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Digital Video Subcommittee

SCTE STANDARD

SCTE 127 2019

Carriage of Vertical Blanking Interval (VBI) Data in North American Digital Television Bitstreams

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1 Scope

This document is identical to SCTE 127 2007 except for informative components which may have been updated such as the title page, NOTICE text, headers and footers. No normative changes have been made to this document.

This document specifies a mechanism for transporting analog vertical blanking interval (VBI) information in compressed digital television bitstreams that use the MPEG-2 Transport Stream format. The VBI data so conveyed is intended to be used to generate the appropriate waveforms for insertion into the VBI of SMPTE 170M (NTSC) video output, or acted upon directly by a receiving device. This mechanism is independent of the coding layer and therefore may be used for any coding technology where carriage in an MPEG-2 PES packet format has been defined (e.g., MPEG-2 Video, MPEG-4 AVC, or SMPTE VC-1).

This design is intended to address the carriage of legacy analog VBI in digital devices such as video encoders, consumer decoders (set-top boxes and televisions), and edge decoders. It is constrained to the output video format of NTSC. However, this does not preclude the carriage in combination with other intermediate video formats or frame rates (which may be present as a result of video format conversion by an encoder).

This document extends the syntax and semantics of ETSI EN 300 472 [2] and ETSI EN 300 468 [3]. It adds data formats in the private data code point space.

This document does not define the carriage of CEA-608 Line 21 Services, CEA-708 DTV Closed Captioning, or generic analog VBI waveforms. For Cable Television systems, refer to ANSI/SCTE 20 [9] (legacy closed captions) and ANSI/SCTE 21 [10] (closed captions and Luma PAM waveform). For ATSC terrestrial broadcasting systems, refer to ATSC A/53, Part 4 [16].

2 Normative References

The following documents contain provisions, which, through reference in this text, constitute provisions of this standard. At the time of subcommittee approval, the editions indicated were valid. All standards are subject to revision, and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the documents listed below.

2.1 Standards from Other Organizations

1. ISO/IEC 13818-1:2000, Coding of moving video and associated audio – Part 1: Systems [MPEG-2 Systems]
2. ETSI EN 300 472 v1.3.1 (2003-01), Digital Video Broadcasting (DVB); Specification for conveying ITU-R System B Teletext in DVB bitstreams
3. ETSI EN 300 468 v1.7.1 2006-05, Digital Video Broadcasting (DVB); Specification for Service Information (SI) in DVB systems
4. SMPTE 170M:2004, Composite Analog Video Signal – NTSC for Studio Applications
5. SMPTE 12M:2002, Time and Control Code
6. CEA-516:1988, North American Basic Teletext Specification (NABTS)

7. CEA-2020:2006, Other VBI Waveforms
8. IEC 61880, Video systems (525/60) – Video and accompanied data using the vertical blanking interval – Analogue interface

3 Informative References

The following documents may provide valuable information to the reader, but are not required when complying with this standard.

3.1 SCTE References

9. ANSI/SCTE 21 2004 Carriage of NTSC VBI Data in Cable Digital Transport Streams
10. ANSI/SCTE 20 2006 Methods for Carriage of Closed Captions and Non-Real Time Sampled Video

3.2 Standards from Other Organizations

11. ETSI EN 301 775 v1.2.1 (2003-05) Digital Video Broadcasting (DVB); Specification for the carriage of Vertical Blanking Information (VBI) data in DVB bitstreams
12. SMPTE RP164:1996 Location of Vertical Interval Time Code
13. EBU Tech 3097-E EBU Time-and-Control Code for television tape-recordings (625-line television systems)
14. SMPTE 125M-1995 Component Video Signal 4:2:2 – Bit-Parallel Digital Interface
15. ITU-R BT.653 Teletext Systems," System C"
16. = ATSC A/53 Part 4:2007, ATSC Digital Television Standard, Part 4 – MPEG-2 Video System Characteristics

