SMPTE STANDARD

Two-Frame Marker for 48(/1.001)-Hz, 50-Hz, and 60(/1.001)-Hz Progressive Digital Video Signals on 1.5 Gb/s and 3 Gb/s Interfaces

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Foreword

SMPTE (the Society of Motion Picture and Television Engineers) is an internationally-recognized standards developing organization. Headquartered and incorporated in the United States of America, SMPTE has members in over 80 countries on six continents. SMPTE's Engineering Documents, including Standards, Recommended Practices, and Engineering Guidelines, are prepared by SMPTE's Technology Committees. Participation in these Committees is open to all with a bona fide interest in their work. SMPTE cooperates closely with other standards-developing organizations, including ISO, IEC and ITU.

SMPTE Engineering Documents are drafted in accordance with the rules given in its Standards Operations Manual.

SMPTE ST 2051 was prepared by Technology Committee 33TS.

Intellectual Property

At the time of publication no notice had been received by SMPTE claiming patent rights essential to the implementation of this Standard. However, attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. SMPTE shall not be held responsible for identifying any or all such patent rights.

Introduction

This section is informative and does not form an integral part of this Engineering Document.

Problems can arise in video formats of frame rate Fr that transport Fr/2 ancillary data services; 48(/1.001)-Hz, 50-Hz, and 60(/1.001)-Hz progressive video signals are examples of such formats and are the subject of the provisions of this Standard.

There is a 50% chance that a SMPTE RP 168 video switch will cut across the middle of an ancillary data block of length 2Tr = 2/Fr, causing the entire ancillary data block to fail its continuity check, and be dropped. By forcing video switches to have two-frame (frame pair) granularity aligned with the boundaries between the 2Tr-length data blocks of the ancillary data service, this problem can be eliminated.

Other processing functions besides switches may also be dependent on frame pair alignment. These include Ancillary Time Code (ATC), de-interlacing processes that create video distortion with period 2/Fr, and multi-channel audio program material encoded into data blocks spanning 2/Fr and embedded into ancillary data space.

1 Scope

This standard defines a Two-Frame Marker for progressive HDTV video formats at 48/1.001(47.95)-Hz, 48-Hz, 50-Hz, 60/1.001(59.94)-Hz, and 60-Hz frame rates. This Two-Frame Marker is multiplexed into serial streams carrying such a video format to govern the alignment of system actions such as switching to the data block boundaries of embedded ancillary data services having one half the frame rate (Fr/2) compared to the video frame rate (Fr). Requirements for use of this Two-Frame Marker are also defined in this standard.

Note1: Users should be aware that equipment manufactured prior to the publication of this standard typically will not comply with its requirements.

Note2: Use of the Two-Frame Marker is optional with progressive video streams at 48/1.001(47.95)-Hz, 48-Hz, 50-Hz, 60/1.001(59.94)-Hz, and 60-Hz frame rates mapped to interlaced serial interfaces at 24/1.001(23.98)-Hz, 24-Hz, 25-Hz, 30/1.001(29.97)-Hz, and 30-Hz frame rates, respectively.

Note3: Use of the Two-Frame Marker is optional with progressive segmented frame video streams at 24/1.001(23.98)-Hz, 24-Hz, 25-Hz, 30/1.001(29.97)-Hz, and 30-Hz frame rates mapped to interlaced serial interfaces at 24/1.001(23.98)-Hz, 24-Hz, 25-Hz, 30/1.001(29.97)-Hz, and 30-Hz frame rates, respectively.

2 Conformance Notation

Normative text is text that describes elements of the design that are indispensable or contains the conformance language keywords: "shall", "should", or "may". Informative text is text that is potentially helpful to the user, but not indispensable, and can be removed, changed, or added editorially without affecting interoperability. Informative text does not contain any conformance keywords.

All text in this document is, by default, normative, except: the Introduction, any section explicitly labeled as "Informative" or individual paragraphs that start with "Note:”

The keywords "shall" and "shall not" indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.

The keywords, "should" and "should not" indicate that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.

The keywords "may" and "need not" indicate courses of action permissible within the limits of the document.

The keyword “reserved” indicates a provision that is not defined at this time, shall not be used, and may be defined in the future. The keyword “forbidden” indicates “reserved” and in addition indicates that the provision will never be defined in the future.

