SMPTE 294M-2001
Revision of
ANSI/SMPTE 294M-1997

SMPTE STANDARD

for Television — 720 × 483 Active Line at 59.94-Hz Progressive Scan Production — Bit-Serial Interfaces

Contents

1 Scope

This standard defines two alternatives for bit-serial interfaces for the 720 × 483 active line at 59.94-Hz progressive scan digital signal for production, defined in ANSI/SMPTE 293M. Interfaces for coaxial cable are defined, each having a high degree of commonality with interfaces operating in accordance with ANSI/SMPTE 259M (BTA Report T-1004 contains additional information regarding the application of these interfaces in practical systems):

a) Dual-link interface (4:2:2P): Each link operating at 270 Mb/s, in which the active data in the Y′, C'_B, C'_R format (equivalent to 8:4:4) are transparently divided, line sequentially, into two data streams, each equivalent to the 4:2:2 component signal of ANSI/SMPTE 259M.

b) Single-link interface (4:2:0P): Operating at 360 Mb/s, in which the active data representing the color-difference components in the Y′, C'_B, C'_R format (equivalent to 8:4:4) are field quincunx down-converted by a factor of two, prior to reformatting with the full luminance data, into a single data stream equivalent to the component signal of ANSI/SMPTE 259M (but at a higher data rate, conceptually 8:4:0).

NOTES

1 The data rate of 360 Mb/s is related by a factor of 4/3 to the basic data rate of 270 Mb/s specified for 4:2:2 component signals in ANSI/SMPTE 259M.

2 The down-conversion of the color-difference components results in an equivalent spatial sampling grid for each that is similar in the horizontal and vertical dimension.

3 The term *line* in this standard refers to the digital line in the 483-line frame raster as described in ANSI/SMPTE 293M.

2 Normative references

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

ANSI/SMPTE 259M-1997, Television — 10-Bit 4:2:2 Component and 4f_{SC} Composite Digital Signals — Serial Digital Interface

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

SMPTE 291M-1998, Television — Ancillary Data Packet and Source Formatting

SMPTE RP 184-1996, Specification of Jitter in Bit-Serial Digital Systems

Approved
December 5, 2001

IEC 60169-8 (1978-01), Radio Frequency Connectors, Part 8: R. F. Coaxial Connectors with Inner Diameter of Outer Conductor 6.5 mm (0.256 in) with Bayonet Lock — Characteristic Impedance 50 Ohms (Type BNC), and Amendment No. 1 (1996-03) and Amendment No. 2 (1997-11)

3 General

3.1 The specification of a system claiming compliance with this standard shall state which of the systems shown in table 1 is implemented.

3.2 The following are notes referring to the nomenclature used in this standard:

– 483P: The 720 samples × 483 active lines at 59.94-Hz progressive scan production standard as described in ANSI/SMPTE 293M;

– f_S: Horizontal parallel data sampling rate, 27 MHz;

– Y′,C′: Main channel luminance, color-difference data;

– Y″,C″: Subchannel luminance, color-difference data;

– Link A: 4:2:2P main channel;

– Link B: 4:2:2P subchannel;

– C'_{Bv}, C'_{Rv}: Vertically filtered and quincunx subsampled color-difference data.

4 Dual-link interface (4:2:2P)

4.1 The main parameters of the dual-link (4:2:2P, 2 × 270 Mb/s) interface are shown in table 1.

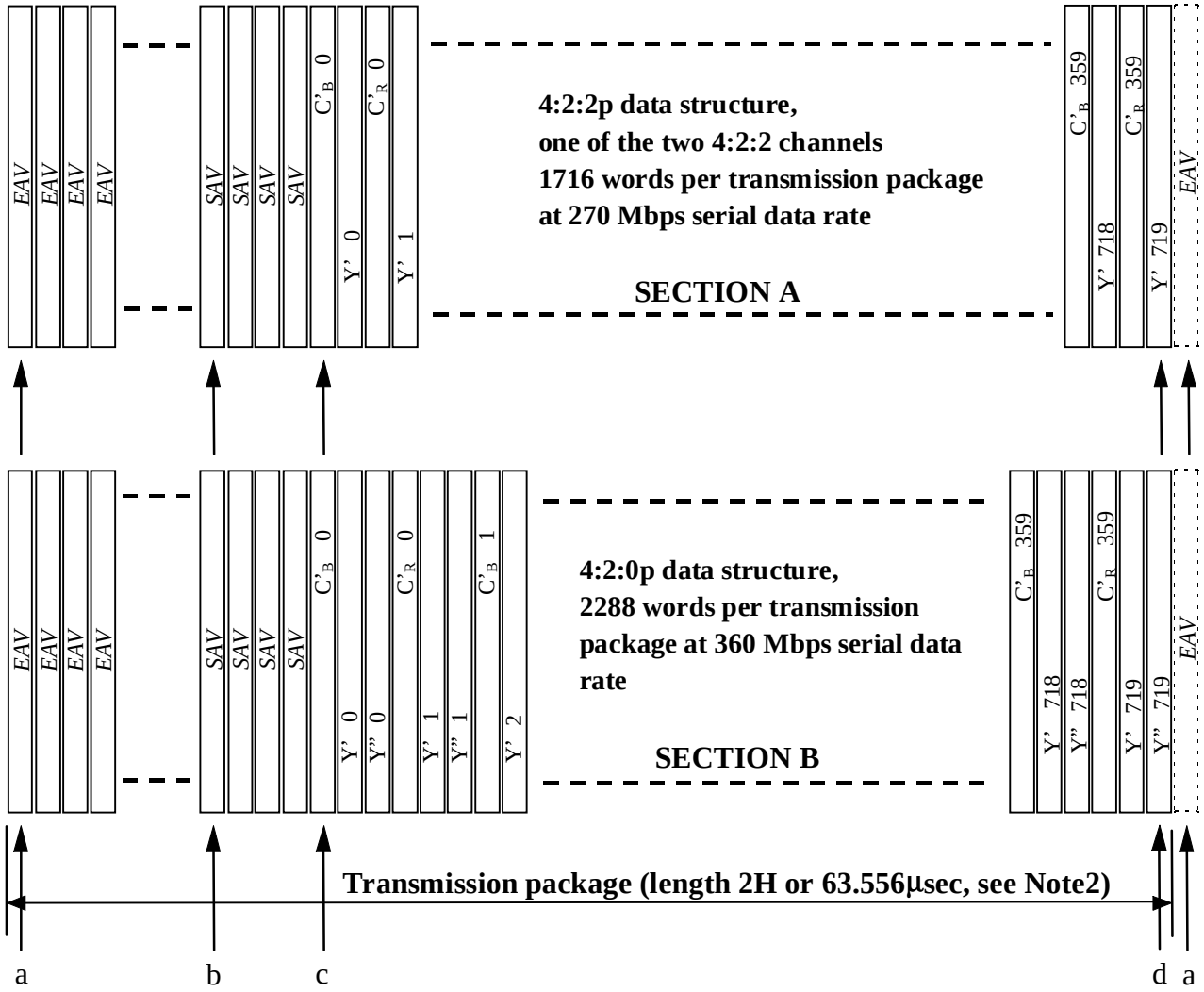
4.2 The processing of the data from the 8:4:4 level of the 720 × 483 active line at 59.94-Hz progressive scan production (see ANSI/SMPTE 293M) is illustrated in figures 1, 2, and 3. Essentially, the odd lines of one field and the even lines of the next field are selected line by line and formed into the data for one interface link, while the even lines of the field and the odd lines of the next field are selected to form the data for the other interface link. In the output field where the odd-numbered lines of the active input field are interface link A, the F bit of the TRS is set to 0 in both links; where the even-numbered lines of the active input field are in link A, the F bit of the TRS is set to 1.

