Recommendation of Structure for SMPTE Documentation of TV Recording Formats Employing Compression Techniques

Report of the Study Group on SMPTE Documentation of Television Recording Formats Employing Compression Techniques (V16.06)

By Mikhail Tsinberg, Study Group Chairman

Introduction

As chairman of the SMPTE Television Recording and Reproduction Technology (TRRT) Committee, it has been my pleasure to shepherd almost all of the digital formats now in use, with the exception of part of the D-1 format, through the standards documentation process. Technology continues its rapid advance, as witnessed by the multitude of recording formats that continue to be offered to users; each one finding a niche for itself in the production or post-production process.

Despite our best efforts, the two digital compression recording formats now in the marketplace have escaped the SMPTE standardization process, much to the chagrin of many users. I believe the reason is simple. Both these formats employ proprietary compression techniques that exploit the human visual system as part of the compression masking algorithms. Because they are subjective in nature and are the result of careful compromise in data reduction, no immediate solution was apparent on how to describe these formats in a standards document without giving away a competitive advantage.

A Study Group was formed, at my request, to provide the TRRT Committee with clear recommendations on how to document digital recording formats for the foreseeable future. Through the dedicated effort of a number of very knowledgeable and respected engineers, under the able chairmanship of Mikhail Tsinberg, the recommendations that follow describe the framework for all new recorder format standards.

The study provides clear guidelines for the documentation of all digital compression formats presented to SMPTE for standardization. It is important to note that every effort has been made to ensure the maximum level of flexibility for format proponents to maintain proprietary algorithms and not to preclude the documentation of any particular format, layer, or machine interface. We are confident that the standards structure proposed by the Study Group satisfies industry requirements — thus, we hope, providing the incentive for all machine and media manufacturers, either of disk or tape, to bring their formats to the SMPTE for standardization.

— Tom Cavanagh, Chairman, TRRT Committee

Section 1: Scope of Paper

A key issue and major distinguishing factor among manufacturers of compression-based digital storage devices has to do with the proprietary algorithms used to compress the video data to be stored. The compression algorithms employed can have a significant impact on the resultant picture quality and deliverable features, readily differentiating one manufacturer over another. Similar to other video compression technology developers involved in such standardization efforts as MPEG-1 and MPEG-2, the algorithm developers for video storage equipment based on compression techniques are hesitant to include algorithm descriptions in standards documents.

A Study Group (SMPTE Study Group V16.06) was created in 1994 by the SMPTE Television Recording and Reproduction Technology (TRRT) Committee to propose a documentation format and procedure for the new generation of digital storage devices utilizing compression technology. This TRRT initiative became necessary due to the hesitation on the part of compression-based VCR makers, offering such equipment on the open market, to reveal proprietary compression schemes. The intent of the Study Group is to provide maximum flexibility in its guidelines to the industry, so as not to preclude possible implementation choices of any given manufacturer. The guidelines are intended to cover the most generic blocks in the chain and be applicable to the widest possible audience, while also providing technical direction to the industry. The output of this Study Group is shown in the documentation guidelines presented here for the TRRT to recommend to the SMPTE for documentation of new recording formats.

The MPEG-1 and recently finalized MPEG-2 standards employ a standardization method that avoids the disclosure of the encoding algorithms. This is achieved through standardization of the data syntax, which is the compressed video/audio data and a set of decoding instructions generated by the encoder. The data syntax allows equipment makers to build compression decoders without knowledge of the compression algorithm employed by the encoder. The disclosed encoder

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syntax must provide sufficient details to ensure complete interchangeability in the compressed data stream, so different decoders conforming to the proposed standard maintain their full functionality. It is advised here that a syntax-based standardization format could also be used by the SMPTE for the standards documentation of compression-based storage devices.

The standards documentation form proposed by this Study Group allows proponents of new recording formats to propose standards documents with or without a detailed description of the proprietary compression algorithms employed. This can be achieved by defining a structure for disclosing only the data syntax standard, as it relates to television recording formats employing compression techniques. The recommendations of this Study Group also give reasonable guidance for documentation of compression-based storage devices unrelated to the compression algorithm itself, such as the mechanical deck, error correction, and interfaces.

