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SERIES J: CABLE NETWORKS AND TRANSMISSION
OF TELEVISION, SOUND PROGRAMME AND OTHER
MULTIMEDIA SIGNALS

Measurement of the quality of service - Part 3

**Hybrid-NR objective perceptual video quality
measurement for HDTV and multimedia
IP-based video services in the presence
of non-encrypted bitstream data**

Recommendation ITU-T J.343.2

ITU-T



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Hybrid-NR objective perceptual video quality measurement for HDTV and multimedia IP-based video services in the presence of non-encrypted bitstream data

Summary

Recommendation ITU-T J.343.2 provides hybrid no reference (Hybrid-NR) objective perceptual video quality measurement methods for HDTV and multimedia when non-encrypted bitstream data are available. The following are example applications that can use this Recommendation:

- potentially real-time, in-service quality monitoring at the headend;
- video television streams over cable/IPTV networks including those transmitted over the Internet using Internet protocol;
- video quality monitoring at the receiver when non-encrypted bitstream data are available;
- video quality monitoring at measurement nodes located between point of transmission and point of reception when non-encrypted bitstream data are available;
- quality measurement for monitoring of a transmission system that utilizes video compression and decompression techniques, either a single pass or a concatenation of such techniques;
- lab testing of video transmission systems.

This Recommendation includes an electronic attachment containing test vectors, including video sequences, bitstream files and predicted objective model scores.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T J.343.2	2014-11-29	9	11.1002/1000/11830-en

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Electronic attachment: Test vectors, including video sequences, bitstream files and predicted objective model scores.

Recommendation ITU-T J.343.2

Hybrid-NR objective perceptual video quality measurement for HDTV and multimedia IP-based video services in the presence of non-encrypted bitstream data

1 Scope

This Recommendation¹ describes algorithmic models for measuring the visual quality of IP-based video services.

The models are hybrid no-reference (Hybrid-NR) models, which use non-encrypted bitstream data and video image data captured at the video player.

As output the models provide an estimate of visual quality on the [1,5] mean opinion score (MOS) scale, derived from five-point absolute category rating (ACR) as in [ITU-T P.910]. The models address low-resolution (VGA/WVGA) application areas, including services such as mobile TV, as well as high-resolution (HD) application areas, including services such as IPTV.

This Recommendation is to be used with videos encoded using [ITU-T H.264] and media payload encapsulated in RTP/UDP/IP packets for the low-resolution and encapsulated in MPEG-TS/RTP/UDP/IP for the high-resolution areas.

The models in this Recommendation measure the visual effect of spatial and temporal degradations as a result of video coding, erroneous transmission or video rescaling. The models may be used for applications such as to monitor the quality of deployed networks to ensure their operational readiness or to benchmark service quality. The models in this Recommendation can also be used for lab testing of video transmission systems.

The models identified in this Recommendation have limited precision. Therefore, directly comparing model results can be misleading. The accuracy of models has to be understood and taken into account (e.g., using [ITU-T J.149]).

The validation test material consisted of video encoded using different implementations of [ITU-T H.264]. It included media transmitted over wired and wireless networks, such as WIFI and 3G mobile networks. The transmission impairments included error conditions such as dropped packets, packet delay, both from simulations and from transmission over commercially operated networks.

The following source reference channel (SRC) conditions were included in the validation test:

- 1080i 60 Hz (29.97 fps);
- 1080p (25 fps);
- 1080i 50 Hz (25 fps);
- 1080p (29.97 fps);
- SRC duration: HD: 10 s, VGA/WVGA: 10 s or 15 s (rebuffering);
- VGA at 25 and 30 fps;
- WVGA at 25 and 30 fps.

¹ This Recommendation includes an electronic attachment containing test vectors, including video sequences, bitstream files and predicted objective model scores.