NOTES

1 Buffering having a minimum duration of one horizontal line is required by this process at each interface, making a minimum transmission delay of two horizontal lines.

Table 1 – Parameters of interface data

System (total serial data rate)	4:2:2P (2 × 270 Mb/s) dual link	4:2:0P (360 Mb/s) single link
Frame rate	60/1.001 Hz	60/1.001 Hz
Word length	10 bits	10 bits
Parallel and multiplexed word rate: channels Y′, Y″ and C'_B/C'_R, C''_B/C''_R + SAV, EAV and auxiliary data	2 × 27 Mwords/s	36 Mword/s
Active lines per frame	483	483
Words per active line (channels Y′ and Y″)	720 and 720	720 and 720
Words per active line (channels C'_B and C'_R)	2× (360 and 360)	360 and 360
Words per horizontal blanking area (SAV/EAV and auxiliary data)	2 × 276 (Total: 2× (483 × 276 = 2 × 133,308/frame)	128 (Total: 483 × 128 = 61,824/frame)
Words in the active picture area	2x (1440 × 483) = 2 x 695,520	2160 × 483 = 1,043,280
Words in the vertical blanking interval (SAV/EAV and auxiliary data)	2x (1716 × 42) = 2 x 72,072	2288 × 42 = 96,096

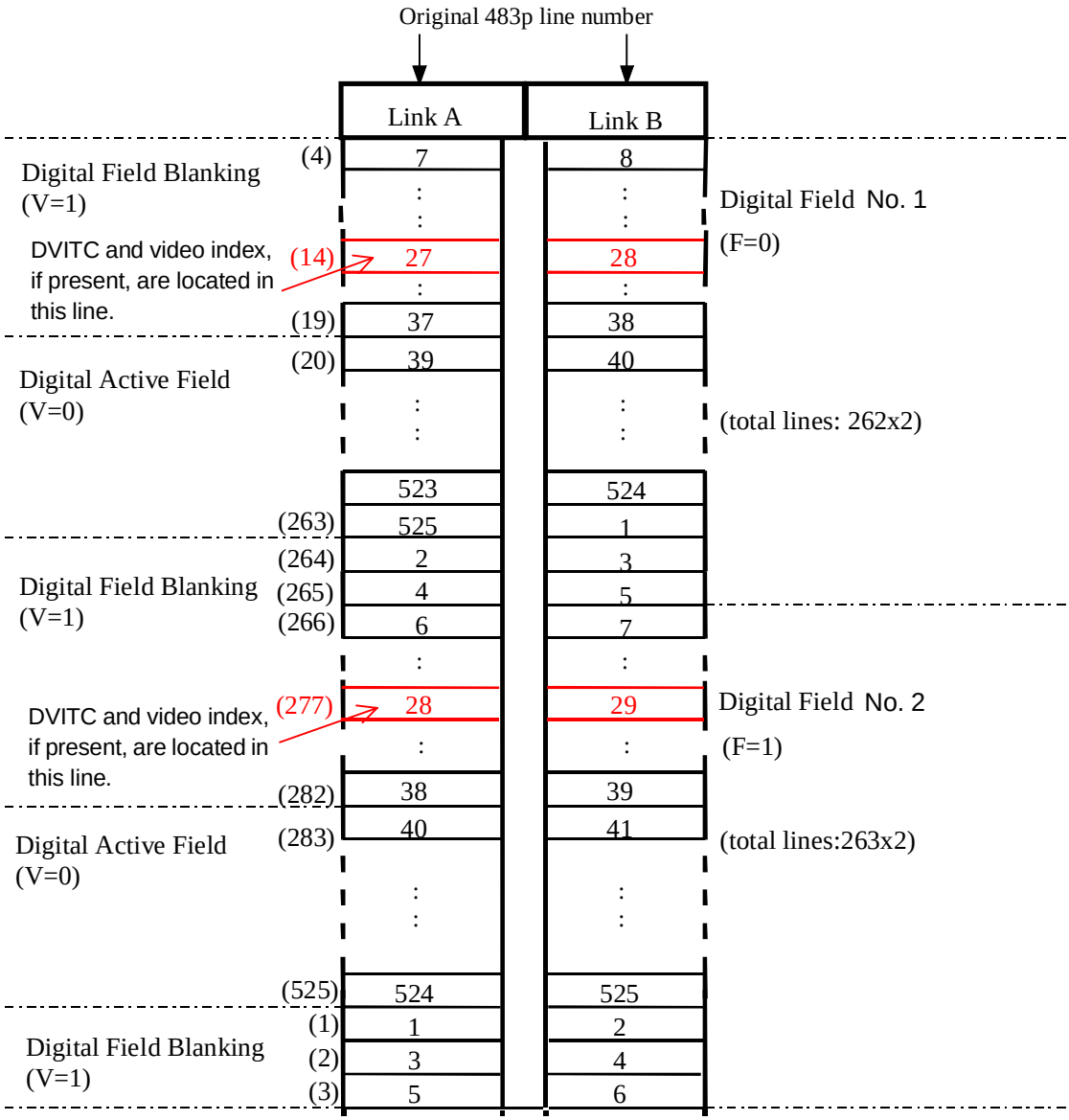


			Word number			
			a	b	c	d
System	Total words per transmission package	Total words of active image data per transmission package	Start of EAV	Start of SAV	Start of active image data	End of active image data
360 Mb/s 4:2:0P	2288	2160	2160	2284	0	2159
270 Mb/s 4:2:2P	1716	1440	1440	1712	0	1439

NOTES

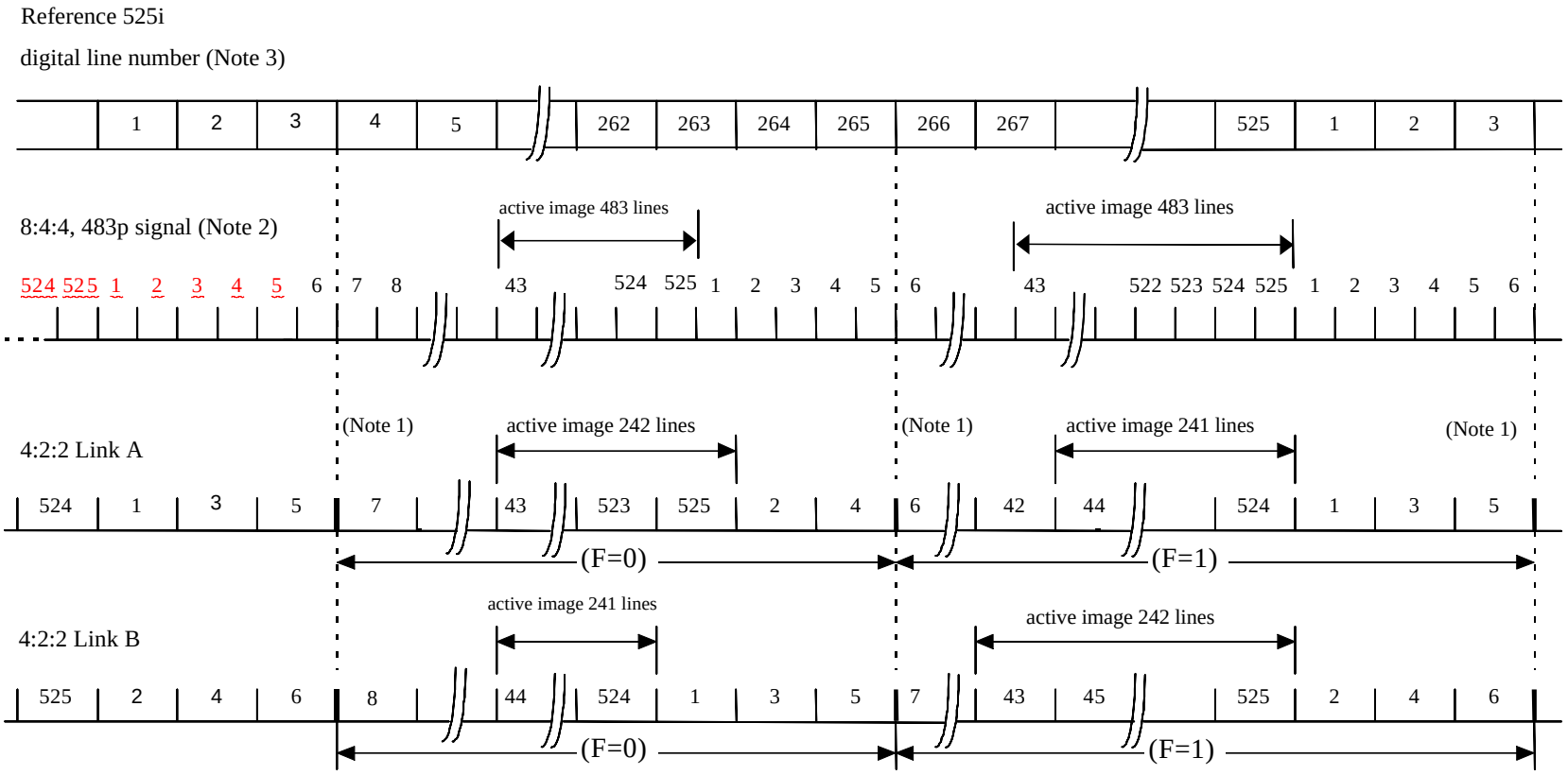
1 The time scales for the 4:2:0P and 4:2:2P systems are different.
2 H denotes one line period of the original 483P signal as specified by ANSI/SMPTE 293M.
3 Color-difference samples are cosited with even-numbered luminance samples and take the half value of the associated luminance sample number.