The recommendations presented in this report follow a multilayer specification model. The guidelines and model are intended to be thorough, yet provide maximum flexibility to manufacturers. Discrete layers as presented here may be bridged or combined to satisfy possible implementation architectures of the manufacturer. A summary description of the methodologies used by this Study Group in the formulation of the documentation guidelines for compression-based storage equipment is given in Section 2. The block diagram of the layers and interfaces is shown in Section 3, followed by a summary outline of the recommended documentation structure in Section 4. The outline is discussed line by line in Section 5.

Table 1 —Model Layers and Corresponding Functions

Layer	Function
[0] Layer	Bit-Stream Storage Device
[1] Layer	Error Protection (Encoder)/Error Correction (Decoder)
[2] Layer	Data Formatter (Encoder)/Data Deformatter (Decoder)
[3] Layer	Compression Decoder
[4] Layer	Compression Encoder

Table 2 —Model Layers and Corresponding Interfaces

Encoder	Decoder	Interface
[1] Layer Input [2] Layer Output	[1] Layer Output [2] Layer Input	Compressed and Formatted Data
[2] Layer Input [4] Layer Output	[2] Layer Output [3] Layer Input	Compressed Data (note that on the encode side, an external input is provided at the Layer [2] input; on the decode side, an external output is provided at the Layer [2] output)
[4] Layer Input	[3] Layer Output	Uncompressed Digital/Analog (note that on the encode side, an external input is provided at the Layer [4] input; on the decode side, an external output is provided at the Layer [3] output)

Section 2: Summary Description of Recommended Documentation Structure

To adequately, efficiently, and most appropriately specify a digital video encoder/decoder standard, it is necessary only to describe the compressed video data *syntax* and the operation of the decoder; that is, the *operation* of the encoder need not be specified. The consequence of a syntax-oriented specification is significant and advantageous to the manufacturer of related electronic equipment because the proprietary nature of the processing algorithms need not be compromised in the process of disclosure or adherence to the system specification. This concept closely parallels the manner in which the MPEG video compression standard has been specified by the world community.

The syntax of a compressed data stream and the operation of the decoder must be described in adequate detail so that it is unambiguous as to how a decoder will treat each item of data in the bit stream. This specification must be described exactly as to how the video and audio signals will be reconstructed from the compressed data stream. If this is the case, then any decoder designed from the specification will operate in exactly the same manner and will produce the same output.

However, since the operation of the encoder is not specified, it can be left up to the manufacturer how to produce the compressed data stream from the input video and audio source (assuming the bit stream itself is compliant with the syntax). This allows for some limited future improvements and modifications to the encoding algorithms, as well as the use of manufacturer-specific encoding techniques without the details of the encoding methods being specified and without compromising compliance with the standard.

Another powerful tool to exploit in the documentation strategy of television recording formats employing compression techniques is the use of a *layered* representation model. By modeling the system and the documentation of the system using uniform layers, the industry is left with the option to independently upgrade the operation of the equipment within a layer without disrupting the overall system standard, provided the input and output of the layer conforms to the system specification. The system documentation model described here has been carefully selected to define layer operations that will allow core functionalities for a future standard to be adequately specified. By clearly defining discrete operations within layers, the model affords manufacturers the opportunity to develop proprietary upgrades within a target layer. For example, one layer in the model is the Bit-Stream Storage Device, which