4 Compliance Notation

"SHALL"	This word or the adjective "REQUIRED" means that the item is an absolute requirement of this specification.
"SHALL NOT"	This phrase means that the item is an absolute prohibition of this specification.
"SHOULD"	This word or the adjective "RECOMMENDED" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
"SHOULD NOT"	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
"MAY"	This word or the adjective "OPTIONAL" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

5 General

5.1 Introduction (Informative)

The VBI data transferred through the mechanism described in this document is intended to be transcoded into the VBI of a companion video channel within an MPEG-2 Transport Stream. However, it also is possible to transmit and transcode a VBI data stream on its own, without a companion video channel. In addition it is possible for a decoder to interpret the data directly, without any intermediate transcoding into the VBI.

The transmission means is generally based on ETSI EN 300 472 [2]. The data transfer uses the private PES packet mechanism of type private_stream_1 as defined by ISO/IEC 13818-1 [1]. Compatibility is intended with the syntax of ETSI EN 301 775 [11], but not support for the specific payloads.

5.2 Constraints

VBI data carried as PES packets as defined here may be either asynchronous (i.e., no synchronization to specific video frames) or synchronized to specific frames of video. The VBI encoding and decoding can therefore be synchronized with the companion video channel, if one is present. When synchronized, PTS samples shall be carried within each PES packet according to ISO/IEC 13818-1 [1]. For more information on the timing and buffer model, see Section 8.

The VBI data stream associated with a service is identified in the Program Map Table (PMT) of the Program Specific Information (PSI) for that service. This mechanism is described in Section 6.
The following restrictions shall apply to the coding of VBI data as described in the present document:

- The VBI PES packets associated with a particular Program shall be carried in a single elementary stream, using a uniquely assigned PID value not used by any other Program Element associated with the same Program.
- A VBI PES packet shall contain data of one and only one video frame.
- VBI data present for a certain line within a certain field shall apply only to that field and line. If the VBI data is intended for other lines or subsequent fields, it shall be coded explicitly for each field and line so intended.
- VBI lines shall be ordered in the PES_data_field structure loop in the same line order as they appeared in the incoming video.
- A given VBI line shall not be coded twice within a given picture field. A line (within a field) shall be coded using one and only one VBI data_field.
- The buffer model defined in Section 8 shall be used. If VBI service types other than those defined in Table 1 and Table 3 are included in this VBI data stream, then they also shall comply with the timing and buffer model defined in Section 8.
- The adaptation_field_control value (as constrained in 300 472 [2]) shall be either "01" or "10". The values "00" and "11" shall not be used.
- Adaptation fields, when present, shall not contain a PCR. Thus, the PMT PCR_PID field shall not be set to a PID value containing this stream.

6 Definition of PSI for extended VBI data streams

The PSI shall conform to the requirements for the VBI_data_descriptor as defined in clause 6.2.46 of ETSI EN 300 468 [3], including the provision that the VBI_data_descriptor shall be used in the program map section of a stream which carries a VBI data_field defined in this document. The appropriate ES_info descriptor loop of the program map section describing a VBI data stream shall contain one and only one VBI_data_descriptor.

As defined in Table 12 in ETSI EN 300 468, the descriptor_tag shall be 0x45.

6.1 VBI_data_descriptor extensions

The syntax and semantics for the VBI_data_descriptor shall be as defined in Table 96 of ETSI EN 300 468 [3]. Although Table 97 of ETSI EN 300 468 defines data_service_id values for several VBI service types, these service types shall not be included in a descriptor signaling this VBI PES payload. Instead, the list of new values is defined in Table 1.

6.1.1 Data Service Identifier extensions

For VBI service types defined in this document, the following table of values shall be used:

Table 1 : data_service_id values for VBI_data_descriptor

data_service_id	**Description (VBI service type)**
0xFF	reserved for future use
0xFE	AMOL 48 / 96
0xFD	Protected 1 (note 1)
0xFC	North American Basic Teletext Specification (NABTS)
0xFB	TVG2X
0xFA	Protected 2 (note 1)
0xF9	Copy Protection
0xF8	Protected 3 (note 1)
0xF7	Vertical Interval Time Code (VITC)
0x80.. 0xF6	reserved for future use
0x00 – 0x7F	reserved by DVB

Note 1: Code points 0xFD, 0xFA, 0xF8 are in use by legacy equipment and are not defined by this standard.

