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ABSTRACT:	This contribution reports on a preliminary study that was conducted, as a first step, to determine the validity of using traditional analog composite video objective measurement techniques (e.g., luminance non-linear distortion, differential gain) on 45 Mbit/s compressed composite video systems. Although video compression algorithms may result in image compression impairments, the primary issue in the development of an objective measurement technique for 45 Mbit/s video systems is whether compression impairments are subjectively detectable. If they occur to an extent that is detectable, then the present analog objective measurement techniques will certainly not be sufficient for assessing the performance of 45 Mbit/s digital video systems. But if the compression impairments are not detectable, then the present analog methods may be sufficient for detecting traditional video signal degradations due to analog processing before and after its digitization. In other-words, measuring how accurately 45 Mbit/s video codecs reproduce static test signals and can traditional analog circuit impairments be accurately measured through the system. This contribution documents a study that used a representative commercially available 45 Mbit/s codec to test the statements above. A subjective evaluation of the quality of the test codec was conducted and it was determined that the compression impairments were not detectable. Next, an assessment of the ability of the codec to reproduce static test signals was conducted. Finally, test signals were predistorted and passed through the compressed video system. The distortions were found to pass linearly through the system; this was determined to be the underlying requirement for the traditional methods to be valid for determining degradation to the compressed video signal.

Objective Measurements Techniques for 45 Mbit/s Compressed Composite Digital Video

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Abstract: This contribution reports on a preliminary study that was conducted, as a first step, to determine the validity of using traditional analog composite video objective measurement techniques (e.g., luminance non-linear distortion, differential gain) on 45 Mbit/s compressed composite video systems. Although video compression algorithms may result in image compression impairments, the primary issue in the development of objective measurement techniques for 45 Mbit/s video systems is whether compression impairments are subjectively detectable. If they occur to an extent that is detectable, then the present analog objective measurement techniques will certainly not be sufficient for assessing the performance of 45 Mbit/s digital video systems. But if the compression impairments are not detectable, then the present analog methods may be sufficient for detecting traditional video signal degradations due to analog processing before and after digitization. In other-words, measuring how accurately 45 Mbit/s video codecs reproduce static test signals and to what extent can traditional analog circuit impairments be accurately measured through the system.

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1. INTRODUCTION

Having an objective method to measure the quality of a video signal is a critical part of the successful introduction and maintenance of new video services. Presently, there are several standardized measurement methods for objectively measuring the quality of analog composite video signals. However, with the introduction and use of digital compressed composite video systems on the rise, there is now a need for an objective measurement method that is valid for evaluating these compressed systems. Although the use of traditional analog test methods to evaluate compressed composite video quality is becoming a common practice, it is questionable weather the analog techniques are valid for these new systems. This contribution documents a preliminary study that was conducted at Bellcore's New Technology Performance Evaluation Laboratory to investigate this issue.

Although video compression algorithms may result in image compression impairments, the primary issue in the development of an objective measurement technique for 45 Mbit/s video systems is whether compression impairments are subjectively detectable. If they occur to an extent that is detectable, then the present analog objective measurement techniques will certainly not be sufficient for assessing the performance of 45 Mbit/s digital video systems. But if the compression impairments are not detectable, then the present analog methods may be sufficient for detecting traditional video signal degradations due to analog processing before and after digitization. In other-words, measuring how accurately 45 Mbit/s video codecs reproduce static test signals and to what extent can traditional analog circuit impairments be reliably measured in 45 Mbit/s digital composite video systems.

To determine to what extent the traditional measurement methods could be used, a three-fold approach was implemented. First, an informal subjective tests with expert viewers was performed, the goal was to determine the type and magnitude of any compression artifacts. Second, objective measurement tests were performed to determine if the static test signals were accurately reproduced. And Third, where appropriate, the static test signals were predistorted in order to determine if signal distortions added prior to transmission through the system would track linearly with distortions measured at the output of the codec. Linear tracking of the distortions was judged a necessary property for the test methods to be applicable to 45 Mbit/s video.

2. METHODOLOGY

The goal of the subjective tests was to determine the type and severity of compression impairments that could be detected as a result of transmission through the codec. VSIF contribution VSIF.1/95-020R3[1] reports on a variety of impairments that have been associated with 45 Mbit/s video. These impairments include color errors, blurring/smearing, object persistence, object retention, spatial edge noise, temporal edge noise, quantizing error, mosquito noise, clipping/thresholding, horizontal sync jitter and line noise distortion. The tests were performed by conducting informal viewing tests with expert viewers in the laboratory. The viewers tried to detect the types of compression impairments listed above.

