SMPTE RECOMMENDED PRACTICE

Alignment of NTSC Color Picture Monitors

1 Scope

1.1 This practice describes an alignment procedure for the consistent and repeatable alignment of television color picture monitors.

1.2 For critical evaluation of picture program material, the aligned monitor shall be used in an environment such as that described in SMPTE RP 166.

2 Normative references

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

SMPTE EG 1-1990, Alignment Color Bar Test Signal for Television Picture Monitors

SMPTE RP 166-1995, Critical Viewing Conditions for Evaluation of Color Television Pictures

3 Test signals and equipment

A video test signal generator providing the following signals shall be available:

– SMPTE color bars with PLUGE (picture lineup generating equipment) signal (SMPTE EG 1)
– unmodulated gray scale (50% APL)
– window signal (100 IRE), also variable in level
– unmodulated variable-level flat field
– crosshatch
– pulse and bar
– multiburst
– centrally placed full-field PLUGE signal

Ideally, a spectroradiometer is the optimum instrument for setting color temperature. Operationally, a split-field optical comparator with a photometer and/or tristimulus (color analyzer) device is required.

4 Definition of terms

All color picture monitors are functionally similar, but the designation of the controls varies among models and manufacturers. (Refer to A.1 for a listing of controls that perform similar functions.)

5 Alignment

Although this practice specifies an operational alignment procedure for television color picture monitors, other alignment procedures are equally valid if they achieve the desired result. All the steps are not required every time the color picture monitor is to be aligned. If the desired results cannot be obtained, then the corrective procedures suggested by the manufacturer should be followed.

If the color picture monitors have an NTSC corrective matrix, the matrix should be switched off during alignment (see A.4). Alignment procedures should be followed in the sequence given below:

– initial conditions (see 5.1)
– initial screen adjustments (see 5.2)
– display uniformity (see 5.3)
– scan size (see 5.4)
– geometry and aspect ratio (see 5.5)
– focus (see 5.6)
– convergence (see 5.7)
– aperture correction (see 5.8)
– chrominance amplitude and phase (see 5.9)
– brightness, color temperature, and gray-scale tracking (see 5.10)
– monitor matching (see 5.11)

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5.1 Initial conditions

The color picture monitor should be turned on and allowed to stabilize for 20–30 minutes. The room ambient lighting should be the same as it is when the monitor is in normal service. Several minutes must be allowed for visual adaptation. All the color picture monitor controls should be in their preset positions. It is important that the aim luminance value, 120 cd/m^2 (35 fL), be used for all the adjustments, except as noted. It is important that the comb filter and NTSC color matrix, if present, be defeated (see A.4).

5.2 Initial screen adjustments

Switch the monitor to the setup position. In this mode, only horizontal lines or bars appear on the monitor screen. Adjust the red, green, and blue screen controls individually so that red, green, and blue signals are barely visible. These adjustments are only preliminary and will be modified later to achieve correct gray-scale tracking (consult manufacturer's procedures).

5.3 Display uniformity

Good display uniformity is essential for color monitor matching. Perceptible variations in luminance levels or discolorations will make monitor matching difficult or impossible.

5.3.1 Purity

Purity is the ability of the gun to excite only its designated phosphor. It is checked by applying a low-level flat-field signal and activating only one of the three guns at a time. The display should have no noticeable discolorations. Purity can also be checked by turning the contrast control to minimum and increasing the brightness control until a medium bright red, green, or blue raster appears. If discolorations are perceptible, then appropriate corrective action should be taken; i.e., degaussing, movement of purity magnets, etc. (see A.5).

5.4 Scan size

The color picture monitor application establishes whether the overscan or underscan presentation of the display will be selected. An underscanned display is one in which the active video (picture) area, including the corners of the raster, is visible within the screen mask. Normal scan brings the edges of the picture tangent to the mask position. Overscan should be no more than 5% (see A.6).

5.5 Geometry and aspect ratio

Geometry and aspect ratio of 4:3 are adjusted with the crosshatch signal by scanning the display device with the green beam only.

