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Case Study: Real-Time Video Quality Monitoring Explored

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In modern, digital broadcast environments, the number of video signals is growing dramatically. The video signal is compressed for transmission, and then routed in many different ways as it makes its way to the end user. Maintaining video quality throughout the transmission path depends on the content and path. Hence the distribution and quality control managers must be able to view, control, and monitor many video signals at the same time. To automate the process Video Clarity created RTM – Real Time Quality Monitoring – to measure the degree of quality degradation by comparing the pre- and post- transmitted signals. It has many user configurable alarms and logs anomalies for later analysis.

Before getting into the RTM case study, we need to define a few terms used throughout this document.

General Video Quality

We are using video quality to define 3 components:

- Picture Quality – an index of eyes ability to understand the picture
- Audio Quality – an index of the ears ability to discern the audio
- Lip Sync – a measurement of the audio to video synchronization

We are also going to define 2 terms:

- Metric – an algorithm that quantifies differences
- Index – an algorithm that measures quality using the Human Visual or Audio System (HVS/HAS).

Types of Errors

For this paper, we assume that video quality testing tools, like the ClearView Analysis System, were used to set the processing (compression) units to their optimal levels. Using tools like the above are helpful in determining the desired video quality thresholds.

Two types of problems can arise with digital television:

- The digital transmission path can fall below acceptable levels and cause a data loss. The effect of the data loss is dependent on the data lost.
- The incoming signal can be malformed – too much simultaneous horizontal and vertical movement – which will cause the processing unit to fail

To understand the errors, we must understand digital transmission and compression in general terms. Digital transforms the analog signal into a series of '1' and '0' and transmits those digital bits over a network. As long as the digital signal makes it from point-to-point, the transmission will be perfect.

To protect the digital integrity various schemes are used:

- forward error correction (FEC) – additional bits are sent so that the receiver can detect and correct for errors (within bounds)
- set-top-box (STB) error concealment – when the receiving box finds a transmission error that is not correctable, it holds the last known good video and attempts to re-sync with the inputted signal

Unfortunately, digital takes up more bandwidth when compared to analog so compression schemes are used to manage the size of the digital signal. Many video CODECs use a Group of Pictures (GoP) frame structure, which consists of independently coded reference frames ("I" frames), motion changes from the last reference frame ("P" frames) and motion changes from the last or next "I" or "P" frame ("B" frames).

If the transmission error results in the loss of a frame, then the type of frame lost determines the duration of the loss:

- A loss of an “I” frame causes all frames until the next “I” frame to be lost
- A loss of a “P” frame affects the quality of all frame from this “P” to the next “I” frame
- A loss of a “B” frame affects only this “B” frame

Due to error concealment techniques during decoding, transmission errors usually affect only a portion of the video as shown below. These concealed errors stay in place until the next time that this portion of the video is updated – either the next “I” frame or if the motion changed in this area of a “P”. An example of a transmission error is shown below. The original is on the left.

Figure 1: Transmission Error with Concealment on the Right

If the video signals require a re-compression or rate-shape to fit into the available bandwidth for transmission, the compression could be too high. In this case, the video can become blurry or blocky. An example of a blocking error is shown below. The original is on the left.

Figure 2: Blocking Error – Too High a Compression on the Right

Video is not the only place where compression, digitization takes place. Most audio CODECs detect high frequency components and encode these with very few bits because the human ear can only hear loud high frequencies. Some algorithms reduce the dynamic range to reduce the amount of data. If a transmission error occurs, the audio will pop or go silent. If the compression is too extreme, the audio will lack depth – i.e. sound tinny or hollow.

