DEVELOPING A GRADING SYSTEM FOR DIGITAL VIDEO QUALITY

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Abstract

This paper describes an "End to End" measurement and analysis philosophy for transport of digital video signals from a centralized distribution point to the consumer. A key component of the effort has been to develop specific and repeatable metrics that describe both the integrity of the signal delivery, as well as its relative subjective quality.

Given that there are a number of approaches and technologies used to deliver linear video content to households, this paper examines the use of multiple transport options commonly deployed in the marketplace today and how metrics can be created to measure the efficacy of the end product as delivered to the consumer. Specifically, the delivery plant considered is based on MPEG 2 transport to the consumer, however the model can easily be conformed to support an MPEG 4 approach.

Central to the measurement efforts employed is the adoption of common terminology to describe known digital video impairments. Further, the ability to describe these impairments in a manner that can be easily understood, communicated, and taught is a key outcome of the effort.

EXECUTIVE SUMMARY

As multichannel video providers achieve parity in the quantity and subscriptions fees for popular television channels and programming, the quality of service (QoS) associated with the delivery platform has become a key differentiator that can significantly impact the successful acquisition of new customers as well as dramatically influence whether a customer is retained. In fact, HDTV can be seen as a clearly defined competitive battleground based almost entirely on the proposition that the recovered video "Quality" must exceed a consumer's current service. According to recent industry studies, quality issues are responsible for 40% or more of all customer churn, second only to cost.[i] In addition, industry analysts have observed that cable system operators risk losing the entire RGU (revenue generating unit) when bundled customers move to an alternative multichannel video programming provider (MVPD).[ii]

With so much at stake, cable system operators must actively participate in the video content delivery chain which includes the creation, management and distribution of HD content. This paper identifies as many as eight critical touch-points in the content distribution process that can directly impact video quality performance and affect the customers' perception of quality and satisfaction with their video services provider. In addition, it is based on the end-user HD experience to provide a more accurate depiction of the impact on quality perception from multiple factors including advanced compression techniques, the nature of source content acquisition, and satellite vs. fiber transport delivery.

While most cable operators focus their quality monitoring efforts from the output of their headend to the consumer set top, achieving optimal and competitive quality assurance requires establishing and applying a consistent system for measuring the quality of digital video and audio from the source to the display device. To achieve this objective, the use of a repeatable grading system that summarizes both the characteristics typically noted by expert or "Golden Eye" viewers as well as impairments the average consumer objects to is key. The challenges associated with creating such a program include the lack of industry accepted standards and practices or inconsistent application of complex technical concepts in an operational environment.

Implementing an end-to-end system for quality assessment requires tools such as probes for measuring the quality and reliability of HD content at each touch-point. In addition to monitoring the probes and applying the grading system to anomalies that are detected and measured, data will need to be exchanged between television programming networks, cable system operators, and others involved in the origination and distribution of HD content in order to address and correct reported shortcomings.

This paper also includes a summary of a grading system that is being used today and examples of the ways that the system is helping to minimize impairments and improve the HD customer's experience. It will conclude with recommendations for steps that the industry can take in order to facilitate the implementation of a quality grading system, such as greater automation of the quality assessment process, additional independent research, and consumer education.

BENEFITS

A recent MRG research report found that 90 percent of cable operators consider video quality monitoring was either "crucial" or "very important", and 58 percent viewed end-user quality of experience (QoE) as critical and needing to be maintained.[iii] Cable operators indicated that service quality issues are one of the main reasons for customer support calls, resulting in a significant reason for customer churn – as much as 40%. With millions of customers across the country, end-user video quality monitoring is an integral part of a cable operator's business," according to the report.

Extrapolating from the report's findings, the level of churn attributed to QoS represents millions of digital video customers, hundreds of millions in annual revenue, and billions in asset value. Given the importance associated with customer retention, several system operators are launching significant efforts to focus on QoS. MRG's analysis found that some cable MSOs are spending as much as $2 – 5 per subscriber per year for QoS.

"With competitive pressures increasing, cable operators need a comprehensive video monitoring solution to ensure they meet customer expectations, or face possible increases in churn and operational costs," the study concluded.

Developing an accepted and customer-driven quality grading system will enable cable system operators to address misperceptions that hinder the use of advanced compression techniques, such as HD3:1 using MPEG-2. If left to applying only the simple math behind 3:1, or the greater compression offered by MPEG-4, potential HD customers would assume that the quality of HD signals cannot be as good as an HD signal using compression levels of 2:1 or lower. However, consumer research conducted by the CMC (Comcast Media Center) and others has demonstrated that by using best case practices for digital video encoding, stat-muxing, and transport, HD3:1 is highly competitive with MPEG-4 via DBS or HD2:1.