Correct geometry and linearity are obtained by adjusting the pin-cushion and scan-linearity controls so that the picture appears without evident distortions from the normal viewing distance.

The following options are available:

– place a linearity (ball chart) overlay onto the face of the CRT display;

– project a linearity slide onto the CRT display with a high-quality slide projector (a long focal length is required);

– use a transparent linearity tape with 2% tolerance markings.

5.6 Focus

An ideal focus target is not currently available on most test signal generators; however, multiburst, crosshatch, or white noise can be used as tools to optimize the focus of the displayed picture.

The focus control should be adjusted at the aim luminance level with all the beams on for optimum picture resolution in the central areas of the picture. (There should be no noticeable loss of definition in the corners.)

5.7 Convergence

Convergence is adjusted with a crosshatch signal. Convergence should be optimized for either normal scan or underscan, depending upon the application. The manufacturer generally provides an alignment sequence to ensure all scanning beams coincide.

5.8 Aperture correction

If aperture correction is used, the amount of aperture correction can be estimated visually by ensuring that the 2T sin^2 pulse has the same brightness as the luminance bar or the multiburst signal when the 3 MHz and 4.2 MHz bursts have the same sharpness and contrast. This adjustment should be verified under normal viewing conditions with picture material, not test signals (see A.7).

5.9 Chrominance amplitude and phase

The chrominance amplitude and phase are adjusted using the SMPTE color bar test signal and viewing only the blue channel. Switching off the comb filter, if present, provides a clear blue channel display (see A.8). The chroma set signal in the SMPTE color bar signal consists of four blue patches, which are to be matched with the four blue bars vertically above them. These blue bars and patches should increase and decrease in brightness equally, once the chrominance amplitude and phase controls have been properly set, as the contrast and brightness controls are varied over their normal range; i.e., they should track (see A.8). Periodically, the red and green channels should be checked individually in a similar manner to verify that the decoders are working properly.

5.9.1 Visual alignment procedure

A visual alignment procedure is given below:

The left blue bar (blue component of the gray bar) is the reference bar and its brightness is affected only by the contrast control. The phase control affects the brightness of the inner two bars and patches. The chroma control affects the brightness of the right outer bar and also the inner two bars. The adjustment sequence is first to adjust the chroma and then the phase so that all the bars and patches are of equal brightness and that black is interspersed between the blue bars. However, should the blue bars not track equally with a change in contrast, then the AFPC (automatic frequency and phase control) probably requires adjustment.

Reduce the contrast until the blue bars and patches are barely visible. (The left-hand bar is the reference bar.) Adjust the phase control so that the right-hand blue bar matches the blue component of the gray patch. Then adjust the AFPC until the two center bars and patches are of equal brightness; the AFPC reacts in the same manner as the phase control. Slight readjustment of the chroma control to achieve uniform blue bars and patches may be necessary. Increase the contrast over its normal range. If the blue bars and patches do not track, repeat the above procedure with slight adjustments of the phase and/or AFPC.

5.10 Brightness, color temperature, and gray-scale tracking

The 100-IRE window signal is used to supply the reference white. Because of typical luminance shading limitations, a centrally-placed PLUGE signal is recommended for setting the monitor brightness control. However, until a centrally-placed PLUGE signal is commonly available, the PLUGE or black set signal provided in the SMPTE color bars signal can also be used for setting the monitor brightness control. (Refer to S. F. Quinn and C. A. Siocos. Pluge method of adjusting picture monitors in television studios — a technical note. *J. SMPTE*, 76: 925, September 1967.)

5.10.1 Reference white

Using a split-field optical comparator, adjust the displayed reference white to the illuminant D_{65} and a luminance value of 120 cd/m^2 (35 fL) (see A.2). If the optical comparator has a variable luminance control, set the reference white on the monitor screen to the specified luminance value with a photometer and then adjust the comparator.