A conformant implementation according to this document is one that includes all mandatory provisions ("shall") and, if implemented, all recommended provisions ("should") as described. A conformant implementation need not implement optional provisions ("may") and need not implement them as described.

Unless otherwise specified, the order of precedence of the types of normative information in this document shall be as follows: Normative prose shall be the authoritative definition; Tables shall be next; followed by formal languages; then figures; and then any other language forms.

3 Normative References

Note: All references in this document to other SMPTE documents use the current numbering style (e.g. SMPTE ST 274:2008) although, during a transitional phase, the document as published (printed or PDF) may bear an older designation (such as SMPTE 274M-2008). Documents with the same root number (e.g. 274) and publication year (e.g. 2008) are functionally identical.

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

SMPTE ST 12-2:2014, Transmission of Time Code in the Ancillary Data Space

SMPTE ST 274:2008, Television — 1920 x 1080 Image Sample Structure, Digital Representation and Digital Timing Reference Sequences for Multiple Picture Rates

SMPTE ST 291-1:2011, Ancillary Data Packet and Space Formatting

SMPTE ST 296:2012, 1280 x 720 Progressive Image Sample Structure – Analog and Digital Representation and Analog Interface

SMPTE ST 318:1999, Television and Audio — Synchronization of 59.94- or 50-Hz Related Video and Audio Systems in Analog and Digital Areas — Reference Signals

SMPTE ST 337:2008, Format for Non-PCM Audio and Data in an AES3 Serial Digital Audio Interface

SMPTE RP 168:2009, Definition of Vertical Interval Switching Point for Synchronous Video Switching

4 Definitions

4.1
Transcode
To decode a data service from a video stream and encode it into a video stream of a different format.

4.2
ATC
Ancillary Time Code

4.3
Fr
Frame rate in Hz of a video signal.

4.4
Tr
Frame period in seconds of a video signal; equal to 1/Fr.

4.5
Frame Pair
Two time-consecutive frames of a video signal for which there is a first frame and a second frame.

4.6
TFM
Two-Frame Marker; SMPTE ST 291-1-compliant packet containing a flag to identify the first frame and the second frame of a Frame Pair for a 48(/1.001)-Hz, 50-Hz, or 60(/1.001)-Hz progressive digital video signal with frame rate Fr.

4.7
Two-Frame Alignment
The start of the first frame of a progressive video Frame Pair with frame rate Fr is aligned with the start of the first field of an interlaced or progressive segmented frame video signal or the frame start of an ancillary data service having frame rate Fr/2. For Progressive video streams with frame rate Fr mapped to dual link interlace transports having frame rates Fr/2, the start of the first frame of a progressive video Frame Pair with frame rate Fr is aligned with the start of the first field of its interlaced transport.

4.8
Two-Frame-Capable
Equipment that is capable of generating and/or passing the Two-Frame Marker (TFM) in its Fr-frame-rate output video stream(s) so that the TFM, all Fr/2 ancillary data services mapped into the stream, and all Fr/2 reference signals related to the stream are in Two-Frame Alignment.

4.9
Two-Frame Capability
Tense of Two-Frame-Capable.

4.10
PCM
Pulse-Coded Modulation, resulting in digital word representations of linear audio samples.

4.11
Non-PCM Audio
Audio program, possibly multichannel, compressed and formatted for transport per SMPTE ST 337.

4.12
Non-PCM Data Block
Group of audio samples in Non-PCM format temporarily associated with a video frame.

5 Two-Frame Marker Specification and Carriage

5.1 Two-Frame Marker Packet Specification

The Two-Frame Marker shall be a SMPTE ST 291-1 Type 2 formatted packet with the following structure:

The value of the DID shall be 46h. The value of the SDID shall be 01h.

The value of the DC shall be 1.

One byte shall be carried in the user data word of the ancillary data packet.

Bit b0 shall be used to identify the first or second frame of a Frame Pair such that:

b0 = 0 indicates the first frame of the Frame Pair

b0 = 1 indicates the second frame of the Frame Pair

Bits b7 to b1 are reserved and shall be set to 0.

5.2 Placement of the Ancillary Data Packet

The Two-Frame Marker packet shall be placed in the luminance (Y') data stream of the horizontal ancillary data space (HANC) defined by the relevant image formatting document for progressive video formats with 48/1.001, 48, 50, 60/1.001, or 60-Hz frame rate, (SMPTE ST 274 System #1, 2, or 3; or SMPTE ST 296 System #1, 2, or 3, or SMPTE ST 2048-2 System #1 to 5).