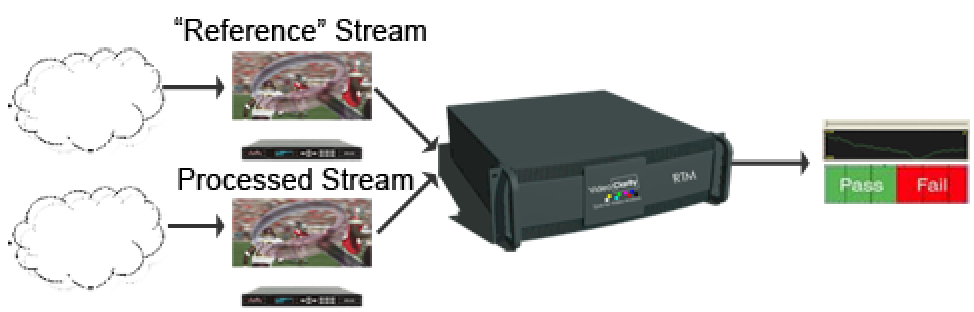
Real-Time Quality Monitoring

As the engineering, operations, or quality manager have you ever been woken up and asked why your signal is off air or recompressed beyond recognition? As a manufacturer have you been told that your equipment fails after 48 hours of continuous use? If you answered yes, you understand the need to continuously monitor your video quality.

To this end, Video Clarity created RTM – Real Time Quality Monitoring – to measure the degree of quality degradation by comparing the pre- and post- transmitted signals. A 3RU system, which reads 2 incoming HD video signals, checks for the presence of a signal, aligns the signals in space and time, and continuously applies quantitative metrics to the Audio and Video. It graphs the incoming signal and metric results while logging the quality scores and alerting on configurable events.

Figure 3: RTM – Monitoring Broadcast OTA compared to Retransmitted Received Signal

Figure 4: RTM - Manufacturing Testing

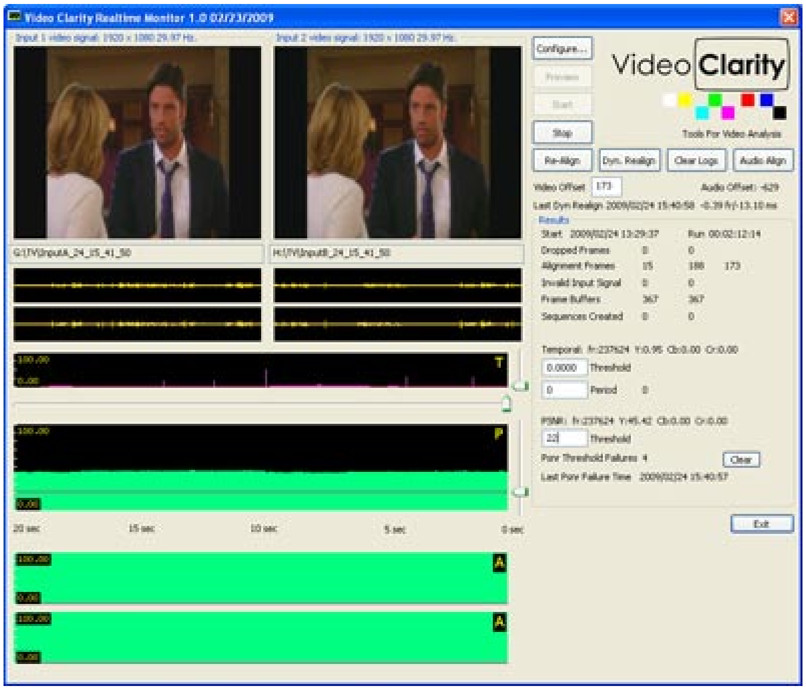


Simply stated RTM performs the following steps

- Reads two Audio and Video signals and Automatically Aligns them
- Continuously Monitors for Loss of Audio and/or Video
- Measures LipSync and Calculates Transmission Delays
- Quantitatively Measures Audio/Video Quality Generating Pass/Fail
- Continuously Logs the Quality Score
- Saves A/V Sequences upon Failures for Additional Analysis & Archival

The system can be controlled through a series of commands sent over an Ethernet socket or via its GUI. In GUI mode, the results are graphed and the logged events are displayed in real-time.

