Standards and Recommended Practices

Proposed SMPTE Standards

Published here for a trial period and public review are two Proposed SMPTE Standards: SMPTE 296M, Television — 1280 x 720 Scanning, Analog and Digital Representation and Analog Interface and SMPTE 297M, Television — Serial Digital Fiber Transmission System for ANSI/SMPTE 259M Signals. The proposals will be submitted to the American National Standards Institute if no adverse comments are received from publication. Comments should be addressed to Carlos V. Girod, Jr., Director of Engineering, at Society Headquarters prior to July 1, 1996. SMPTE 296M may be purchased from Headquarters for $18.00 and SMPTE 297M for $13.00.

Proposed Withdrawal of SMPTE Recommended Practices

The Standards Committee has approved withdrawal of three SMPTE Recommended Practices: RP 60-1991, Labels for Cartridge Spools for 2-in Quadruplex Video Magnetic Tape; RP 101-1991, Requirements for Recording American National Standard Time and Control Code on Quadruplex Video Tape Recorders; and RP 102-1991, Frequency Response and Operating Level of Recorders and Reproducers for Audio 2 Record for 2-in Quadruplex Video Magnetic Tape Operating at 15 and 7.5 in/s. Withdrawal action was initiated because the practices are no longer being used and, therefore, should be withdrawn. The practices were published in the August 1991 issue of the *Journal*. Comments should be addressed to Carlos V. Girod, Jr., at Society Headquarters prior to July 1, 1996. All comments from *Journal* publication will be reviewed prior to further processing of the withdrawal action.

Approved American National Standards

Seven American National Standards were approved by the American National Standards Institute recently: ANSI/SMPTE 1-1996, Video Recording — 2-in Magnetic Recording Tape; ANSI/SMPTE 83-1996, Motion-Picture Film (16-mm) — Edge Numbers — Location and Spacing; ANSI/SMPTE 111-1996, Motion-Picture Film — Prints Made on Continuous Contact Printers — Exposed Areas for Picture and Audio; ANSI/SMPTE 263M-1996, Television Digital Recording — 1/2-in Type D-3 Composite and 1/2-in Type D-5 Component Formats — Tape Cassette; SMPTE 278M-1996, Television Digital Recording — 19-mm Type D-6 — Content of Helical Data and Time and Control Code Records; ANSI/SMPTE 279M-1996, Digital Video Recording — 1/2-in Type D-5 Component Format — 525/60 and 625/50; and ANSI/SMPTE 291M-1996, Television — Ancillary Data Packet and Space Formatting. ANSI/SMPTE 1, 83 and 111 are available from Headquarters for $10.00 each: ANSI/SMPTE 263M for $30.00; ANSI/SMPTE 278M for $24.00; ANSI/SMPTE 279M for $50.00; and ANSI/SMPTE 291M for $16.00.

— Carlos V. Girod, Jr., P.E.,
Director of Engineering

SMPTE Journal, May 1996

PROPOSED SMPTE STANDARD

SMPTE 296M

for Television — 1280 × 720 Scanning, Analog and Digital Representation and Analog Interface

Contents

1 Scope

This standard defines a family of raster scanning systems for the representation of stationary or moving two-dimensional images sampled temporally at a constant frame rate and having an image format of 1280 x 720 and an aspect ratio of 16:9 as given in table 1. This standard specifies:

– R′G′B′ color encoding;

– R′G′B′ analog and digital representation;

– Y′P′BP′R color encoding, analog representation and analog interface; and

– Y′C′BC′R color encoding and digital representation.

An auxiliary component A may optionally accompany Y′C′BC′R; this representation is denoted Y′C′BC′RA.

A bit-parallel digital interface is incorporated by reference in clause 12.

NOTE – Throughout this standard, references to signals represented by a single primed letter (e.g., R′, G′, and B′) are equivalent to the nomenclature in earlier documents of the form $E_{R'}$, $E_{G'}$, and $E_{B'}$, which in turn refer to signals to which the transfer characteristics in 5.4 have been applied. Such signals are commonly described as being gamma corrected.

Table 1 – Scanning systems

System nomenclature	Samples per active line (S/AL)	Active lines per frame (AL/F)	Frame rate (Hz)	Scanning format	Reference clock (f_s) MHz	Samples per total line (S/TL)	Total lines per frame
1 1280 × 720/60/1:1	1280	720	60	Progressive	74.25	1650	750
2 1280 × 720/59.94/1:1	1280	720	60/1.001	Progressive	74.25/1.001	1650	750

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 274M-1995, Television — 1920 × 1080 Scanning and Interface

SMPTE RP 160-1991, Three-Channel Parallel Analog Component High-Definition Video Interface

SMPTE RP 177-1993, Derivation of Basic Television Color Equations

CIE Publication 15.2 (1986), Colorimetry, Second Edition

IEC 169-8 (1978), 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)

ITU-R BT.709-2, Parameter Values for the HDTV Standards for Production and International Programme Exchange

3 General

3.1 The specification of a system claiming compliance with this standard shall state:

– which of the scanning systems of table 1 are implemented;

– which of the analog R′G′B or Y′P′BP′R and/or which of the digital R′G′B, Y′C′BC′R, or Y′C′BC′RA interfaces are implemented;

– whether the system implements the system colorimetry or interim implementation; and

– whether the digital representation employs eight bits or ten bits.

3.2 Digital code word values in this standard are expressed as decimal values in the ten-bit representation. An eight-bit system shall round or truncate to the most significant eight bits according to provisions to be described.

4 Scanning

4.1 Scanning shall be based on a reference clock of the sampling frequency indicated in table 1, which shall be maintained to a tolerance of ± 10 ppm.

4.2 A frame shall comprise the indicated total lines per frame, each line of equal duration determined by the sampling frequency and the samples per total line (S/TL). Each line shall be uniformly scanned from left to right; lines in a frame shall be uniformly scanned from top to bottom. Lines are numbered in time sequence according to the raster structure described in clause 6.

4.3 Timing instants in each line shall be defined with respect to a horizontal datum denoted by 0_H which is established by horizontal synchronizing (sync) information in clauses 8 and 11. Each line shall be divided into a number of reference clock intervals, of equal duration, indicated by the column S/TL in table 1.

5 System colorimetry

5.1 Equipment shall be designed in accordance with the colorimetric analysis and optoelectronic transfer function defined in this clause. This corresponds to ITU-R BT.709.

5.2 Digital representation and treatment of wide-gamut color signals are not specified in the current edition of the international standard for HDTV colorimetry, ITU-R BT.709. In particular, coding ranges for digital primary components R′, G′, and B′ are not specified. Designers of new equipment are urged to take into account the approach and current status of international agreement.