Figure 1 – Multiplexed horizontal data stream



NOTE – Each link (link A and link B) has a field quincunx line (interlaced) structure to obtain compatibility with a 480-line interlaced system. Therefore, digital fields No. 1 and No. 2 exist in each link.

Figure 2 – Dual-link interfaced (4:2:2P) line numbering and packaging



NOTES

1 Transmitted digital field boundaries as identified in figure 2.
2 ANSI/SMPTE 293M defines 483 progressive line numbers.
3 The definition of 525 interlace digital line numbers is contained in ANSI/SMPTE 125M.

Figure 3 – Line structure for converting a single 8:4:4 data stream into dual 4:2:2 channels

2 The resulting data in each link should not be used for interlaced (29.97 frames/s) moving image presentation without spatial filtering, which is required to avoid interline flicker and aliasing.

3 Figure 1 section A shows how the luminance and color-difference signals are multiplexed within a transmission package.

4.3 These data are then converted into two serial streams at 270-Mb/s data rate in accordance with ANSI/SMPTE 259M.

4.4 The timing difference between these two data streams shall not exceed 100 ns at the source.

5 Single-link interface (4:2:0P)

5.1 The main parameters of this 360-Mb/s system are shown in table 1.

5.2 The processing of the data from the 8:4:4 level of the 720 × 483 active line at 59.94-Hz progressive scan production (see ANSI/SMPTE 293M) is illustrated in figures 1 and 4.

5.3 The active color-difference components C'_B, C'_R are vertically filtered and subsampled to a field quincunx pattern as shown in figures 4 and 5. This results in a sample grid for the color-difference components that is twice the spacing in both the horizontal and vertical dimensions, respectively. The quincunx arrangement of sampling sites is field alternating vertically. The number of samples in two active lines is now 720 for Y′, 720 for Y″, and 720 for C'_B/C'_R combined, for a total of 2160.

NOTE – Examples of a basic minimal vertical color-difference filter and an adaptive color-difference filter are shown in figures A.1 and A.2, respectively. In either case, an appropriate matching delay is required in the luminance data.

5.4 The Y′, Y″, and C'_B/C'_R data are interleaved at sample level as illustrated in figure 1, in the order C'_B, Y′, Y″, C'_R,Y′, Y″, C'_B, etc.

5.5 TRS data, SAV, and EAV are added with a digital blanking interval of 120 samples, as shown in figure 1.

NOTE – The resulting data stream has a data rate in serial form (10 bits) of 360 Mb/s in the format of ANSI/SMPTE 259M only at the transmission level. The total line of 2288 samples occupies approximately 63.5 μs.

5.6 The F bit in codeword 3 in SAV/EAV shall be set to 0 or 1 identifying the quincunx sequence. If the 525 interlaced signal studio sync is used as reference, the frame coinciding with the first interlaced field shall be designated as F = 0 (see clause 6).

5.7 The data are then converted into a serial digital bit stream; the data rate is 360 Mb/s.

6 Digital timing reference sequences (SAV, EAV)

6.1 SAV and EAV timing reference signals shall define the start and end of active data and may be used to maintain synchronization across the digital interface.

6.2 An SAV or EAV sequence shall comprise four consecutive codewords: a codeword of all ones, a codeword of all zeros, another codeword of all zeros, and a codeword including F, V, H (field, vertical, and horizontal), P3, P2, P1, and P0 (parity) bits.

An SAV sequence shall be identified by having H = 0; EAV shall have H = 1. V is set as shown in figures 2 and 4. The definition is based on the ANSI/SMPTE 125M convention. F is set as defined in 5.6.

Tables 2 and 3 show the details of the coding.

6.3 Every transmission package shall include a four-sample EAV sequence and a four-sample SAV sequence.

7 Ancillary data signal format

Ancillary data are transmitted through interfaces specified in clauses 4 and 5 as ancillary data packets conforming to SMPTE 291M. Ancillary data may be inserted in any portion of the data stream not occupied by timing reference signals or video data. Two categories of ancillary data, HANC and VANC, are defined for different portions of the data stream. Note that the three-word header used to identify ancillary data is the same for HANC and VANC, although 8-bit representation of the header is permitted for VANC only.

