

# Subjective Quality Monitoring

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## ABSTRACT

The migration to digital broadcast is changing the way engineers view the broadcast process, at times in perhaps unexpected ways. The once-routine process of broadcast quality control has become cumbersome and unreliable, with vendors attempting to shoe-horn Rube Golbergesque offerings to the industry. The time for responsiveness to the market demands of the production and broadcast industries has come, and engineers may look forward to their voice being heard more clearly in the short term.

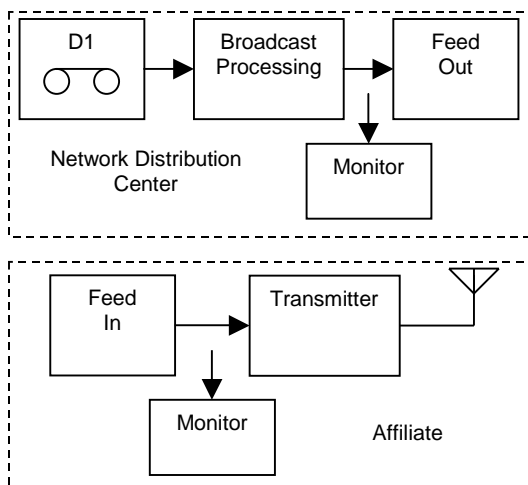


Fig 1. Monitoring takes place in the distribution center after pre-processing for transmission, and at the affiliate after receipt of transmission.

## BACKGROUND

More and more frequently, video is becoming embodied in digital representations. Work flow within the post-production or broadcast studio is becoming digital-to-digital, particularly with the motion of the broadcast industry towards digital-only transmission.

Revolutionary changes in workflow have come with the de-emphasis of analog broadcasting

techniques. Perhaps the most far-reaching changes are brought about with the introduction of digital compression as a standard part of the video distribution stream.

In the post-production house, a major new book of business has developed - the compression of video content onto DVDs. This requires aggressive compression using parameters compatible with widely available home DVD players. It is the post-production engineer's responsibility to minimize compression artifacts in the finished product. A tool to measure the subjective effect of the error introduced in the compression process would relieve the engineer from responsibility for visually verifying the output quality.

In the case of distribution of video from a broadcast network distribution center to its affiliates, analog quality failure may occur either within the central location or during the transmission process. Typically, broadcast quality is affected by the reliability of the transmission (multipath, signal strength, etc.) The affiliate monitors received quality, and uses this measure to guarantee the quality of its broadcasts (figure 1.)

With the switch to digital transmission, new error sources may be introduced during the compression process, but delivery errors are eliminated from the transmission path through the use of digital error correction. This reversal of conventional wisdom overturns a mind-set deeply ingrained in the broadcast culture, but should be embraced as it is based on important principals of digital broadcast.

Processing at the network includes digital video compression in preparation for digital transmission. Digital video compression is a technique in which lower transmission bit rates are achieved at the expense of perceived video quality. This makes error monitoring at the head end a critical broadcast function (figure 2.)

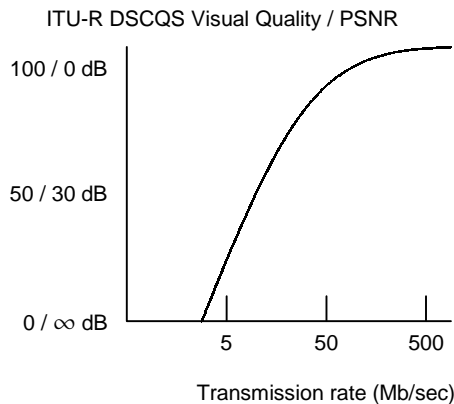


Fig 2. The compression process trades increased noise for lower transmission rates.

Conversely, digital transmissions are coded in such a way as to negate the effects of noise on the carried stream. This is accomplished through the process of forward error correction, which incorporates enough redundant information to detect and correct errors in the transmission. The primary function of affiliate monitoring becomes reporting the rate at which this forward error correction takes place in order to warn of impending transmission line failures.

The nature of error introduced by digital compression techniques differs from what would be expected based on the hard-earned intuition deriving from analog broadcast experience. Modern digital compression techniques define rate-reduction techniques based upon principles of human vision. Ideally only information which is not visible to the human eye is removed from the video stream. Peak Signal to Noise Ratio (PSNR) or Mean Square Error (MSE) metrics do not account for human perception, and are unreliable measures of the subjective quality of the processed content.