7 PES packet format

The PES packet format shall be as defined in ETSI EN 300 472 [2], sections 4 through 4.3, and as more fully defined here.

7.1 Definition of PES data field

The data_unit_id shall be as defined in Table 3.

7.1.1 Syntax for the extended PES data field

The full syntax for the PES packet is shown in Table 2 below. The shaded areas are the syntax defined in ETSI EN 300 472 [2].

Table 2: Syntax for the extended PES_data_field

Syntax	No. of bits	Mnem.	Description
PES_data_field () {			
data_identifier	8	uimsbf	See EN 300 472
for (I = 0; i < N; i++) {			
data_unit_id	8	uimsbf	See EN 300 472
data_unit_length	8	uimsbf	0x00 .. 0xFF
} if (data_unit_id == 0xD0) {			
amol48_data_field ();			
} else if (data_unit_id == 0xD1) {			
amol96_data_field ();			
} else if (data_unit_id == 0xD5) {			
nabts_data_field ();			
} else if (data_unit_id == 0xD6) {			
tvg2x_data_field ();			
} else if (data_unit_id == 0xD7) {			
cp_data_field();			
} else if (data_unit_id == 0xD9) {			
vitc_data_field ();			
} else if (data_unit_id == 0xFF) {			See EN 300 472
/* No data field */			
}			
for (i = 0; i < N; i++) {			
stuffing_byte	8	bslbf	'11111111'
}			
}			
}			

7.1.2 Data Identifier

The value of data_identifier shall be 0x99 (as also defined in Table 2 of ETSI EN 301 775 [11]).

7.1.3 Data Unit Identifier extensions

The following table defines the data_unit_id values for this specification:

Table 3 : data_unit_id values

data_unit_id	Value
0x00 to 0xC6	reserved by DVB
0xC7 to 0xCF	user defined
0xD0	AMOL48
0xD1	AMOL96
0xD2	reserved for future use
0xD3	Protected 1 (note1)
0xD4	Protected 2 (note1)
0xD5	NABTS
0xD6	TVG2X
0xD7	Copy Protection
0xD8	Protected 3 (note1)
0xD9	VITC
0xDA to 0xE5	reserved for future use
0xE6 to 0xFE	user defined
0xFF	stuffing

Note 1: Code points 0xD3, 0xD4, 0xD8 are in use by legacy equipment and are not defined by this standard.

7.1.4 Method of Calculating line_offset and field_parity from line_number

In the VBI data_field structures defined in the subsequent Sections, the line_number values shall be per Figure 7 of SMPTE 170M [4]. The method of calculating values for field_offset and field_parity shall be:

```
IF (line_number) > 263
THEN
    {field_parity = 0; line_offset = line_number – 263}
ELSE
    {field_parity = 1; line_offset = line_number}
```

7.2 AMOL48 PES data field

Table 4: Syntax of the amol48_data_field

Syntax	No. of bits	Mnem	Description
amol48_data_field() {			
reserved_future_use	2	bslbf	‘11’
field_parity	1	bslbf	‘0’, ‘1’
line_offset	5	uimsbf	10 – 22, inclusive
amol48_data_block	41	bslbf	
Trailer	7	bslbf	‘0000000’
}			

Semantics for the amol48_data_field

amol48_data_block: this field corresponds to the 41 bits following the 7-bit start-of-message header of the AMOL-48 waveform, as defined in CEA-2020 [7].

Data packets are inserted in the same order as they are intended to arrive at the AMOL decoder or to be transcoded into the VBI. Data bits are inserted in the PES packet in the same order as they would appear in the VBI.

