RP 213-2001

# SMPTE RECOMMENDED PRACTICE

# MPEG-2 Operating Ranges



## Table of contents



## 1 Scope

This practice specifies the structure and parameters of the data for interfacing MPEG-2 4:2:2 profile and digital audio in the professional environment.

The purpose of this practice is to facilitate video and audio bitstream interchange between MPEG-2 compliant equipment.

An overview of associated documents in given in annex C.

The combination of this document and those referenced in annex C will assist design and application of MPEG-2-based professional television equipment that facilitates bitstream interchange among different applications and over a wide set of user requirements.

This practice is limited to the video and audio parameters of such a system.

This practice defines the MPEG-2 operating ranges. These ranges constrain characteristics of the MPEG-2 4:2:2 profile to ensure bitstream interchange in the professional environment. These operating ranges are subsets of ISO/MPEG profiles and levels. This practice defines two operating ranges for standard-definition television and three operating ranges for high-definition television. It also defines a hierarchial relationship among the ranges.

All the MPEG-2 data structures defined in this practice are ISO/IEC 13818-2 4:2:2 profile compliant and as such are decodable by MPEG-2 4:2:2 profile compliant stand-alone decoders at the appropriate level. Inasmuch as the 4:2:2 profile also requires stand-alone decoders to decode main profile structures (4:2:0), existing main profile sources can be accommodated.

## 2 Normative references

The following standards contain provisions, which, through reference in this text, constitute provisions of this practice. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this practice are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below.

AES3-1992, Digital Audio Engineering — Serial Transmission Format for Two-Channel Linearly Represented Digital Audio Data

ANSI/SMPTE 293M-1996, Television — 720 x 483 Active Line at 59.94-Hz Progressive Scan Production — Digital Representation

SMPTE 274M-1998, Television — 1920 x 1080 Scanning and Analog and Parallel Digital Interfaces for Multiple Picture Rates

SMPTE 296M-2001, Television — 1280 x 720 Progressive Image Sample Structure — Analog and Digital Representation and Analog Interface

SMPTE 302M-1998, Television — Mapping of AES3 Data into MPEG-2 Transport Stream



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SMPTE 308M-1998, Television — MPEG-2 4:2:2 Profile at High Level

SMPTE 327M-2000, Television — MPEG-2 Video Recoding Data Set

SMPTE 328M-2000, Television — MPEG-2 Video Elementary Stream Editing Information

SMPTE RP 202-2000, Video Alignment for MPEG-2 Coding

ISO/IEC 13818-2:2000, Information Technology — Generic Coding of Moving Pictures and Associated Audio Information: Video

ITU-R BT.601-5 (10/95), Studio Encoding Parameters of Digital Television for Standard 4:3 and Wide-Screen 16:9 Aspect Ratios

ITU-R BT.709-4 (09/00), Parameter Values for the HDTV Standards for Production and International Programme Exchange

ITU-R BT.1358 (02/98), Studio Parameters of 625 and 525 Line Progressive Scan Television Systems

## 3 Application

The flexibility of MPEG-2 compression allows MPEG-2-based equipment to meet the diverse operational requirements of a broad range of professional television applications. Although some applications might be served by choosing a specific operating point, different users have different constraints and objectives, and may choose different specific operating parameters.

Cognizant of these considerations, this practice specifies the following:

– Operating ranges including constrained bit rates and group-of-pictures (GoP) structures;

– Operating ranges created for random access and editing capability;

– Spatial alignment of coded images;

– Use of 48-kHz sampled digital audio.

This practice, in conjunction with documents specified in annex C, describe parameter choices available in MPEG-2 and the factors to be taken into account when defining an MPEG-2-based system. Specific operating parameter choices will depend on the individual application requirements, including editing capability, storage capacity, contribution feeds, and distribution/emission bandwidth.

In making this selection for a given application environment, it is further recognized that tradeoffs among many different parameters must be considered. Such considerations include the bitstream overhead imposed by various operating range constraints, the required degree of bitstream interoperability among various types of broadcast equipment, and overall system complexity.

Additional information about system interoperability is given in annex B.

For audio, no single worldwide compressed standard has been adopted; various transmission systems are in use depending upon geographic area. Global audio interchange can, therefore, only be achieved by specifying a noncompressed audio format.

