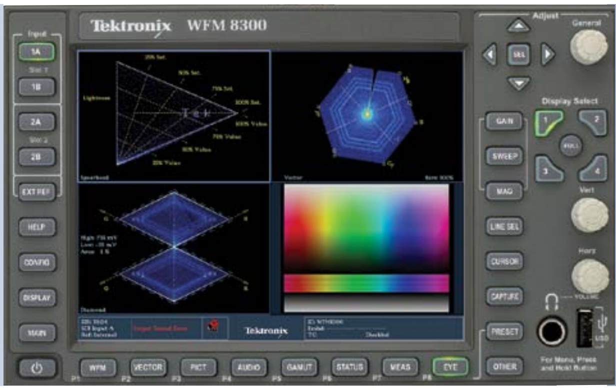

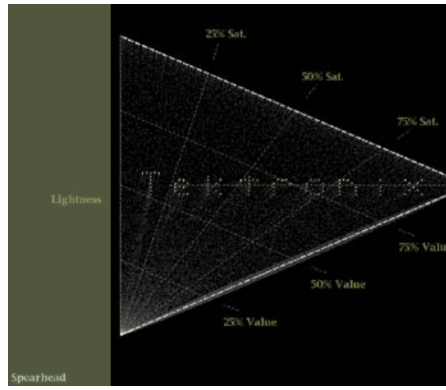

Preventing Illegal Colors

Application Note

Color gamut compliance is important to ensure faithful reproduction of program content, without distortion in the transmission system or the picture display.

Tektronix has developed several monitoring displays to help identify and resolve gamut violations and to assist with artistic color correction.

Monitoring the color gamut of a component video signal is not a routine activity for the majority of those working in the video industry. But, if you create video with a graphics workstation or perform technical or creative adjustments on cameras, you are keenly aware of the potential problems that can occur when the R'G'B' (red, green, blue) color gamut is violated. Vibrant colors lose their brilliance when transmitted or recorded, destroying the visual impact you achieved on a computer display or a studio monitor. Many facilities are hybrid, working with a variety of different formats, analog or digital, standard definition or high definition, that complicate the process further.

To prevent the undesired impact of color gamut violations, Tektronix has developed several displays that simplify assessment of proper gamut compliance. The Diamond and Split Diamond displays are component vector displays that offer reliable indication of gamut violations within the R'G'B' domain. Anytime an R'G'B' signal or color difference component signal is out of gamut, the trace on the Diamond display appears outside the boundaries of one or both of the two diamond-shaped elements of the electronic graticule. If no violations exist, the trace remains on or within the limits of the graticule. In addition to reliable gamut indication, the Diamond display indicates inter-channel gain and timing errors, and can also be used to set black balance.

The Spearhead display can be used with the Split-Diamond display to show the artistic metrics of color value and color saturation within the valid gamut of the signal. Color correction is simplified with the Spearhead display because RGB gain and black level adjustments can be viewed while maintaining gamut compliance.

The Arrowhead display can be used on component signals to determine if the signal is within gamut for a composite PAL or NTSC signal, without the need to process the signal through a composite encoder.

The Lightning display facilitates quick alignment of component color bar signals to ensure correct amplitude and timing of the signal. A traditional vector display only shows the two color difference components, whereas the Lightning display shows the luma and color difference components.

Familiarity with the terms gamut, legal and valid is essential to understanding the potential problems that Tektronix gamut displays help to eliminate.

