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SMPTE STANDARD

SMPTE 170M-2004Revision of
SMPTE 170M-1999

for Television — Composite Analog Video Signal — NTSC for Studio Applications



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1 Scope

1.1 This standard describes the composite analog color video signal for studio applications: NTSC, 525 lines, 59.94 fields, 2:1 interlace with an aspect ratio of 4:3.

1.2 This standard specifies the interface for analog interconnection and serves as the basis for the digital coding necessary for digital interconnection of NTSC equipment.

NOTE - Parts of the NTSC signal defined in this standard differ from the final report of the Second National Television System Committee (NTSC 1953) due to changes in technology and studio operating practices.

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 indicated below.

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 1 (1996-03) and Amendment 2 (1997-11)

ISO 10526:1999 / CIE S005/E-1998, CIE Standard Illuminants for Colorimetry

ISO/CIE 10527, Colorimetric Observers

3 General description of signal

The composite color video signal shall contain an electrical representation of the brightness and color of a scene being analyzed (the active picture area) along defined paths (scan lines). The signal shall also include synchronizing and color reference signals that allow the geometric and colorimetric aspects of the original scene to be correctly reconstituted at the display. The synchronizing and color reference signals shall be placed in parts of the composite color video signal that are not visible on a correctly adjusted display. Certain portions of the composite color video signal that do not contain active picture information shall be blanked (forced below black level) in order to allow retrace of scanning beams in some types of cameras and display devices.

3.1 The video signal representing the active picture area shall consist of:

- a wideband luminance (brightness) component with setup (see clauses 10 and 12), and no upper bandwidth limitation for studio applications;
- a pair of simultaneous chrominance (coloring) components, amplitude modulated on a pair of suppressed subcarriers of identical frequency ($f_{sc} = 3.579545... \text{ MHz}$) in quadrature (i.e., with a 90° difference in phase).

3.2 The video signal representing the active picture area shall correspond to the scanning of the image at uniform velocities from left to right and from top to bottom. The velocities shall be such that the picture is repetitively scanned on 525 nominally horizontal lines, with alternate lines scanned on each vertical pass. This process is described as 2:1 interlace (see clauses 11 and 13).

3.3 The aspect ratio of the active picture area shall be four units horizontally to three units vertically.

3.4 The composite color video signal shall be produced by an NTSC encoder that functions as follows:

3.4.1 The input signals to an NTSC encoder shall be time-coincident green, blue, and red video signals (G B R), with no setup and of equal amplitude when conveying picture information with no color content (see clause 4). Horizontal and vertical synchronizing signals and reference subcarrier shall also be required.

NOTE – Throughout this standard, references to signals represented by a single letter, e.g., G, B, and R, are equivalent to the nomenclature in earlier documents of the form EG', EB', and ER', which, in turn, refer to signals to which the transfer characteristics given in clause 5 have been applied. Such signals are commonly described as being gamma corrected.

3.4.2 Within the encoder, the green, blue, and red (G B R) video signals shall be matrixed to form one of two component sets, each comprising luminance (Y) and two color-difference signals (see clause 6); Y, B-Y, and R-Y or Y, I, and Q. The choice of component set is influenced by decisions regarding color component bandwidth; the final encoded signal shall be otherwise identical (see clause 7 and annex B).

3.4.3 After low-pass filtering, the color-difference signals (B-Y and R-Y or I and Q) shall be fed to balanced, quadrature-phase, subcarrier amplitude modulators.

3.4.4 The modulated subcarrier signals shall be added to the luminance signal, along with setup, blanking, sync, and burst (a color synchronizing signal) to form the composite output video signal.

3.5 There shall be a fixed frequency and phase relationship between the subcarrier in the burst signal, the subcarriers conveying the color-difference signals, and the horizontal and vertical synchronizing signals (see clauses 11 and 13).

3.6 The luminance and color-difference components of the composite color video signal at the encoder output shall be time-coincident.