The goal of the objective tests was to determine if the standard analog test methods using static test signals were applicable to 45 Mbit/s video systems. The tests were designed to measure the transmission parameters in the conventional manner and, where appropriate, to determine if signal distortions added prior to transmission through the codec would track linearly with distortions measured at the output of the codec. If the output distortions do not track reasonably well with the input distortions, it could be surmised that the compression algorithm is acting in a nonlinear fashion on the test signal, thus, nullifying the results obtained with it. The output distortions do need to track reasonably well to have confidence in the results obtained with the test signal.

Measurements were made using a Tektronix VM700A Video Measuring System. Test signal distortions were created using a Tektronix TG1001 Programmable Test Signal Generator. Other test signals were obtained from a Tektronix 1910 Digital Signal Generator. The tests were performed on a commercially available 45 Mbit/s compressed composite video codec. The objective test that were evaluated are define in Bellcore Document GR-338-CORE[2] and are listed in Table 4-1 of this document.

3. SUBJECTIVE TESTS

The goal of the subjective tests was to determine the type and severity of the VSIF compression impairments that could be attributed to the 45 Mbit/s video codec. Informal viewing tests were conducted in the laboratory using expert viewers. The viewers were laboratory personnel experienced with detecting impairments resulting from compressed video algorithms such as MPEG 1 and MPEG 2. The viewer could switch between the source picture (before transmittal through the codec) and the test picture (after transmittal through the codec) at will to make his determination. The viewing was conducted in the laboratory and the viewer was allowed to adjust the ambient lighting and the monitor brightness and contrast controls in any manner to aid him in detecting impairments. He also could position himself as close to or as far away from the monitor as desired.

3.1. Summary of the Subjective Test Results

The following three sequences, two from movies and the other a dynamic test pattern, were used in the tests:

1) "Dancing" - A 10- second sequence from the movie, "Living Daylights". The sequence shows several partners waltzing on an outdoor terrace with a street in the background. A panning view shows the dancers in the foreground, and horse-carriages and people walking in the street background.

2) "Top Gun" - A 10-second sequence from the movie, "Top Gun". This sequence shows a pilot flying an F16 jet in a dogfight with another jet. There are views of the pilot in the cockpit and of the two jets.

3) "Color Wheel" - A 5-second sequence showing a wheel rotating at a speed of 90 degrees per second over a stationary background. The wheel consists of ten black spokes, each 18 degrees wide and emanating from the center to the outside edge of the picture. The stationary background consists of 10 color spokes, each 36 degrees wide, emanating from the outside edge of the picture and ending at one side of a solid white decagon figure located at the center of the screen and with a width of about half the screen width.

The three test sequences were stored on a video storage disc and each was played back in a continuous loop until the next sequence was requested by the viewer.

Results indicated that none of five viewers used in the tests could detect any impairments on any of the three test sequences transmitted through the codec. Furthermore, none of the viewers could reliably choose the reference picture when presented the reference and test pictures in random order. These results were surprising and unexpected in light of the VSIF contribution reporting the variety of impairments associated with 45 Mbit/s codecs. One possible explanation could be that the list of impairment artifacts was based on observations made over the past several years on older versions of codecs and that the performance of newer versions has been greatly improved.

The results (no visible impairments) obtained in the viewing tests indicate that possibly little or no interframe compression coding is used in the codec compression algorithms. Thus, without the need to deal with impairments correlated with the amount of motion and detail in the transmitted image, current standard analog tests using static test signals may be sufficient for assessing the performance of 45 Mbit/s video systems using the latest versions of 45 Mbit/s codecs.

4. Objective Tests

The goal of the objective tests was to determine the applicability of using standard analog test methods on 45 Mbit/s compressed composite video systems. The objective tests that were evaluated are define in Bellcore Document GR-338-CORE and are listed in Table 4-1 of this document.

In addition to performing measurements with standard test signals, measurements were also performed, where appropriate, with test signals exhibiting various amounts of added distortion of the type being measured. As discussed previously, this was done to determine if the distortions tracked reasonably well through the codec. In all tests where it was appropriate to do so, any distortion in the test signal was accounted for in the measurement of the codec distortion.

4.1. Summary of the Objective Test Results

The results of tests 1-16 in GR-338-CORE are presented in Table 4-1 below. The codec results listed are the measurements of the non-distorted test signal. As can be seen from Table 4-1, the static test signal was reproduced reasonably well, only three of the tests slightly exceeded the BR-338-CORE medium–haul analog criteria. The medium-haul analog criteria from GR-338-CORE are also given in Table 4-1 for comparison. In that table, parameter values for measurements that did not meet the GR-338 criteria are boxed.