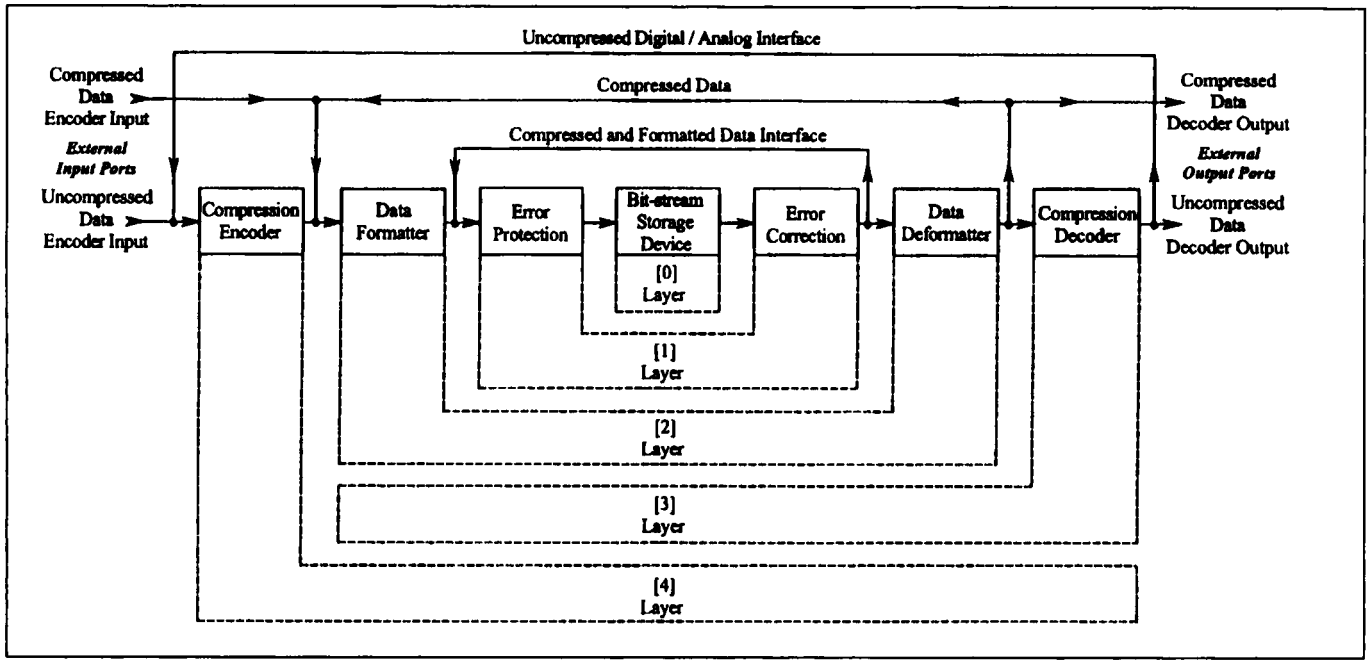

Figure 1. Layer and interface model.

could be different media for different manufacturers and applications. Another layer is the Compression Encoder, which could be upgraded with future advancements in technology, independently of the entire system chain. The Layer and Interface Model developed by this Study Group is described in Section 3 of this document.

Section 3: Layer and Interface Model

The documentation structure proposed herein uses a multilayer interface model, represented in Fig. 1. The model has been designed to consider the *encoding* and *decoding* functions and their interfaces. Each function is encapsulated by a *layer*. Each layer and associated function is depicted in the figure and listed in Table 1. Layers may be combined to satisfy possible implementation choices of the manufacturer.

The significance of a layered model is that corresponding layers on the encode side and decode side can be readily interfaced, as shown in Table 2. Also, components within layers can be modified and upgraded without altering the system, provided the layer interface specifications at the physical and signal layer are conforming to the system specification.

Section 4: Outline of Recommended Documentation Structure (Refer to Fig. 1)

[0] Layer Specifications: Bit-Stream Storage Device

0.1 Media Specifications
0.1.1 Removable Media
0.1.1.1 Physical Characteristics
0.1.1.2 Package
0.1.1.3 Record Footprint
0.1.1.4 Raw Data Rate with Overhead
0.1.2 Nonremovable Media
0.1.2.2.1 Maximum Sustained Data Rate
0.1.2.1 Physical Characteristics
0.1.2.2 Data Interface

[1] Layer Specifications: Error Protection (Encoder)/ Error Correction (Decoder)

1.1 Channel Code Specifications
1.2 Error Protection/Correction
1.3 Data Interface Specification

[2] Layer Specifications: Data Formatter (Encoder)/Data Deformatter (Decoder)

2.1 Data Formatter Specifications
2.2 Compressed Video Data, Compressed Audio Data, and Auxiliary Data Digital Interface Specifications
2.2.1 Physical Layer Specifications
2.2.2 Signal Layer Specifications

[3] Layer Specifications: Compression Decoder

3.1. Compressed Video Data and Auxiliary Data Syntax Specifications
3.2. Compressed Audio Data Syntax Specifications
3.3. Compressed Video Data, Compressed Audio Data, and Auxiliary Data Interface Specifications
3.3.1. Physical Layer Specifications
3.3.2. Signal Layer Specifications

