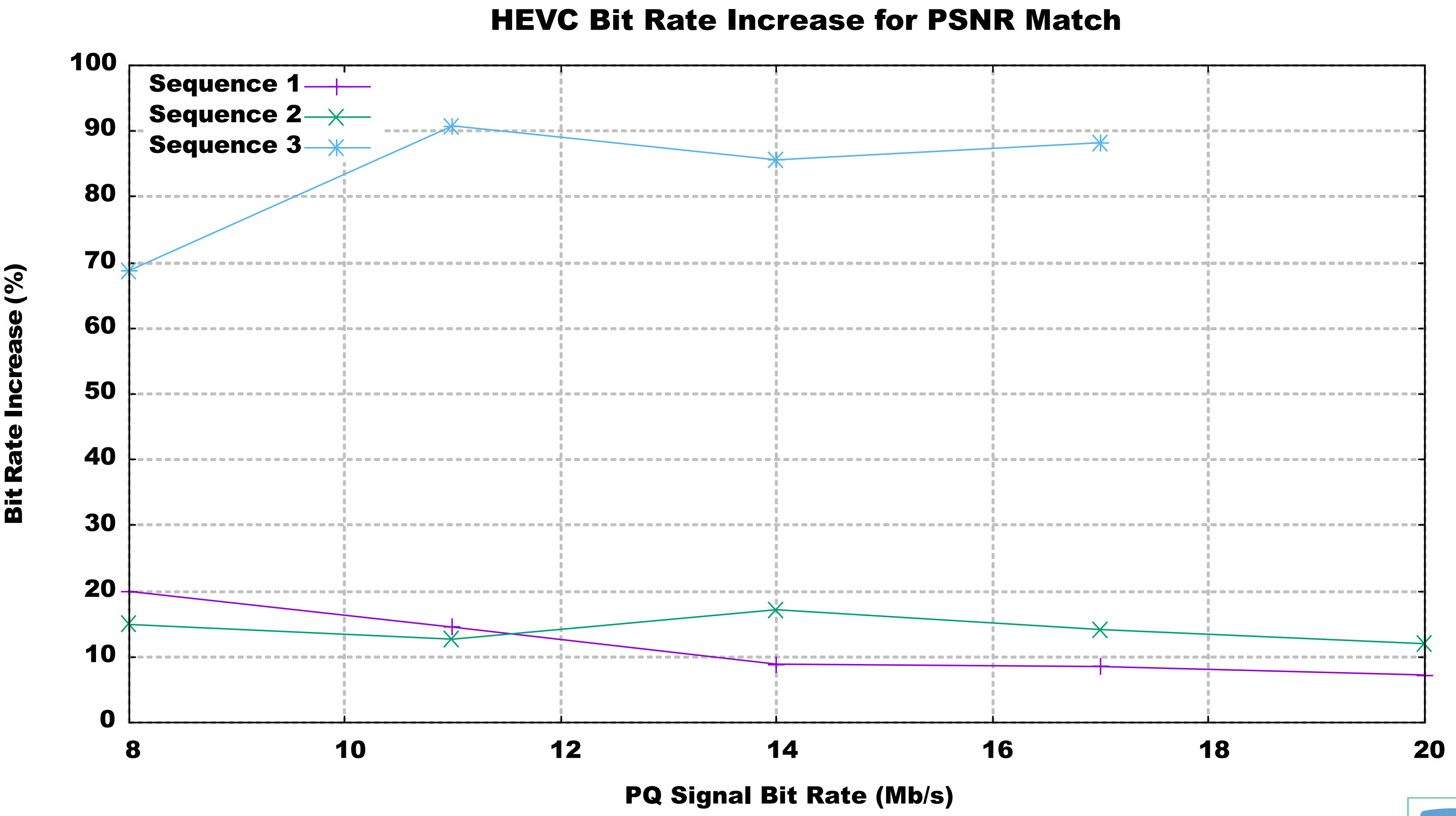


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