This research has helped to demonstrate that HD3:1 can allow cable operators to launch more HD content using less bandwidth and without sacrificing the customer QoE. It also underscores that there is a tremendous opportunity - and need - for consumer education concerning all of the factors that affect their viewing experience.

INTRODUCTION

Existing industry standards describe video quality comparison of the video measured at any point along the delivery path to a source reference; a referenced video quality measurement which determines how much a system or process has degraded a given video service. However, they do not address a significant issue which is the true quality of the video as measured at all critical touch points in the delivery path as well as at the consumer display. Regardless of the Herculean efforts to improve the video source and delivery systems, the quality of the video delivered to the cable subscriber can be no better than the worse case video quality at any touch point.

Source providers, equipment manufacturers, and MSOs have made tremendous improvements to their video transport and delivery systems. The challenge is to find further significant video quality improvements to the end video product as delivered to the cable consumer. Given that technical advances have allowed for greater density of channels in a multiplex while achieving approximate parity with earlier efforts has resulted in a tangible increase in plant capacity. The balance associated with “Quality vs Quantity” continues to be a complex and challenging equation to solve. That said, the improvements associated with upgrading one area of the Content Distribution Chain can be marginalized by other impact points and in some cases made worse. Cumulative degradation, which occurs as a video service is created or acquired, processed or re-encoded, delivered through various networks, groomers, commercial ad insertion equipment, and finally to the customer’s set tops, is an emerging area of opportunity to improve.

Prior to digital video, the quality of video delivery systems was measured using vertical interval test signals (VITS), Vertical Interval Reference Signals (VIRS), and performance metrics outlined in documents such as ANSI/EIA/TIA-250-C. Operations engineers could use these test signals at numerous points in the distribution chain without impact to the service to perform measurement of the quality of the delivery of analog video. Today, transmission operations engineers are more likely to use MPEG analyzers to determine the quality of the delivery path. Typically these analyzers are used to measure known impairments as part of ETSI TR 101-290 compliance such as continuity counter errors, missing PIDs and Jitter performance. While this approach is effective for measuring transport stream errors such as packet loss, MPEG analyzers do not provide any ability to measure customer perceived video quality particularly as it relates to subjective components (i.e. sharpness, noise, macro-blocking, etc.)

Further, the consumer marketplace has overwhelmingly adopted larger display screens that provide enhanced noise reduction, filtering, improved contrast ratios, and materially greater resolution which result in the ability to see enhanced details in all video content. Unfortunately this ability also facilitates more critical viewing of digital impairments or “artifacts” inherent to digital video compression and transmission. The obvious result is that these impairments whether they are associated with HDTV or SDTV, are becoming much more evident to customers and there is considerable mis-information present in the marketplace. One example is channels branded as "HD" which show a majority of their content as standard definition 480i video "upconverted" to HD. Another example is larger consumer displays which are often broadly lumped together and referred to as "HD Displays" while the viewing characteristics between the different types can be dramatically different, particularly under varying lighting and "off-axis" viewing conditions.

The confusion in the consumer marketplace is understandable, given the complexity of the topic in general, as well as the technical appreciation required to acknowledge all of the possible reasons behind a given video quality impairment. Differences in the video quality displayed by various brands and types of monitors and increasingly rapid video monitor response rates add to the confusion. While video engineers evaluate video quality using defined parameters such as viewing angles and distance from the monitors, there are differences in ambient conditions of monitor locations consumers likely do not appreciate.

VIDEO QUALITY TOUCH-POINTS

The examples of video quality measurement provided in this paper are based upon analysis that is being conducted by the Quality Assurance team for the CMC, which is currently placing nearly 2Gbps of MPEG2 video onto the an IP network for delivery to cable markets. Drawing 1 is a simplified view showing a typical service path of an HD signal broadcast out to cable subscribers.

As an example, assume that there is a sporting event being produced at the *Venue* which needs to be transported back to the studio where an on-air announcer is providing commentary. The transport path, whether satellite or fiber, is very likely being compressed, particularly if the feed is native HD. This initial compression causes digital impairments that will never completely be removed from the "video" and as you will see, can become materially worse as they travel thru the distribution chain to the consumer.