Brightness, color temperature, and gray-scale tracking controls are interactive. Achieving all the correct results simultaneously requires adjustments which reduce but do not completely correct the perceived error(s). The adjustment sequence must be performed several times, each time with smaller incremental adjustments.

5.10.2 Preferred method

An optical comparator is used to set the color temperature of the white point, using the monitor R,G,B gain controls. If the optical comparator does not have an output level equivalent to the reference luminance level, then it is necessary to adjust the contrast so that the white signal matches the brightness of the optical comparator.

Gray-scale tracking is most easily set using a color photometer, but it must have adequate low-light sensitivity. The procedure is as follows:

1) Initialize the white point of the colorimeter using a 100-IRE window signal.

2) Reduce the input signal to about 10-20 IRE.

3) Adjust the monitor screen controls for matching RGB values as measured by the color photometer.

4) Using the PLUGE signal, set the brightness control so that the darker patch of the PLUGE just merges with the reference black level, but the brighter patch is clearly distinguishable from where the monitor will be normally viewed (see A.10).

5) Readjust the input to a 100-IRE window signal.

6) Adjust RGB gain controls, as necessary, to obtain the reference white values.

7) Repeat steps (1) through (6) until RGB measurements at both high- and low-luminance levels track closely.

8) Gray-scale tracking can be most accurately verified by measuring the color of the window pattern with the color photometer as the intensity of the window pattern is varied from the low-light IRE level through the middle steps of gray to 100 IRE. A variable window will, in most cases, provide more accurate results than using a variable-intensity flat field.

Alternatively, an unmodulated 50% APL stairstep signal can be used to verify gray-scale tracking throughout the displayed scale (see A.12).

5.10.3 Alternate method

1) Place the split-field optical comparator against the face of the monitor and over the center of the white area of the window pattern. Adjust the color picture monitor contrast control for a brightness match with the split-field optical comparator (see A.12). Adjust the red, green, and/or blue gain controls so that the monitor has a close match in color with the split-field optical comparator.

2) Display a 50% APL unmodulated stairstep signal. Then adjust the red, green, and/or blue screen controls to produce visual neutrals in the darker picture areas.

3) Using the PLUGE signal, set the brightness control so that the darker patch of the PLUGE just merges with the reference black level, but the brighter patch is clearly distinguishable from where the monitor will be normally viewed (see A.10).

4) Repeat steps (1) to (3) for optimum results.

The gray-scale signal (50% APL unmodulated stairstep signal) should now be visually neutral (black to white) and the reference white should have the desired color temperature and luminance value.

5.11 Monitor matching

When color matching two or more color monitors, the same alignment steps should be performed on each monitor in turn (see A.3).

CAUTION – Monitors cannot be matched without the same phosphor sets, similar display uniformity characteristics, and similar sharpness, etc. (see A.14).

The most noticeable faults on color monitors are the lack of uniform color presentations and brightness shading. Color matching of monitors for these parameters can be most easily assessed by observing flat-field uniformity of the picture at low, medium, and high amplitudes. Once monitor calibration has been satisfactorily completed in the monitors to be matched, apply an unmodulated flat field, first at a low level (15 to 30 IRE), then at a mid-level (45 to 60 IRE), and finally at a high level (not to exceed 80 IRE), and observe the color and brightness changes over the entire surface of the monitors to be matched. The patterns of non-uniformity in both intensity and color must be similar among the monitors, at all three levels, if average scene material displayed on these monitors are to match.

There could be other reasons why the monitors do not match. Most often, the problems relate to incorrect adjustments, usually in this sequence: AFPC, color temperature and brightness of the reference white, and brightness control.

Generating test patterns needed to determine the ability of monitors to match may be most easily accomplished in the studio by using the color background generator in the production switcher. It should have the capability of generating the variable level luminance and color fields.

If a color background generator is unavailable, the SMPTE color bars can be used in monitor matching. When comparing the yellow-cyan bars, where the eye has good phase discrimination, any phase difference between the monitors may be compared; with the red-magenta bars, the chrominance level may be visually compared.

