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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

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**Hybrid-RRe objective perceptual video quality  
measurement for HDTV and multimedia  
IP-based video services in the presence of a  
reduced reference signal and encrypted  
bitstream data**

Recommendation ITU-T J.343.3

ITU-T





## Recommendation ITU-T J.343.3

### Hybrid-RRe objective perceptual video quality measurement for HDTV and multimedia IP-based video services in the presence of a reduced reference signal and encrypted bitstream data

#### Summary

Recommendation ITU-T J.343.3 provides hybrid reduced-reference encrypted (Hybrid-RRe) objective perceptual video quality measurement methods for HDTV and multimedia when a reduced reference signal and 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 a reduced reference signal and encrypted bitstream data are available;
- video quality monitoring at measurement nodes located between point of transmission and point of reception when a reduced reference signal and 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*
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Electronic attachment: Test vectors, including video sequences, bitstream files and predicted objective model scores.



## **Recommendation ITU-T J.343.3**

### **Hybrid-RRe objective perceptual video quality measurement for HDTV and multimedia IP-based video services in the presence of a reduced reference signal and encrypted bitstream data**

#### **1 Scope**

This Recommendation<sup>1</sup> describes algorithmic models for measuring the visual quality of IP-based video services.

The models are hybrid reduced-reference encrypted (Hybrid-RRe) models, which use features extracted from the unimpaired reference video signal, packet header information, and video image data captured at the video player. The models operate without parsing or decoding the packet payload. Thus, these models can be used with encrypted bitstream data as well as non-encrypted bitstream data.

As output the models provide an estimate of visual quality on the [1,5] difference mean opinion score (DMOS) 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.

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: 10s, VGA/WVGA: 10 s or 15 s (rebuffering);
- VGA at 25 and 30 fps;
- WVGA at 25 and 30 fps.

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<sup>1</sup> 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:

<b>Test factors</b>
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 (VGA/WVGA only): up to 50% of SRC
<b>Coding technologies</b>
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 side-channels and encrypted bitstream data are available;
- video quality monitoring at measurement nodes located between point of transmission and point of reception when side-channels and 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.

## 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.342] Recommendation ITU-T J.342 (2011), *Objective multimedia video quality measurement of HDTV for digital cable television in the presence of a reduced reference signal*.
- [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 terms defined elsewhere:

**3.1.1 hybrid reduced reference model** [ITU-T J.343]: An objective video quality model that predicts subjective quality using the decoded video frames, packet headers, video payload and features extracted from the reference video. Such models can be deployed in-service but cannot analyse encrypted video.

**3.1.2 hybrid reduced reference encrypted model** [ITU-T J.343]: An objective video quality model that predicts subjective quality using the decoded video frames, packet headers, and features extracted from the reference video. These models can be deployed in-service and are suitable for use with 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
DMOS	Difference Mean Opinion Score
HRC	Hypothetical Reference Circuit
Hybrid-RR	Hybrid Reduced Reference
Hybrid-RRe	Hybrid Reduced Reference encrypted
LUT	Look-Up Table

MPEG	Moving Picture Experts Group
PES	Packetized Elementary bitStream
PVS	Processed Video Sequence
RR	Reduced Reference
SRC	Source Reference Channel (or Circuit)
VQEG	Video Quality Experts Group
VQM	Video Quality Metrics

## 5 Conventions

None.