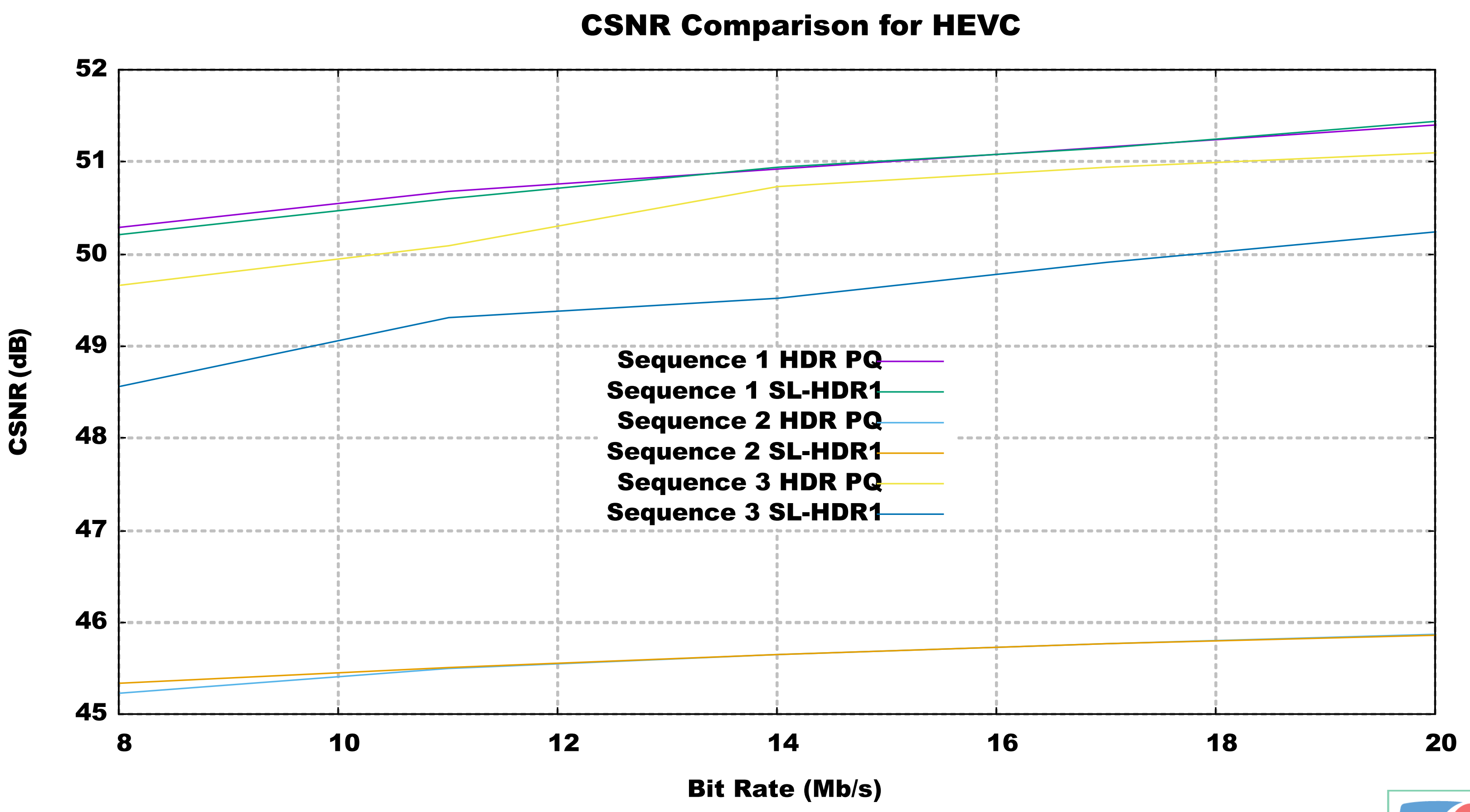