4 Input signals

4.1 The green, blue, and red (G B R) input signals shall be suitable for a color display device having primary colors with the following chromaticities in the ISO/CIE 10527 system of specifications:

		x	y
Green	(G)	0.310	0.595
Blue	(B)	0.155	0.070
Red	(R)	0.630	0.340

NOTES

1 The display primaries with the chromaticities specified above are commonly referred to as the SMPTE C set.

2 This specification does not preclude the continued use of equipment built to the color encoding/decoding parameters of the NTSC 1953 color television transmission standard for which the chromaticities in the ISO/CIE 10527 system were specified at the following values:

		x	y
Green	(G)	0.21	0.71
Blue	(B)	0.14	0.08
Red	(R)	0.67	0.33

4.2 The system reference white is an illuminant which causes equal primary (input) signals to be produced by a reference camera and which is produced by a reference reproducer (display device) when driven by equal primary signals. For this system, the reference white is specified in terms of its ISO/CIE 10527 chromaticity coordinates, which have been chosen to match those of ISO 10526 / CIE S005/E illuminant D_{65} :

$$x = 0.3127 \quad y = 0.3290$$

4.3 The input signals shall have no setup. Their amplitudes shall be equal for picture areas whose chromaticity corresponds to the system reference white. System nominal peak white shall be represented by input signals whose amplitudes are 100 IRE units for G, B, and R.

NOTE – IRE units are a linear scale for measuring the relative amplitudes of signals. An IRE unit has no absolute value, unless defined (see annex B).

5 Transfer characteristics

The reference reproducer for this system is representative of cathode ray tube displays, which have an inherently nonlinear electro-optical transfer characteristic. To achieve an overall system transfer characteristic that is linear, it is necessary to specify compensating non-linearity elsewhere in the system. In the NTSC system, this is done at the signal source. For purposes of precision, particularly in digital signal processing applications, exactly inverse characteristics are specified for the reference camera and reproducer.

The respective transfer characteristics shall be as defined in 5.1 and 5.2. It is recognized that operating values may vary from the precise values given in order to meet operational requirements in practical systems.

5.1 Opto-electronic transfer characteristic of reference camera

$$V_C = 1.099 \times L_C^{(0.4500)} - 0.099 \text{ for } 0.018 \leq L_C \leq 1$$

$$V_C = 4.500 \times L_C \text{ for } 0 \leq L_C < 0.018$$

where V_C is the video signal output of the reference camera, normalized to the system reference white, and L_C is the light input to the reference camera, normalized to the system reference white.

5.2 Electro-optical transfer characteristic of reference reproducer

$$L_T = [(V_r + 0.099)/1.099]^{(1/0.4500)} \text{ for } 0.0812 \leq V_r \leq 1$$

$$L_T = V_r/4.500 \text{ for } 0 \leq V_r < 0.0812$$

where V_r is the video signal level driving the reference reproducer, normalized to the system reference white, and L_T is the light output from the reference reproducer, normalized to the system reference white.

NOTE – The description above is a more technically correct definition of the transfer function (gamma correction), particularly in dark areas of the picture, than the form used in older documents, viz., "having a transfer gradient (gamma exponent) of 2.2 associated with each primary" and "signals shall be gamma corrected through application of an exponential transfer gradient inverse to that assumed in the display; i.e., $1/2.2$ (0.455...)."

6 Matrixing of the signals

The green, blue, and red (G B R) video signals shall be matrixed to form one of two baseband component sets of luminance (Y) and two color-difference signals: Y, B-Y, and R-Y or Y, I, and Q.