The following hypothetical reference circuit (HRC) conditions were included in the validation test for each resolution:

Test factors
Video resolution: 1920 × 1080 interlaced and progressive
Video frame rates: 29.97 and 25 fps
Video bitrates: 1 to 30 Mbit/s (HD), 100 kbit/s to 3 Mbit/s (VGA/WVGA)
Temporal frame freezing (pausing with skipping) of up to 50% of video duration
Transmission errors with packet loss
Rebuffering (VGQ/WVGA only): up to 50% of SRC
Coding technologies
ITU-T H.264/AVC (MPEG-4 Part 10)
Tandem coding

1.1 Applications

The applications for the estimation model described in this Recommendation include, but are not limited to:

- potentially real-time, in-service quality monitoring at the headend;
- video television streams over cable/IPTV networks including those transmitted over the Internet using Internet protocol;
- video quality monitoring at the receiver when non-encrypted bitstream data and processed video sequence (PVS) are available;
- video quality monitoring at measurement nodes located between point of transmission and point of reception when non-encrypted bitstream data and PVS are available;
- quality measurement for monitoring of a transmission system that utilizes video compression and decompression techniques, either a single pass or a concatenation of such techniques;
- lab testing of video transmission systems.

1.2 Limitations

The video quality estimation model described in this Recommendation cannot be used to fully replace subjective testing.

When frame freezing was present, the test conditions had frame-freezing durations up to 50% of SRC duration. The models in this Recommendation were validated for measuring video quality in a rebuffering condition (i.e., video that has a steadily increasing delay or freezing without skipping) only for VGA/WVGA. The models were not tested on other frame rates than those used in TV systems (i.e., 29.97 fps and 25 fps, in interlaced or progressive mode).

If forward error correction techniques are employed, the models in this Recommendation may not be used.

It is important that no additional transmission errors occur between the collection point of the bitstream data and the capture point of the PVS.

It should be noted that in case of new coding and transmission technologies producing artifacts, which were not included in this evaluation, the objective model may produce erroneous results. Here, a subjective evaluation is required.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T H.264] Recommendation ITU-T H.264 (2014), *Advanced video coding for generic audiovisual services*.

[ITU-T J.149] Recommendation ITU-T J.149 (2004), *Method for specifying accuracy and cross-calibration of Video Quality Metrics (VQM)*.

[ITU-T J.343] Recommendation ITU-T J.343 (2014), *Hybrid perceptual bitstream models for objective video quality measurements*.

[ITU-T P.910] Recommendation ITU-T P.910 (2008), *Subjective video quality assessment methods for multimedia applications*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 hybrid no reference model [ITU-T J.343]: An objective video quality model that predicts subjective quality using the decoded video frames, packet headers, and video payload. Such models can be deployed in-service but cannot analyse encrypted video.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CODEC	Coder-Decoder
HRC	Hypothetical Reference Circuit
Hybrid-NR	Hybrid No Reference
LUT	Look-Up Table
MOS	Mean Opinion Score
MPEG	Moving Picture Experts Group
NR	No (or Zero) Reference
PES	Packetized Elementary bitStream
PVS	Processed Video Sequence
QP	Quantization Parameter
SRC	Source Reference Channel (or Circuit)
VQEG	Video Quality Experts Group
VQM	Video Quality Metrics

5 Conventions

None.

6 Performance metrics

A summary of this and other hybrid models may be found in [ITU-T J.343]. See [b-VQEG Hybrid] for a complete analysis of the models included in this Recommendation.

7 Description of the hybrid no-reference methodology

This Recommendation specifies objective video quality measurement methods that use both processed video sequences and bitstream data. The bitstream data may be provided in the forms of elementary bitstream (ES), packetized elementary bitstream (PES) or packet video (Figure 1).

Hybrid-NR models use only PVS and non-encrypted bitstream data, as shown in Figure 1 and Figure 2.