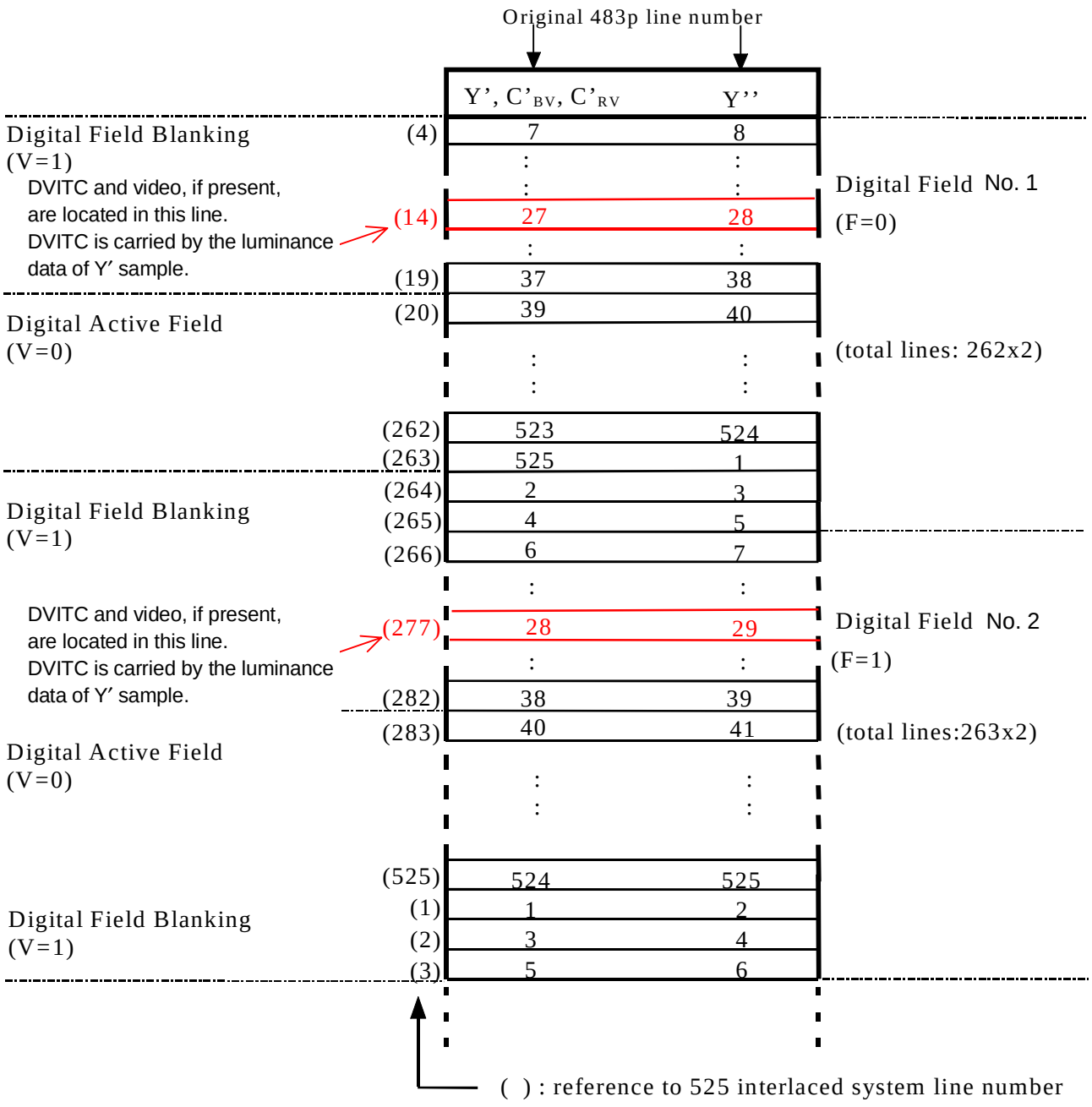


Figure 4 – Single-channel interface (4:2:0P) line numbering and packaging

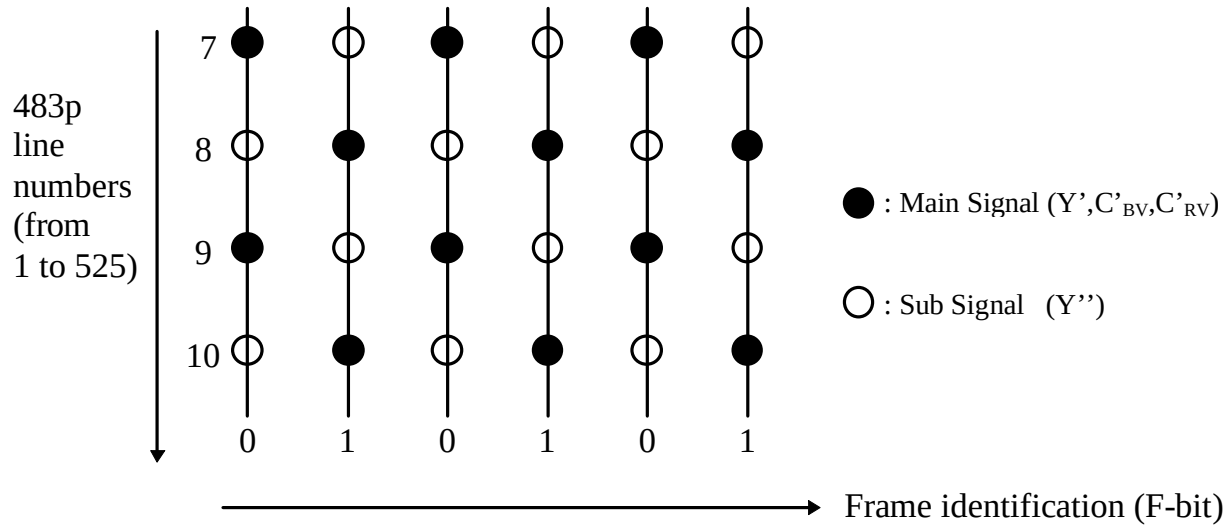


Figure 5 – Sampling grid for color-difference data in line/field quincunx pattern in 4:2:0P

Table 2 – Video timing reference codes

Bit number		(MSB) 9	8	7	6	5	4	3	2	1	(LSB) 0
Word	Value										
0	1023	1	1	1	1	1	1	1	1	1	1
1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0
3	See table 3	1	F	V	H	P3	P2	P1	P0	0	0