A necessary prerequisite of using the standard analog test signals and methods for assessing the performance of 45 Mbit/s codecs was that distortions added to the test signal need to track reasonably well, that is, track linearly through the codecs. Parameters where distortion was added to the source test signal and tested for linearity through the codecs are indicated in the table. As it can be seen in the table, the tracking was determined to be satisfactory in all cases where linearity was tested.

Table 4-1. 45 Mbit/s Digital Video Codec Performance Measurements

Test/Parameter	Unit	Distortion Tracking Tests Performed	GR-338-CORE Med.-Haul Analog	Codec	Distortion Test Ranges	Distortion Tracked Linearity
Insertion Gain	IRE	YES	+5.9 to -5.5	-0.5	+6%,-10%	YES
Gain-Frequency Distortion						
0.5 MHz	dB	YES	±0.25	-0.11	±2%, ±10%	YES
1.0 MHz	dB	YES	±0.35	-0.21	±2%, ±10%	YES
2.0 MHz	dB	YES	±0.48	-0.37	±2%, ±10%	YES
3.0 MHz	dB	YES	±0.60	-0.46	±2%, ±10%	YES
3.58 MHz	dB	YES	±0.35	-0.49	±2%, ±10%	YES
4.2 MHz	dB	YES	±0.70	-0.75	±2%, ±10%	YES
Field Time Distortion	%	NO	3 p-p	0.3	NA	NA
Line Time Distortion	%	YES	1 p-p	0.5	±1%, ±10%	YES
Short Time Distortion	%	NO	2	0.8	NA	NA
Long Time Distortion, 3 sec. settling time	%	NO	8	0.2	NA	NA
Chrom-Lum Gain Inequality	%	YES	±4	-5.5	±2%, ±10%	YES
Chrom-Lum Delay Inequality	ns	YES	±33	0.6	±10ns, ±50ns	YES
Chrominance Nonlinear Gain						
20 IRE Chroma Signal	%	YES	±5	0.0	±2%, ±10%	YES
80 IRE Chroma Signal	%	YES	±5	-0.3	±2%, ±10%	YES
Chrominance Nonlinear Phase	deg	YES	2	-0.3	±1°, ±6°	YES
Luminance Nonlinear Distortion	%	YES	4	1.1	2%, 25%	YES
Transient Sync Signal Nonlinearity	%	NO	2	0.6	NA	NA
Dynamic Gain						
Picture	%	NO	3	0.0	NA	YES
Sync	%	NO	1.6	0.1	NA	YES
Differential Gain	%	YES	5	0.94	±1%, ±10%	YES
Differential Phase	deg	YES	1.3	0.29	±.5°, ±3°	YES
Chrom-Lum Intermod Distortion	%	YES	2	0.0	±1%, ±6%	YES
Signal-to-Noise (4.3 MHz LPF, NTC-7 Weighting, 5 IRE Ramp @ 95 IRE Ped, Tilt Null)	db	NO	NA	62.8	NA	NA

5. Summary

Results of the subjective tests with expert viewers indicated that no compression artifacts could be detected on any of the test sequences transmitted through the codec. Furthermore, the viewers could not reliably choose between the reference sequences and sequences transmitted through the codecs. The significance of these results is that, without the need to deal with the compression impairments, the current objective test methods, alone, may be sufficient for assessing the video performance of 45 Mbit/s digital video systems.

The results of the objective tests indicated that the static test signals were reproduced accurately and that the codec met the medium-haul specification in GR-338-CORE; except in three cases where they slightly exceeded the criteria. The tracking of distortion through the codecs was satisfactory in all cases where pre-distortion was added to the test signal. Although reasonable tracking alone may not insure correspondence to absolute video quality, it is sufficient to indicate poor performance when a system fails to meet an established requirement.

Based on these findings, further investigation into this topic is recommended. The results of this preliminary study warrant further investigation into this topic using a large sample of commercially available codecs. The results of future work could lead to recommended methods and parameter limits for 45 Mbit/s compressed composite digital video systems.

6. References

1 Video Services Industry Forum (VSIF) Contribution, VSIF.1/95-020R3, "Artifact List for Video on 45 Mbit/s Systems," August 20, 1995.

2 GR-338-CORE, "Television Special Access and Local Channel Service – Transmission Parameter Limits and Interface Combinations," Issue 1, December 1995.