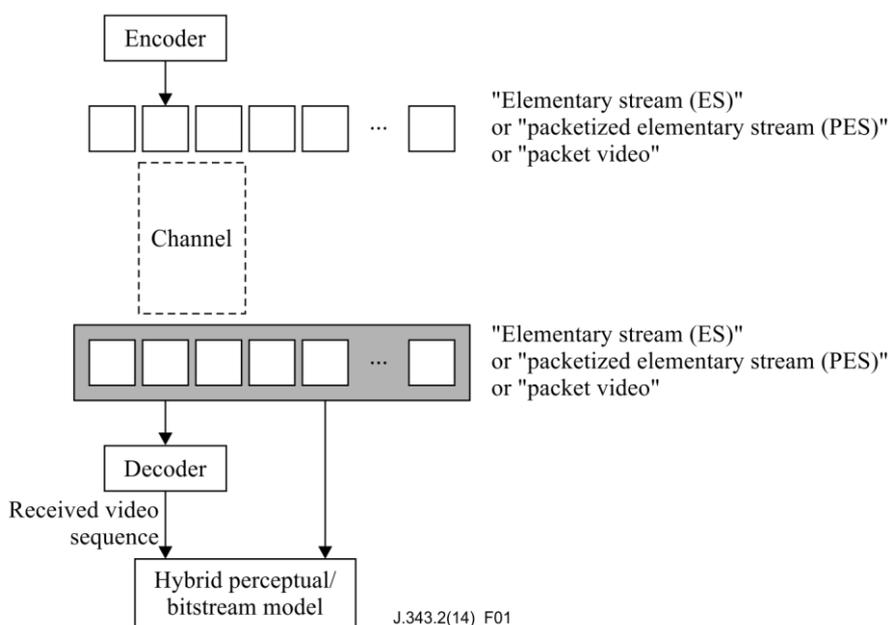
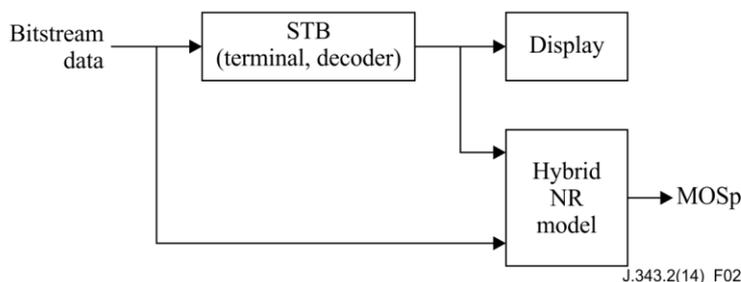


Figure 1 – Block-diagram depicts the core concept of hybrid perceptual bitstream models



MOSp: predicted MOS by the model

Figure 2 – Block-diagram of the Hybrid-NR model

8 Models

Annex A contains the full disclosure of the model included in this Recommendation. The model is YHyNR.

Annex A

YHyNR

(Hybrid-NR model)

(This annex forms an integral part of this Recommendation.)

A.1 Introduction

The YHyNR model first computes a video quality metrics (VQM) value using quantization parameter (QP) and the error area (log) using a predefined look-up table (LUT). Then, post-processing is applied to reflect various impairments due to transmission errors.

A.2 Hybrid-NR VQM computation

A.2.1 Feature computation

A.2.1.1 Quantization parameter and error area

In ITU-T H.264/AVC, the QP is an important factor for video quality. The averaged QP and I frame QP are computed as follows:

$$QP_{ave} = \frac{1}{NumFrame} \sum_{\langle VideoFrame \rangle} QP[i]$$

$$QP_{Iframe} = \frac{1}{NumIframe} \sum_{\langle I\ frame \rangle} QP[i]$$

where *NumFrame* is the total number of frames and *NumIframe* is the number of *I* frames.

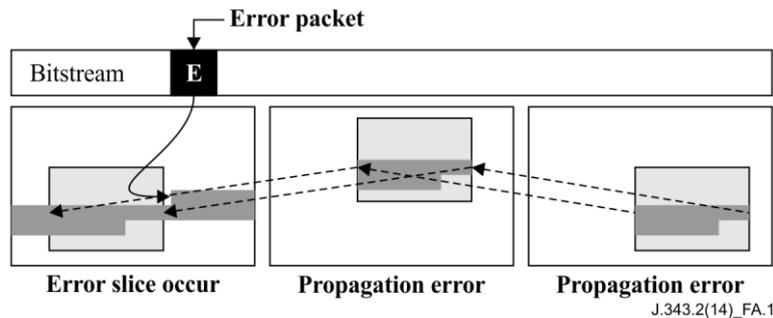


Figure A.1 – Error areas due to transmission errors

To reflect the effects of transmission errors, an error area can be calculated using an ITU-T H.264/AVC decoder (Figure A.1). The transmission error pixel may be categorized into two types. One is an error pixel due to erroneous packets and the other is the propagation of error pixels. The error pixels due to erroneous packet can be directly calculated during decoding and the propagation error pixels are calculated using the reference frame index and motion vectors. First, an error map is produced as follows:

$$ErrorMap[i, j, k] = \begin{cases} 1 & \text{if } Video[i, j, k] = Error \\ 0 & \text{otherwise} \end{cases}$$

where (i, j) is a spatial index and k is temporal index.