The studio camera is likely the very best source of video quality we will consider here as the conditions are controlled, the lighting is optimal, and there is very little opportunity to induce impairments beyond those introduced by the camera optics. Typically, material is mixed between the *Venue*, the camera, and server playback of pre-recorded media in *Master Control.* Given the cost associated with media storage, particularly HD native content, *Video Servers* will ingest content utilizing compression and induce another set of impairments. Again, the deeper the compression the more likely video impairments will result.

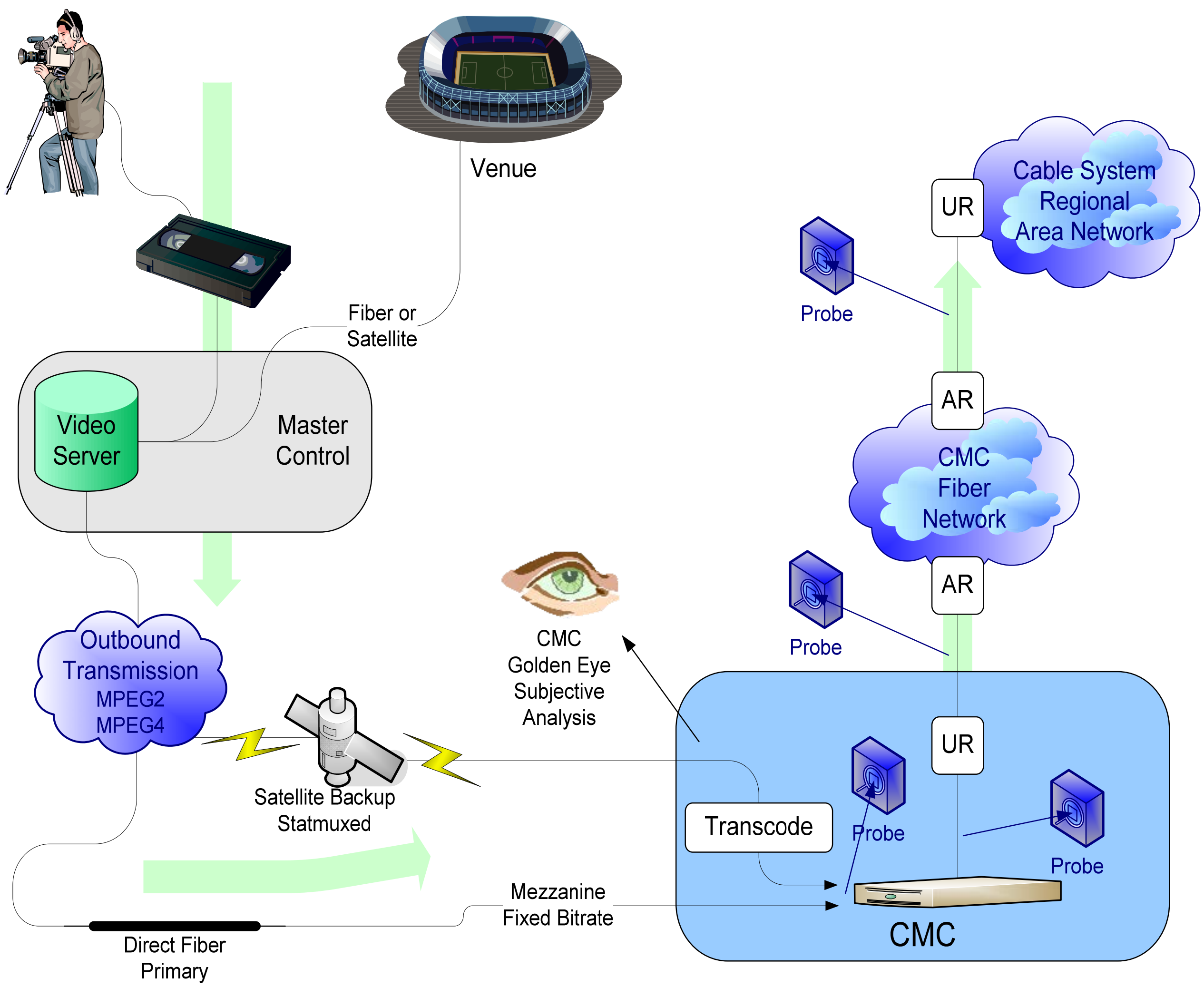
T he next step in the process is associated with transporting the video signal from Master Control to the *Outbound Transmission* system. In many cases this is where a significant impact can occur in the overall delivered video quality product. All major programming providers utilize compression, whether it is MPEG 2 or MPEG 4 based, to maximize the use of satellite or terrestrial fiber bandwidth. Traditional approaches for MPEG 2 statistically multiplexed HD bandwidth usage here are in the range of 12 to 15 Mbps per channel, but there are exceptions in both directions. Whatever the approach, the outcome can be seen at the baseband video output of the satellite receiver or receiver/transcoder and in all cases there are video impairments.