## 4 MPEG-2 video parameters

### 4.1 Operating ranges

Within professional applications of MPEG-2, including the HDTV extensions to MPEG-2 as defined by SMPTE 308M, five operating ranges are defined in this clause as shown in figure 1. Separate long- and short-GoP ranges are defined for both main level and high level systems. Additional operating ranges may be added as required to meet future HDTV requirements.

Operating ranges 1 and 2 cover the MPEG-2 4:2:2P@ML options including the standard 525-line and 625-line SDTV formats.

Operating ranges 3 and 4 cover the MPEG-2 4:2:2@HL including:

480-line progressive scan
576-line progressive scan
720-line progressive scan
1080-line interlaced scan
1080-line progressive scan (up to 30-Hz frame rate)

Net bit rates specified for each operating range are maximum video bit rates and shall include all data that are included in video buffer verifier (VBV) calculation.

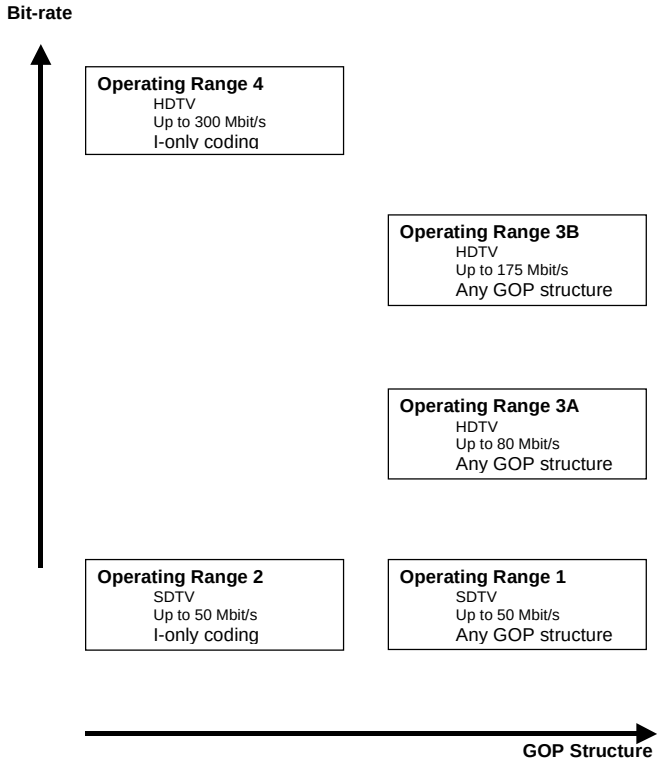


**Figure 1 – SMPTE operating ranges**

#### 4.1.1 Operating range 1 (SDTV — Any GoP)

Operating range 1 covers SDTV coded at up to 50 Mbit/s and may use temporal predictive coding.

For GoP structures greater than one, future equipment designs should conform to this operating range. This will facilitate bitstream interchange over the full range of MPEG-2 main level compliant equipment. (See note below.)

#### 4.1.2 Operating range 2 (SDTV — I-only)

Operating range 2 covers SDTV coded at up to 50 Mbit/s, using no temporal predictive coding. For this operating range, an encoder rate control should ensure that no frame exceeds a limit of 50 Mbit/s divided by the number of frames per second. For example, at 29.97 I-frames per second, no frame may have more than 1,668,328 bits net data or, at 25 I-frames per second, no frame may have more than 2,000,000 bits net data.

For SD I-frame-only applications, future equipment designs should conform to this operating range. When coupled with the bitstream constraints defined in 4.4, this will facilitate bitstream interchange over the full range of MPEG-2 main level compliant equipment. (See note below.)

#### 4.1.3 Operating ranges 3A and 3B (HDTV — Any GoP)

Operating range 3A covers HDTV coded at up to 80 Mbit/s, and may use temporal predictive coding.

Operating range 3B covers HDTV coded at up to 175 Mbit/s, and may use temporal predictive coding. (See note below.)

#### 4.1.4 Operating range 4 (HDTV — I-only)

Operating range 4 covers HDTV coded at up to 300 Mbit/s, using no temporal predictive coding. For this operating range, an encoder rate control should ensure that no frame exceeds a limit of 300 Mbit/s divided by the number of frames per second. For example, at 29.97 I-frames per second, no frame shall have more than 10,010,000 bits net data.