$$ErrorFrame[k] = \sum_{(i, j) \in frame} ErrorMap[i, j, k]$$

Then, isolated error frames are removed, which may not affect overall perceptual quality as follows:

$$ErrorFlag[k] = \begin{cases} 1 & \text{if } ErrorFrame[k] \times \left(\sum_{l=k-searchrang}^{k+searchrang} ErrorFrame[l] - ErrorFrame[k] \right) > 0 \\ 0 & \text{otherwise} \end{cases}$$

The error area is calculated as follows:

$$ErrorArea = \frac{1}{NumFrame \times NumPixelImage} \sum_{\{k|ErrorFlag[k]=1\}} ErrorFrame[k]$$

A.2.1.2 Green block feature

Some videos may contain mono-color blocks due to severe transmission errors. A feature (*Greenblk*) reflecting this impairment is computed as follows:

$$Uzero_{pixel}(i, j, k) = \begin{cases} 1 & U(i, j, k) = 0 \\ 0 & \text{otherwise} \end{cases}$$

$$Vzero_{pixel}(i, j, k) = \begin{cases} 1 & V(i, j, k) = 0 \\ 0 & \text{otherwise} \end{cases}$$

$$Uzero_{line}(j, k) = \sum_{i=1}^{width} Uzero_{pixel}(i, j, k)$$

$$Vzero_{line}(j, k) = \sum_{i=1}^{width} Vzero_{pixel}(i, j, k)$$

$$Uzero_{flag}(j, k) = \begin{cases} 1 & Uzero_{line}(j, k) > width/8 \\ 0 & \text{otherwise} \end{cases}$$

$$Vzero_{flag}(j, k) = \begin{cases} 1 & Vzero_{line}(j, k) > width/8 \\ 0 & \text{otherwise} \end{cases}$$

$$Uzero = \sum_{k=1}^{NumFrameheight} \sum_{j=1}^{width} Uzero_{flag}(j, k)$$

$$Vzero = \sum_{k=1}^{NumFrameheight} \sum_{j=1}^{width} Vzero_{flag}(j, k)$$

$$Greenblk = \frac{1}{NumFrame} (Uzero + Vzero)$$

Here, U is the u channel and V is the v channel in the yuv video format.

A.2.1.3 Freeze feature

To compute a freeze feature (FRZ_{total}), the frame difference is calculated using the luminance channel as follows:

$$FrameDiff(k) = \frac{1}{FramePixelSize} \sum_{(i,j)} |Y(i, j, k) - Y(i, j, k-1)|$$

$$FreezeFlag(k) = \begin{cases} 1 & \text{if } FrameDiff(k) < Th_{frz} \\ 0 & \text{otherwise} \end{cases}$$

$$FRZ_{total} = \sum_k FreezeFlag(k)$$

A.2.1.4 Total number of packets and number of packet loss

The total number of packets (*TotalPacket*) is computed as follows:

$$TotalPacket = \begin{cases} TS \text{ packet number} & \text{if TS protocol} \\ \frac{1}{180} RTP \text{ PayloadSize} & \text{otherwise} \end{cases}$$

The number of packet loss (*TotalPacket_{loss}*) is computed as follows:

$$TotalPacket_{Loss} = \begin{cases} TS \text{ loss packet number} & \text{if TS protocol} \\ \frac{1}{180} (RTP \text{ loss packet number} \times \text{Average RTP : packet size}) & \text{otherwise} \end{cases}$$

Then two features (X_{enc} , Y_{enc}) are computed by taking a log function as follows:

$$\begin{aligned} X_{enc} &= \log_{10}(TotalPacket) \\ Y_{enc} &= \log_{10}(TotalPacket_{LOSS} + 1) \end{aligned}$$

A.2.2 VQM computation

A.2.2.1 VQM computation using non-encrypted bitstream data and LUT

A predefined LUT is used for VQM calculation. The two-dimensional LUT has the x-axis for QP values and the y-axis for the log error area. The inputs to LUT are computed as follows:

$$\begin{aligned} X &= QP_{ave} + QP_{Iframe} \\ Y &= \log_{10}(ErrorArea + 1) \end{aligned}$$

Using an LUT, $HNR1_{enc}$ is computed as follows:

$$\begin{aligned} HNR1 &= LUT(X, Y) \\ HNR1 &= \max(HNR1, 1.0) \end{aligned}$$

The function (*LUT*) uses the bilinear interpolation. The LUT for HD and the LUT for VGA/WVGA are provided electronically in the Excel file attached to this Recommendation.