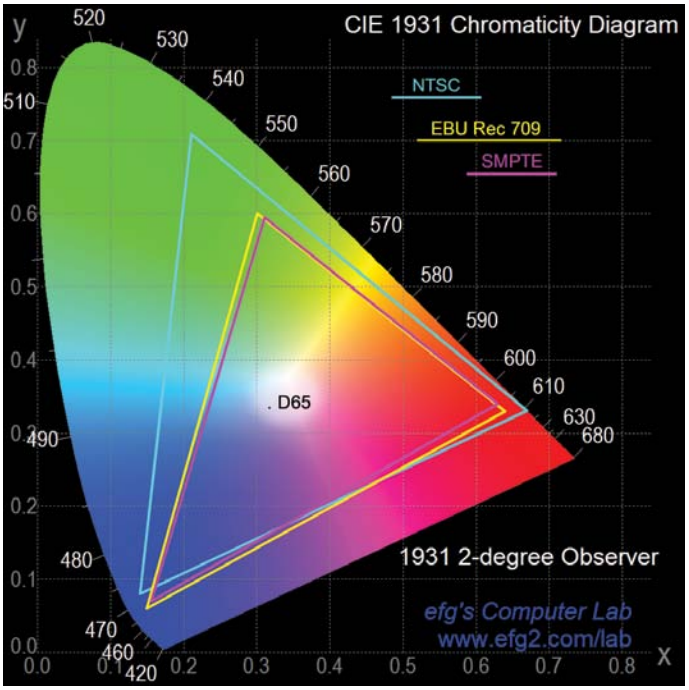

Figure 1. CIE xy Diagram with color coordinates used by NTSC, SMPTE and Rec. 709.

Defining Legal and Valid Gamut

The term gamut has been used to refer to the range or gamut of colors reproducible by a television system when a scene is illuminated by a reference white (6500-degree illuminant D for NTSC/PAL and High Definition Systems). Gamut is defined by the chromaticity value or CIE chromaticity coordinates for a given system. This range of colors, of variable saturation, is reproduced in the picture monitor by the R'G'B' signal values. When R'=G'=B', the components are of equal value, and the image is colorless to the extent it represents the monochrome signal or reference white (shades of gray or gray-scale) on a properly adjusted picture monitor. Otherwise, a colored hue of nonzero saturation results. All colors within the gamut of reproducible colors are possible by independently adjusting the values of the R'G'B' signals.

Because the values of the R'G'B' signals directly represent these colors, the term gamut is often used to refer to the voltage range of R'G'B' signals. R'G'B' signals extending outside the specified voltage range, or gamut, may produce desirable color values (albeit outside the system color gamut) on a given picture monitor, but may be clipped or compressed in subsequent signal processing, distorting the color when displayed on another picture monitor.

For example, R'G'B' systems have an upper gamut limit of 700 mV and a lower gamut limit of 0 mV. If any channel of an R'G'B' signal exceeds either the upper or lower limit, a gamut violation exists. Violation of gamut limits makes the signal illegal. Legal signals are simply those signals that do not violate the signal voltage limits for the particular format in use, i.e., signals within the allowed signal limits for that format. Legal signals, however, can be invalid in color-difference formats like Y'P'bP'r. The allowed range for the luma signal is 0 mV to 700 mV, and for the color difference signals P'b and P'r, the range is ±350 mV.