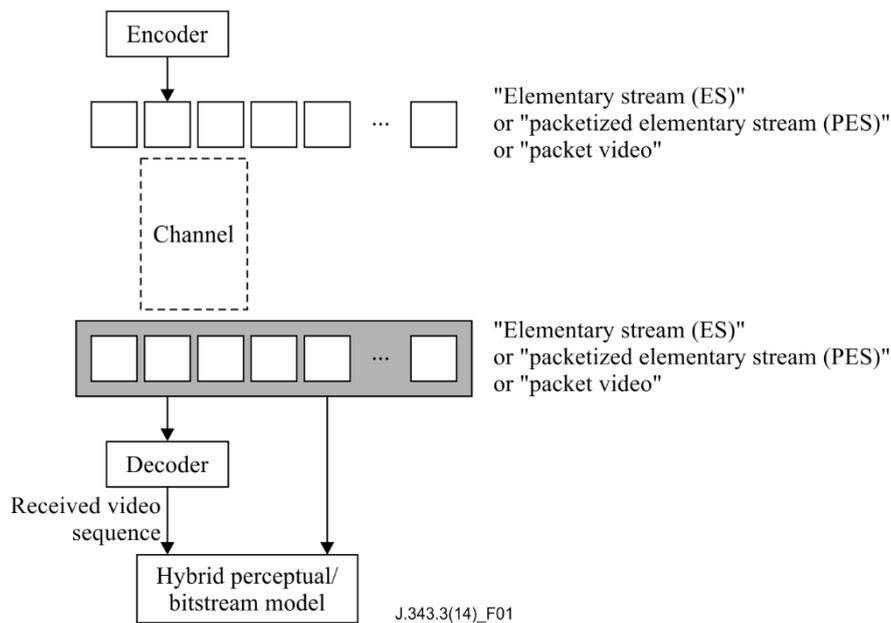
## 6 Performance metrics

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.

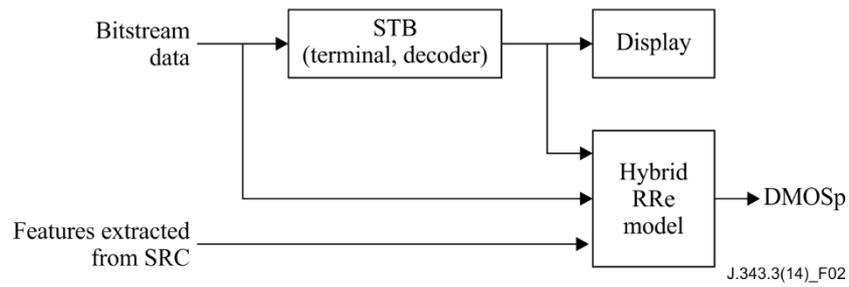
## 7 Description of the hybrid reduced-reference methodology

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).

In addition, Hybrid-RRe models also use features extracted from source video sequences. Figure 2 shows a Hybrid-RRe model. In addition to the bitstream data, the Hybrid-RRe model uses the features extracted from the SRC. Where the Hybrid-RR models have access to all of this data, the Hybrid-RRe models do not have access to the video payload. Therefore, these models can be used with encrypted bitstreams.



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



DMOSp: predicted DMOS by the model

**Figure 2 – Block-diagram depicts the Hybrid-RRe model**

## 8 Models

Annex A contains full disclosures of the model included in this Recommendation. The model is YHyRRe.

## Annex A

### YHyRRe (Hybrid-RRe model)

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

#### A.1 Introduction

The YHyRRe model first computes a video quality metrics (VQM) value using the total number of packets and number of packet loss using a predefined look-up table (LUT). Then, the EPSNR value is computed using [ITU-T J.342]. Finally, post-processing is applied to reflect various impairments due to transmission errors.

#### A.2 Hybrid-RRe VQM computation

##### A.2.1 Feature computation

##### A.2.1.1 Total number of packets and number of packet loss

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

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

The number of packet loss (*TotalPacket<sub>loss</sub>*) is computed as follows:

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

Then two features (*X<sub>enc</sub>*, *Y<sub>enc</sub>*) are computed as follows:

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

##### 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:

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

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

$$U_{zero\_line}(j, k) = \sum_{i=1}^{width} U_{zero\_pixel}(i, j, k)$$

$$V_{zero\_line}(j, k) = \sum_{i=1}^{width} V_{zero\_pixel}(i, j, k)$$

$$U_{zero\_flag}(j,k) = \begin{cases} 1 & U_{zero\_line}(j,k) > width/8 \\ 0 & otherwise \end{cases}$$

$$V_{zero\_flag}(j,k) = \begin{cases} 1 & V_{zero\_line}(j,k) > width/8 \\ 0 & otherwise \end{cases}$$

$$U_{zero} = \sum_{k=1}^{NumFrameheight} \sum_{j=1}^{width} U_{zero\_flag}(j,k)$$

$$V_{zero} = \sum_{k=1}^{NumFrameheight} \sum_{j=1}^{width} V_{zero\_flag}(j,k)$$

$$Greenblk = \frac{1}{NumFrame} (U_{zero} + V_{zero})$$

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

### A.2.1.3 Freeze features

To compute a freeze feature, the frame difference is calculated using the luminance channel:

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

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

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

$$FreezeFlag_{occur}(k) = \begin{cases} 1 & \text{if } FreezeFlag(k) = 1 \text{ and } FreezeFlag(k-1) = 0 \\ 0 & otherwise \end{cases}$$

$$FRZ_{num} = \sum_k FreezeFlag_{occur}(k)$$

The maximum freeze length " $FRZ_{max}$ " is also calculated, which is the longest freeze interval. Thus three freeze features are calculated:  $FRZ_{total}$ ,  $FRZ_{num}$ ,  $FRZ_{max}$ .