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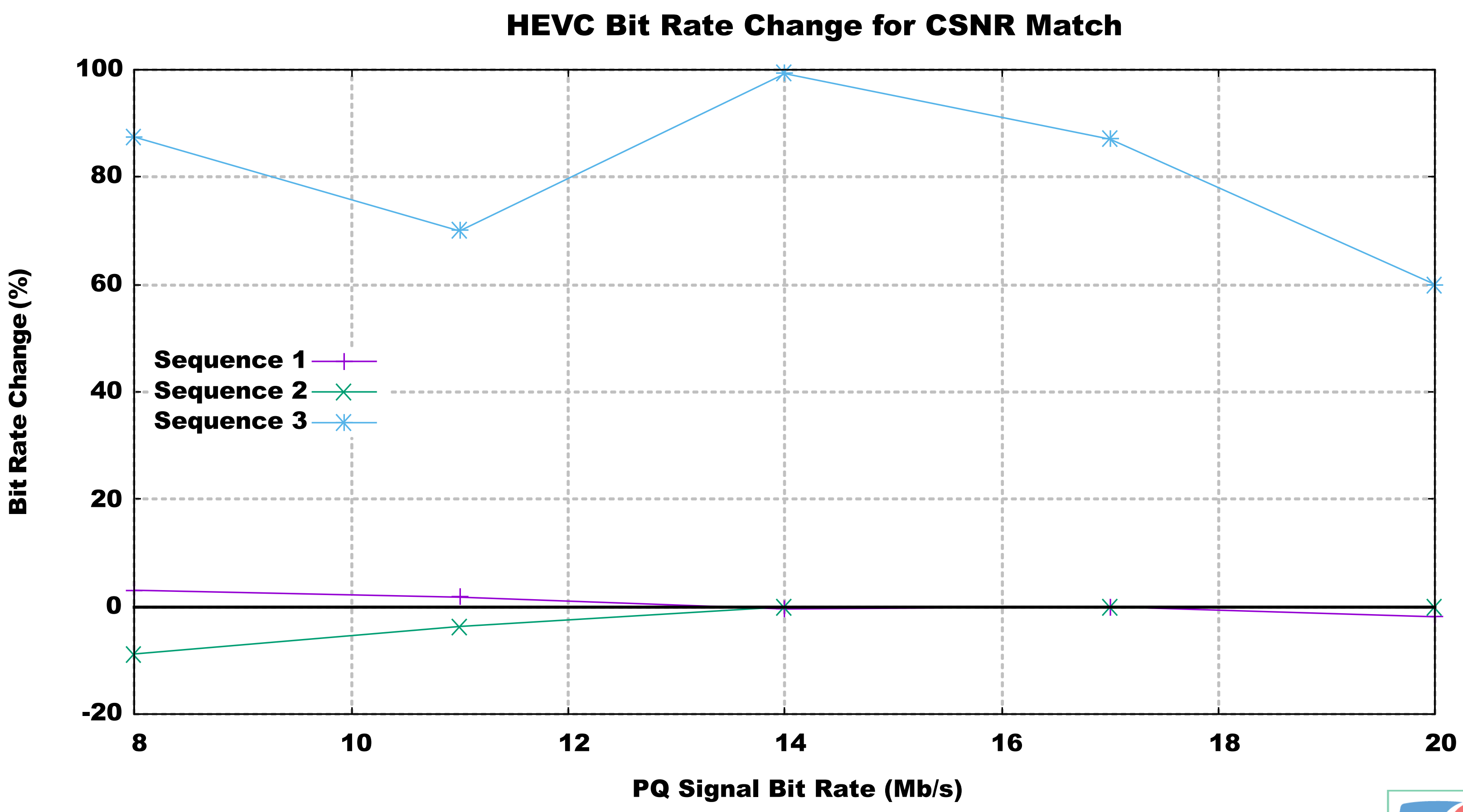
HEVC Bit Rate Change for CSNR Match
Bit Rate Change (%)
100
80
60
40
20
0
-20
8
10
12
14
16
18
20
PQ Signal Bit Rate (Mb/s)
Sequence 1
Sequence 2
Sequence 3

# A Note on Metadata Bit Rate

- The maximum size of the metadata SEI message per frame is 251 bytes.
- Based on that, an upper bound on metadata bit rate is:
  - 50 fps progressive content: 100 kb/s
  - 60 fps progressive content: 120 kb/s
- We have observed the actual rate is typically a quarter of this
- 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
  - This conclusion needs to be further validated with mainstream quality metrics
- AVC seems to be more sensitive than HEVC
- Touze and Kerkhof (2017) reported similar results with different metrics and equipment

# Q&A

- Questions?
- Thanks!

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