The CMC's Quality Assurance Team is also monitoring content that is distributed over *Direct Fiber*. The connections, which will serve all of the major programming providers, will operate at a higher bandwidth usage model to minimize the impairments associated with the *Outbound Transmission*.

Once the signal arrives at the CMC, it is either converted to MPEG 2 if required or presented to the *Imagine Encoder* as a Gigabit interface. The efficiency associated with removing the need to take the receiver output down to its baseband video components and then re-encoding has allowed the opportunity to integrate 3 HD signals into a single multiplex while sustaining competitive video quality.

As Drawing 1 shows, the output of the *Imagine Encoding* system is then transmitted onto the Fiber Backbone for distribution.

While not specifically addressed in this paper, downstream impairments can obviously be caused by local re-encoding, rate-shaping or grooming as well as local Ad Insertion systems. Further, the set-top box, the consumer display device, and the viewing environment all play a contributory role in recovered video quality.



Drawing 1

The working assumption is that if the video source is of superior quality, the re-packaging encoders are performing optimally, and the network is functioning as it should, then the video from the source should be delivered to the consumer with little degradation and the availability of the service should not be an issue. However, it is critical that as a service provider, the CMC tracks not only the video quality but the performance of the delivery platforms in order to determine the quality of each service, as best as possible.

To measure the uptime performance of its HD video delivery over the fiber network, CMC has installed a system of MPEG transport stream probes placed strategically across its network to monitor the availability of each of the video services transported. It is important to note that only service availability (i.e. Packet Loss as an example) is monitored through automated means. CMC has been using the MPEG probe system since January, 2008 to measure its delivery performance, optimize the network, and to accumulate fault data for statistical and alerting purposes. Table 1 shows an example of several weeks of performance data collected on a per program basis facilitating analysis and review; note the anomaly that occurred at Site 11, Red, yellow and green color coding indicates the severity of the impact.

Programs by Imparied Seconds	Source (in)	CMC (out)	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14
Channel A	2	16	11	10	11	11	11	14	11	18	11	11	168	11	11	11
Channel B	1	1	0	0	0	0	0	0	0	6	0	0	160	0	0	0
Channel C	9	2	1	1	1	1	1	1	1	5	1	1	159	1	1	1
Channel D	0	12	11	10	11	11	11	11	11	15	8	11	168	11	7	10
Channel E	1	7	2	2	2	2	2	2	2	6	2	2	160	2	2	2
Channel F	9	19	9	9	9	9	10	9	9	13	9	9	167	9	8	9

Programs by Imparied Seconds	Site 15	Site 16	Site 17	Site 18	Site 19	Site 20	Site 21	Site 22	Site 23	Site 24	Site 25	Site 26	Site 27	Site 28	Site 29
Channel A	12	11	20	11	11	10	14	11	11	14	16	11	11	11	11
Channel B	0	0	4	3	2	2	2	1	1	2	7	1	0	2	0
Channel C	1	1	5	2	1	1	2	1	1	2	6	1	1	1	1
Channel D	10	10	15	8	10	10	12	7	11	12	16	11	11	11	10
Channel E	3	2	6	2	2	2	2	3	3	6	5	3	2	2	2
Channel F	9	8	14	8	9	8	9	14	14	17	12	15	8	10	9

Table 1

SUBJECTIVE ANALYSIS

Because the probe system only measures the transport stream delivery quality data, CMC developed and implemented a *Golden Eye* program to ascertain a subjective video quality rating of the sources of services it delivers. This data is accumulated over time and used to determine average video quality of each service placed on the backbone.

This program is a subjective video quality assessment method devised by the CMC using trained observers to perform subjective quality measurements of the source video, which is then processed and placed onto an IP network. Each service is viewed for 10 minutes on a predetermined schedule, which ensures random quality measurements. There are considerable differences noted between content that is aired (i.e. SD infomercials on the Overnight block, legacy or older material that is upconverted during Day-part, and first run Native HD material in Primetime.) It is important to note that these channels are marketed as “High Definition”, “HD” or “High Def” and the consumer expectation is not a variable.