The TFM packet shall be inserted into the luminance (Y') data stream of any one line of the horizontal ancillary data space starting from the second line after the line of the switching point defined in RP168, and before the first line of active video. The specific packet location is detected by the receiver searching the horizontal ancillary data space for the DID and SDID codes of the packet.

6 Use of the Two-Frame Marker

6.1 Two-Frame Marker and Two-Frame Capability (Normative)

Equipment meeting the requirements of this standard shall be Two-Frame-Capable, according to the definition in Section 4.

6.2 Conditions for Two-Frame Capability (Normative)

For equipment to be defined as being Two-Frame-Capable, Two-Frame Alignment shall be maintained between the output video stream at frame rate Fr and an interlaced reference signal input at frame rate Fr/2, according to the definition in Section 4. This reference signal can be either a SMPTE ST 318 composite analog video signal, or a tri-level sync signal derived from a SMPTE ST 274 system #4, 5, or 6 digital video stream or from a SMPTE ST 274 or SMPTE ST 2048-2 Progressive Segmented Frame digital video stream.

When multiple data services at frame rate Fr/2 are also transported in the Fr frame rate video stream through Two-Frame-Capable equipment, the first frame shall be the same for all of them.

6.3 Examples of Use of the Two-Frame Marker (Informative)

Figure 1 shows an example of a broadcast video plant carrying progressive video at frame rate **Fr**. A distributed interlaced reference signal at frame rate Fr/2 is used to synchronize all video paths throughout the plant. Two-Frame-Capable equipment is marked with an asterisk (*) in Figure 1.

The interfaces transporting the progressive video may also be transporting various types of ancillary data, per SMPTE ST 291-1 provisions. The following are examples of alignment criteria between the ancillary data and the progressive video stream.

Example: Transport of ATC in ancillary data:

When **ATC** at frame rate Fr/2 is transported in Two-Frame-Capable equipment, the first frame of the output video stream(s) at frame rate Fr carries ATC_VITC1, or the first of two ATC_LTC packets having the same frame count.

Example: Transport of Non-PCM Audio in ancillary data:

When **Non-PCM Audio** at block rate Fr/2 is transported in Two-Frame-Capable equipment, the first frame of the output video stream(s) carries the first half of the Non-PCM Audio data block.

The alignments of ATC and Non-PCM Audio described above, and the alignments defined for other data services at frame rate Fr/2 to video at frame rate Fr, are commonly referred to as Two-Frame Alignment.