Furthermore, while acceptance of the resulting quality is the responsibility of the affiliate, the actual compression process must take place at the broadcast station, prior to transmission. It is both the novel nature of the error introduced by the compression process and the removal of the error-introducing broadcast processing stage from the network distribution center to the affiliate that have reshaped the test environment in the digital environment.

## SINGLE-ENDED QUALITY MONITORING

It may seem that single-ended quality monitoring is the solution to remote compression quality monitoring (figure 3.) This solution places compression artifact detection at the signal source, where final say over delivered quality resides.

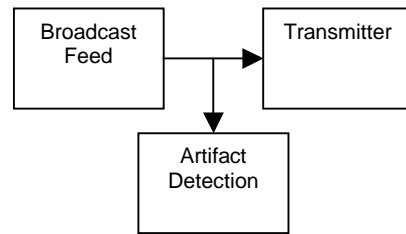


Fig 3. Single-ended quality monitoring at the signal source.

However, this technique is based upon a heuristic definition of "compression error." The monitor scans the video stream searching for common compression artifacts - blocking artifacts, duplicate frames, and Gaussian noise. Difficulties arise when the source material contains effects resembling compression artifacts, when compression quality drops below an acceptable level without showing the specific anticipated artifacts, or when the compression algorithm used does not match that for which the heuristic formulae have been determined. The net result is excessive false alarms and an inability to guarantee error detection. The primary motivation for use of this technique seems to be placing control in the affiliate office, where it arguably belongs.

## DOUBLE-ENDED QUALITY MONITORING

A far more sophisticated technique is double-ended quality monitoring, where compression errors are measured at the distribution center (figure 4.) Direct comparison of the processed and unprocessed inputs allows more sophisticated measures to be put in place, ranging from PSNR or MSE to weighted measures incorporating human vision modeling.

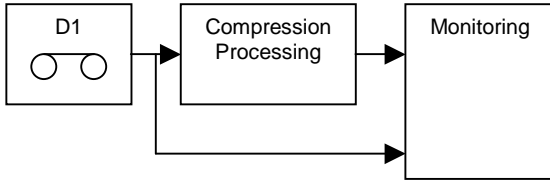


Fig 4. Double-ended quality monitoring is performed at the Broadcast Center, and compares compressed and unprocessed content.

The double-ended quality monitor must synchronize the processed and unprocessed inputs, and then compare their content using some weighting function. PSNR and MSE poorly correlate to the visual effect of introduced error, and are not very good measures of subjective quality. Three bodies of theory resulting in measuring techniques address this issue; Sarnoff Labs' JNDmetrix™, NASA's DVQ, and Futureware's Visibel™. Sarnoff Labs' JNDmetrix is an approach based on subband decomposition, and was greatly improved upon by NASA's DVQ, which implements a 2-D DCT measurement followed by a time-based subband decomposition. Futureware's Visibel™ technique relies upon three-dimensional transform-based decorrelation, and catches all visible errors regardless of their source or the choice of compression technique.

Generally speaking, double-ended quality monitoring produces more reliable indications of subjective quality, but effectively removes the affiliate from the monitoring process.

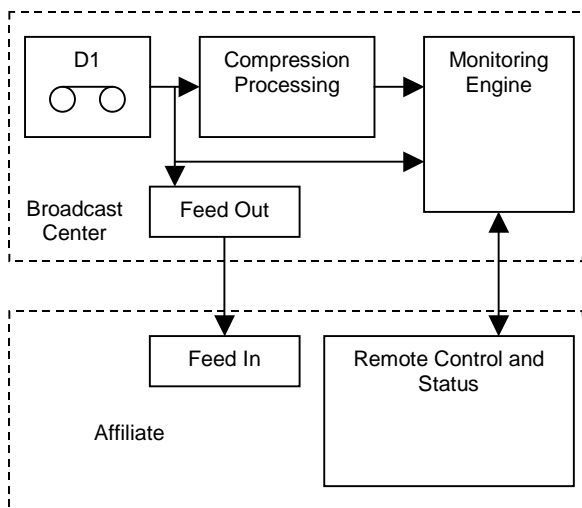


Fig 5. Remote monitoring and control gives the affiliate high-confidence subjective quality measures and allows remote quality control.