7.3 AMOL96 PES data field

Table 5: Syntax of the amol96_data_field

Syntax	No. of bits	Mnem	Description
amol96_data_field() {			
reserved_future_use	2	bslbf	'11'
field_parity	1	bslbf	'0', '1'
line_offset	5	uimsbf	10 – 22, inclusive
amol96_data_block	88	bslbf	
}			

Semantics for the amol96_data_field

amol96_data_block: this field corresponds to the 88 bits following the 8-bit start-of-message header of the AMOL-96 waveform, as defined in CEA-2020 [7].

Data packets are inserted in the same order as they are intended to arrive at the AMOL decoder or to be transcoded into the VBI. Data bits are inserted in the PES packet in the same order as they would appear in the VBI.

7.4 NABTS PES data field

Table 6: Syntax of the nabts_data_field

Syntax	No. of bits	Mnem.	Description
nabts_data_field) {			
reserved_future_use	2	bslbf	'11'
field_parity	1	bslbf	'0', '1'
line_offset	5	uimsbf	10 – 22, inclusive
framing_code	8	bslbf	'11100111'
nabts_data_block	264	bslbf	
}			

Semantics for the nabts_data_field

nabts_data_block: this 264-bit field corresponds to the 33 bytes following the clock-run-in and framing-code sequence of an NABTS data packet, as defined in CEA-516 [6]. See also ITU-R BT.653-x System C [15]. The nabts_data_block shall only be encoded with the Data Packet structure of CEA-516 [6]. Data bits shall be inserted in the same order as they appear in the VBI.

7.5 TVG2X PES data field

Table 7: Syntax of the TVG2X_data_field

Syntax	No. of bits	Mnem	Description
TVG2X_data_field() {			
reserved_future_use	2	bslbf	‘11’
field_parity	1	bslbf	‘0’, ‘1’
line_offset	5	uimsbf	10 – 22, inclusive
TVG2X_data_block	32	bslbf	
}			

Semantics for the TVG2X_data_field

TVG2X_data_block: this field corresponds to the 32 active data bits following the clock run-in and framing code of the TVG2X waveform, as defined in CEA 2020 [7]. Data bits are inserted in the PES packet in the same order as they appear in the VBI.

7.6 VITC PES data field

Table 8: Syntax of the vitc_data_field

Syntax	No. of bits	Mnem	Description
vitc_data_field() {			
reserved_future_use	2	bslbf	‘11’
field_parity	1	bslbf	‘0’, ‘1’
line_offset	5	uimsbf	14 – 22, inclusive
vitc_data_block	64	bslbf	(CRC word and sync bits are not transmitted. MSB first for the data)
}			

Semantics for the vitc_data_field

vitc_data_block: this field corresponds to the 64 active data bits (excluding the sync bits), as defined in SMPTE 12M [5]. See also SMPTE RP164 [12] and EBU Tech 3097 [13]. Bit number 9 of the timecode shall be mapped into the MSB of the vitc_data_block. The CRC and the VITC sync bits shall not be transmitted.

7.7 Copy Protection

Table 9: Syntax of the cp_data_field

Syntax	No. of bits	Mnem	Description
cp_data_field() {			
reserved_future_use	2	bslbf	‘11’
field_parity	1	bslbf	‘0’, ‘1’
line_offset	5	uimsbf	20
cp_data_block	2	bslbf	
reserved	6	bslbf	'111111'
}			

Semantics for the cp_data_field

cp_data_block: this field corresponds to bits 7 and 8 as defined in IEC 61880 [8], section B.2. Bit 7 shall be mapped to the MSB of cp_data_block

8 Timing and Buffer Models

For asynchronous VBI streams, decoders should provide a best effort reconstruction, but decoders need not reconstruct accurately or completely. No buffer model exists for asynchronous operation.

Synchronized VBI streams are accomplished by the inclusion of DTS and PTS timestamps in the MPEG-2 PES packet header. See Section 5.2. PES packets with PTS, when used, shall be conveyed in the bitstream in presentation order (i.e., not video encoded frame order) and, therefore, shall be monotonically increasing except for PCR discontinuities. The buffer model for synchronized VBI streams shall be as defined below.