5.3 Picture information shall be linearly represented by red, green, and blue tristimulus values (RGB), lying in the range 0 (reference black) to 1 (reference white), whose colorimetric attributes are based upon reference primaries with the following chromaticity coordinates, in conformance with ITU-R BT.709, and whose white reference conforms to CIE D_{65} as defined by CIE 15.2:

	CIE x	CIE y
Red primary	0.640	0.330
Green primary	0.300	0.600
Blue primary	0.150	0.060
Reference white	0.3127	0.3290

5.4 From the red, green, and blue tristimulus values, three nonlinear primary components, R′, G′, and B′, shall be computed according to the optoelectronic transfer function of ITU-R BT.709, where L denotes a tristimulus value and V′ denotes a nonlinear primary signal:

$$V' = \begin{cases} 4.5L, & 0 \le L < 0.018 \\ 1.099L^{0.45} - 0.099, & 0.018 \le L \le 1.0 \end{cases}$$

5.5 To ensure the proper interchange of picture information between analog and digital representations, signal levels shall be completely contained in the range specified between reference black and reference white specified in 7.7 and 12.5, except for overshoots and undershoots due to processing.

5.6 The Y′ component shall be computed as a weighted sum of nonlinear R′G′B′ primary components, using coefficients calculated from the reference primaries according to the method of SMPTE RP 177:

$$Y' = 0.2126R' + 0.7152G' + 0.0722B'$$

5.7 Color-difference component signals P'_B and P'_R, having the same excursion as the Y′ component, shall be computed as follows:

$$P'_B = \frac{0.5}{1 - 0.0722}(B' - Y')$$

$$P'_R = \frac{0.5}{1 - 0.2126}(R' - Y')$$

These components may be coded as C'_B and C'_R components for digital transmission.

6 Raster structure

6.1 For details of vertical timing, see figures 1 and 2.

6.2 In a system according to this standard, each frame shall comprise 750 lines including:

– Vertical blanking: lines 1 though 25 inclusive (including vertical sync, lines 1 through 5 inclusive) and lines 746 through 750 inclusive; and

– Picture: 720 lines, lines 26 through 745 inclusive.

6.3 Ancillary signals may be conveyed during lines 7 through 25 inclusive. Ancillary signals shall not convey picture information although they may be employed to convey other related or unrelated signals, coded similarly to picture information. Further specification of ancillary signals is outside the scope of this standard.

6.4 During time intervals not otherwise used, the R′, G′, B′ or Y′, P'_B, C'_B, P'_R, and C'_R components shall have a blanking level corresponding to zero.

6.5 The production aperture defines a region 1280 samples by 720 lines. The horizontal extent of the production aperture shall have the 50% point of its leading transition at reference clock 0 and the 50% point of its trailing transition at clock 1279. The production aperture defines the maximum extent of picture information (for further information, consult annex A).

6.6 The clean aperture of the picture defines a region 1248 samples in width by 702 lines high, symmetrically located in the production aperture. The clean aperture shall be substantially free from transient effects due to blanking and picture processing. An encroachment of six samples maximum on each of the left and right edges of the production aperture is allowed for horizontal blanking errors generated by analog processing. Vertical blanking shall be as specified with zero tolerance (see annex A).

6.7 The aspect ratio of the image represented by the production aperture shall be 16:9. The sample aspect ratio is 1:1 (square pixels).

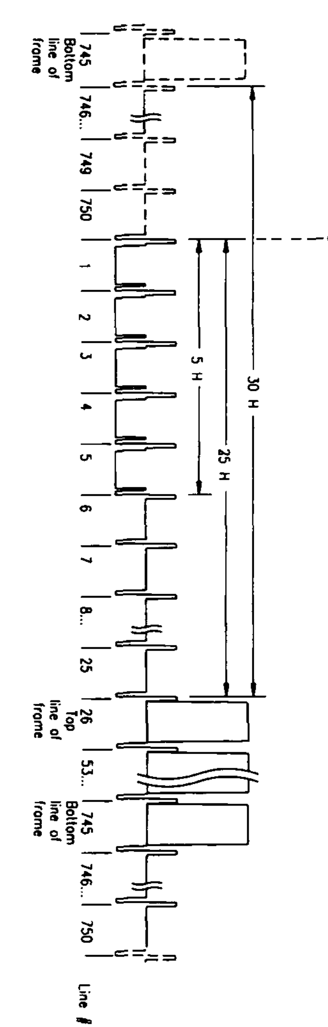


Figure 1 – Vertical timing (analog representation)

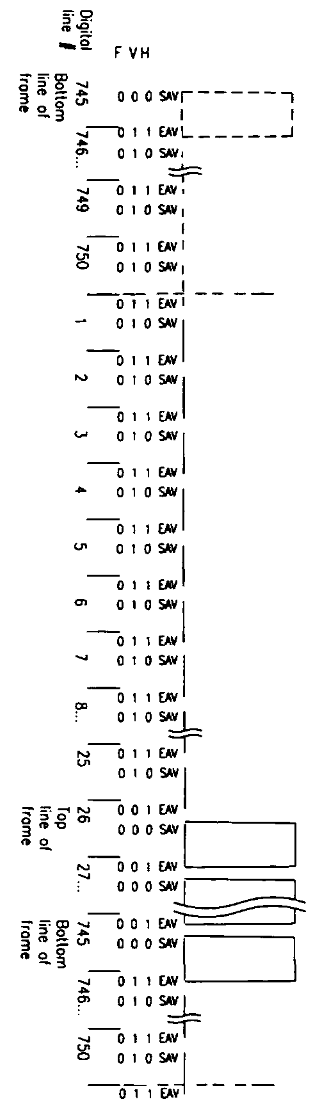


Figure 2 – Vertical timing (digital representation)

6.8 The center of the picture shall be located at the center of the production aperture, midway between samples 639 and 640, and midway between lines 385 and 386.

6.9 Each edge of the picture width, measured at the 50% amplitude point, shall lie within six reference clock intervals of the production aperture.

7 Digital representation

7.1 Digital representation shall employ either R'G'B' or Y'C'BC'R components as defined in clauses 5 or 6, uniformly sampled.

7.2 The digital signals described here are assumed to have been filtered to reduce or prevent aliasing upon sampling (for information regarding filtering, consult annex B).

7.3 R'G'B' signals and Y' signals shall have bandwidth nominally 30 MHz. $C'_BC'_R$ signals shall have bandwidth nominally half that of the associated Y' signal.

7.4 R'G'B' signals, and the Y' signal of the $Y'C'_BC'_R$ interface, shall be sampled orthogonally, line- and picture-repetitive, at the sampling frequency, f_S. The period of the sampling clock shall be denoted T.