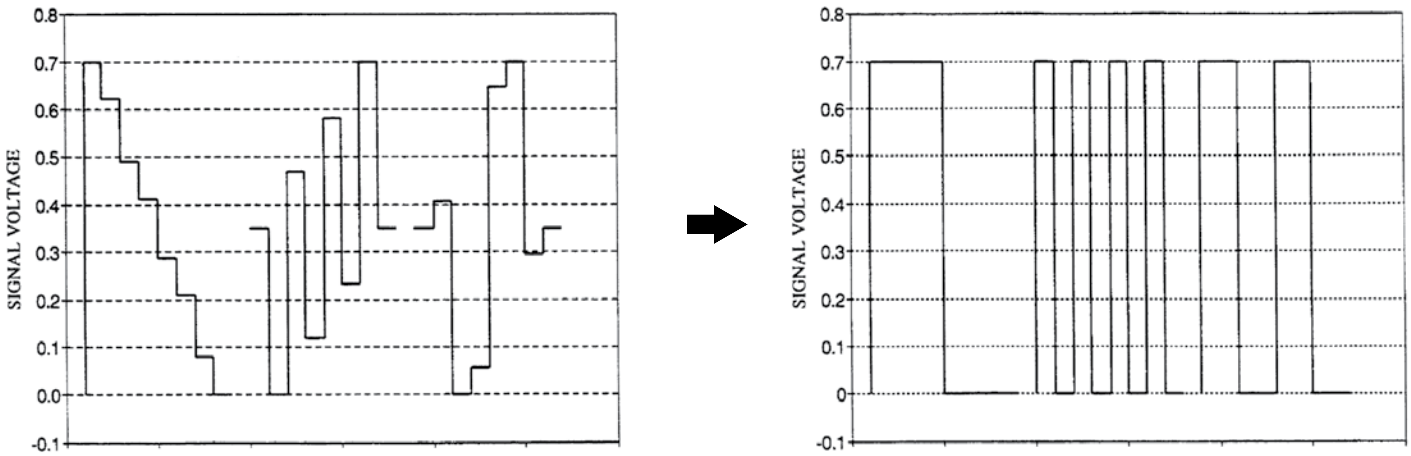

Figure 2A. Legal and valid color-difference signal translates to a legal R'G'B' signal.

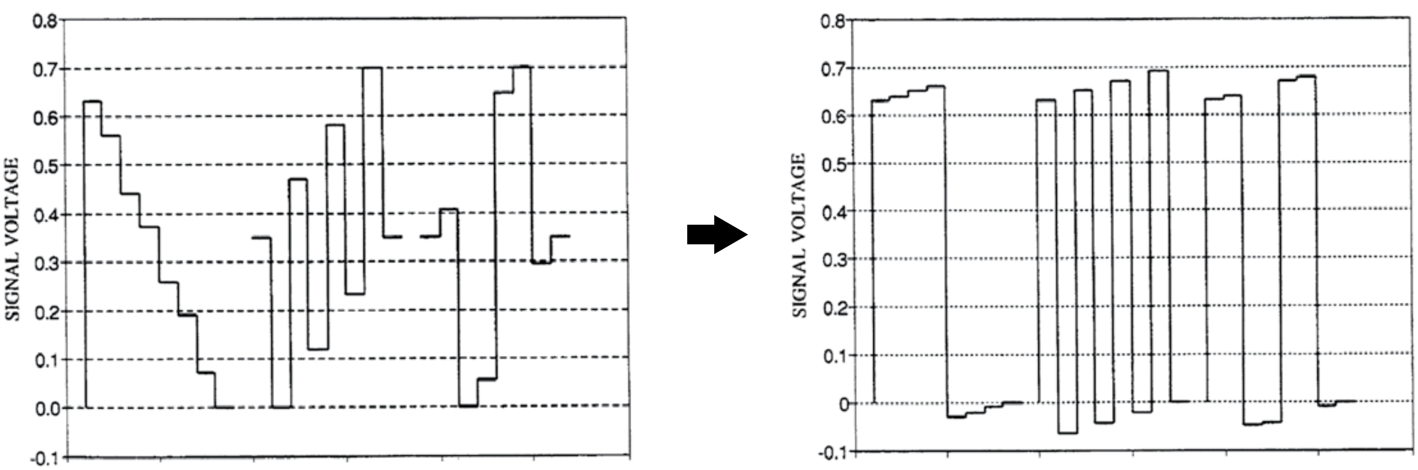

Figure 2B. Distorted but legal color-difference signal translates to an invalid R'G'B' signal.

A valid signal is one that is within color gamut and remains legal when translated into any other format. A valid signal is always legal, but a legal signal is not necessarily valid. The latter case most often occurs with a color-difference format component signal, where the signal levels are not independent, as they are in R'G'B' systems. The following description explains how a simple gain distortion in a color difference component signal can make the signal invalid, though not illegal. Figure 2A shows a legal and valid color difference signal (top) and the legal R'G'B' signal (bottom) into which it translates. In Figure 2B, however, the luminance channel of the color difference signal (top) is distorted; as it has a relative gain of only 90 percent. When the distorted signal is transcoded to the R'G'B' format (bottom), the result is an illegal signal – all three components extend below the minimum allowed signal level. Since the distorted color difference signal cannot be translated into a legal R'G'B' signal, it is said to be invalid. Additionally, other forms of distortion can create a variety of invalid signals.