6.1 Luminance (Y) and the color-difference signals B-Y and R-Y can be matrixed from G, B, and R according to the following formulas:

$$\begin{aligned} Y &= + 0.587G + 0.114B + 0.299R & \text{BASE EQUATION} \\ B-Y &= - 0.587G + 0.886B - 0.299R \\ R-Y &= - 0.587G - 0.114B + 0.701R \end{aligned}$$

6.2 The color-difference signals I and Q can be matrixed from color-difference signals B-Y and R-Y according to the following formulas:

$$\begin{aligned} I &= - 0.2680... (B-Y) + 0.7358... (R-Y) \\ Q &= + 0.4127... (B-Y) + 0.4778... (R-Y) \\ &(\dots\text{approximate values}) \end{aligned}$$

6.3 The color-difference signals I and Q can also be directly matrixed from G, B, and R video signals according to the following formulas:

$$\begin{aligned} I &= - 0.2746... G - 0.3213... B + 0.5959... R \\ Q &= - 0.5227... G + 0.3112... B + 0.2115... R \\ &(\dots\text{approximate values}) \end{aligned}$$

NOTE – This standard assumes input signals (G B R) to the encoder without setup. The luminance signal (Y) generated by the luminance equation above is, therefore, also without setup. Adjustment to achieve the required luminance signal, including setup, is performed in the encoding equations defined in clause 10.

It should be noted that this practice differs from the NTSC 1953 specification, which utilized input signals to the encoder having setup on them and, hence, not requiring the addition of setup in the encoder.

It should also be noted that the coefficients given for G, B, and R in the luminance base equation are precise values; i.e., $0.587 G = 587/1000 G$, etc.

7 Filtering of signals

7.1 This standard does not impose a bandwidth restriction on the luminance part of the NTSC signal. Care should be taken to ensure that appropriate filtering is applied before the signal is fed to bandwidth-limited devices.

7.2 The color-difference signals shall be bandwidth limited prior to modulation as follows:

- less than 2 db down at 1.3 MHz;
- at least 20 db down at 3.6 MHz.

(See figure 1 for an example of the baseband, modulated carrier, and encoded [composite] signal passbands.)

7.3 The low-pass filters that are used with the baseband color-difference signals should have characteristics with a minimum of ringing and overshoot (Gaussian filter characteristics, for example).

NOTE to clause 7 – This standard does not preclude the continued use of equipment built to the NTSC 1953 color television transmission standard for which the I signal bandwidth is as specified in 7.2 and the Q signal bandwidth is limited as follows:

- at 0.4 MHz less than 2 db down;
- at 0.5 MHz less than 6 db down;
- at 0.6 MHz at least 6 db down.

When the overall bandwidth is not limited to less than 5 MHz, use of wideband, equiband chroma signals provides improved chroma resolution for signal processing in the studio.

When the composite NTSC signal is transmitted (or recorded on some types of video tape recorders), the overall bandwidth is normally limited to less than 5 MHz, typically 4.2 MHz as for broadcasting. In such cases, if it is desired to permit recovery at the receiver of the wideband I signal, as provided in the NTSC transmission specifications, it is necessary to decode and re-encode with the appropriate narrowband Q channel filter prior to transmission (or recording). (See SMPTE EG 27 for further information.)

This standard does not preclude the application of more sophisticated filtering techniques to any combination of the luminance, color-difference, or chrominance signals, provided care is taken not to degrade picture quality on display devices not equipped for operation with the sophisticated filtering techniques.

8 Subcarrier modulation

8.1 After low-pass filtering, the B-Y and R-Y (or I and Q) signals shall be fed to balanced, quadrature-phase, subcarrier amplitude modulators.

This process yields suppressed-carrier amplitude modulation in which the subcarrier chrominance signals (chroma) reduce to zero when the G B R input signals are of equal amplitude.

8.2 A gated and filtered signal derived from subcarrier, called the burst, shall be added in the horizontal blanking interval of each line, excluding the nine-line vertical sync interval, as a synchronizing signal and amplitude reference for the chrominance signals. The burst signal shall be inverted in phase from the reference subcarrier.

8.3 The modulated subcarrier signals (B-Y and R-Y or I and Q) shall be added to the luminance signal along with sync, blanking, setup, and burst to form the composite output video signal (N).

9 Timing

The input signals to the encoder shall be time coincident. Similarly, all the components that make up the encoded composite video signal (N) shall be time coincident at the output of the encoder (see figure 2). The recommended tolerance for time coincidence shall be ± 25 ns for any pair of nominally coincident signals.