The Golden Eye observer assigns a level of quality to the channel under test based on their observations of any impairment during the test cycle. A sample of the Golden Eye observer subjective test results is shown in Table 2 and is based on the test criteria which are listed in Table 3.

At the heart of video service quality grading is the use of common industry terms, definitions, and tolerances to known digital video impairments such as contouring, haloing, macroblocking, noise, smearing, and pumping. While these terms are commonly used for describing artifacts that impair the customer's QoE, it is very important that Golden Eye analysis apply them in a consistent manner. Table 3 was developed in order to assure a common language to describe the nature of the digital artifact presence in the video being analyzed.

Understanding there will always be some level of each of these impairments in every digital video service, and that some are more irritating to the cable subscribers than others, weighting of each impairment measurement type is required. After each impairment type is graded, the impairments that are more irritating to the consumer must be assigned a greater weighting. The total of the six impairment types combine with these weightings to determine an overall score. This provides a view of program picture quality and the probable offending impairment types contributing to lower quality scores.

Date	Time	Channel	Program	CONTOUR	HALO	MACRO	NOISE	SMEAR	PUMP	Channel Entry Total	Channel Average
12/15/2008	12:15	A	Program 1	2	2	2	2	3	3	44	44
12/19/2008	23:40:00	A	Program 2	4	4	4	4	5	4	82	82
12/24/2008	04:32:00	A	Program 3	3	4	5	4	4	5	86	86
12/15/2008	12:20	B	Program 1	2	2	3	2	3	2	48	48
12/19/2008	23:50:00	B	Program 2	3	4	3	3	4	3	65	65
12/24/2008	04:39:00	B	Program 3	3	3	4	4	3	3	71	71
12/15/2008	12:25	C	Program 1	2	2	2	2	4	4	48	48
12/19/2008	23:56:00	C	Program 2	2	3	3	3	3	3	58	58
12/24/2008	04:45:00	C	Program 3	3	4	3	3	2	4	63	63
12/16/2008	11:20:00	D	Program 1	2	3	2	5	5	2	64	64
12/19/2008	24:05:00	D	Program 2	5	4	5	4	5	4	90	90
12/24/2008	05:00:00	D	Program 3	3	4	2	3	3	4	59	59
12/16/2008	11:25:00	E	Program 1	2	2	4	4	2	4	66	66
12/24/2008	05:52:00	E	Program 2	5	3	4	4	5	4	81	81
12/16/2008	11:30:00	F	Program 1	2	2	2	4	3	4	56	56
12/24/2008	06:01:00	F	Program 2	4	3	4	3	2	4	68	68