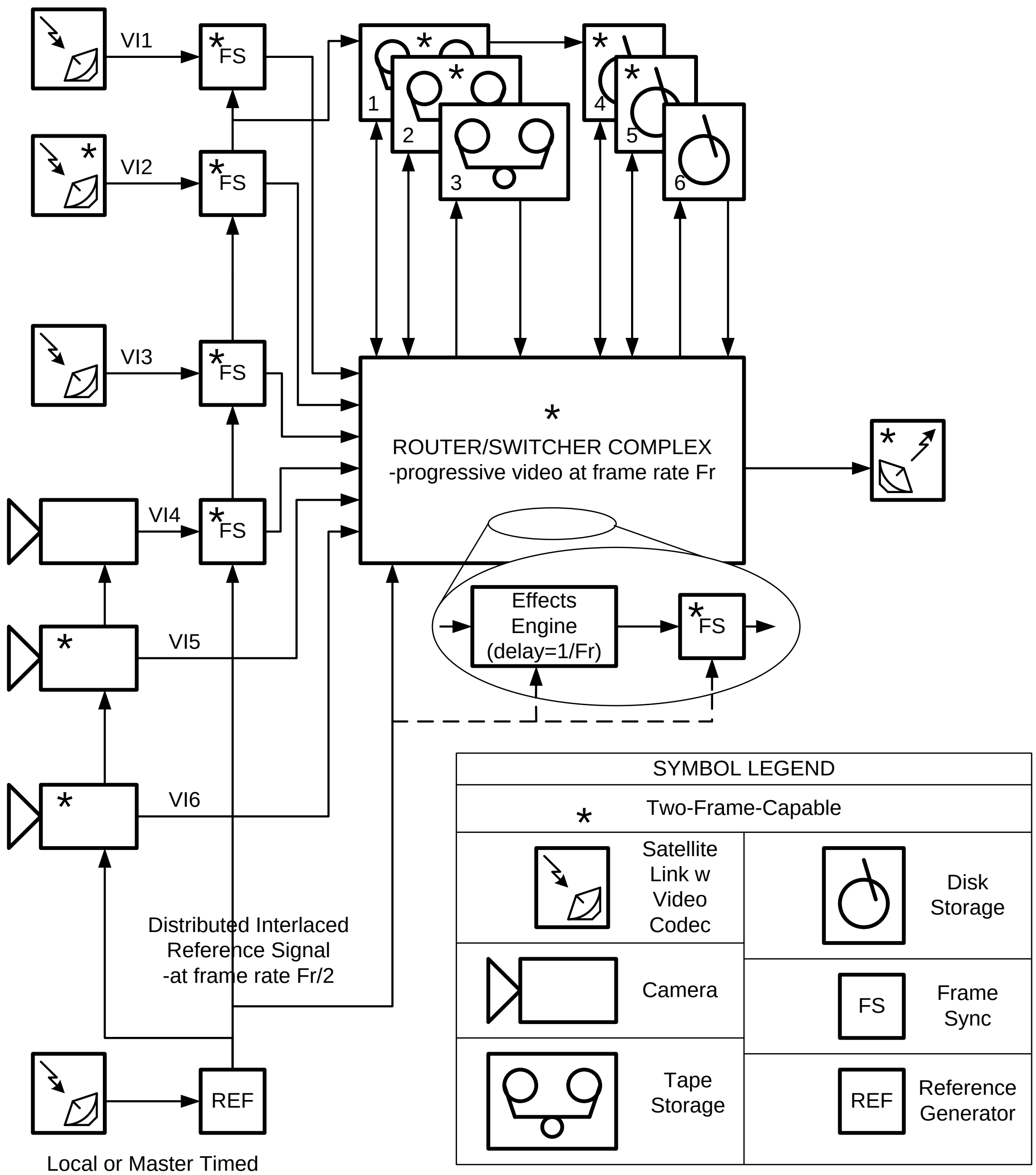

Figure 1 – System Diagram Example of a Two-Frame-Capable Video Plant

6.4 Processing Equipment Actions on Fr/2 Services in Fr Progressive Video (Informative)

Table 1 (informative) lists four video services and signals at frame rate Fr/2 that can potentially be impacted by the state of their synchronization relative to the host progressive video stream at frame rate Fr.

Three of them, ATC, Non-PCM Audio, and the TFM can be present in the input digital video.

The fourth signal in this table is the Reference Signal input at frame rate Fr/2.

It is possible that there may be a conflict in the synchronization state indicated by any one of these four services relative to at least one other. In order to permit resolution of such a conflict, the table shows these four Fr/2 services in a series of pair-priority combinations to indicate which service's synchronization information prevails in each combination. The definition of these priorities is:

> In the case of misalignment between a pair of services, the Priority 2 service is adjusted for Two-Frame-Alignment with the Priority 1 service;
>
> For each priority-pair case, the actions that are taken to ensure Two-Frame Alignment are listed.

Equipment that is to be classified as Two-Frame-Capable performs the automatic actions defined in Table 1.

For priority-pair cases for which there is no automatic action, the system-level action is performed.

The disallowed cases in Table 1 indicate that it is not allowed for ATC binding to the video stream to take priority over both TFM nor for Non-PCM Audio data services to take priority over ATC. It follows that neither Non-PCM Audio nor ATC may take priority over TFM.

The ***automatic actions*** performed by Two-Frame-Capable equipment require no user input. ***System-level actions*** on the other hand are performed according to a policy defined by the end-user to achieve desired behavior. For example, system-level actions may be taken to correct Two-Frame alignment errors over multiple services, or to maintain low system throughput delay.

Equipment is classified as either ***video processing*** or ***video sourcing*** for the purpose of defining Two-Frame-Capability conditions. Video processing equipment can perform spatial and limited temporal changes to the signal while maintaining the same input and output frame rate. The temporal changes are limited to variations in throughput delay.

A tape deck playing back video at the rate it was recorded is a video processing device, where the processing amounts to virtually infinite delay. From the broadcast plant perspective, the communication link comprised of a compression/data-link/decompression system is considered to be video processing equipment.