7.5 A sampling instant in a line is denoted in this standard by a number from 0 through one less than the total number of samples in a line. Sample number 1390 corresponds to the 0_H datum. The sample numbering is shown in figure 3.

7.6 Sampled data at the interface shall be such that appropriate sin(x)/x correction occurs during conversion of the signal to the analog domain.

7.7 Digital R', G', B' and Y' components shall be computed as follows:

$$L'_D = \text{Floor}\,(219DL' + 16D + 0.5);\ D = 2^{n-8}$$

where L' is the component value in abstract terms from zero to unity, n takes the value 8 or 10 corresponding to the number of bits to be represented, and L'_D is the resulting digital code. The unary function Floor yields the largest integer not greater than its argument.

NOTE – This scaling places the extrema of R', G', B', and Y' components at code words 64 and 940 in a ten-bit representation, or code words 16 and 235 in an eight-bit representation.

7.8 Digital C'_B and C'_R components of the $Y'C'_BC'_R$ set shall be computed as follows:

$$C'_D = \text{Floor}\,(224DC' + 128D + 0.5);\ D = 2^{n-8}$$

where C' is the component value in abstract terms from –0.5 to +0.5, and C'_D is the resulting digital code. The unary function Floor yields the largest integer not greater than its argument.

NOTE – This scaling places the extrema of C'_B and C'_R at code words 64 and 960 in a ten-bit representation, or code words 16 and 240 in an eight-bit representation.

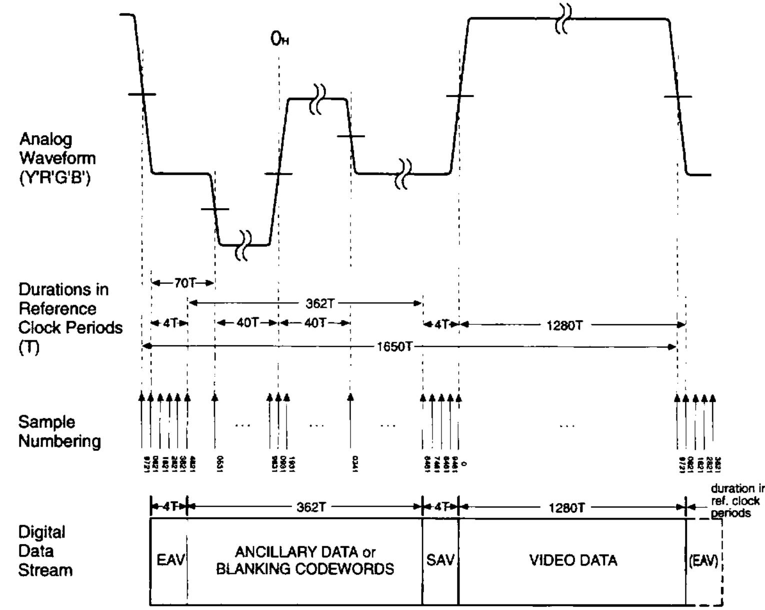
7.9 C'_B and C'_R signals shall be horizontally subsampled by a factor of two with respect to the Y' component. C'_B and C'_R samples shall be cosited with even numbered Y' samples (for information regarding filtering, consult annex B).

The subsampled C'_B and C'_R signals shall be time-multiplexed on a sample basis in the order $C'_BC'_R$. The first data word of an active line shall be a C'_B sample. The multiplexed signal is referred to as C'_B/C'_R.

7.10 Code values having the eight most significant bits all zero or all one — that is, ten-bit codes 0, 1, 2, 3, 1020, 1021, 1022, and 1023 — are employed for synchronizing purposes and shall be prohibited from video, any auxiliary component (A), ancillary signals, and ancillary data.

7.11 A system having an eight-bit interface may round video signals to eight bits and then discard the two least significant bits. The two least significant bits of all other data across the interface shall be truncated without rounding.

7.12 For Y', R', G', and B' signals, undershoot and overshoot in video processing may be accommodated by the use of code words 4 through 63 and code words 941 through 1019 in a ten-bit system, or code words 1 through 15 and code words 236 through 254 in an eight-bit system.



NOTES
1 Horizontal axis not to scale.
2 0_H is the analog horizontal timing reference point.
3 A line of digital video extends from the first word of EAV to the last word of video data.

Figure 3 – Analog and digital timing relationships

For C'_B and C'_R signals, undershoot and overshoot in video processing may be accommodated by the use of code words 4 through 63 and code words 961 through 1019 in a ten-bit system, or code words 1 through 15 and code words 241 through 254 in an eight-bit system.

8 Digital timing reference sequences (SAV, EAV)

8.1 SAV (start of active video) and EAV (end of active video) timing reference signals shall define synchronization across the digital interface. Figures 2 and 4 show the relationship of the SAV and EAV sequences to digital and analog video.

8.2 An SAV or EAV sequence shall comprise four consecutive code words: a code word of all ones, a code word of all zeros, another code word of all zeros, and a code word including F (field/frame), V (vertical), H (horizontal), P3, P2, P1, and P0 (parity) bits. An SAV sequence shall be identified by having H = 0; EAV shall have H = 1 (tables 2 and 3 show details of the coding).

8.3 In the digital representation, each scan line shall include a four-sample EAV sequence commencing 110 clocks prior to 0_H, and a four-sample SAV sequence commencing 256 clocks after 0_H. Digital lines shall be numbered and the numbering shall change state prior to the horizontal timing point (0_H), as shown in figure 2. The EAV sequence immediately preceding the 0_H datum of line 1 shall be considered to be the start of the digital frame.

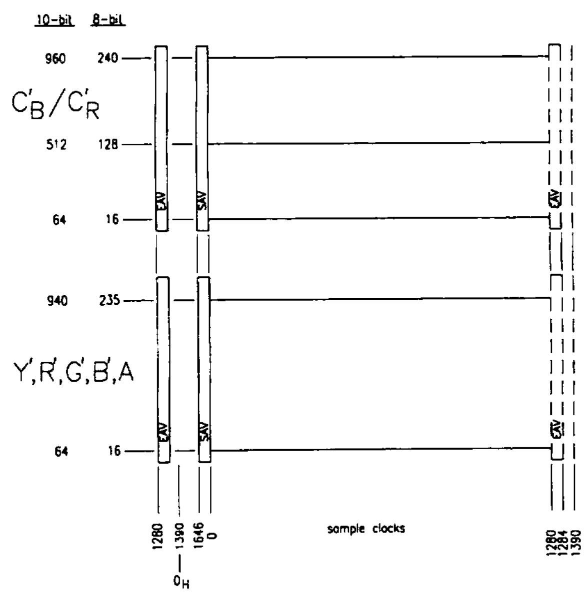


Figure 4 – Digital signal scaling and timing references

Table 2 – Video timing reference codes

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

Table 3 – Protection bits for SAV and EAV

Bit number		9	8	7	6	5	4	3	2	1	0
Function		1 Fixed	F Fixed	V	H	P3	P2	P1	P0	0 Fixed	0 Fixed
Value of (F/V/H)	0	1	0	0	0	0	0	0	0	0	0
	1	1	0	0	1	1	1	0	1	0	0
	2	1	0	1	0	1	0	1	1	0	0
	3	1	0	1	1	0	1	1	0	0	0

8.4

– The EAV and SAV of all lines shall have F = 0.