Table 3 – Word 3, data and protection bits for SAV and EAV

Bit number	9	8	7	6	5	4	3	2	1	0
Function	1 Fixed	F	V	H	P3	P2	P1	P0	0 Fixed	0 Fixed
SAV during digital field blanking in digital field No.1	1	0	1	0	1	0	1	1	0	0
EAV during digital field blanking in digital field No.1	1	0	1	1	0	1	1	0	0	0
SAV during digital active field No. 1	1	0	0	0	0	0	0	0	0	0
EAV during digital active field No. 1	1	0	0	1	1	1	0	1	0	0
SAV during digital field blanking in digital field No.2	1	1	1	0	1	1	0	0	0	0
EAV during digital field blanking in digital field No. 2	1	1	1	1	0	0	0	1	0	0
SAV during digital active field No. 2	1	1	0	0	0	1	1	1	0	0
EAV during digital active field No. 2	1	1	0	1	1	0	1	0	0	0
NOTE – Digital field blanking and digital active field are defined in figures 2 and 4.										

NOTES

1 In the case of a dual-link interface (4:2:2P), ancillary data are transmitted through link A.

2 The words not used to transmit ancillary data must have the following values:

– Those corresponding to Y′ and Y″ samples must have the value 040_h;

– Those corresponding to C'_B/C'_R and C''_B/C''_R samples must have the value 200_h.

7.1 HANC data

HANC data are permitted in all horizontal intervals, but not in the active portion of lines. HANC data are of 10-bit format, and each block of HANC data is preceded by the three-word ancillary data header

$$000_h \quad 3FF_h \quad 3FF_h.$$

Because of the existence of both 8- and 10-bit equipment, for detection purposes, all values in the ranges 000_h-003_h and $3FC_h$-$3FF_h$ shall be considered equivalent to 000_h and $3FF_h$, respectively.

The ancillary data header may occur multiple times during each horizontal blanking period if different blocks of data are transmitted.

All permitted data identification words and data formats shall exclude the protected values (000_h to 003_h) and ($3FC_h$ to $3FF_h$).

7.2 VANC data

VANC data are permitted only in the active portion of reference 525 interlaced system lines 1-13, 15-19, 264-276, and 278-282. The relationship between the 525 progressive line number and the reference 525 interlaced system line number is described in figures 2 and 4. Lines 14 and 277 are reserved for digital vertical interval time code (DVITC) and video index. VANC data are of 8-bit format, and each block of VANC data shall be preceded by the three-word ancillary data header

$$000_h \quad 3FF_h \quad 3FF_h$$

Because of the existence of both 8- and 10-bit equipment, for detection purposes all values in the ranges 000_h-003_h and $3FC_h$-$3FF_h$ must be considered equivalent to 000_h and $3FF_h$, respectively.

The ancillary data header may occur multiple times during each line if different blocks of data are transmitted.

All permitted data identification words and data formats shall exclude the protected values (000_h to 003_h) and ($3FC_h$ to $3FF_h$).

8 Digital vertical interval time code and video index

Digital vertical interval time code (DVITC) and video index, if present, are carried by the data in the active portion of reference 525 interlaced system lines 14 and 277.

Note – In the case of a dual-link interface (4:2:2P), DVITC and video index data are transmitted through link A.

8.1 DVITC

This signal, if present, is carried by the luminance data in the active portion of reference 525 interlaced system lines 14 and 277.

NOTE – In the case of a single-link interface (4:2:0P), DVITC is carried by the luminance data (Y′) samples.

8.2 Video index

This signal, if present, is carried by the color-difference data in the active portion of reference 525 interlaced system lines 14 and 277. A total of 90 8-bit data words is represented serially by DATA(2) of the 720 color-difference samples of the active portion of the line.

The first color-difference word of the active portion of line (C'_B 0 sample in figure 1) represents the least significant bit (bit 0) of video index word 0. The second color-difference word represents bit 1 of the same word, etc. The last color-difference word of the active portion of the line (C'_R 359 sample in figure 1) represents the most significant bit (bit 7) of video index word 89.

For all samples, a value of 204_h represents a binary one for the appropriate video index bit, and a value of 200_h represents a binary zero for the appropriate video index bit.

NOTE – These data may be corrupted by compression systems.

9 Signal levels and specifications

These specifications are defined for measurement of the serial output of a source derived from a parallel domain signal whose timing and other characteristics meet good studio practices.

The clock frequencies shall be:

a) Dual-link interface (4:2:2P): 270-MHz serial clock locked to the 27-MHz system reference;

b) Single-link interface (4:2:0P): 360-MHz serial clock locked to the 27-MHz system reference.

9.1 The output of the generator shall be measured across a 75-ohm resistive load connected through a short coaxial cable.

9.1.1 The generator shall have an unbalanced output circuit with a source impedance of 75 ohms and a return loss of at least 15 dB over a frequency range of 5 MHz to the clock frequency of the signal being transmitted (see ANSI/SMPTE 259M for measurement dimensions and methods).

9.1.2 The peak-to-peak signal amplitude shall be 800 mV ± 10%.

9.2 The dc offset, as defined by the midamplitude points of the signal, shall be nominally 0.0 V ± 0.5 V.

9.3 The rise and fall times, determined between the 20% and 80% amplitude points, shall be no less than 0.5 ns and no greater than 1.50 ns.