Table 1 – Processing Equipment Actions on Fr/2 Services in Fr Progressive Video (Informative)

<table>
<tr><th colspan="2">Fr/2 Service Priority-Pairs</th><th colspan="2">Actions* to Achieve Two-Frame Alignment</th></tr>
<tr><th>Priority 1</th><th>Priority 2</th><th>*Automatically Performed by Equipment</th><th>*Performed at the System-Level</th></tr>
<tr><td>Reference Signal</td><td>Non-PCM Audio</td><td rowspan="2">adjust two-frame position by 1/Fr</td><td>delay Non-PCM block-start by 1/Fr</td></tr>
<tr><td>Non-PCM Audio</td><td>Reference Signal</td><td>delay Reference Signal by 1/Fr</td></tr>
<tr><td>Reference Signal</td><td>ATC</td><td rowspan="2">adjust two-frame position by 1/Fr</td><td>none</td></tr>
<tr><td>ATC</td><td>Reference Signal</td><td>delay Reference Signal by 1/Fr</td></tr>
<tr><td>Reference Signal</td><td>TFM</td><td rowspan="2">regenerate TFM with Two-Frame Alignment to Reference Signal</td><td>none</td></tr>
<tr><td>TFM</td><td>Reference Signal</td><td>delay Reference Signal by 1/Fr</td></tr>
<tr><td>Non-PCM Audio</td><td>ATC</td><td colspan="2">case not allowed</td></tr>
<tr><td>ATC</td><td>Non-PCM Audio</td><td>none</td><td>delay Non-PCM block-start by 1/Fr</td></tr>
<tr><td>Non-PCM Audio</td><td>TFM</td><td rowspan="2">regenerate TFM with Two-Frame Alignment to Non-PCM block-start</td><td>none</td></tr>
<tr><td>TFM</td><td>Non-PCM Audio</td><td>delay Non-PCM block-start by 1/Fr</td></tr>
<tr><td>ATC</td><td>TFM</td><td>regenerate TFM with Two-Frame Alignment to ATC</td><td>none</td></tr>
<tr><td>TFM</td><td>ATC</td><td colspan="2">case not allowed</td></tr>
</table>

If the TFM packet is not detected on the 48(/1.001)-Hz, 50-Hz, or 60(/1.001)-Hz progressive video input, the equipment can insert the TFM packet into that digital serial stream with Two-Frame Alignment.

Note: Examples of this condition are found with video inputs VI1, VI3, and VI4 in Figure 1.

If the TFM packet is present on the 48(/1.001)-Hz, 50-Hz, or 60(/1.001)-Hz progressive video input, the equipment can pass or transcode the TFM packet into the output serial stream.

Equipment with frame sync capability can provide additional delay beyond one frame period, if required, to produce Two-Frame Alignment in its output video. The equipment can also provide information to the user of this additional delay. Frame deletion or repetition for re-timing asynchronous input video in such equipment commences on the two-frame boundary and span two frames.

Note: An example of this condition is on video input VI2 in Figure 1.

Equipment with no frame buffering capability should provide a measure of the offset between the start of the first frame of output video and the start of the first field of the interlaced reference signal in pixel periods of the video format. This information can be used for system delay management as described in Condition (2) of Section 6.6 below.

6.5 Sourcing Equipment Actions on Fr/2 Services in Fr Progressive Video (Informative)

Video sourcing equipment creates a video signal by sampling optical sensors or stored data. A tape deck playing back at one-fourth of the recorded speed by replicating or interpolating between video frames to produce four for every one stored is a video source.

As per the definition in Section 4, Two-Frame-Capable video source equipment can generate the TFM and all Fr/2 ancillary data services mapped to its progressive output video in Two-Frame-Alignment with each other and with related Fr/2 reference signals.

Storage devices that are Two-Frame-Capable can decode the TFM packet and store the Two-Frame Marker information along with the program material. If the device plays back that video at the recorded frame rate with Two-Frame Alignment, at that instant it represents video processing equipment that regenerates the TFM packet from the stored information, and inserts it into the output serial stream with Two-Frame Alignment. If the device plays back at a different frame rate, at that instant it represents video sourcing equipment that generates the TFM packet and inserts it into the output serial stream with Two-Frame Alignment. In Figure 1, video storage devices 1, 2, 4, and 5 meet this requirement.