– The EAV and SAV of lines 1 through 25 inclusive and lines 746 through 750 inclusive shall have V = 1.

– The EAV and SAV of lines 26 through 745 inclusive shall have V = 0.

– The EAV of line 1 shall be considered the start of the digital frame.

8.5 A line which in the analog representation is permitted to convey ancillary signals may convey digitized ancillary signals.

NOTE – The inclusion of line number information following the EAV sequence is under study.

9 Ancillary data

9.1 Ancillary data may optionally be included in the blanking intervals of a digital interface according to this standard.

9.2 Any interval between the end of EAV and the start of SAV may be employed to convey ancillary data packets.

9.3 The interval between the end of SAV and the start of EAV of any line that is outside the vertical extent of the picture, and that is not employed to convey digitized ancillary signals, may be employed to convey ancillary data packets.

9.4 Independent ancillary data packets may be conveyed across each of the three R', G', and B' channels, or across each of the three Y', C'_B/C'_R, and A channels.

9.5 In the case of 10-bit representation, intervals not used to convey SAV, video data, EAV, or ancillary data shall convey the code word 64 (black) in the R', G', B', Y', or A channels, or 512 in the C'_B/C'_R channels. They shall be 16 and 128, respectively, in the case of 8-bit representation.

9.6 In the case of 10-bit representation, code words 0, 1, 2, 3, 1020, 1021, 1022, and 1023 shall be prohibited from ancillary data words. In the case of 8-bit representation, code words 1 and 255 shall be prohibited from ancillary data words.

NOTE to clause 9 – Specifications of the details of ancillary data will be the subject of future SMPTE standards.

10 Bit-parallel interface

The electrical and mechanical parameters of the bit-parallel interface are specified in clauses 11 through 15 of ANSI/SMPTE 274M, which are incorporated by reference.

11 Analog sync

11.1 Details of analog sync timing are shown in figures 1, 3, and 5 and are summarized in table 4.

11.2 A positive zero-crossing of a trilevel sync pulse shall define the 0_H datum for each line. A negative-going transition precedes this instant by 40 reference clock intervals, and another negative-going transition follows this instant by 40 reference clock intervals.

11.3 Positive transition of a trilevel sync pulse shall be skew symmetric with a rise time from 10% to 90% of 4 ± 1.5 reference clock periods. The 50% point of each negative transition shall be coincident with its ideal time within a tolerance of ± 3 reference clock periods.

Table 4 – Analog sync timing

		Duration (T)	Tolerance (T)
a	See figure 5	40	± 3
b	See figure 5	1540	− 6 + 0
c	See figure 5	40	± 3
d	See figure 5	260	− 0 + 6
e	See figure 5	260	− 0 + 6
	Sync rise time	4	± 1.5
	Total line	1650	
	Active line	1280	−12 + 0

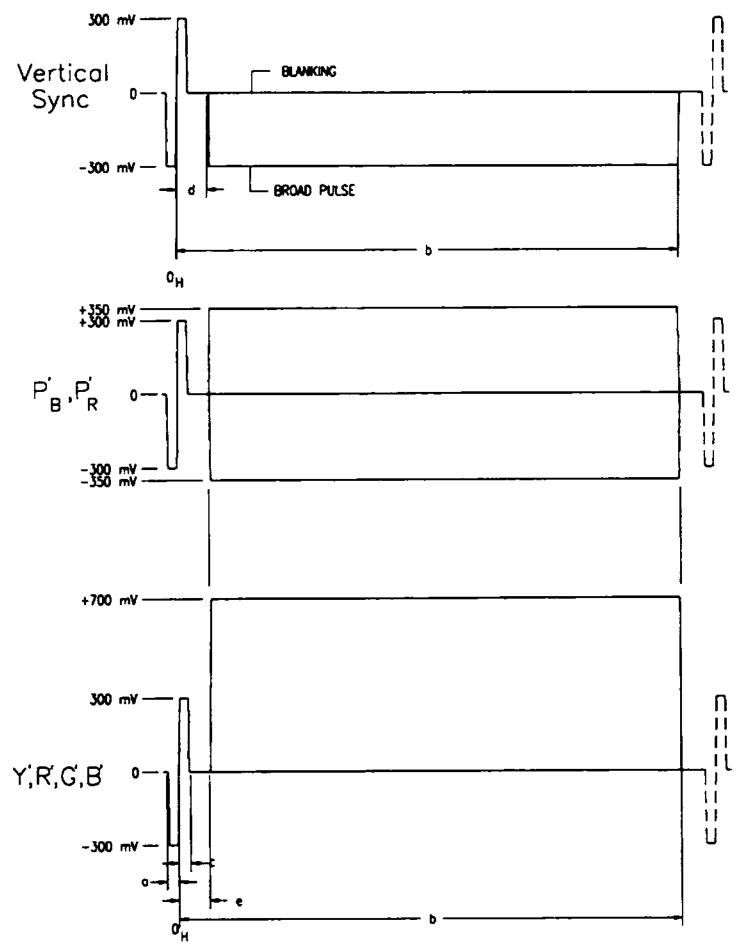


Figure 5 – Analog levels and timing

11.4 The positive peak of the trilevel sync pulse shall have a level of + 300 mV ± 6 mV; its negative peak shall have a level of – 300 mV ± 6 mV. The amplitude difference between positive and negative sync peaks shall be less than 6 mV.

11.5 Each line that includes a vertical sync pulse shall maintain blanking level, here denoted zero, except for the interval(s) occupied by sync pulses. During the horizontal blanking interval, areas not occupied by sync shall be maintained at blanking level, here denoted zero.

11.6 Each frame shall commence with five vertical sync lines, each having a broad pulse. The leading 50% point of a broad pulse shall be 260T after the preceding trilevel zero-crossing. The trailing 50% point of a broad pulse shall be 1540T after the preceding trilevel zero-crossing.

12 Analog interface

12.1 An analog interface according to this standard may employ either the R'G'B' component set or the Y'P'BP'R component set.