When video is converted during distribution to formats other than NTSC, this VBI encoding shall not be modified and shall retain NTSC line numbers with appropriate PTS timestamps for 29.97fps. Video conversion of the video to other than 29.97 fps (e.g. 24fps) can result in subsequent synchronization errors downstream.

As provided in ETSI EN 300 472 [2], the PES packet shall be constrained as follows:

- PES_packet_length set to the value (N x 184) – 6, where N is an integer, so that the PES packet finishes at the end of a Transport Stream packet.
- data_alignment_indicator set to ‘1’ indicating that access units are aligned with the PES packets.
- PES_header_data_length set to 0x24.
- The PES packet header is followed by as many stuffing bytes as are required to make up the header data length, so that the entire PES packet header is 45 bytes long.

8.1 Buffer Model

This is the Transport System Target Decoder (T-STD) model for carrying this encoded analog VBI data intended for NTSC systems. This buffer model does not apply to:

- Other uses – for example, the carriage of non-analog-VBI data such as CEA-708 digital closed captioning or new applications.

- Video formats other than NTSC – for example, 24fps 3:2 pull-down

Note: This buffer model is not the same as the teletext decoder model in clause 5 of ETSI EN 300 472 [2].

The buffer model block diagram is shown in Figure 1 below. Refer to Figure 2 and ISO/IEC 13818-1:2000 [1], clause 2.4.2 for context within the complete Transport Stream. Figure 2 shows the concept of an ith byte from the Transport Stream being selected for processing as shown in Figure 1.

All the bytes of the Transport Stream packets whose payload contains the PES packets of this specification shall be modeled as transferred into TB_m on receipt. All properties of TB_m shall be identical to TB_n defined in [1]. As provided in [1], the size of TB_m is therefore 512 bytes.

The maximum number of lines, MaxLines, supported for any given access unit (frame of video containing two fields) shall enable simultaneous encoding of data on both fields of all VBI lines (10-22), and therefore shall be 26. This is the upper bound of l.

The maximum per line payload size, LS_l, shall be constrained to the NABTS [10] payload, of 35 bytes. Therefore, LS_l shall be 37 bytes, including the data_unit_id, data_unit_length fields.

The total PES packet payload size per frame shall be (MaxLines * LS_l) + 1[1] = 963 bytes. Therefore, the maximum PES packet size is 963 + 45 = 1008 bytes. This requires a maximum of 6 integral Transport Stream packets, or a maximum of 1128 bytes total, including any necessary stuffing. Since this is for NTSC only, the FrameRate is 30*1000/1001 = 29.97 fps. Finally, the maximum average bitrate, MaxRate, for a Program Element containing the PES packets of [1] shall not, therefore, exceed 8 * 1128 * 29.97 = 270,450 bps.

RX_m is the rate at which data are removed from TB_m and shall be as follows. If TB_m is empty, then RX_m shall be zero, else RX_m = 1.20 x MaxRate = 324,539 bps.

B_m is the access unit assembly buffer and its properties shall be identical to B_n defined in [7], except for its size, BS_m. BS_m shall be twice the size of the maximum packetized size computed above, 2 * 1128 = 2256 bytes.

In summary:

- t(i) is the ith byte of the Transport Stream input (if the PID matches) to TB_m
- TB_m is the transport buffer for the download stream
- TBS_m is the size of TB_m and is set to 512 bytes
- RX_m is the rate data are moved from TB_m to B_m and is 324,539 bps
- B_m is the main buffer for VBI elementary stream m.
- BS_m is the size of buffer, B_m, measured in bytes = 2256.
- $A_m(j)$ is the j-th access unit in elementary stream n. $A_m(j)$ is indexed in decoding order
- $td_m(j)$ is the decoding time, measured in seconds, in the system target decoder of the j-th access unit in elementary stream m.
- $P_m(k)$ is the k-th presentation unit in elementary stream m. $P_m(k)$ results from decoding $A_m(j)$. $P_m(k)$ is indexed in presentation order.

[1] Including data_identifier field.