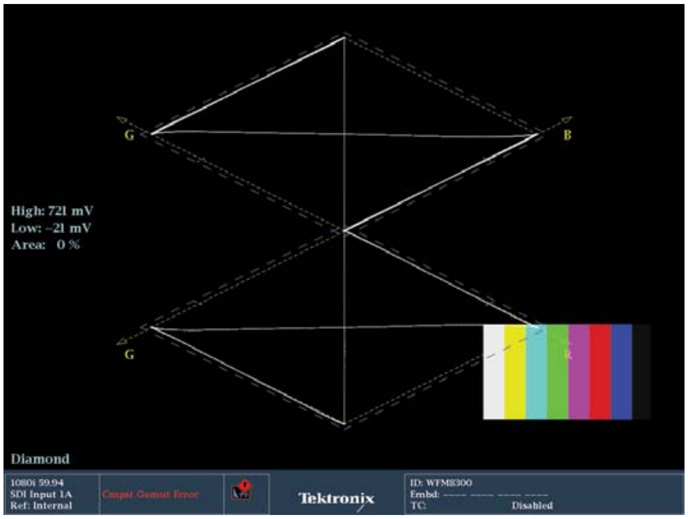

Figure 3. Diamond display with 100% Color Bars.

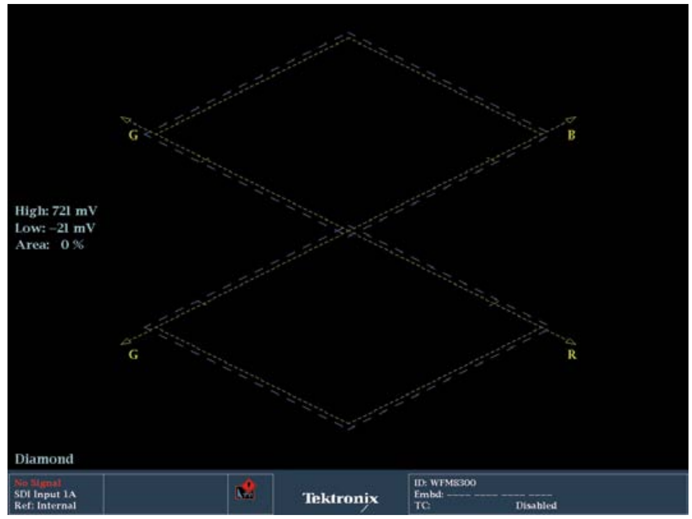

Figure 4. Diamond display graticule.

Creating the Diamond Displays

When looking at the Diamond display of a 100% color bars signal in Figure 3, the manner in which the display is constructed is not intuitively obvious. Looking at a diamond graticule with no waveform (Figure 4), you will notice that the green and blue components form the upper diamond in the display, while green and red comprise the lower diamond.

The equation used to combine the green and blue components to drive the vertical axis of the upper diamond is B'+G', while B'–G' drives the horizontal axis. Figure 5 illustrates what the B'+G' and B'–G' waveforms look like for a 100% color bars signal and how their combination creates the diamond shape. In Figure 5, the points on each waveform correspond to the numbers at each corner of the diamond. Using these numbers, you can follow the path taken by the trace made by a 100% color bars signal. R'+G' and –(R'+G') form the lower diamond in the display in a similar manner.

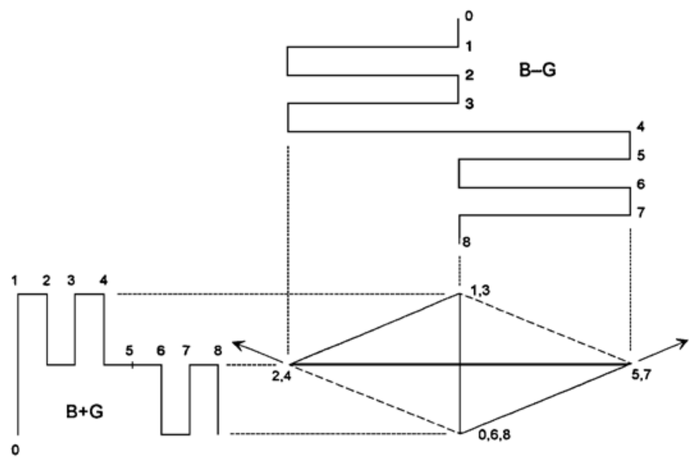

Figure 5. Formation of upper diamond with G' and B'.