12.2 R'G'B' signals and Y' signals shall have bandwidth nominally 30 MHz.

12.3 For analog originating equipment, P'BP'R signals shall have the same bandwidth as the associated Y' signal. For digital originating equipment, P'BP'R signals shall have half the bandwidth of the associated Y' signal.

12.4 Each component signal shall be conveyed electrically as a voltage on an unbalanced coaxial cable into a pure-resistive impedance of 75 Ω.

12.5 For the Y' component, reference black (zero) in the expressions of clause 5 shall correspond to a level of 0 Vdc, and reference white (unity) shall correspond to 700 mV.

12.6 P'B, and P'R components are analog versions of the C'B and C'R components of 5.7, in which zero shall correspond to a level of 0 Vdc and reference peak level (value 0.5 of equations in 5.7) shall correspond to a level of +350 mV.

12.7 Trilevel sync according to clause 11 shall be added to each analog component.

12.8 Each of the electrical signals in an analog interface employs a connector that shall conform to IEC 169-8, with the exception that the impedance of the connector may be 75 Ω or to SMPTE RP 160.

Annex A (informative)
Production aperture

A.1 Production aperture

A production aperture for the studio digital signal defines an active picture area of 1280 pixels by 720 lines for use in origination and post-production of television signals conforming to this standard.

A.2 Analog blanking tolerance

A.2.1 The duration of the maximum active analog video signal measured at the 50% points is standardized as 1280 clock periods. However, the analog blanking period may differ from equipment to equipment and the digital blanking may not coincide with the analog blanking in actual implementation.

A.2.2 To accommodate the active video duration in picture origination sources, it is desirable to have analog blanking match digital blanking. However, recognizing the need for reasonable tolerance in implementation, analog blanking may be wider than digital blanking (see figure 5).

A.2.3 To accommodate a practical implementation of analog blanking within various studio equipments, a tolerance of six clock periods is provided at the start and end of active video. Accordingly, the analog tolerance to parameters b and e of table 4 is as follows:

Parameter	Definition	Nominal value (T)	Tolerance (T)
b	0_H to end of active video	1540	– 6 + 0
e	0_H to start of active video	260	– 6 + 0

Preferred practice is to provide a full production aperture signal at the output of an analog source prior to first digitization, reserving the tolerance for possible subsequent analog processes.

A.2.4 The relationship of the associated analog representation (inclusive of this tolerance) with the production aperture is shown in figure 5.

A.3 Transient effects

A.3.1 Improper digital processing of the edges of the picture may introduce transients near the edges. Such effects are to be minimized or avoided by use of appropriate techniques, for example, repetition or mirroring of pixels at the production aperture edges prior to digital filtering.

A.3.2 The following factors contribute to analog transient effects:

– Bandwidth limitation of component analog signals (most noticeably, the ringing on color-difference signals);

– Analog filter implementation;

– Amplitude clipping of analog signals due to the finite dynamic range imposed by the quantization process;

– Use of digital blanking in repeated analog-digital-analog conversions; and

– Tolerance in analog blanking.

A.4 Clean aperture

A.4.1 The bandwidth limitation of an analog signal (pre- and post-filtering) can introduce transient ringing effects which intrude into the active picture area. Also, multiple digital blanking operations in an analog-digital-analog environment can increase transient ringing effects. Furthermore, cascaded spatial filtering and/or techniques for handling the horizontal and vertical edges of the picture (associated with complex digital processing in post-production) can introduce transient disturbances at the picture boundaries, both horizontally and vertically. It is not possible to impose any bounds on the number of cascaded processes which might be encountered in the practical post-production system. Hence, recognizing the reality of those picture edge transient effects, the definition of a system design guideline is introduced in the form of a subjectively artifact-free area, called clean aperture.

A.4.2 The clean aperture defines an area within which picture information is subjectively uncontaminated by all edge transient distortions. In order to minimize the effects on subsequent compression or transmission processes, the contaminated area should be confined within 16 pixels and 9 lines of the production aperture edges.

A.4.3 This gives rise to a minimum clean aperture of 1248 horizontal active pixels by 702 active lines whose quality is guaranteed for final release. The clean aperture lies within the production aperture as shown in figure A.1.

A.4.4 It is good practice to minimize variations in analog blanking and to use techniques in digital processing that minimize or prevent transients in the allowed contaminated area as well as inside the clean aperture.

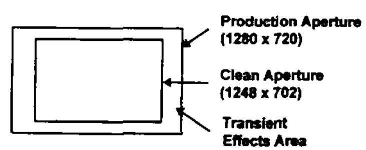


Figure A.1 – Clean aperture

Annex B (informative)
Pre- and post-filtering characteristics

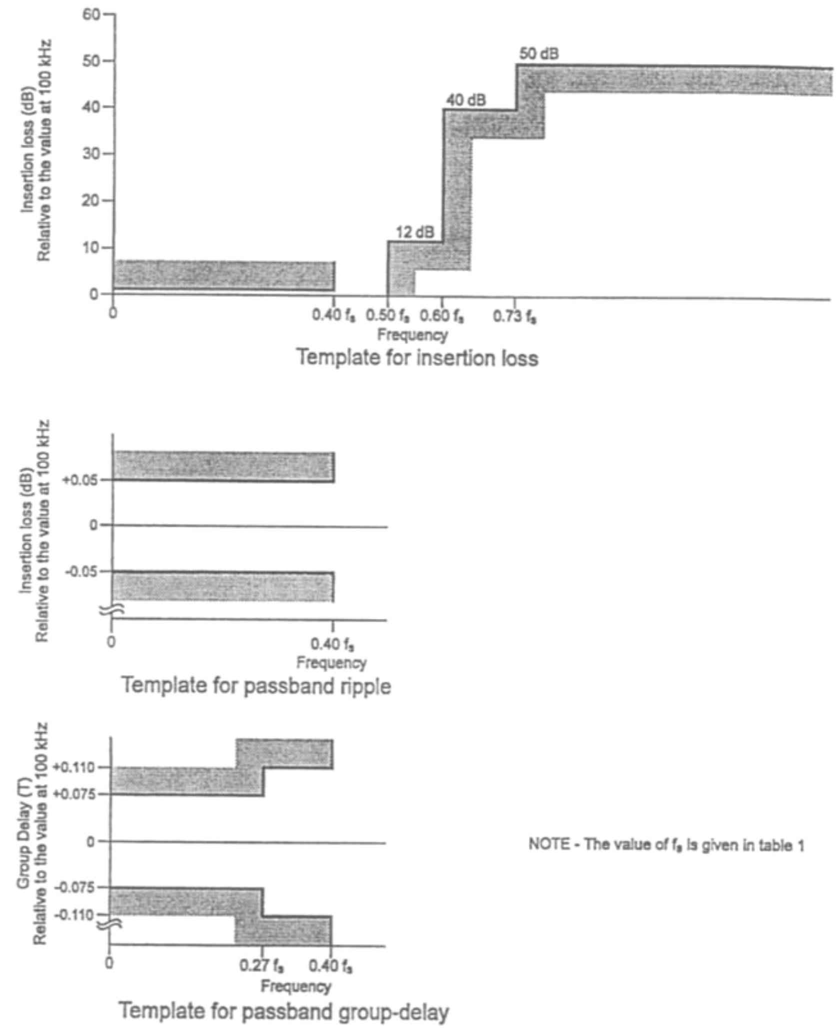
B.1 Figure B.1 depicts example filter characteristics for pre- and post-filtering of Y′, R′, G′, and B′ component signals. Figure B.2 depicts example filter characteristics for pre- and post-filtering of P'_B and P'_R component signals.