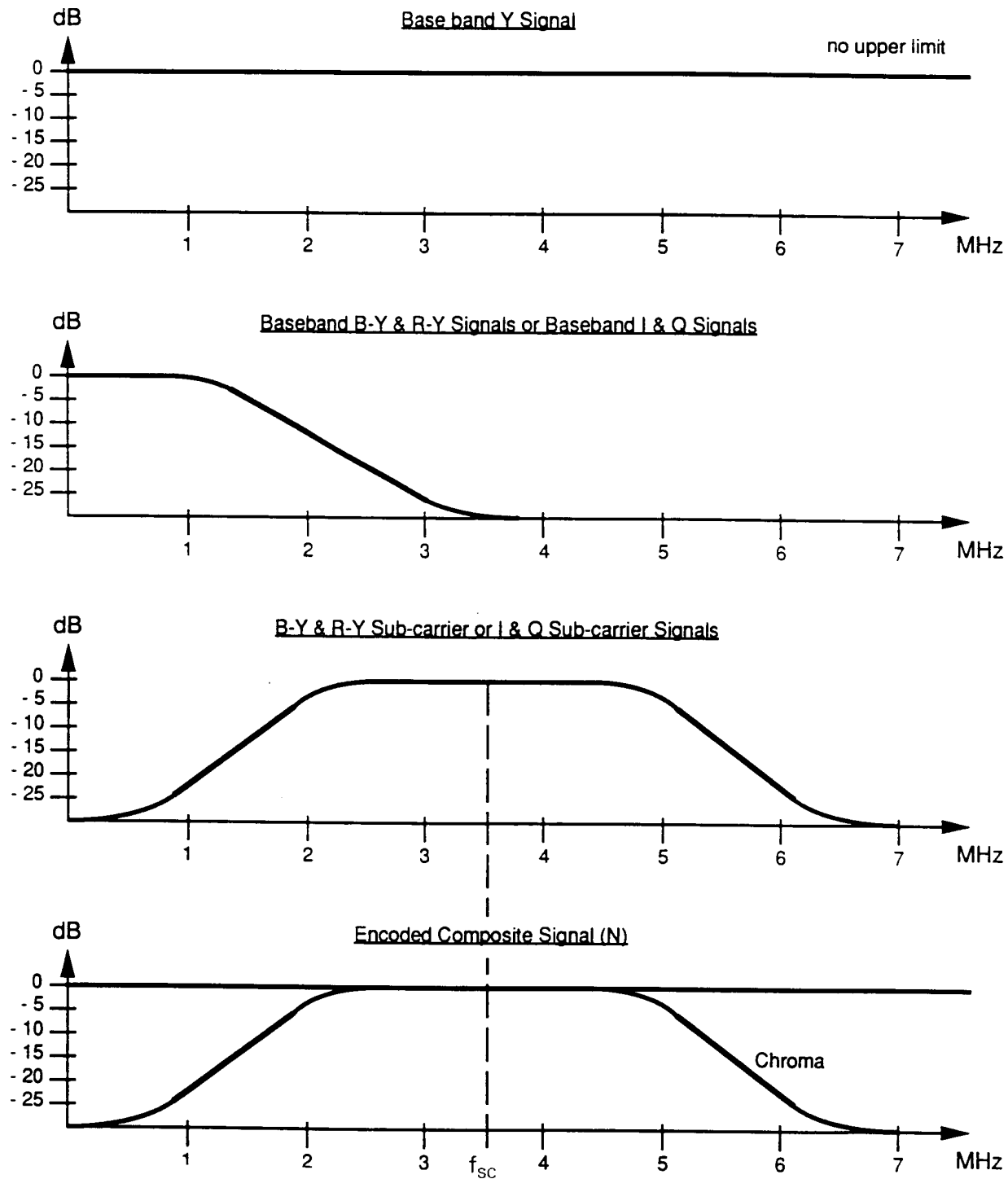


Figure 1 – Examples of signal passbands