Bandwidth Considerations

Color difference component formats have unequal signal bandwidths. The luma (Y') channel typically has at least twice the bandwidth of the color difference (P'b, P'r or B'–Y', R'–Y') channels. When converting a signal from a color difference format to R'G'B' (as in a picture monitor), the unequal transition risetimes create signal excursions that temporarily exceed the valid range of the R'G'B' signal, resulting in gamut violations. Because level clipping of these transitions may have little or no impact on the picture, some video professionals feel that such gamut violations are acceptable for R'G'B' systems. However, other gamut detection approaches that utilize fixed-level detection schemes would report an error when these out-of-gamut transients occur.

To minimize false gamut alarms, Tektronix Diamond display circuitry incorporates low pass filters, suitable for the format being used, to reduce such transient-based gamut errors. This allows operators to ignore fast transients that have minimal effect on the picture, instead placing their emphasis on visually disturbing violations: those that occur for longer periods of time over wider areas of the picture. Such an approach frees operators to make subjective judgments as to the degree of gamut violations that they consider acceptable. Figure 6 is a block level view of the circuitry used to drive the Diamond display.

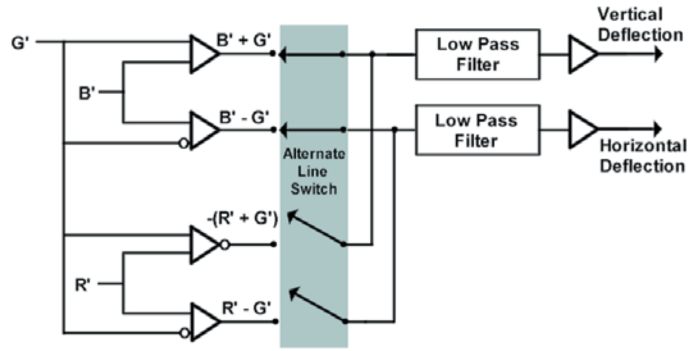

Figure 6. Low pass filter reduces high frequency transients that exceed gamut limits.

Interpreting Gamut Violations

The Diamond display is the most reliable and useful R'G'B' gamut violation indicator available for several reasons. Because the top diamond in the Diamond display indicates levels of blue and green signal components, while the bottom diamond displays only red and green, it is easy to identify which channel or channels are in error when manipulating the R'G'B' signal. The Diamond display shows neither false alarms nor allows severe gamut errors to slip by without being displayed. Another important advantage of the Diamond display is its ability to be used as a subjective measure of the severity of a gamut violation. Again, the Diamond display is a tool for monitoring the effects of creative adjustments. It is not intended to be a measurement tool.

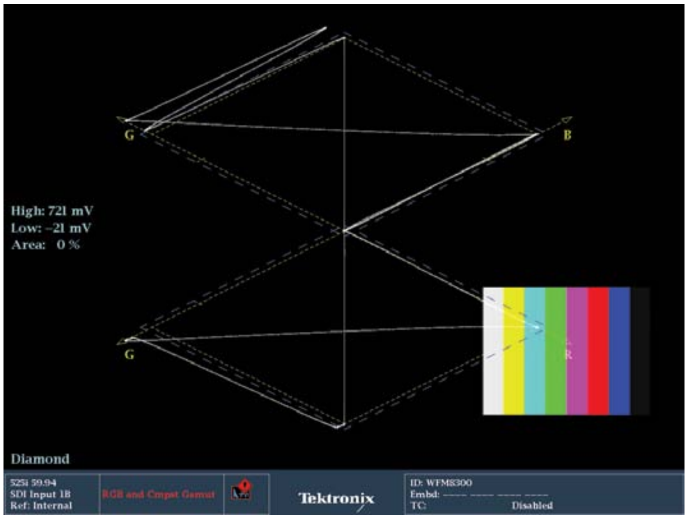

Figure 7. Diamond display using 100% color bars with green amplitude error.