Table 2

Compression Artifact Definitions		Compression Artifact Ratings			
CONTOURING	**1**	**2**	**3**	**4**	**5**
Contouring is a defect where abrupt changes between shades of the same color create color bands instead of a gradual change. This can be seen during scenes with a large amount of smooth color or in scenes where this is a color contrast change like in wide-angle sunsets, dawns, or clear blue skies.	Present in all scenes.	Present in most scenes.	Present, but not distracting to viewing.	noticeable, but not consistently seen.	no contouring.
HALOING	**1**	**2**	**3**	**4**	**5**
Haloing is typically seen around areas of high contrast, such as sharp lines, text edges, and graphics. On close inspection, part of the graphic appears to extend into the background. Halling can manifest as smaller details in graphics appearing to soften or loose edge resolution resulting in apparent blocking along graphic edges.	Heavy blocking that occurs on the edges of all objects on the screen.	Blocking along the edges of most objects.	Localized blocking noticeable along the edges of objects; always present at the edges of all text and graphics.	Blocking occurring at the edges of logos only.	no haloing.
MACROBLOCKING	**1**	**2**	**3**	**4**	**5**
Macroblocking is a defect where the edges of blocks or rows of blocks, are typically seen as a grid-like-pattern. This defect often occurs during dissolves from one scene to another or during action scenes involving a great deal of complex movement. Another way this artifact is presented is with small to large pixels and/or blocks containing corrupted or green pictures. This is caused by transmission or transport anomalies.	The whole screen Blocks up, regardless of scene content. **Note: This is a very rare event.**	10 - 15 seconds of blocking covering half of the of screen. e.g. Consistent blocking occurs during every scene transition, fade/dissolves, action scenes, etc.	5 - 10 seconds of blocking covering at least half the screen. e. g. Blocks occur at the focus of the screen; often during motion.	3 - 5 seconds of blocking around a small portion of screen. e.g. Scene transitions / dissolves / short action scenes (explosions).	no blocks.
NOISE	**1**	**2**	**3**	**4**	**5**
Noise appears as random speckles on an otherwise smooth surface and can significantly degrade video quality. Although noise often detracts from an image, it is sometimes desirable since it can add a grainy look that is reminiscent of film. Noise can also increase the apparent sharpness of an image.	Black speckle clusters that manifest clearly defined block edges. Closely resembles traditional Macroblocking, though not associated with motion.	Scenes presenting a raining effect of black speckles that cluster and move into the foreground. e.g. Noise that manifests itself and is a distraction within the scene.	Scenes with black speckles that appear to be moving on static backgrounds. e.g. walls, curtains, or sky that appear to have movement in the background.	Black dots that randomly pop into any portion of the scene.	No noise.
SMEARING	**1**	**2**	**3**	**4**	**5**
Smearing is a defect where part of the image remains fixed in space while the adjacent parts of the image moves leaving a trail. Smearing may also be observed in faces or across large areas of a similar type that have fine detail (e.g. grass fields). Smearing commonly affects facial color tones causing video to take on an unnatural look.	Regular loss of object detail that manifests as localized blocking on a face or a material.	Losing object detail on faces or materials that are the focus of scene.	Intermittent loss of object detail on faces or materials.	Individual or unrelated occurrences of object detail loss	no smearing.
PUMPING	**1**	**2**	**3**	**4**	**5**
Pumping is a defect where the video or parts of the video appear to pulse at a regular interval. This is typically seen in areas of smooth neutral colors.	All scenes with static backgrounds begin to block and bleed to the foreground.	Noticeable movement on static backgrounds during both motion and still scenes. e.g. Noticeable on an overhead view of a golf course or a wall of wood paneling.	Scenes that have minor regular movement on static backgrounds.	Low motion scenes that have intermittent but not constant movement on static backgrounds.	No pumping.

Table 3

SOURCE PROCESSING QUALITY

In addition to the Probe data and the Subjective Video Quality Analysis, the CMC also relies on Imagine's ICE-Q® technique to measure its HD delivery performance. How the human visual system perceives various video characteristics is built into the ICE-Q® measurement system, such as sensitivity to analog and digital noise, spatial and temporal frequency, and factors such as luminance, color, texture and edges. Imagine's research has found that the accuracy of an objective measurement system is primarily dependent on how closely its results correlate with subjective test results from a pool of expert and ordinary viewers. In addition, since different video coding standards exhibit different types of artifacts, a good objective measurement system should be tuned and optimized for a particular video coding environment, e.g., MPEG-2 or MPEG-4 AVC.

The ICE-Q system processes every macroblock of every frame, using variable bit rate coding to achieve and maintain constant video quality. The system selects the optimal macroblocks and frames by using the objective video quality measurement system to preserve the highest video quality at the lowest possible bit rate. The ICE Broadcast System continually measures its ability to process the input signal as accurately as possible (i.e. with minimal added impairments).

The actual grading system relies on a convenient approach using a numerical scale of 1 to 100, with 100 representing the compressed source quality. For example, a score of “97” may be defined as Just Noticeable Difference (JND), in which expert viewers can rarely discern the difference between the compressed source and the re-processed signal. A score of “95” may be defined as the point of No Material Degradation (NMD), in which differences from the source can be perceived more frequently than with JND, but the quality is still excellent. Furthermore, the system can be designed such that “97” is the target average grade over time, while “95” is the target minimum quality. It is also important to design the grading system such that the numerical increments are reasonably linear with respect to subjective video results. In other words, the subjective quality difference between “97” and “95” should be similar to the subjective gap between “95” and “93.”