9.4 Overshoot of the rising and falling edges of the waveform shall not exceed 10% of the amplitude.

9.5 The jitter in the timing of the rising edges of the data signal shall be measured in accordance with SMPTE RP 184. Measurement and parameters are defined in SMPTE RP 184 and shall have the following values for compliance with this standard:

Timing jitter lower band edge	10 Hz	f1
Alignment jitter lower band edge	1 kHz	f3
Upper band edge	>1/10 clock rate	f4
Timing jitter, UI = unit interval	0.2 UI p-p	A1
Alignment jitter	0.2 UI p-p	A2
Test signal	Color bars	
Serial clock divider	≠10	

NOTES

1 A1, A2, f1, f3, and f4 are measurement parameters defined in SMPTE RP 184.

2 Color bars are chosen as a nonstressing test signal for jitter measurements. Use of a signal with long runs of zeros may give misleading results.

3 Use of a serial clock divider value of 10 is acceptable under conditions described in SMPTE RP 184 (annex B). However, it may mask word-correlated jitter components. The divider value should be stated in conjunction with equipment jitter specifications.

9.6 The input to the serial receiver signal shall present an impedance of 75 ohms with a return loss of at least 15 dB over a frequency range of 5 MHz to the clock frequency of the signal being transmitted.

10 Connector and cable types

10.1 The connector shall have the mechanical characteristics conforming to the 50-ohm BNC type. Mechanical dimensions of the connector may produce either a 50- or 75-ohm impedance. However, the electrical characteristics of the connector and its associated interface circuitry shall provide a resistive impedance of 75 ohms and shall permit it to be used at frequencies up to 850 MHz. Where a 75-ohm connector is used, its mechanical characteristics shall interface reliably with the nominal 50-ohm BNC type defined by IEC 60169-8.

10.2 Application of this standard does not require a particular type of coaxial cable. It is necessary for the frequency response of the cable loss, in decibels, to be approximately proportional to $\sqrt{f}$ from 1 MHz to the clock frequency of the signal being transmitted to ensure correct operation of automatic cable equalizers over moderate to maximum lengths.

11 Channel coding

11.1 The channel coding scheme shall be scrambled NRZI.

11.2 The generator polynomial for the scrambled NRZI shall be G1 (X) = $X^9 + X^4 + 1$. The polarity-free scrambled NRZI sequence shall be produced for G2(X) = X + 1. The input signal to the scrambler shall be positive logic (the highest voltage represents data 1 and the lowest voltage data 0).

11.3 The data word length shall be 10 bits.

12 Transmission order

The least significant bit (LSB) of any data word shall be transmitted first.

Annex A (informative)
Vertical color-difference filter

An example of a vertical color-difference filter and subsampling principles in 4:2:0P single-link coaxial cable interference is shown in figure A.1.

To avoid vertical frequency loss in the pass band, especially when multiple conversions between dual-link (4:2:2P) and single-link (4:2:0P) interface signals are required, an adaptive color-difference filter is recommended. An example of this type of filter is shown in figure A.2. The luminance signal shall be delayed to match the color-difference filtering delay.