For HD I-frame-only applications, future equipment designs should conform to this operating range. When coupled with the bitstream constraints defined in 4.4, this will facilitate bitstream interchange over the full range of MPEG-2 compliant equipment.

NOTE – No lower bit rate limit is specified in ISO/IEC 13818-2. Please refer to this standard for the precise details.

#### 4.1.5 Relationships among operating ranges

Relationships among different operating ranges are illustrated in figure 2.

Operating range 2 is a subset of operating ranges 1 and 4. Operating range 1 is a subset of operating ranges 3A and 3B. Operating range 3A is a subset of operating range 3B.

### 4.2 Compatibility with ISO/IEC 13818-2

For all operating ranges, the MPEG buffer model defined in ISO/IEC 13818-2 (MPEG-2) shall be respected. The bit rates specified are all maximum bit rates, and shall include all data that are included in the MPEG-2 buffer (VBV) calculation.

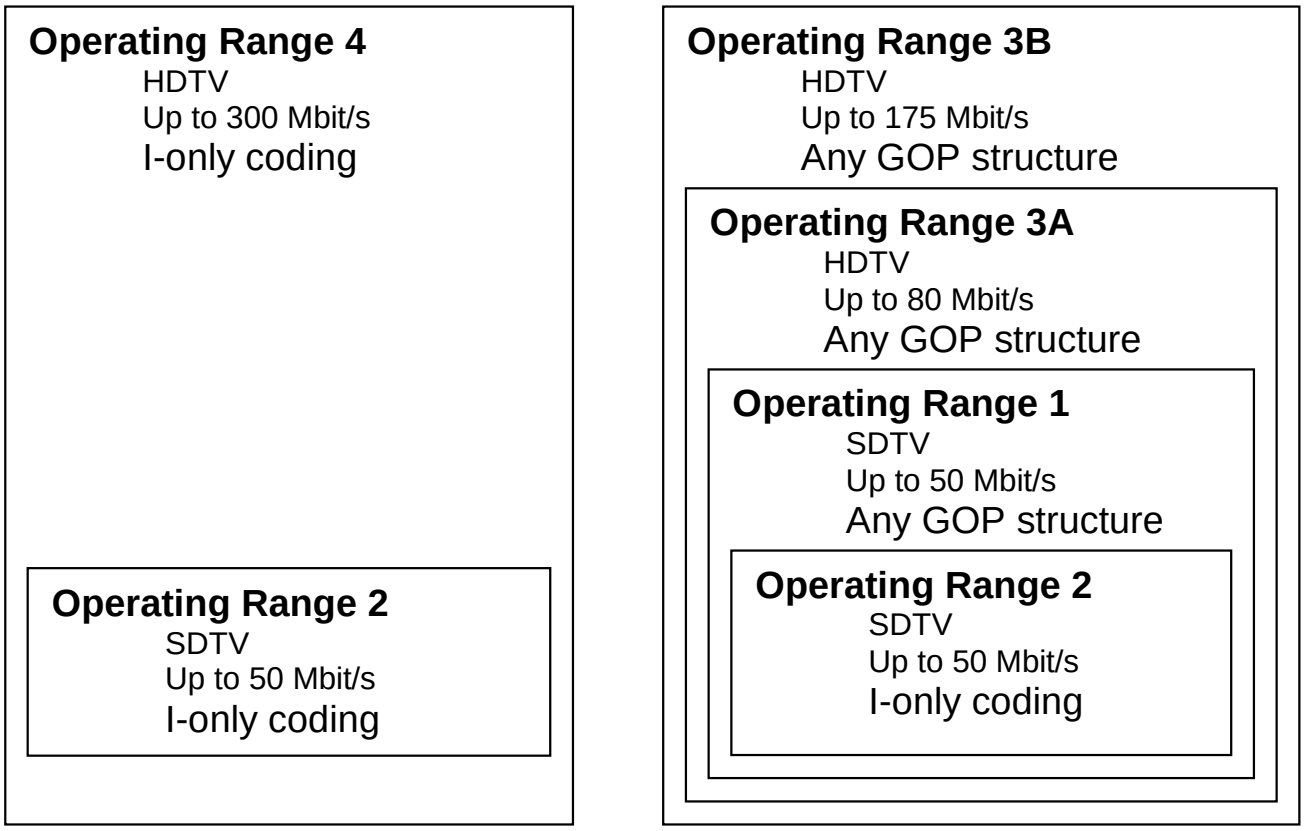


**Figure 2 – Relationships among operating ranges**

For operating ranges 2 and 4 using I-only GoP structure, the video elementary stream is also constrained such that no frame exceeds the additional limits specified in 4.1.2 and 4.1.4.