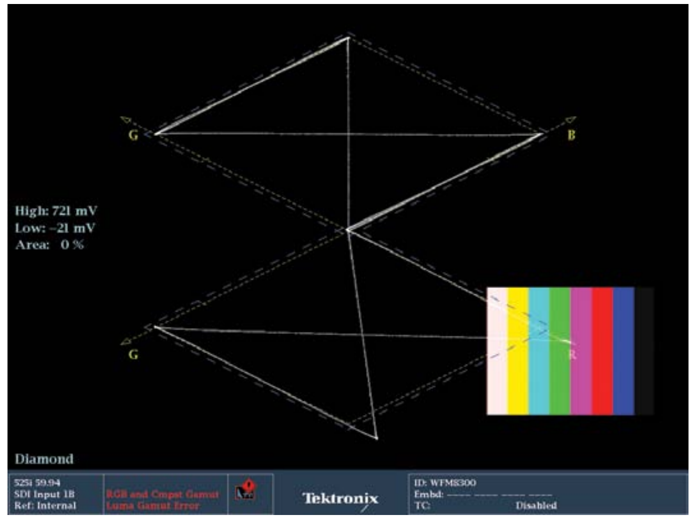

Figure 8. 100% Color Bars with red error.

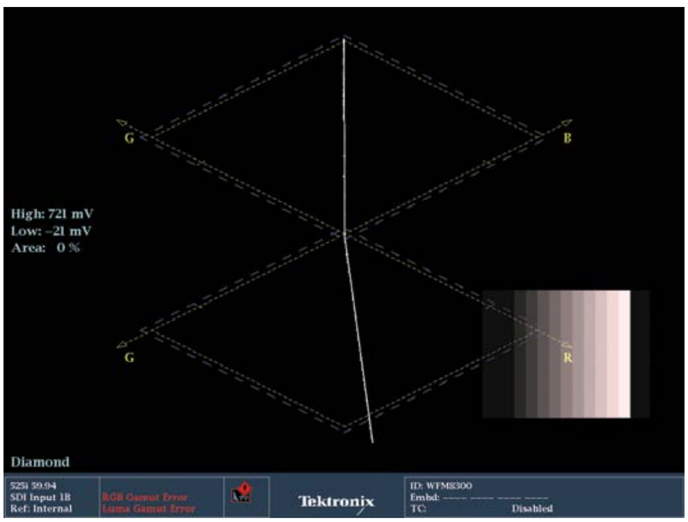

Figure 9. 10 step staircase with red imbalance.

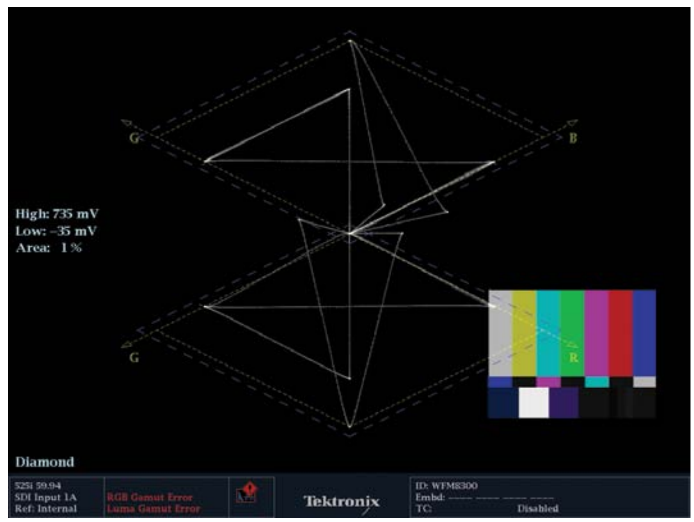

Figure 10. Diamond display using SMPTE Color Bars signal exceeds R'G'B' limits.