6.6 Non-Two-Frame-Capable Equipment (Informative)

Equipment within the plant that is not Two-Frame-Capable might drop the TFM packet. One of the two following conditions should apply in this case.

1) Two-frame boundary management can be lost if the non-Two-Frame-Capable equipment has indeterminate throughput delay. Note: an example is the case with storage devices 3 and 6 in Figure 1.

2) Two-frame boundary management can be maintained through equipment with known throughput delay by the addition of Two-Frame-Capable buffering equipment where necessary, such as frame synchronizers.

   Note: Figure 1 shows a view into the Router/Switcher Complex of an Effects Engine with a constant processing delay of 1/Fr. Adding a Two-Frame-Capable frame synchronizer after the non-Two-Frame-Capable equipment adds in a second delay of 1/Fr to re-establish Two-Frame Alignment for that video path.

Annex A Bibliography (Informative)

SMPTE ST 12-1:2014, Time and Control Code

SMPTE ST 2048-1:2011, 2048 x 1080 and 4096 x 2160 Digital Cinematography Production Image Formats FS/709

SMPTE ST 2048-2:2011, 2048 x 1080 Digital Cinematography Production Image FS/709 Formatting for Serial Digital Interface

Annex B   Description of Two Frame Marker Issue (Informative)

Problems can arise in video formats of frame rate Fr that transport Fr/2 ancillary data services; 48(/1.001)-Hz, 50-Hz, and 60(/1.001)-Hz progressive video signals are examples of such formats and are the subject of the provisions of this Standard.

Figures B.1a and B.1b show spatial representations of a data stream carrying such a video format, with horizontal (H-time) and vertical (V-time) progression. Also present are a data service in horizontal ancillary data space (HANC) having a block length of roughly 2Tr = 2/Fr, and possibly other data services in vertical ancillary data space (VANC). An interlaced reference signal has its first field aligned with the first frame of a Frame Pair in the progressive video signal. This relationship was defined for time and control code in SMPTE ST 12-1 and was extended to Ancillary Time Code (ATC) in SMPTE ST 12-2.

These conceptual figures will be used to explain a transmission problem concerning the ancillary data; some examples are given of affected ancillary data services.

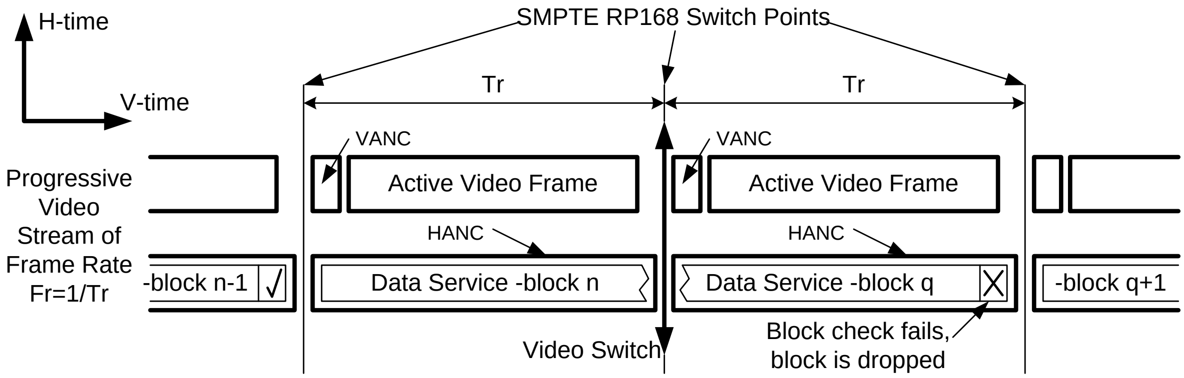

Figure B.1a: Example of Progressive Video at 48(/1.001) Hz, 50, or 60(/1.001)Hz Frame Rate (switch shown causes corrupted/incomplete block q in data service)