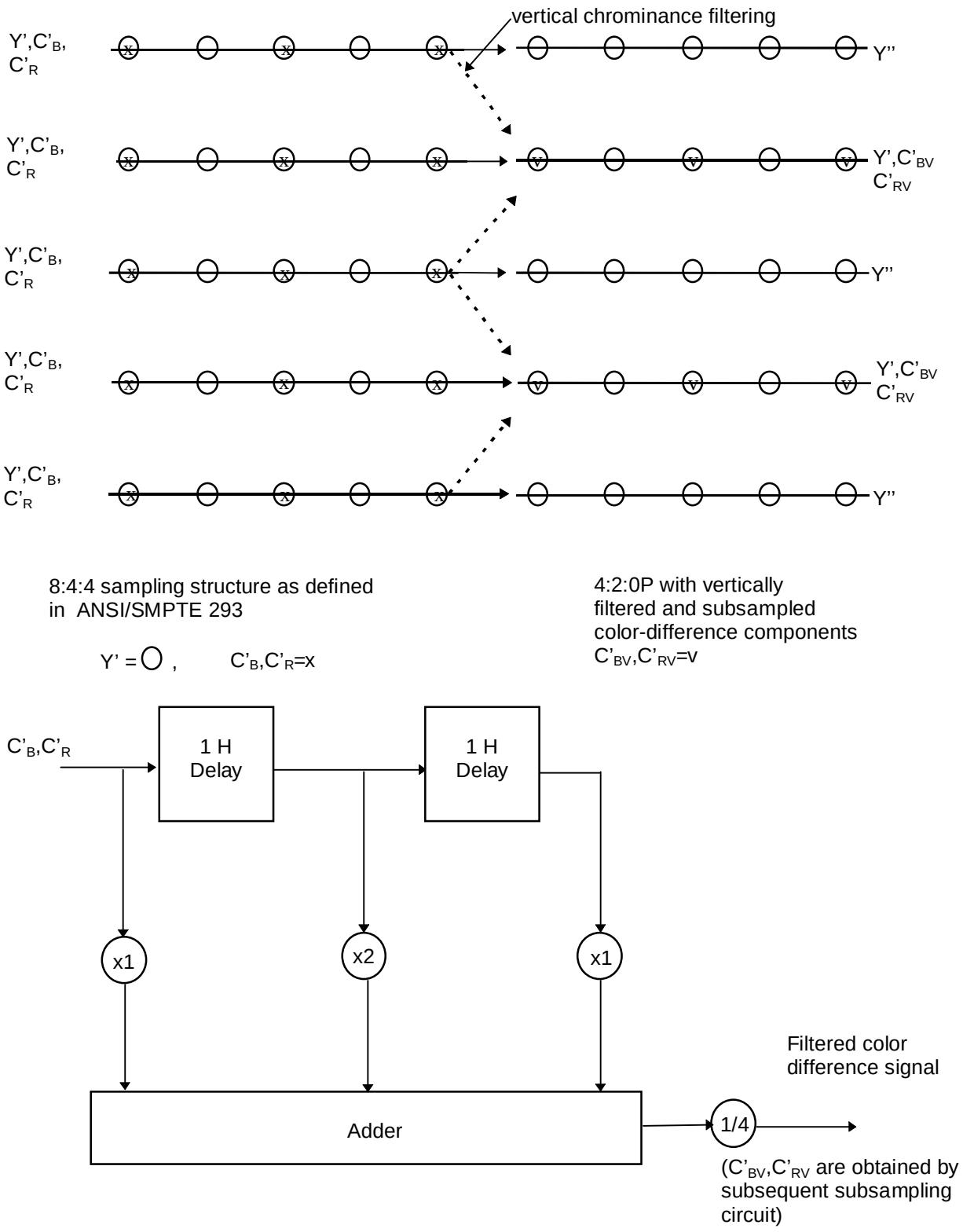
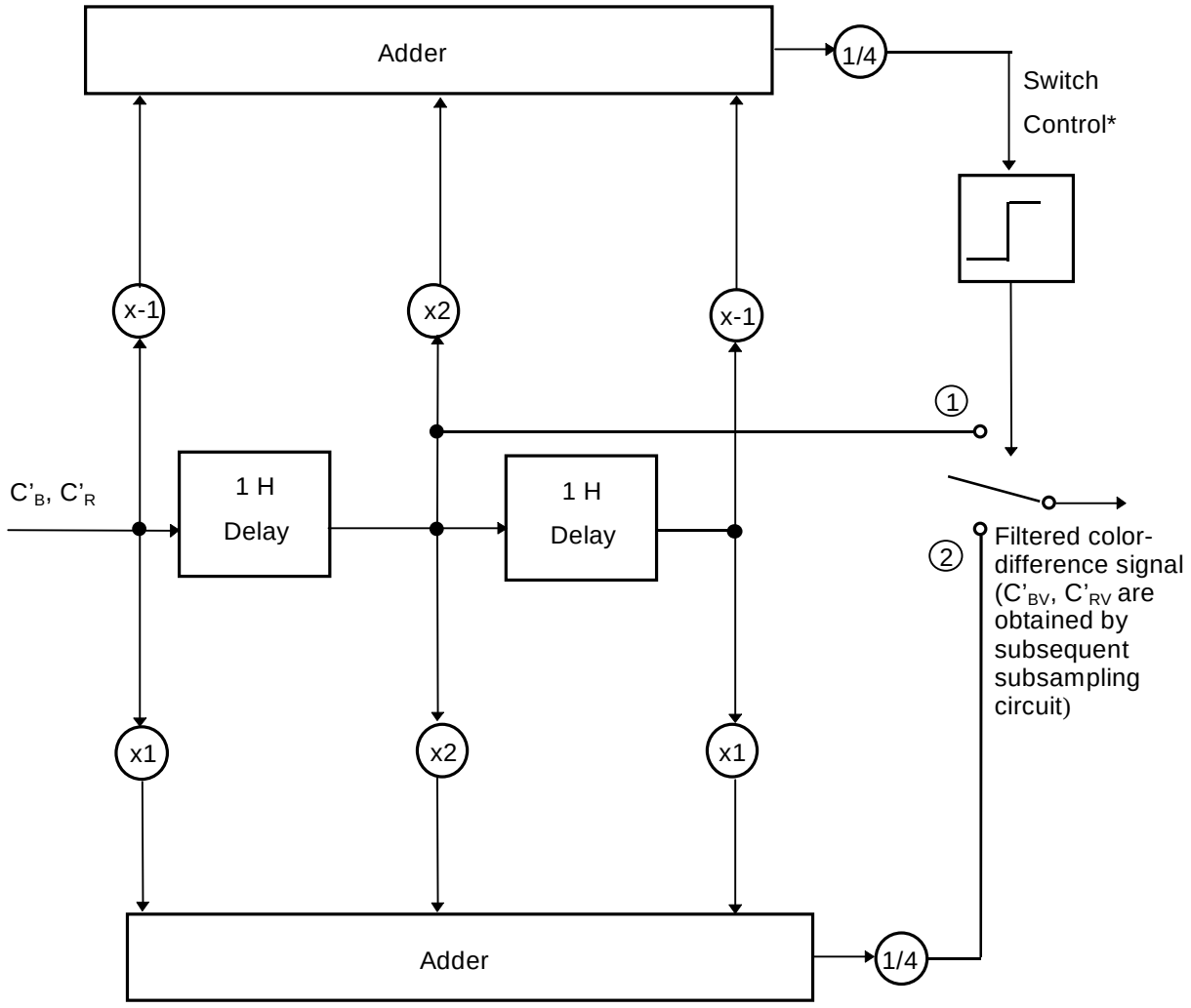


Figure A.1 – Example of a minimal color-difference filter and subsampling principles in a 4:2:0P single-link coaxial cable interface



NOTE – Switch control logic: If the absolute color-difference data value is more than or equal to 6/255, use switch position 2; otherwise, the switch shall be in position 1.

Figure A.2 – Example demonstrating an adaptive filter used for the color-difference components Before subsampling the 8:4:4 data into a 4:2:0P quincunx signal

Annex B (informative)
Bibliography

ANSI/SMPTE 125M-1995, Television — Component Video Signal 4:2:2 — Bit-Parallel Digital Interface

BTA Report T-1004, Video Signal Interfaces for EDTV-II Studio Equipment