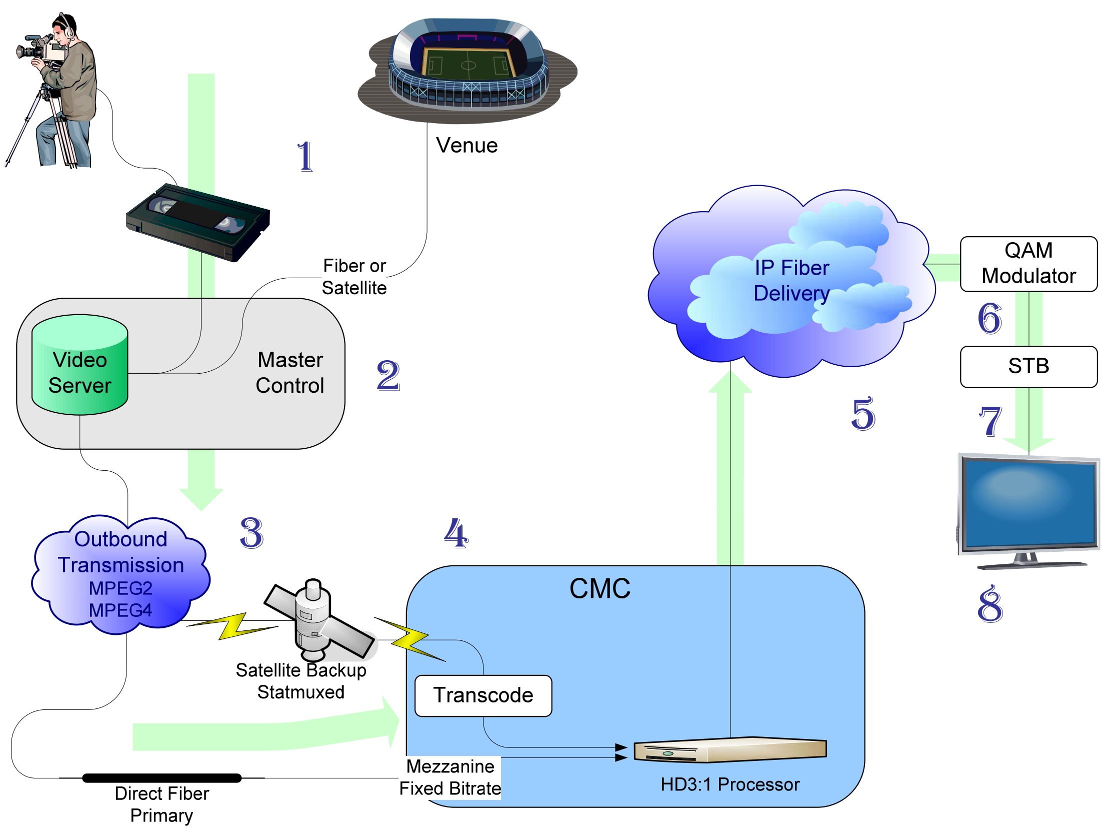
The CMC has created a summary report structure that allows the organization to monitor the incoming video quality and availability, its delivery performance, and the performance of the fiber network delivery. The level of quality is calculated from the CMC Golden Eye subjective video quality measurements, the video processor quality grading, and the delivery performance of the backbone as measured by the MPEG2 probe system. Each of these metrics is prioritized to determine actions on channels of impaired delivery quality. Channel uptime and events of packet loss are most critical followed by the Imagine quality scoring, then the CMC Golden Eye subjective scores which have the lowest priority. The results displayed in Table 4 are examples of actual video services placed on the fiber network at the CMC.

	Dec 1 - 8			Dec 8 - 15			Dec 15 - 22			Dec 22 - 29			Dec 29 - Jan 5		
Programs	Source Quality (OMC)	Average Grade	CMC Delivery	Source Quality (OMC)	Average Grade	CMC Delivery	Source Quality (OMC)	Average Grade	CMC Delivery	Source Quality (OMC)	Average Grade	CMC Delivery	Source Quality (OMC)	Average Grade	CMC Delivery
Channel A	83	98.16	5	83	98.10	80	69	98.05	35	71	97.90	16	71	97.83	8
Channel B	72	97.51	4	72	97.59	14	65	97.56	6	65	97.61	13	70	97.60	9
Channel C	81	97.90	4	80	97.98	4	77	97.95	14	67	97.99	5	67	97.99	16
Channel D	74	95.28	5	73	95.12	3	70	95.28	3	76	95.27	2	76	94.92	1
Channel E	92	95.12	3	92	95.17	80	63	94.95	8	63	94.87	4	70	95.01	7
Channel F	79	96.14	3	86	96.19	7	75	95.99	9	73	95.91	4	73	96.05	7

Table 4

QUALITY TOUCH POINTS

To maximize video quality across the delivery environment there are eight key "Touch Points" that begin at source acquisition and end with the consumer display. Video quality measurements at each touch point should be made using a non-referenced approach though a referenced approach is acceptable where a reference source is available. A referenced measurement is a comparison of the video under test to the source video providing a measurement of difference between the two; a level of degradation. A non-referenced video quality measurement is made without a comparison to the source video, which is not available at most touch points, and is the more telling measurement of the two. Drawing 2 shows the video delivery path with the Touch Points indicating critical measurement points and opportunities to improve video quality.