A.2.2.2 Resizing

To consider resized video, the video resolution of the bitstream data is also considered (Figure A.2). If the video is reduced before encoding, HNR_1 is adjusted as follows:

$$\begin{aligned} ImageSize &= width \times height \\ ImageSize_{Bitstream} &= width_{codec} \times height_{codec} \\ HNR_2 &= \begin{cases} b_1 \times \log_{10}(HNR_1) + 1 & \text{if } ImageSize_{Bitstream} < ImageSize \times r_1 \\ b_2 \times \log_{10}(HNR_1) + 1 & \text{else if } ImageSize_{Bitstream} < ImageSize \times r_2 \\ b_3 \times \log_{10}(HNR_1) + 1 & \text{else if } ImageSize_{Bitstream} < ImageSize \times r_3 \\ b_4 \times \log_{10}(HNR_1) + 1 & \text{else if } ImageSize_{Bitstream} < ImageSize \times r_4 \\ HNR_1 & \text{otherwise} \end{cases} \end{aligned}$$

where $(r_1 = \frac{1}{8}, r_2 = \frac{1}{4}, r_3 = \frac{4}{9}, r_4 = \frac{1}{2}, b_1 = 2.5, b_2 = 3.5, b_3 = 4.0, b_4 = 4.5)$. Figure A.3 shows the mapping function for resizing.

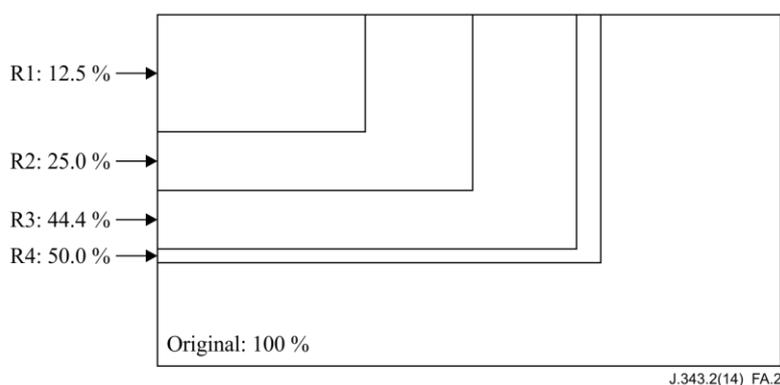


Figure A.2 – Resizing examples

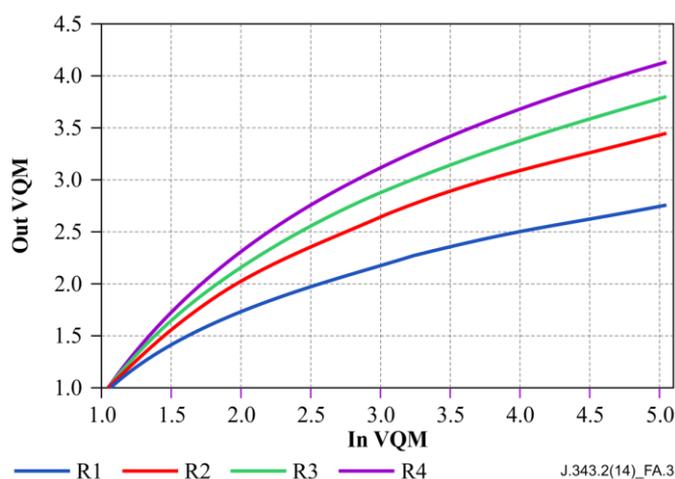


Figure A.3 – Mapping function for resizing

A.2.2.3 VQM computation using encrypted bitstream data and LUT

Using an LUT, $HNRI_{enc}$ is computed as follows:

$$HNRI_{enc} = LUT_{enc}(X_{enc}, Y_{enc})$$

The function (LUT_{enc}) uses the bilinear interpolation. The LUT for HD and the LUT for VGA/WVGA are provided electronically in the EXCEL file attached to this Recommendation.