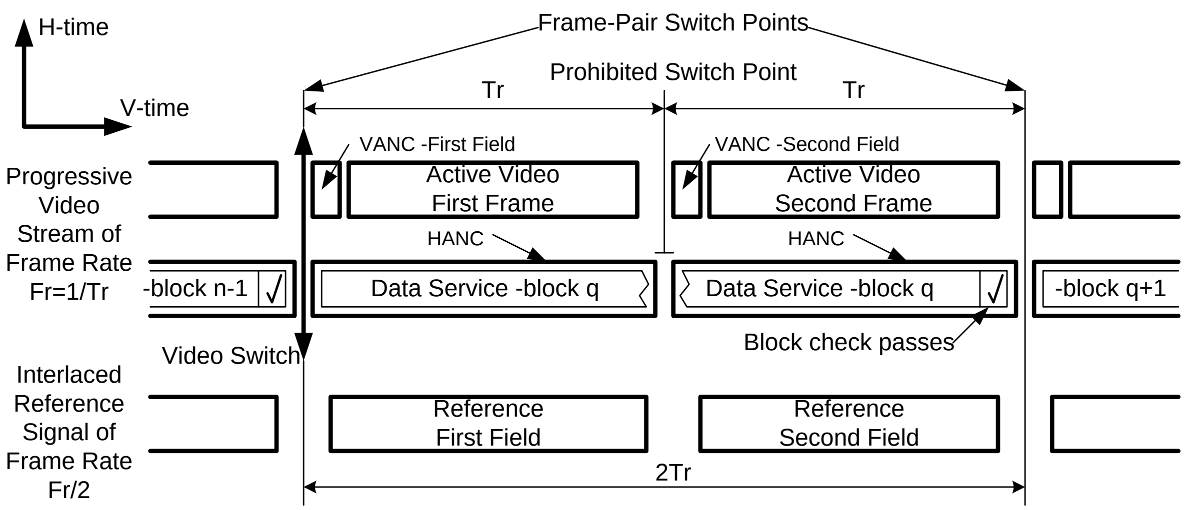

Figure B.1b: Frame/Field Alignment Example for Progressive Video at 48(/1.001) Hz, 50, or 60(/1.001)Hz Frame Rate (switch points allowed only between complete blocks of data service – no data corruption)

Figure B.1a shows the corruption of 2Tr-length blocks of embedded ancillary data (Data Service in Figure B.1a) caused by video switches with time granularity of Tr. There is a 50% chance that the video switch will cut across the middle of a 2Tr ancillary data block, as shown by the switch from Block n on the left to Block q on the right in Figure B.1a. This causes the entire ancillary data block to fail its continuity check, and be dropped.

This problem can be eliminated by forcing video switches to have two-frame (Frame Pair) granularity aligned with the boundaries between the 2Tr-length data blocks of the ancillary data service as shown in Figure B.1b. The video switch produces an ancillary data switch from Block n-1 to Block q that results in no dropped data blocks. (It is assumed that the 2Tr ancillary data services are themselves aligned with defined phase to a reference signal of frame period 2Tr that is common to all the components of the video and data plant).

Other processing functions besides switches may also be dependent on Frame Pair alignment.

Affected applications include:

1) Ancillary Time Code (ATC)

   ATC is a form of ancillary data service with length 2Tr. A decoder will detect ATC data packets in two contiguous frames with the same frame count, or in the case of VITC, identify the ATC-VITC1/ATC-VITC2 pair. A video switch as shown in Figure B.1a can disturb this ATC-pair sequence, and is likely to cause an ATC reader to wait until a non-errored block of data is received after the switch point before treating it as a valid time code count update. It will then be decoding with an inaccurate frame count.

2) Deinterlacing/reinterlacing processing

   There is the potential for image distortion by a train of processing steps that starts with de-interlacing (e.g. from 1080i30 to 1080p60) and ends with re-interlacing (e.g. back to 1080i30). The video de-interlacing footprint repeats with a two-field period; alternate lines of progressive video at frame rate Fr may be interpolated from an interlaced source at frame rate Fr/2. If a subsequent re-interlacing process is misaligned relative to the original sequence, it will not map progressive frames back to the original field numbers from which they were created; those fields may instead be comprised entirely of interpolated video lines. Correct alignment on the other hand would allow the re-interlaced video signal to consist entirely of original lines. Thus spatial and temporal distortion arising from the de-interlacing process may be reduced in the final interlaced video image. Frame-pair delineation will provide this field-indexing link across the progressive video span. This link is illustrated in Figure B.1b if the Reference Signal is re-labelled as “Interlaced Video Input Stream of Frame Rate Fr/2”.

3) Embedded non-PCM audio

   Non-PCM audio embedded as ancillary data can also be based on an Fr/2 frame rate, and thus also be adversely affected by video switches that can occur on any frame at rate Fr. Again, the mechanism of Figure B.1b will allow this to be avoided.