B.2 The passband frequency of the component Y′, R′, G′, and B′ signals is nominally 30 MHz.

B.3 The value of the amplitude ripple tolerance in the passband is 0.05 dB relative to the insertion loss at 100 kHz.

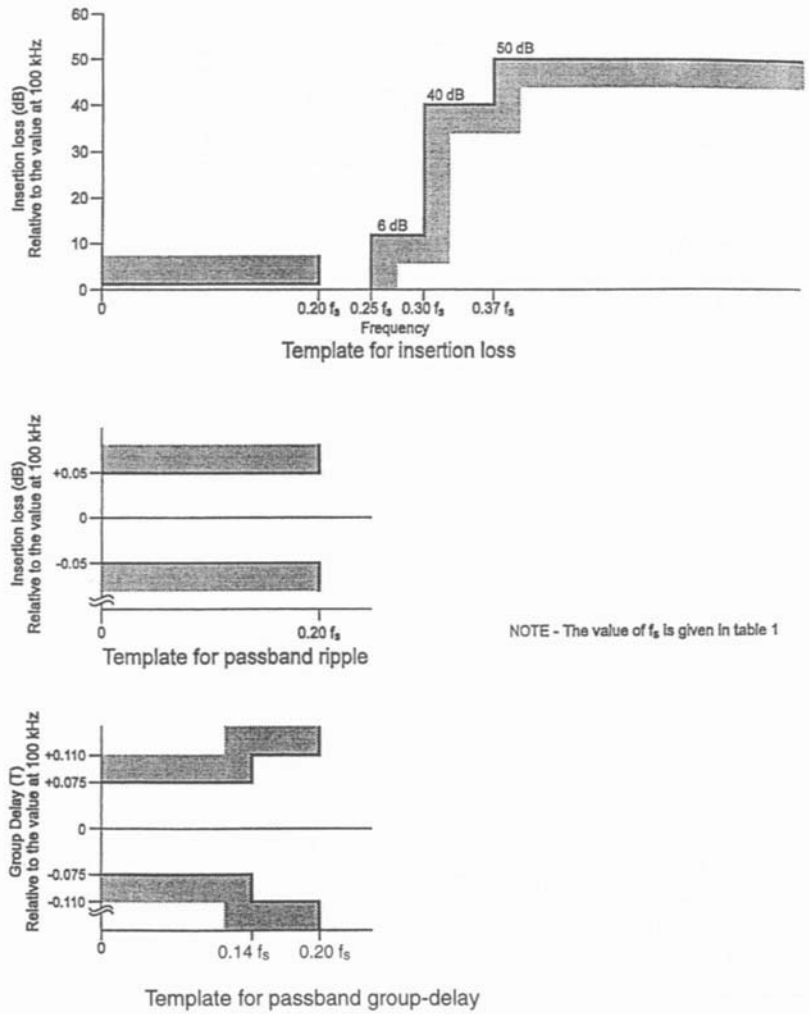
B.4 The insertion loss characteristics of the filters are frequency-scaled from the characteristics of ITU-R BT.601. Insertion loss is 12 dB or more at half the sampling frequency of the Y′, R′, G′, and B′ components, and 6 dB or more at half the sampling frequency of the P'_B and P'_R components relative to the insertion loss at 100 kHz.

B.5 The specifications for group-delay in the filters are sufficiently tight to produce good performance while allowing the practical implementation of the filters.



NOTE - The value of f_s is given in table 1

Figure B.1 – Filter template for Y′ and R′G′B′ components



NOTE - The value of f_s is given in table 1

Figure B.2 – Filter template for P'_B and P'_R components

Annex C (informative)
Bibliography

ANSI/ANSI/SMPTE 24OM-1995, Television — Signal Parameters 1125-Line High-Definition Production Systems

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

PROPOSED SMPTE STANDARD

for Television —

Serial Digital Fiber Transmission System for ANSI/SMPTE 259M Signals

1 Scope

1.1 This standard defines an optical fiber system for transmitting bit-serial digital signals. It is specifically intended for transmitting ANSI/SMPTE 259M serial signals (143 through 360 Mb/s). Its optical interface specifications and end-to-end system performance parameters are otherwise compatible with SMPTE 292M, which covers transmission rates of 1.3 through 1.5 Gb/s.

1.2 In this standard, "shall" denotes a mandatory provision of the standard; "should" denotes a provision that is recommended but not mandatory; and "may" denotes features included at the option of the designer whose incorporation makes the system performance, cost, and/or convenience of installation more attractive to the user.

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 referenced 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 indicated below.

ANSI/SMPTE 259M-1993, Television — 10-Bit 4:2:2 Component and $4f_{sc}$ NTSC Composite Digital Signals — Serial Digital Interface

ANSI/EIA/TIA-455-107-1989, (Factory Testing), Return Loss for Fiber Optic Components

ANSI/EIA/TIA-455-108-1989 (Field Testing), Return Loss for Fiber Optic Components

ANSI/EIA/TIA-492AAAA-1989, Detail Specification for 62.5 µm Core Diameter/125 µm Cladding Diameter Class Ia Multimode, Graded-Index Optical Waveguide Fibers

ANSI/EIA/TIA-492BAAA, Detail Specification for *Class IVa Dispersion-Unshifted Single-Mode Optical* Waveguide Fibers Used in Communications Systems

ANSI/EIA/TIA-604-3-1993, (FOCIS) Fiber Optic Connector Intermateability Standards

IEC 169-8 (1978), 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 Appendix (1993), Information for Interface Dimensions of 75-Ohm Characteristic Impedance Connectors with Unspecified Reflection Factors

IEC874-7 (1990), Part 7: Fibre Optic Connector Type SC/PC

3 Optical transmission system specifications (see annex A for definitions of fiber terms)

3.1 *Transmitter and receiver units physical* packaging and connectors

The transmitter (Tx) and receiver (Rx) units may be packaged either as standalone assemblies, or as a part of other television equipment. Tx/Rx electrical domain interface connectors, if required, shall be 75-ohm type BNC female per IEC 169-8. Tx and Rx unit optical domain connectors and their mating input *and output cable sections shall be type SC/PC as per* IEC 874-7.