[4] Layer Specifications: Compression Encoder

4.1 Compressed Video Data Syntax Specifications
4.2 Compressed Audio Data Syntax Specifications
4.3 Auxiliary Data Format
4.4 Video, Audio, and Auxiliary Data Interface Specifications
4.4.1 Physical Layer Specifications
4.4.2 Signal Layer Specifications

Section 5: Detailed Description of Recommended Documentation Structure (Refer to Fig. 1)

A line-by-line description of each item in the Section 4 Outline of Recommended Documentation Structure is

provided here, corresponding to the layers and interfaces provided in Fig. 1. The recommendations presented here follow this multilayer specification model. It is recommended by this Study Group that the SMPTE model be a syntax-based standardization format for the standards documentation of compression-based storage devices. This structure permits manufacturers of such equipment to reveal interfaces and conform to standards with a limited disclosure of only the data syntax standard, as it relates to television recording formats employing compression techniques. In this way, proponents of new recording formats can provide standards documents with or without a detailed description of the proprietary compression algorithms employed.

Once adopted by the SMPTE, the Outline of Recommended Documentation Structure shall be followed by manufacturers of compression-based storage devices in specifying their equipment and interfaces. The line-by-line description that follows provides guidelines to the SMPTE and manufacturers for the disclosure of this necessary information. This Study Group has carefully proposed this model and outline to include only those items absolutely necessary to allow industry standardization and disclosure.

Note that the documentation structure shall permit external data inputs and data outputs at the uncompressed and compressed data layers, as depicted in Fig. 1 (external input and output ports). Although not limited to this example, an external CCIR 601 video interface could be provided. These input and output port descriptions, at the physical and signal layers, shall be specified in a conforming manner following these documentation guidelines for the video, audio, and auxiliary data.

Line-by-Line Description: Bit-Stream Storage Device

Layer	Outline Item	Description
[0]	Bit-Stream Storage Device Layer Specification	• This "inner" layer of the model contains the actual bit-stream storage device. • The input to the layer on the encode side is compressed, formatted, error-protected data, ready to be stored on the storage device. • The output of the layer on the decode side is raw data from the storage device ready to be error corrected, deformatted, and decompressed.
0.1	Media Specifications	• There are two forms of media storage devices: removable and nonremovable. • An example of a removable medium is a tape that can be transported readily by a user from one machine to another. • An example of a nonremovable medium is a hard disk.
0.1.1	• Removable Media	• If removable media is a part of the storage device, then items 0.1.1.1 through 0.1.1.4 shall be specified by the manufacturer. Such information allows for manufacturability and interchangeability.
0.1.1.1	• Physical Characteristics	• The specific physical dimensions and characteristics of the removable media shall be specified in order to permit other equipment conforming to the proposed standard to accept this form of removable media.
0.1.1.2	• Package	• The removable media packaging specifications shall be provided, such as for tape, floppy, or CD-ROM.
0.1.1.3	• Record Footprint	• The physical location of the data on the removable media shall be specified, including the data type and headers.
0.1.1.4	• Raw Data Rate with Overhead	• The raw data operating rate shall be specified. The rate should include the overhead required for protection and formatting. If raw data are subdivided into more than one channel, then the data rate and bandwidth shall be specified.
0.1.2	• Nonremovable Media	• If nonremovable media is a part of the storage device, then items 0.1.2.1 through 0.1.2.2 shall be specified by the manufacturer. Such information allows for manufacturability and interchangeability. Nonremovable media could be packaged as a removable assembly; for example, a hard-disk assembly.
0.1.2.1	• Physical Characteristics	• The physical characteristics of the nonremovable media shall be specified, and the size and capacity should be disclosed.
0.1.2.2	• Data Interface Specifications	• Data interfaces shall be specified to permit manufacturability of equipment at this layer in the model. However, because the media itself is not readily removable, its exact packaging and footprint need not be disclosed.
0.1.2.2.1	• Maximum Sustained Data Rate	• The maximum sustained data rate at the interface shall be disclosed.

Line-by-Line Description: Error Protection and Correction

Layer	Outline Item	Description
[1]	Error Protection (Encoder)/ Error Correction (Decoder) Layer Specification	• This layer performs the error protection on the encode side and the error correction on the decode side. • The input to the layer on the encode side is compressed, formatted data; the output of the layer is the data with error protection, ready to be stored on the storage device. • The input to the layer on the decode side is raw data from the storage device; the output of the layer is error-corrected data ready to be deformatted and decompressed.
1.1	Channel Code Specifications	• The specifications of the channel code shall be provided so that the layer can perform the channel codec operations into and out of the bit-stream storage device.
1.2	Error Protection/Correction	• The error protection and correction conforming to the requirements of the channel coding algorithm shall be revealed.
1.3	Data Interface Specification	• Data interfaces shall be specified to permit manufacturability of equipment at this layer in the model.