Red, Green or Blue Errors

During creative adjustments, the Diamond display removes any guesswork in determining which R'G'B' channels are exceeding gamut limits. Because the green channel is used in both the top and bottom diamonds, a green channel gamut violation affects both halves of the display equally. In Figure 7, the green channel of a 100% color bars signal is about 10 percent high. Notice how the display skews in the green direction. Just as important, the properly scaled blue and red channels on the right-hand side of the display show that the signal levels in those channels are correct.

Shifting the gamut error to the red channel produces the display shown in Figure 8. This affects only the lower half of the display, which is skewed in the direction of the R (red) graticule arrow. The same error on a monochrome staircase signal results in a similarly skewed display, shown in Figure 9.

The Diamond display is a reliable gamut indicator for two fundamental reasons. First, it does not give “false positive” indications. That is, if the displayed signals are within their appropriate diamond graticules, there is no R'G'B' gamut violation. Second, the Diamond display does not indicate “false negatives.” If the signal is outside the diamond graticules, it is out of gamut and subject to distortion.

When the familiar NTSC SMPTE Color Bars signal is used, the conversion to R'G'B' color space causes the signal to exceed the diamond as shown in Figure 10. Therefore, the SMPTE Color Bars signal is invalid within R'G'B' space, even though the signal is valid within composite color space.

Figure 11. Video Session display, showing RGB and Composite Gamut Errors.

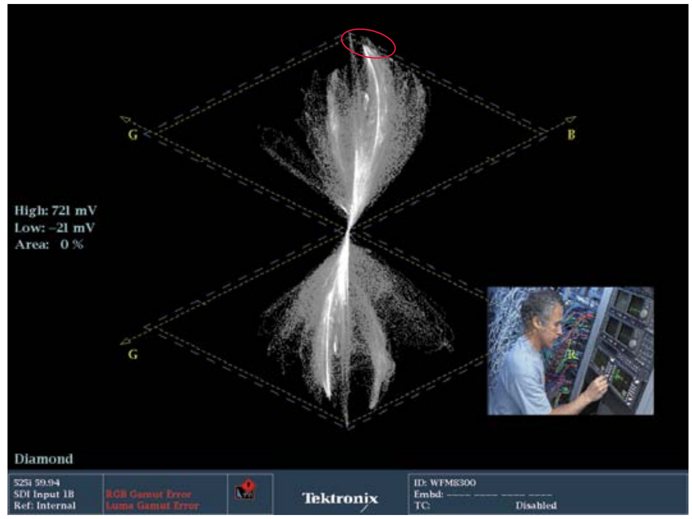

Figure 12. Diamond display with live signal.

Subjective Analysis

Perhaps the most fundamental advantage of the Diamond display is that it supports subjective assessment of gamut violations. Traditional, hard-decision, go/no-go gamut indicators cannot discriminate between very minor gamut violations that may have no noticeable impact on a picture and serious violations that warrant immediate attention.

Gamut violations of short duration appear as faint lines or dots outside the diamond-shaped graticule boundary. The larger the picture area exceeding the gamut, the brighter the trace or dot that appears outside the graticule limits. Therefore, the degree to which signals are near or just outside the gamut limit can be subjectively evaluated by the operator without the confusion caused by hard-decision level detectors.

Gamut violations can also be observed on the Video Session display, as shown in Figure 11. For the R'G'B' gamut space, upper and lower case letters are used to indicate violations above and below threshold limits respectively. For example, "R" and "r" are used for the red component, and appear on the Video Session display when the gamut limits are exceeded above and/or below the user-specified thresholds. The Video Session display also includes composite gamut and luma gamut indicators to complement the R'G'B' indicators, providing a comprehensive view of gamut compliance.