6 Noncomposite monitors

Similar adjustment procedures, with the exception of chrominance amplitude and phase, can be followed with noncomposite color monitors. It should be noted that the setting of the brightness control is performed visually using the appropriate PLUGE signal (see A.10).

Annex A (informative)
General information

A.1 Controls

The following controls perform similar functions:

- screen, low-light, background, bias, cut-off, black balance, low level;
- gain, highlight, white balance, drive;
- chroma, saturation;
- phase, hue;
- color hold, AFPC, APC, oscillator lock;
- black level, brightness;
- contrast.

A.2 Reference white

Reference white is obtained when a color video signal at a 100-IRE unit luminance level with zero color subcarrier is displayed on a properly aligned color picture monitor.

When a 100-IRE unit reference patch is used, it should be located in the center of the raster for consistency because of luminance shading artifacts.

The use of a center located window pattern of about 15% of the active picture area is recommended when making any peak white adjustments or measurements. This type of pattern more closely represents real program video in its operating requirements of a monitor than does a flat field.

Some monitors, often depending on CRT type, are not capable of producing a linear light output level as high as 120 cd/m^2 (35 fL). They should produce a minimum peak operating level of 100 cd/m^2 (about 30 fL) in order to be considered useful in critically evaluating video signals.

A.3 Photometric measurement devices

Adjustment of the television reference white to a specific value of color or luminance cannot be done reliably by eye from personal visual memory; it requires a light-measuring instrument. Various devices exist on the market.

Each monitor must first be aligned to the absolute color reference and brightness because color picture tubes vary from batch to batch and manufacturer to manufacturer. Therefore, the same meter indication may not be the same for two or more monitors. This is usually done with a split-field optical color comparator as an operational quality instrument. Spectroradiometers are preferred for laboratory and research facilities. After the color balance is established, the R,G,B data can be transferred, with a photometer or other light-measurement device calibrated from the reference monitor.

NOTE – Personnel using split-field optical color comparators must have normal color vision.

There are devices using light-measuring cells and meter indication that produce results in a very short time and can eliminate differences in visual perception among people who align monitors. It must be remembered, however, that these devices can only transfer standards and can supply no absolute reference.

A.4 NTSC corrective display matrix

The NTSC corrective matrix in a display device is intended to correct any colorimetric errors introduced by the difference between the camera primaries and the display tube phosphors.

NOTE – It must not be used during monitor alignment setup, and should not be used when critically evaluating a video signal.

A.5 Purity and degaussing

A very critical evaluation of purity can be made by examining the red or green or blue beam landing with a magnifying glass.

Generally, the integral degaussing system does a better job of degaussing the internal shield and picture tube than an external hand-held coil. External degaussing is more effective for magnetized cabinet parts.

A.6 Scan size

The underscan position of the monitor allows viewing of the entire active image, permits studio technical personnel to be vigilant for video defects, and enables the producer/director to check the framing of the scene. Determination of whether the picture is within the safe action or safe title areas should be made by a special safe title/action generator which is keyed over the video signal or geometric overlays to conform to SMPTE RP 27.3.

A.7 Aperture correction

Aperture correction is used to correct for the aperture distortion caused by the finite size of the picture tube scanning beams. The effect of this impairment is most noticeable as a loss of fine picture details. The aperture control is adjusted for a relatively flat modulation transfer function (MTF) on the picture monitor screen.

The amount of aperture correction is adjusted with a test signal giving amplitude/frequency characteristics. A 2T pulse and bar signal is recommended.

A.8 Chrominance amplitude and phase

Some versions of comb-filter decoders add a one-line delay in the vertical dimension of color transitions, separating or overlapping the transitions. In the case of the color bar signal going through this type of decoder, there is often a separation of the bar and the patch below it, making it more difficult to observe an exact match between the two pieces of information. There are adaptive comb filters that have gotten around this difficulty. They can present as clear a transition between the bar and patch as can be obtained in the notch filter position.