The Tx unit light source shall be connected to its type SC/PC output optical connector via a short pigtail of single-mode fiber specified in ANSI/EIA/TIA-492BAAA, if it is not physically installed and interconnected to that connector in a receptacle (see annex A.1.4). A multimode fiber pigtail per specification ANSI/EIA/TIA-492AAAA is acceptable if the Tx unit is intended exclusively for multimode link applications. The Tx unit's label shall indicate which type of pigtail, if any, is installed.

The Rx unit optical receiver shall be connected to its type SC/PC input optical connector via a short length of *multimode fiber specified in ANSI/EIA/TIA-492AAAA,* if it is not physically installed and interconnected to that connector in a receptacle (see annex A.1.4).

3.2 Transmitter unit

The transmitter unit shall produce an intensity-varying optical output signal per table 1 when modulated by an electrical signal with specifications per ANSI/SMPTE 259M.

3.3 Receiver unit

The receiver unit shall output an electrical signal per ANSI/SMPTE 259M when receiving an optical signal per table 2.

Table 1 – Optical transmitter output signal specifications

Transmission circuit fiber	SM (MM optional)	MM (62.5/125 µm) [1]
Light source type	Laser	Laser or LED [2] [3]
Optical wavelength	1310 nm ± 40 nm	1310 nm ± 40 nm
Maximum spectral line width between half-power points	10 nm	30 nm
Maximum output power	– 7.5 dBm	– 7.5 dBm
Minimum output power	– 12 dBm	– 12 dBm
Rise and fall times	< 1.5 ns (20% to 80%), with < 0.5 ns difference	< 1.5 ns (20% to 80%), with < 0.5 ns difference
Extinction ratio	5:1 *minimum*, 30:1 *maximum*	5:1 *minimum*
Jitter ("UI" = unit interval)	0.135 UI maximum	0.135 UI maximum
Maximum reflected power	4%	4%
Electrical/optical transfer function	Logic "1" maximum intensity Logic "0" minimum intensity	

NOTES

1) See 3.4.1.3 for optional MM fiber type.
2) LEDs may not function reliably at higher ANSI/SMPTE 259M bit rates.
3) Tx units intended solely for multimode transmission link applications shall be so marked.

Table 2 – Optical receiver input signal specifications

Transmission circuit fiber.	Single-mode	Multimode
Maximum input power	– 7.5 dBm	– 7.5 dBm
Mimimum input power	– 20 dBm	– 20 dBm
Detector damage threshold	+ 1 dBm minimum	– 4 dBm minimum

3.4 Optical fiber circuit and connector specifications

3.4.1 Optical fiber type options

The user may use either single-mode fiber or multimode fiber of either of two types to establish a point-to-point optical circuit between the transmitter and receiver SC/PC optical connectors. A point-to-point circuit may consist of one or multiple serially interconnected sections of the selected type of optical fiber in **cables**, **jumpers**, and/or **patch cords**, when assembled in accordance with ANSI/EIA/TIA-568-A (see annex A for definitions of terms). Mixing fiber types in the multiple sections of a point-to-point circuit is physically possible, but technically unacceptable.

3.4.1.1 Single-mode optical fiber shall comply with ANSI/EIA/TIA-492BAAA (class IVa dispersion-unshifted, 9/125 micron step index [SI] fiber), and have a maximum attenuation of 1.0 dB per kilometer at 1310 nm.

3.4.1.2 Multimode optical fiber shall comply with ANSI/EIA/TIA-492AAAA (62.5/125 micron graded-index [GI] fiber), and have a maximum attenuation of 1.5 dB per kilometer at 1310 nm.

3.4.1.3 The system designer may elect to use already-installed 50/125 micron graded-index fiber circuits. This choice will result in a loss budget reduction of approximately 3 dB over values calculated for 62.5/125 micron fiber circuits.

3.5 Optical connector specifications (excerpted from ANSI/EIA/TIA-568-A)

3.5.1 Type (see annex A for definitions of terms)

Telecommunications industry type SC/PC optical **connectors**, **adapters**, and **receptacles** shall be used in **cables**, **patch cords**, and/or **pigtails** which interconnect Tx and Rx units to the multimode or single-mode fibers comprising the first and last segments of a multiple section transmission circuit. Use of other types of connectors, adapters and receptacles at intervening connection points is the purview of the transmission circuit designer or installer.

Note on Tx/Rx optical interface design: Optical transmission link manufacturers may assert compliance with this standard if jumpers or physical adapters are provided to interface other terminal equipment connectors to SC/PC connectors, adapters, or receptacles.

The dimensions of simplex SC/PC connectors and adapters, to include keys and keyways, shall meet ANS/EIA/TIA-604-3. Multimode and single-mode connectors and adapters shall have these same dimensions to permit intermating the two optical fiber types through adapters. The designer shall employ an obvious and consistent practice to visually differentiate the two types. As specified in ANSI/EIA/TIA-568-A, the multimode connector and adapter may be beige and the single-mode connector and adapter blue. Alternatively, text markings on the equipment may be used to specify the type of fiber to be used in the transmission circuit.

3.5.2 Return loss

Type SC/PC connectors shall have optical return losses as follows, with measurements performed at 23°C ± 5°C, in accordance with ANS/EIA/TIA-455-107 (factory testing) and ANSI/EIA/TIA-455-108 (field testing):

Fiber type	Minimum return loss
62.5/125 micron multimode	20 dB
8-10/125 micron single-mode	26 dB

Annex A (informative)
Definitions of optical domain transmission media and connector terms

A.1 Optical fiber and cable assemblies

A.1.1 Cables contain one or more sheathing-encased individual optical fibers, arranged in a bundle or flat ribbon configuration. Fiber counts selected for high-density cables will be the designer's choice between the need for conduit space conservation and the need for convenient optical fiber cable management.

A.1.2 Jumpers, patch cords, and **fiber circuit extenders** are special-purpose optical fiber cables containing one or more fibers, each enclosed in a protective sheath.

A.1.3 Hybrid optical/copper cables are assemblies of one or more multimode and/or single-mode sheathed fibers, and two or more electrically-insulated copper wires or braids. They are fabricated for use in special applications such as interconnection of camera heads and base stations. Their specifications are to be defined in a separate SMPTE standard.

A.1.4 Pigtails are single fibers encased in a plastic material, but not including a protective sheath. They are fabricated for installation within terminal equipment to extend a fiber circuit from an interconnection panel receptacle to an optical device located within the equipment. They shall be terminated at the interconnection panel end in a type SC/PC connector. The other end termination shall be made as recommended in relevant telecommunications industry practices.