For HD, the following adjustment is made:

$$if (Resolution = HD \text{ and } PVQM > HNRI_{enc} + 0.5 \text{ and } PVQM > 2.7)$$

$$HNRI_{enc} = \frac{1}{2} (HNRI_{enc} + PVQM)$$

A.2.3 Post-processing

A.2.3.1 Post-processing for VQM computed using non-encrypted bitstream data and LUT

The VQM value computed using non-encrypted bitstream data and LUT ($HNRI_1$) is used as input (vqm_{in}) for the post-processing in this clause.

First, the green block impairment is reflected as follows:

$$vqm_1 = \begin{cases} MIN(vqm_{in}, 1.6) & \text{if } Greenblk > 1.0 \\ MIN(vqm_{in}, 2.5) & \text{if } Greenblk > 0.0 \\ vqm_{in} & \text{otherwise} \end{cases}$$

Second, the frame rate is considered only for VGA/WVGA as follows:

$$vqm_2 = \begin{cases} MIN(vqm_1, 3.2) & \text{if } fps < 6 \\ MIN(vqm_1, 3.5) & \text{if } fps < 10 \\ vqm_1 & \text{otherwise} \end{cases}$$

Finally, the freeze impairment is reflected as follows:

$$FRZ_{temp} = \begin{cases} FRZ_{total} - \left(1 - \frac{fps}{fps_{original}}\right) \times \frac{fps_{original} \times VideoSec}{FRZ_{total}} & \text{if } Resolution = VGA \text{ or } Resolution = WVGA \\ & \text{otherwise} \end{cases}$$

$$FRZ_{log} = MIN(\log_{10}(FRZ_{temp} + 1.0), 2.3)$$

$$vqm_{out} = \begin{cases} MIN(vqm_2, 4 - \log_{10}(FRZ_{log} - 0.3) \times 3.8) & \text{if } FRZ_{log} > 1.3 \\ vqm_2 & \text{otherwise} \end{cases}$$

This final VQM value (vqm_{out}) computed using PVS and non-encrypted bitstream is a YHyNR value.

A.2.3.2 Post-processing for VQM computed using encrypted bitstream data and LUT

The VQM value computed using encrypted bitstream data and LUT ($HNRI_{end}$) is used as input (vqm_{in}) for the post-processing in this clause.

First, the green block impairment is reflected as follows:

$$vqm_1 = \begin{cases} MIN(vqm_{in}, 1.6) & \text{if } Greenblk > 1.0 \\ MIN(vqm_{in}, 2.5) & \text{if } Greenblk > 0.0 \\ vqm_{in} & \text{otherwise} \end{cases}$$

Second, the frame rate is considered for VGA/WVGA as follows:

$$vqm_2 = \begin{cases} MIN(vqm_1, 3.2) & \text{if } fps < 6 \\ MIN(vqm_1, 3.5) & \text{if } fps < 10 \\ vqm_1 & \text{otherwise} \end{cases}$$

Finally, the freeze impairment is reflected as follows:

$$FRZ_{temp} = \begin{cases} FRZ_{total} - \left(1 - \frac{fps}{fps_{original}}\right) \times \frac{fps_{original} \times VideoSec}{FRZ_{total}} & \text{if } Resolution = VGA \text{ or } Resolution = WVGA \\ & \text{otherwise} \end{cases}$$

$$FRZ_{log} = MIN(\log_{10}(FRZ_{temp} + 1.0), 2.3)$$

$$vqm_{out} = \begin{cases} MIN(vqm_2, 4 - \log_{10}(FRZ_{log} - 0.3) \times 3.8) & \text{if } FRZ_{log} > 1.3 \\ vqm_2 & \text{otherwise} \end{cases}$$

This final VQM value (vqm_{out}) computed using PVS and encrypted bitstream is a YHyNRe value.

A.2.3.3 Final VQM

For HD, the YHyNR value is outputted as a final VQM value.

For VGA/WVGA, the average of the YHyNRe and YHyNR values is outputted as a final VQM value.

Bibliography

- [b-VQEG Hybrid] Video Quality Experts Group (2014), *Hybrid Perceptual/Bitstream Validation Test Final Report*.

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