If the notch filter position is the only position that can be accurately set for chrominance and phase levels, it is the only position that should be used for critical evaluation of program material.

In many cases, where the adjustment of both filter positions can be clearly observed, a single adjustment of the front panel chroma and phase controls will yield a slightly different result when switching between the two filter positions. This situation should be correctable with internal adjustments to one or both of the decoders. (See information supplied by the manufacturer for details.)

The alignment accuracy of the chrominance amplitude and phase and subsequent tracking of the blue bars is greatly increased by using the SMPTE color bar signal. Visual adjustment of the four blue bars for equal brightness when spaced over the screen is difficult. The use of the SMPTE color bar signal increases the alignment accuracy by placing the blue signals to be matched directly adjacent to each other. The eye can then perceive brightness differences without the effects of purity or shading.

A.9 Chrominance dot crawl

A color monitor has basically two modes of operation: color and monochrome. In the monochrome mode, the monitor will display a color program in black and white by disabling the chrominance circuitry. Depending upon the type of monitor, the monochrome mode may have wide-band luminance information going to the picture tube and hence show the chrominance dot crawl, or a subcarrier trap (notch filter) will be switched into the circuit and thus limit the bandwidth of the luminance channel. If the dot crawl is present on the monitor screen in the monochrome mode, the brightness rendition is higher than it should be because of a phenomenon called subcarrier dot rectification.

A.10 Black level

Setting the black-level control is extremely important as it affects the interpretation of scene contrast. With a reference black-level signal applied at the input, the setting is correct when the active scanning lines are just at the point of visual extinction from normal viewing distance; generally 4 to 6 picture heights (see SMPTE RP 166). The PLUGE is a signal designed to simplify this adjustment.

The PLUGE is currently found in the lower right-hand corner of the black area of the SMPTE color bar signal. Studies have shown that because of luminance shading, this geometric area can no longer be considered representative. It is recommended that the PLUGE signal be placed in the central 25% area of the screen for proper setup.

The PLUGE signal consists of two small vertical ribbons, one slightly above and the other slightly below the encoded reference black level of the source. When setting the black level, it is imperative that the ambient lighting and viewing conditions be the same as when the monitor is in service.

The black level should be adjusted to the point where the darker patch just merges with the reference black level, but the brighter patch is clearly distinguishable from where the monitor will be normally viewed.

A.11 Color temperature

The split-field optical comparator is placed over the center of the reference white area on the monitor face. The central area of the monitor screen must be used when adjusting reference white (100 IRE units) for the correct color temperature and brightness.

Reference white has the correct color temperature and luminance when there is a visual match between the reference area of the split-field optical comparator and the face of the monitor screen. In trying to obtain a perfect match, the eye will become tired and lose color discrimination. To avoid these effects, the eyes should occasionally be diverted to look elsewhere, preferably on a neutral area.

A.12 Gray scale

The color monitor must be capable of reproducing a neutral scale without perceptible color at any level between reference black and white.

In order to minimize the effect of color shading, it is best to evaluate gray-scale tracking using a variable level window or full-field signal. Alternatively, a 50% APL unmodulated stairstep test signal can be used.

The monitor gray scale can be evaluated with an unmodulated gray-scale test signal including burst and with all controls and switches set for the intended operating conditions.

A.13 Shading

Color shading is a variation in color temperature throughout the displayed picture area.

Luminance shading is a variation in light intensity throughout the displayed picture area.

These characteristics are inherent properties of the CRT and will affect color monitor matching.

A.14 Phosphor characteristics

The color display coordinates, expressed in terms of the CIE 1931 x,y chromaticity coordinate values, are:

	x	y
Red	0.630	0.340
Green	0.310	0.595
Blue	0.155	0.070

The tolerance for x and y is ± 0.005.

Annex B (informative) **Bibliography**

SMPTE RP 27.3-1989, Specifications for Safe Action and Safe Title Areas Test Pattern for Television Systems