- $tp_m(k)$ is the presentation time, measured in seconds, in the system target decoder of the k-th presentation unit in elementary stream n.
- $L_m(l)$ is the l-th line data of the presentation unit in elementary stream m. $P_m(k)$ results from decoding $A_m(j)$. $P_m(k)$ is indexed in presentation order.
- $tl_m(l)$ is the presentation time, measured in seconds, in the system target decoder of the l-th line of the k-th presentation unit in elementary stream m.
- L_l is the l-th line buffer.
- LS_l is the size of the l-th line buffer L, or 37 bytes.

All buffers shall not overflow, but all may underflow.

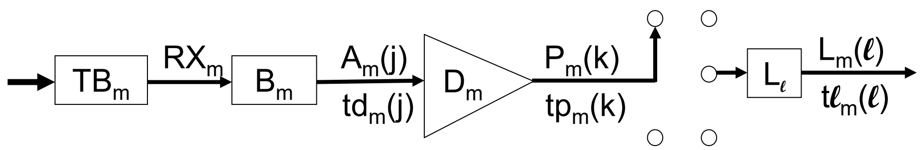

Figure 1: T-STD model

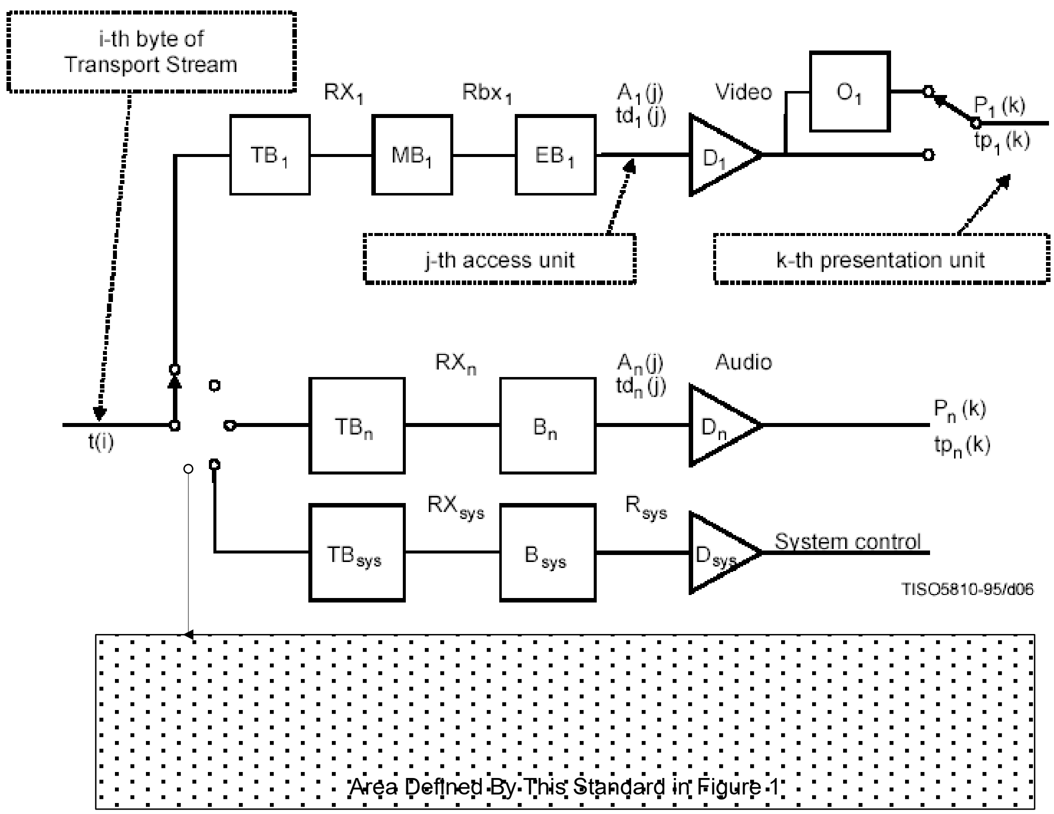

Figure 2: T-STD context (informative)