Figure 5: RTM – Graphical User Interface (GUI)

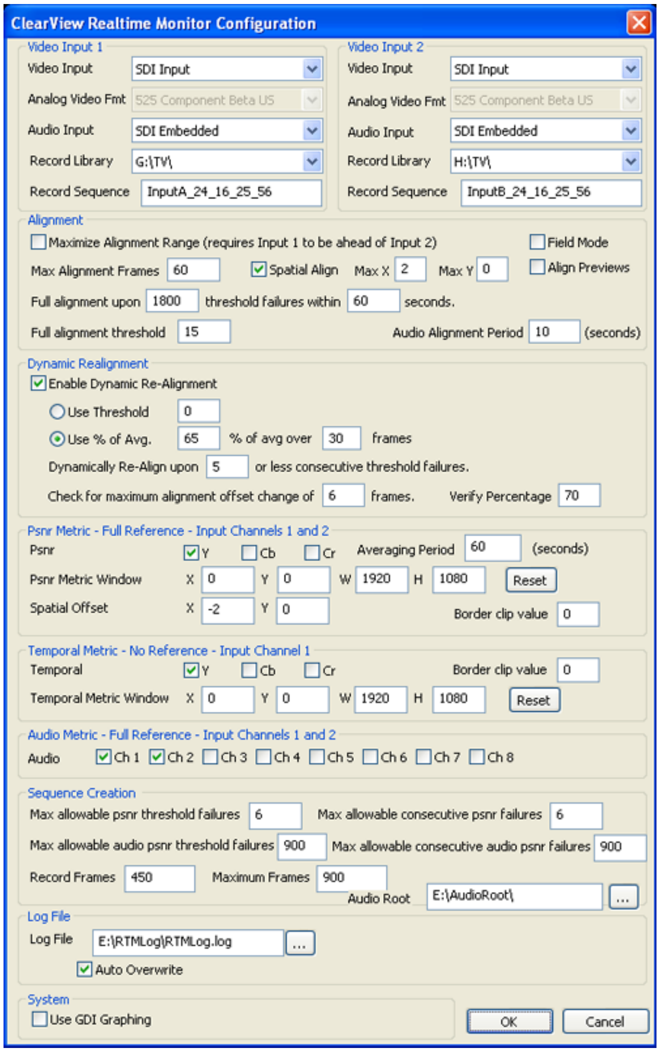


Regardless of the interface the logged events include

- Loss of Audio and/or Video on the input (“Reference” or “Broadcast” above)
- The Offset between Audio and Video (Lip Sync checker)
- The Delay between the two Videos (transmission and/or processing delay)
- Quantitative Quality Metric Score
- Degraded Audio and Video Quality below a pre-set limit
- Number of times that the system had to re-align based on frame(s) loss

The events are configurable such that a degraded signal below the pre-set limit may be set to trigger only if it occurred for X frames out of Y. Events are logged with the corresponding time code, and the failed signals – before and after the error - are saved for further analysis.

Figure 6: RTM - Configuration



The bit streams are easily imported into the ClearView Video Analysis systems, which includes Objective, Perceptual, and Subjective testing tools.

ClearView Solution

ClearView Video Analysis generates test signals, captures live inputs, and inputs compressed or uncompressed files. It then aligns the audio and video and reports lip-sync issues. It calculates the DMOS, JND, and/or PSNR scores. It uses the Sarnoff algorithm ported to JND (using the VQEG database) and the MS-SSIM algorithm ported to DMOS (using the University of Texas database). It also lets you view the "reference" and "processed" signals side-by-side or their difference maps for your own subjective evaluation.

Our Objective, Perceptual and Subjective tools are further discussed on our website at www.videoclarity.com/WhitePapers.html.

The Author

Bill Reckwerdt has been involved in digital video since the early 90's from digital compression, video on demand, to streaming servers. He received his MS specializing in Behavioral Modeling and Design Automation from the University of Illinois Urbana-Champaign.

He is currently the VP of Marketing and the CTO for Video Clarity, which makes quantitative, repeatable video quality testing tools. For more information about Video Clarity, please visit their website at www.videoclarity.com.