Drawing 2

Touch Point 1 is a measurement point at the source, such as a live event venue or a dubbing house. This is a critical point requiring non-referenced video quality measurements. Video artifacts are caused by analog to digital conversion and tape to digital storage conversion requiring compression of the video.

Touch Point 2 at the Master Control facility requires non-referenced measurements because there are many video sources required to create a video service. Service degradation causes include varying levels of video quality of programs and commercials and failures of automation resulting in loss of video or the wrong video played out. This is also the point where the CMC will be placing mezzanine encoders for direct fiber delivery.

Touch Point 3 can be a referenced measurement assuming the service provider is also the owner of the MPEG encoders and multiplexors and that a reference, uncompressed source is available. Service challenges include poor video encoding and multiplexor bit starvation causing the six video impairments described in Table 1.

Touch Point 4 is the point of entry into the CMC facilities and requires a non-referenced measurement. The service is left intact as MPEG encapsulated onto IP. The affects to video are typically due to packet loss on terrestrial delivery systems and packet loss on satellite delivery systems that are due to RF conditions. However, because this is the first point at which CMC has access to the video service, effectively making it the point of demarcation, the video service must be validated.

Touch Point 5 is interface to and from the CMC IP delivery system and requires referenced measurements assuming reference from the delivery source is available. This is the first point in the service path where the affects to the video service caused by processing can be measured. Degradations of the video service at this point are often caused by over processing and bit starvation of the multiplexor.

Touch Point 6 is a measurement point from a monitor tap of the QAM devices. This point requires non-referenced measurements because there is no reference source available. Video degradation is caused by local conditions of delivery, grooming, and commercial add insertion.

Touch Point 7 is a measurement point within the set top box in the customer's home. This requires non-referenced measurements, since there is no reference source available. Video degradations can be caused by HFC delivery and conditions within the customer's home.

Touch Point 8 is a non-referenced measurement point within consumer video displays measuring the performance on the very end of the delivery path. Clearly, this is the point where all upstream events and conditions affect the perceived video quality as well as transmission availability as presented to the cable customer.

CONCLUSION

With the increasing importance of Quality of Service as a key marketplace advantage, the ability to measure, report on, and improve video quality delivered to the consumer is an essential tool for improving competitive strategy. Replicating both ideal and imperfect viewing conditions within the software algorithms of Picture Quality Analysis tools is critical to automating non-referenced video quality measurements.

In addition, accumulated video quality scores provide MSOs reliable and repeatable metrics. This data can be used for engaging content providers (and all parties involved in content management and distribution) in a collaborative effort to achieve the best possible viewing experience for the customer. Additionally, industry accepted video quality measurements and grading enables MSOs to perform regular proof of performance maintenance of cable systems.

In the long term, digital video quality grading must take place in all devices in the path, from source to consumer, which can impact the quality of video. Further, instantaneous scoring is necessary for best determining devices and systems in the video service path that are contributing to the degradation of video quality and accumulated scores will enable trending and isolation of issues that lead to quality impacts and impairments.

It is the authors' hope that this paper helps to stimulate further discussion and movement toward a common system and automated processes for measuring and scoring digital video quality from an unreferenced source based on industry accepted tolerances.

Summary of Video Quality Measurement "Lessons Learned"

- Linear video is subject to varying video quality from one channel to another as well as from one program to another. It is also evident that video quality varies from one source provider to the next due to source acquisition and delivery approaches.

- Time of day has a direct impact on type of content being aired and whether it is high quality native HD or legacy SD upconverted material.

- MPEG 4 transcodes to MPEG 2 cause new "mini" macro-block impairments.

- Older film product and marginal quality associated with film to video transfers also have a significant impact on QoE.

- Live sports that is over compressed (whether it occurs on the path from the *Venue*, the *Outbound Transmission* or as part of a downstream re-encode process) can and will cause significant and visible impairments.

- Display viewing distance and "off-axis" viewing can impact perceived video quality.

- Display size, type, native resolution capability, contrast ratio, and pixel size and shape can have impacts on recovered video.

- Deeper compression approaches such as HD 3:1 prevent the use of downstream "Rate Shaping" or "Grooming" as the impacts to the recovered QoE are dramatic.

Acknowledgements

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