## A.2.2 VQM computation

### A.2.2.1 VQM computation using encrypted bitstream data and LUT

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

$$HNR1_{enc} = LUT_{enc}(X_{enc}, Y_{enc})$$

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.

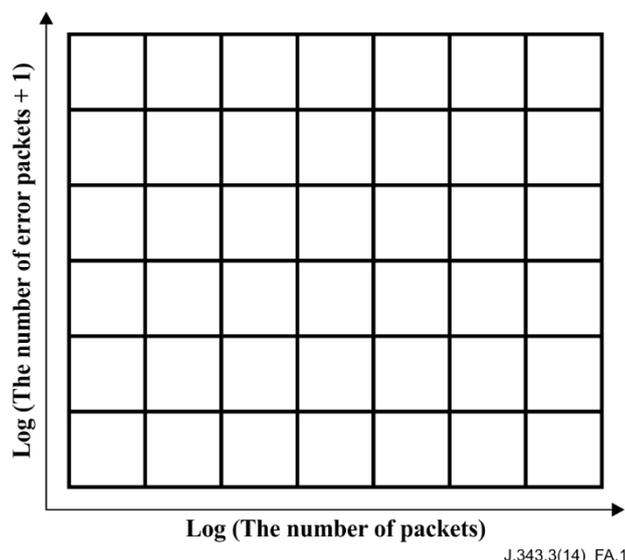


Figure A.1 – A look-up table for VQM computation

### A.2.2.2 EPSNR

The EPSRR value ( $EPSNR$ ) is computed without the post-processing using [ITU-T J.342] at the corresponding side channel bandwidth.

### A.2.3 Post-processing

#### A.2.3.1 Post-processing for the VQM value computed using encrypted bitstream data

The VQM value computed using encrypted bitstream data and LUT ( $HNRI_{enc}$ ) 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:

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

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

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

### A.2.3.2 Post-processing for the EPSNR value

The EPSNR value ( $EPSNR$ ) is used as input ( $vqm_{in}$ ) for the post-processing in this clause.

First, upper and lower bounds are applied with scaling as follows:

$$vqm_1 = \begin{cases} 1.4 & \text{if } vqm_{in} < 23 \\ 4.4 & \text{if } vqm_{in} > 42 \\ \frac{3}{19}(vqm_{in} - 23) + 1.4 & \text{otherwise} \end{cases}$$

Second, the error rate is considered as follows:

$$ErrorRate = \frac{TotalPacket_{Loss}}{TotalPacket + TotalPacket_{Loss}}$$

$$vqm_2 = \begin{cases} vqm_1 - 1 & \text{if } ErrorRate > 0.01 \\ vqm_1 & \text{otherwise} \end{cases}$$

Third, the error area is considered as follows:

$$vqm_3 = \begin{cases} MIN(vqm_2, 1.5) & \text{if } ErrorArea > 20 \\ MIN(vqm_2, 2.0) & \text{if } ErrorArea > 10 \\ MIN(vqm_2, 3.0) & \text{if } ErrorArea > 5 \\ vqm_2 & \text{otherwise} \end{cases}$$

Finally, the number of freeze, maximum freeze length and the total freeze are considered as follows:

$$vqm_4 = \begin{cases} MIN(vqm_3, 2.2) & \text{if } FRZ_{max} > 100 \\ MIN(vqm_3, 2.5) & \text{if } FRZ_{max} > 50 \\ vqm_3 & \text{otherwise} \end{cases}$$

$$vqm_5 = \begin{cases} MIN(vqm_4, 2.5) & \text{if } FRZ_{total} > 100 \\ MIN(vqm_4, 3.0) & \text{if } FRZ_{total} > 60 \\ vqm_4 & \text{otherwise} \end{cases}$$

$$EPSNR_{out} = \begin{cases} MIN(vqm_5, 2.5) & \text{if } FRZ_{num} > 12 \\ vqm_5 & \text{otherwise} \end{cases}$$

### A.2.3.3 Final VQM

The final VQM is computed by averaging the EPSFR value ( $EPSNR_{out}$ ) and  $vqm_{out}$  as follows:

$$VQM_{final} = \frac{1}{2}(EPSNR_{out} + vqm_{out}).$$

## Bibliography

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



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