Line-by-Line Description: Data Formatter and Deformatter

Layer	Outline Item	Description
[2]	Data Formatter (Encoder)/ Data Deformatter (Decoder) Layer Specification	• This layer performs the data formatting on the encode side and the data deformatting on the decode side. • The input to the layer on the encode side is compressed data; the output of the layer is data that has been formatted with headers and descriptors, ready to be error protected and stored on the storage device. • The input to the layer on the decode side is error-corrected data from the stoage device, which is deformatted by this layer; the output of the layer is deformatted data that is decompressed.
2.1	Data Formatter Specifications	• The details of the data formatting are required in order to properly implement the normal and variable-speed modes of operation. This is required for formatting and deformatting.
2.2	Compressed Video Data, Compressed Audio Data, and Auxiliary Data Digital Interface Specifications	• This layer interfaces with the error protection layer and compression encoder layer at the encode side, and the error correction layer and compression decoder layer at the decode side. Both the physical and signal layer specifications of these interfaces shall be provided.
2.2.1	Physical Layer Specifications	• The mechanical and physical details at the interface to this layer shall be provided, including the connector type.
2.2.2	• Signal Layer Specifications	• The electrical signal layer details at the interface to this layer shall be provided.

Line-by-Line Description: Compression Decoder

Layer	Outline Item	Description
[3]	Compression Decoder Layer Specification	• This layer of the model performs the data decompression at the decoder. The input to this layer is compressed video data, audio data, or auxiliary data sources. • The input to the layer at the decoder is error-corrected data from the storage device, which has been deformatted and prepared to be decompressed by this layer. The output of this layer is the uncompressed data stream.

3.1	Compressed Video Data and Auxiliary Data Syntax Specifications	• In order to ensure complete interchangeability, the exact specifications of the compressed video data and auxiliary data syntax specifications shall be disclosed.
3.2	Compressed Audio Data Syntax Specifications	• The exact specifications of the audio data syntax specifications shall be disclosed.
3.3	Compressed Video Data, Compressed Audio Data, and Auxiliary Data Interface Specifications	• Physical and signal layer interface specifications into and out of this data decompression layer are required. Such specifications shall be provided for any compressed video data, compressed audio data, and/or auxiliary data.
3.3.1	• Physical Layer Specifications	•The mechanical and physical details at the interface to this layer shall be provided, including the connector type.
3.3.2	• Signal Layer Specifications	•The electrical signal layer details at the interface to this layer shall be provided.

Line-by-Line Description: Compression Encoder

Layer	Outline Item	Description
[4]	Compression Encoder Layer Specification	• This layer performs the data compression at the encoder. The output of this layer is uncompressed video data, uncompressed audio data, and/or auxiliary data. • The input to the layer at the encoder is an uncompressed data stream. The output of this layer is compressed data, which is formatted and error protected before storage on the storage device.
4.1	Compressed Video Data Syntax Specifications	•To ensure complete interchangeability, the exact specifications of the compressed video data syntax specifications shall be disclosed. The disclosure of the video data compression algorithms for the video data to be stored by the bit-stream storage device is not required.
4.2	Compressed Audio Data Syntax Specifications	• The exact specifications of the audio data syntax specifications shall be disclosed. The disclosure of the audio data compression algorithms for the audio data to be stored by the bit-stream storage device is not required.
4.3	Auxiliary Data Format	•To ensure complete interchangeability, the exact specifications of the auxiliary data syntax specifications shall be disclosed.
4.4	Video, Audio, and Auxiliary Data Interface Specifications	• Physical and signal layer interface specifications into and out of this data compression layer are required. Such specifications shall be provided for any video, audio, and/or auxiliary data.
4.4.1	• Physical Layer Specifications	•The mechanical and physical details at the interface to this layer shall be provided, including the connector type.
4.4.2	• Signal Layer Specifications	•The electrical signal-layer details at the interface to this layer shall be provided.