Devices operating in operating ranges 2 and 4 may have constraints that preclude processing a VBR input directly. For interoperability in the case that a CBR device cannot process a VBR input, that CBR device should pad the incoming VBR signal up to the appropriate maximum bit rate. If any constant bit rate device has inserted such padding, it should remove this padding at its interoperable output interface (see annex A for further details).

NOTE – ISO/IEC 13818-2 treats constant bit rate (CBR) systems to be a constrained version of variable bit rate (VBR) systems; consequently, all systems specified by this practice should be capable of interoperation within a VBR environment.

### 4.3 Spatial alignment of coded image

To ensure optimal multigeneration picture performance, the spatial alignment of coded images specified in SMPTE RP 202 should be applied to both MPEG-2 encoders and decoders.

### 4.4 MPEG bitstream parameters

Operating ranges 2 and 4 are primarily defined to facilitate bitstream interchange within an I-frame-only MPEG-2 VTR (video tape recorder) environment. The key requirements of such recorders are listed below:

– A fixed number of coded bits (bytes) per I-frame;

– To allow random access features, similar to those available on analog VTRs, some additional constraints are required as follows:

  – A defined slice structure;
  – The repeat of sequence headers on each frame;
  – The repeat of nondefault quantization tables on each frame;

– In addition, to facilitate the conversion of elementary streams to transport streams, an accurate vbv_delay value should be carried in the video elementary stream. The value of 0xffff (i.e., variable bit rate) is not allowed. The vbv_delay value may be relied on for remultiplexing elementary streams into transport streams.

SMPTE 356M is an example of an operating range 2 compression system for an MPEG-2 VTR.

## 5 Audio interchange

For audio, no single worldwide compressed standard has been adopted; various transmission systems are in use depending upon geographic area. Global interchange can, therefore, only be achieved by specifying a noncompressed audio format.

All equipment should, at minimum, support the use of two AES/EBU audio data streams (four audio channels) of 16-bit minimum resolution plus VUC bits. It is recommended that these audio data streams be limited to 48-kHz sampling.

## **Annex A** (informative)
## Variable bit rate and constant bit rate

Some devices have a great deal of flexibility to deal with bursts of data, as might happen when coding a difficult video scene. These devices use variable data rate by increasing data rates when necessary to preserve quality, and decreasing data rates with easier content to improve efficiency. These devices, therefore, are sometimes referred to as providing constant-quality operation.

Other devices inherently operate with data rate constrained to a constant value. When data rate is fixed, there will be some picture quality variation, which will be a function of the picture complexity. If data rates are sufficiently high, these variations can be imperceptible. The ease of processing constant bit rate streams is, therefore, attractive in some applications.

Regardless of the type of compression (VBR or CBR), all practical systems need some limits on allowable bit rate variations. To address this, MPEG-2 specifies a buffer model for both compression and transport. It is the responsibility of the compression encoder to manage the data rate, through varying quantization granularity, to avoid buffer overflow or underflow.

Perhaps the most familiar example of VBR implementation is DVD, where storage efficiency is especially critical. The average bit rate on a DVD is around 4.8 Mbit/s while the peak rate may be 9.8 Mbit/s. Professional television equipment has used both VBR and CBR; VBR is popular with some disk recorders, while CBR compression has generally been used on tape and in some editing disk recorders.

With clear applications for both VBR and CBR in the professional domain, this practice facilitates an approach to interconnect VBR and CBR components in a system. This approach is based on an interface in which VBR signals are padded up to CBR by those devices which must use CBR processing, then the padding is removed when returning to a VBR environment.

## **Annex B** (informative)
## **Interoperability**

There is confusion in the minds of many people who use systems about the interoperability between system components. One of the reasons for this is that the degree of interoperability varies in different situations.

This is a recommended approach to creating a common language that allows users and providers to understand more clearly what is meant by interoperability.