## REMOTE DOUBLE-ENDED QUALITY MONITORING

By remote monitoring of the double-ended solution, the combination of reliable subjective monitoring, affiliate control, and ease of use are obtained. Here the quality monitor is placed in the broadcast center, but operated remotely from the affiliate (figure 5.) This technique obviates the false negative problem, giving the affiliate confidence in the subjective quality of its received video stream.

Feedback from the remote monitor may be communicated to the affiliate or the broadcast center. Warnings communicated to the affiliate can be used to report quality failures, but cannot be used for corrective purposes. Warnings communicated to the broadcast center could be interpreted by an engineer and used to adjust compression engine settings as needed.

For the purposes of remote monitoring, simple error reporting may not be sufficient. If closer control is desired, an animated segment of badly distorted frames may be delivered to the remote sensor for display and analysis.

## MEASUREMENT INTERPRETATION

Another of the features distinguishing the various subjective measures is the expressive nature of the measure itself. The ITU defines a Single Stimulus Continuous Quality Scale (SSCQS) and a Double Stimulus Continuous Quality Scale (DSCQS), which describe picture quality in dimensionless units from 0 to 100. Sarnoff Lab's JNDmetrix is not only the least reliable of the human visual system-based measures, but it is undefined for quality levels below the first Just Noticeable Difference (JND.)

The Visibel, by contrast, is scaled to convey information to engineers in a meaningful and practical way. The Visibel is defined by direct analog to the Decibel, and is scaled so that, under defined viewing parameters, errors that are at the limit of visibility to the human eye are defined as 0 vB. Relative visibility above and below this threshold is defined in a sensible way. Error that would be indiscernible at double the standard viewing distance is defined as 6 vB; while error which would be imperceptible at one-half the distance is defined as -6 vB.

## POST-PRODUCTION

In the post-production studio, visual quality is often monitored by video engineers working late-night shifts, blearily studying the same video sequence perhaps dozens of times. Introduction of reliable subjective quality monitoring will relieve the engineer of much of the monotony of this job, improve productivity, and give the customer an absolute measure of the subjective quality of the final product.

Perhaps the most difficult quality problem in the post-production studio is the compression of video for consumer consumption, i.e., DVD authoring. Introduction of a uniform subjective quality scale introduces the possibility of integrating a compression engine with a quality monitor to dynamically adjust the compression parameters to guarantee a particular compression ratio with minimum visual degradation and without human intervention (figure 6.)

## SURVEY OF PRODUCT EMBODIMENTS

The players in this field include Pixelmetrix, Rohde & Schwartz, Snell & Wilcox, Tektronics and Futureware (table 1.)

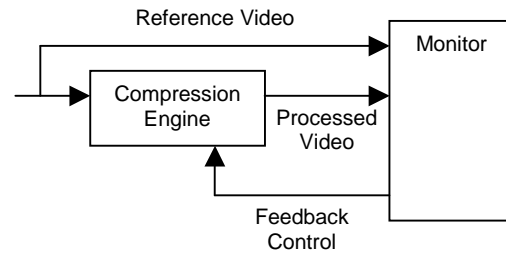


Fig 6. Visibel-driven MPEG compression gives optimal compression rates without human intervention.

## CONCLUSION

Futureware has developed a product line whose feature set shows great innovation and unrivalled convenience of use. Engineers can now count on reliable reporting of error conditions without the inconvenience of false alarms. Monitoring responsibility may be taken by an affiliate with a practical and easy to use remote interface. Metrics are calibrated in units compatible with the industry-standard dimensionless unit, the decibel, presenting error measures in an intuitive format. Finally, compression and subjective error measurement are integrated into a single unit, fine-tuning the process of high-quality compression.

Manufacturer	Product	Technology	Reliability	Remote Sensing / Compression	Availability
Pixelmetrix	DVStation	Single-Ended	many false reports	no / no	now
Rohde & Schwartz	DVQ	Double-Ended (optional Single-Ended mode)	good, but requires alignment	yes / external	now
Snell & Wilcox	MVA200	Single-Ended	many false	no / no	now
Tektronics	PQM300	Single-Ended	many false	no / no	withdrawn
Tektronics	PQA200	Double-Ended	good	no / no	now
Futureware	vB100	Double-Ended Remote	best	yes / no	in production
Futureware	vB100 MPEG2 option	Double-Ended Remote, MPEG-2 compression	best	yes / yes	in production

Table 1. A summary of competing products in the picture quality measurement space.