A.2 Type SC/PC optical connectorization components

Type SC/PC **connectors**, **adapters**, and **receptacles** have evolved from three decades of fiber optic connection device development in the global telecommunications industry. The SC family was designed and first installed in 1984, and is now the preferred or specified family for all new construction among virtually all standards-setting organizations worldwide.

A.2.1 Connectors are installed at both ends of all fibers in single, duplex, or multiple fiber patch cords, and sheath-protected multifiber cables. Connectors are also installed at one end of pigtails whose other ends are physically affixed to optical Tx and Rx devices located within user equipment.

A.2.2 Adapters are installed in rack- and wall-mounted patch panels in telecommunications closets and equipment rooms to intermate connector-terminated fibers. They are the optical equivalent of double-ended BNC barrels or panel-mounted adapters used to interconnect tandem lengths of coaxial cable. Adapters provide mechanical means for precisely butting together projecting fiber connector ferrules. They are used to physically establish circuits consisting of serially-connected lengths of multimode and single-mode cable fibers or pigtails.

Adapters also accommodate the intermating of a single-mode light source output pigtail to a multimode transmission circuit input, and the intermating of a single-mode transmission circuit output to a multimode optical receiver input pigtail. Telecommunications industry practice allows the use of single-mode pigtails in a Tx unit to interface multimode fiber circuits. In an Rx unit, multimode pigtails may be used to receive optical signals from single-mode fiber circuits.

A.2.3 Receptacles are installed in terminal equipment to provide the interface between internally installed optical Tx and Rx devices and premises (plant) cabling circuits. A receptacle may physically comprise half of an adapter, with light sources or photo diodes physically installed in the other half. Such receptacles may be physically mounted on Tx or Rx unit PC boards. When a multimode or single-mode E/O or O/E transducer is mounted on a printed circuit board which cannot be physically located at the interface panel, interconnection to the panel receptacle is established by a pigtail (see 3.1).

Annex B (informative)
Optical transmission circuit design and performance options (see annex C for electrical signal conditioning options)

B.1 Tx and Rx unit selection criteria

The power budget of a fiber optic transmission link is the arithmetic difference between the table 1 optical source minimum output power and the table 2 optical receiver maximum input power. The minimum power budget required for transmission of a signal between source and destination equipment is the fiber's attenuation at the 1310-nm transmission wavelength, plus the sum of the measured or specified losses at all splice points and in connectors, which may be as high as 1 dB per splice or connection. The system designer is advised to include a 3 dB to 6 dB "contingency" loss in setting up the loss budget of a long multisection circuit.

Higher costs for single-mode Tx and Rx units needed to meet a specific loss budget may be offset by the use of lower cost multimode fiber throughout the circuit. However, the "minimum fiber bandwidth" of multimode fibers (expressed as a maximum "bandwidth-kilometer" value in the fiber specification) forces the use of single-mode fiber in any circuit which may eventually be required to transport 1.3 Gb/s to 1.5 Gb/s HDTV signals. This fiber type choice requirement has no equivalent in coaxial transmission circuit loss calculations.

B.2 Multimode and single-mode fiber transmission characteristics

The distances over which digital signals can be transmitted on multimode and single-mode fibers without errors have "cliff effect" circuit length limits caused by "modal" and "chromatic" dispersion phenomena, respectively. Multimode fibers accept multiple input light rays (modes) from the light source at maximum angles of incidence defined by the "acceptance cone" (numerical aperture - NA) of the fiber. Propagation delays of the pulse-carrying rays reflected from boundary to boundary in the core increase with distance. The "cliff effect" distance of multimode fiber, calculated from its "bandwidth-kilometer" rating (see above), is that distance at which the signal is no longer recoverable, because the time of arrival of pulses transported by many rays masks signal transition points or overlaps pulses from adjacent signal unit intervals.

Contrary to popular conception, even the most expensive semiconductor laser light source does not emit light at a single wavelength. The single ray transmitted down the 8.0 to 10.0 micron core experiences different propagation delay at each wavelength within the 10-nm maximum spectral line width output of the laser (table 1). The "cliff effect" point of single-mode fiber, many kilometers further down the fiber, is that distance at which the time of arrival of pulses transported at the spectral wavelength extremes mask signal transition points, or overlap pulses from adjacent signal unit intervals.

B.3 E/O transducer digital signal processing limitation

Designers should be aware that ANSI/SMPTE 259M serial signals can contain substantial low-frequency energy. Transducers used in ANSI/SMPTE 259M signal transmission must therefore employ appropriate coupling time constants, clamping, and power-control loops. Proper performance can be verified by test transmission of the SDI checkfield signals specified in SMPTE RP 178.

Annex C (informative)
Electrical domain signal interface and signal processing options

C.1 Coaxial cable equalization

ANSI/SMPTE television standards and SMPTE recommended practices (RPs) and engineering guidelines (EGs) encourage the incorporation of signal processing circuits for reconditioning a signal after it has suffered distortions or deterioration in transmission over coaxial cable. Designers are encouraged to include such circuitry and functions in the Tx and Rx units as included or optional features. A prime example is an automatic equalizer.

C.2 Multiplexed ancillary data streams and/or network operations control signals

Telecommunications industry fiber transmission link protocols may require the multiplexing of various ancillary data serial digital bit streams with the pay load signal. These may include, but are not limited to, protocols for transmission circuit-performance monitoring, system operations automation, and automatic diversity routing upon loss of signal at the receiver, etc. To facilitate transmission of such signals, designers may incorporate circuitry in the Tx and Rx units for multiplexing and demultiplexing their bit streams for transportation integrated with the optical signal "pay load." The presence of such circuitry shall not affect the pay load output signal bit rate, waveform, and other parameters.

Annex D (informative)
Laser safety information

Visible and nonvisible radiation from laser diodes and LEDs used in optical fiber communications systems is considered to be a safe application of laser technology. Light output is entirely confined to the core of the interconnected fiber, and does not leak through the cladding and outer sheath. If the pigtail of an active light source is disconnected, damage to the eye is remotely possible under the most unlikely possibility that a person would look directly into the fiber at close range for an extended period of time.

Publications of the U.S. Government Food and Drug Administration's Center for Devices and Radiological Health, ANSI, and IEC provide guidance on practices to be followed in working with optical fiber communications systems. They also contain information on labeling requirements for modules containing a laser/LED light source coupled to the outside via a pigtail or optical connector.

Annex E (informative)
Bibliography

ANSI Z136.2-1988, Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources

ANSI/EIA/TIA-568-A-1991, Commercial Building Telecommunications Wiring Standard

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