The idea behind the approach is to define four levels of interoperability. These levels bear a resemblance to the OSI model in that the lower level of interoperability is about interoperation at the physical layer and the link layer, the middle level is about interoperation at the transport layer, and the highest level of interoperation is about interoperation at the presentation and application layers. This approach assumes that interoperability is about the interconnection of a sender and a receiver connected by a transport mechanism. Thus, levels of interoperability may be changed by altering the capabilities of any of the three components.

**Interoperability level 1 — Communication level**

This is the lowest level. If equipment is interoperable at this level, then that equipment can communicate but is not able to understand the internal content of the file. An example of operation at this level is FTP of files, where servers are used as a store of files.

**Interoperability level 2 — Structure level**

Interoperability at level 2 requires that equipment communicate at level 1 and in addition understand the internal structure of the signal.

– Thus, signals can be passed between devices but need to be interoperable at level 2 in order to be able to process the signals. Examples are: SDTI SMPTE 305.2M, SDI ITU-R BT.656, ATM, etc.

– For example, if two VTRs are connected in a record/playback configuration, and the record machine displays an error message to say that it had an incoming signal but cannot record it, then these machines are regarded as being interoperable at level 2. (The machines can understand that a signal is arriving but it is of a format that the record machine cannot handle.)

**Interoperability level 3 — File and stream level**

Equipment operating at this level can understand and process essence and parse data, but there may be distortions in the essence or some of the data may not be understood fully or not map onto the receiving equipment's data structures.

Thus, for example, when a file is transferred from word processor A to word processor B, the result is that all the text is readable and imported. However, often the drawings do not come out correctly and there are errors in the layout. The interconnection is, therefore, a level 3 connection.

In the broadcast world, in order to achieve interoperation at level 3, equipment must understand detailed information about the bit structure of the essence, packetization structures, and file formats that are used to convey essence and metadata. Examples are: SDTI-CP, DV DIF blocks, MXF.

**Interoperability level 4 — Signal level**

Level 4 interoperability is achieved when all the essence and metadata are available to be used.

In order to understand this level, it is easiest to introduce the concept of the value of a signal or data. This is an adaptation of standard economic concepts. As a signal undergoes processing, work is put into the essence and the metadata thus sorting and developing the information communicated by the signal. It is said that the value of the signal is increased. However, if a signal is processed in a way that reduces its appeal to the intended end-user, for example, distorted through the application of compression, then it is said that the value of the signal is decreased.

For equipment to be interoperable at this level, all essence and metadata must be handled in a way that does not diminish their value after allowance has been made for any value added by the processing within the unit.

This level is therefore most applicable to the essence. Every broadcasting organization has an intrinsic view of the minimum quality that it requires, an important component of the value, and therefore needs to understand the quality delivered by connecting two items of equipment. Thus for an organization to regard equipment as interoperable at level 4, that equipment must be

capable of delivering the organization's minimum quality. Within this level, standards are applied which define the signal generation (e.g., ITU-R BT.601) as well as encoding and decoding algorithms for compression. This level also includes the definitions of metadata and data essence types.

It is recognized that levels 1, 2, and 3 are easier to confirm than level 4. However, the user group agrees that level 4 is the area that causes most of the difficulty when building systems and therefore must be part of a user requirement.

This practice is located in interoperability levels 1 and 2.

In order to meet the requirement for a minimum predictable picture quality and to guarantee full interoperability through a chain of different equipment, specifications may be required which are located in interoperability level 4 as well as levels 3, 2, and 1.

## **Annex C** (informative)
## **Overview and bibliography of related documents**

### C.1 Related documents

The relationships among the related documents are shown in figure C.1.

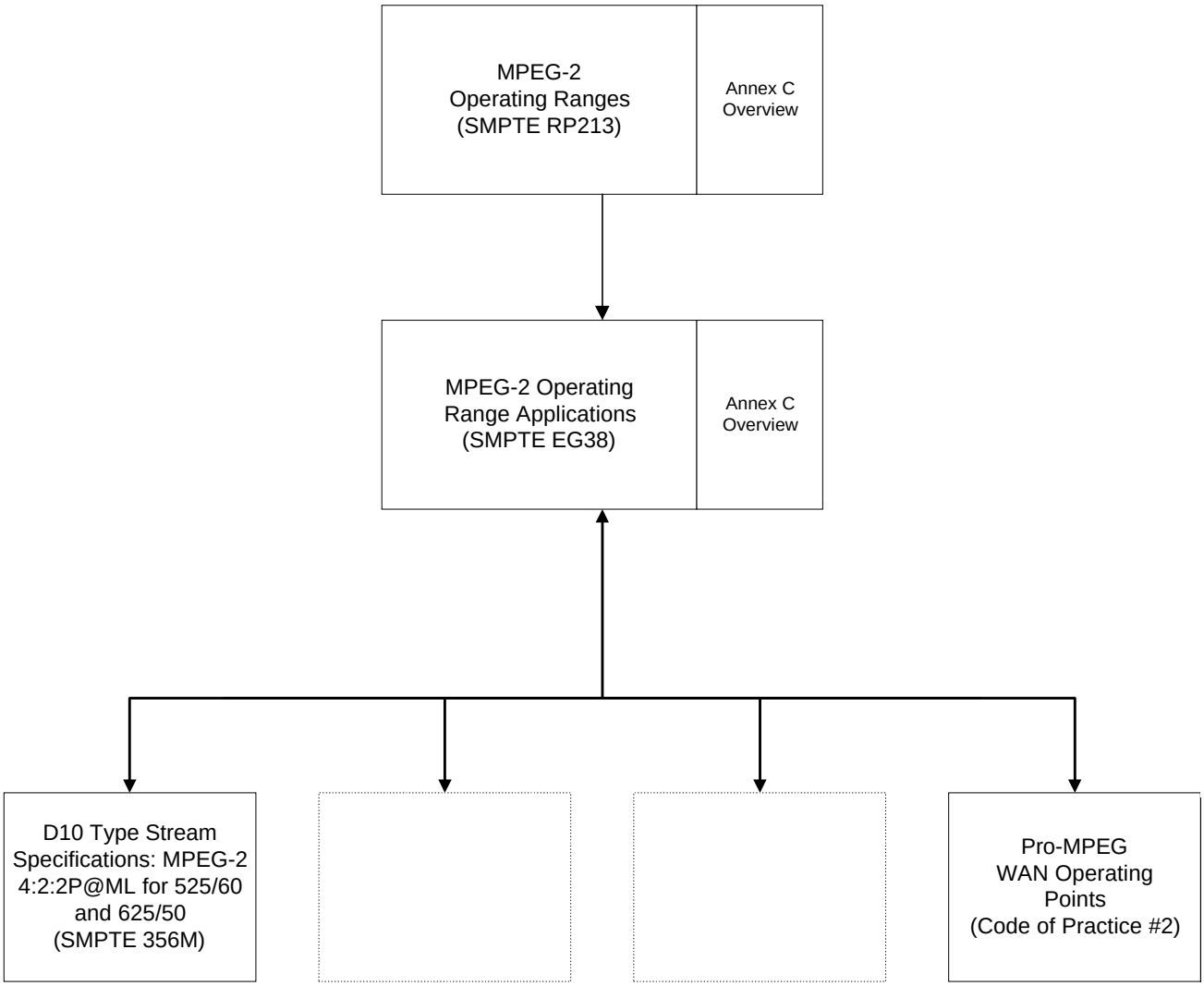


**Figure C.1 – Related documents**

### C.2 Bibliography

SMPTE 305.2M-2000, Television — Serial Data Transport Interface (SDTI)

SMPTE 356M-2001, Television — Type D-10 Stream Specifications — MPEG-2 4:2:2P@ML for 525/60 and 625/50

SMPTE EG 38-2001, MPEG-2 Operating Range Applications

Pro-MPEG Code of Practice #2, May 2000, WAN Operating Points

EBU D89-2000, Quality and Interoperability in a 625/50 Digital Television Production Environment using MPEG Compression

EBU/SMPTE Task Force for Harmonized Standards for the Exchange of Program Material as Bitstreams, Final Report: Analyses and Results, July 1998, SMPTE J.107(9): 603-815; 1998 September

ITU-R BT.656-4 (02/98), Interfaces for Digital Component Video Signals in 525-Line and 625-Line Television Systems Operating at the 4:2:2 Level of Recommendation ITU-R BT.601 (Part A)