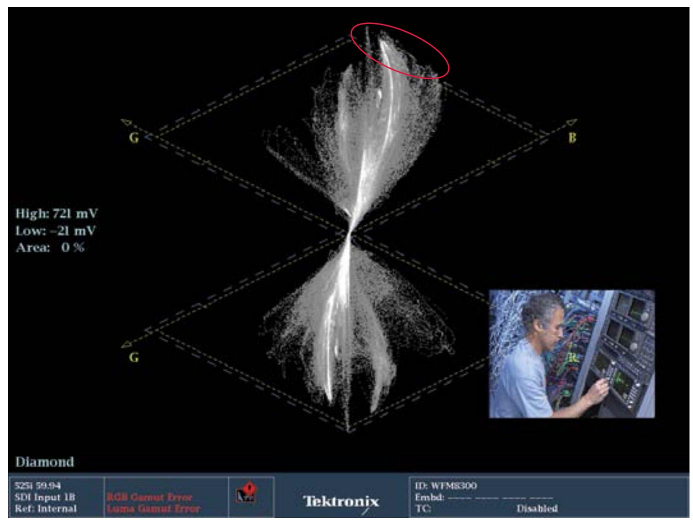

Figure 13. Diamond display with live signal and gamut errors.

For example, you might determine, with the help of the Diamond display, that the extent of the gamut violation shown in Figure 12 is minor enough that it would not be noticeable in the final product, and therefore not worth worrying about. However, the gamut violations in Figure 13 should be corrected before releasing the program. A go/no-go gamut indicator could not provide the same “feel” for the severity of the violation. With nothing more than a gamut violation indicator as a guide, you would at the very least waste time investigating the extent of the error, and might ultimately perform unnecessary equipment adjustments to eliminate the indication.

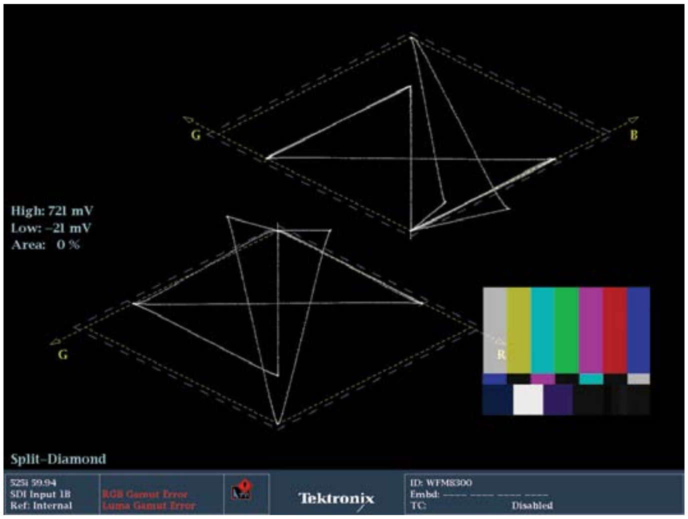

Figure 14. Split Diamond display using SMPTE Color Bars.

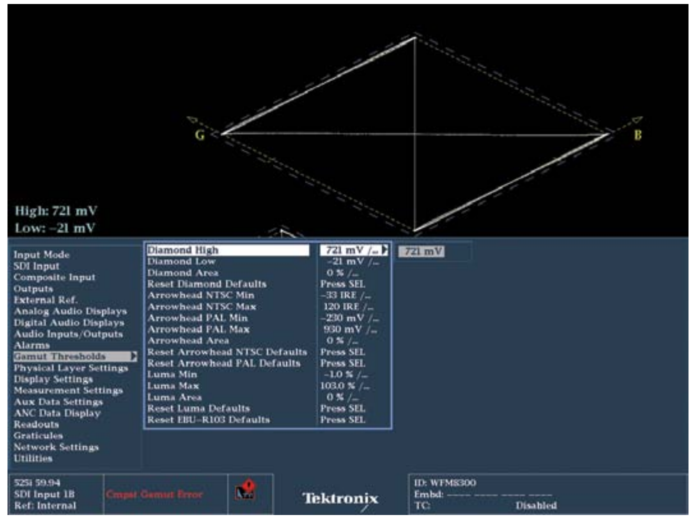

Figure 15. Configuring gamut limits on the WFM8300.

The Diamond display is also available in a Split Diamond style, as shown in Figure 14. The upper and lower displays are separated to permit minor transitions in the black region to be more clearly observed. The opposite diamond in a traditional Diamond display might have masked these errors. With the Split Diamond display, it is much easier to determine black levels in each of the R', G' and B' components.

Additionally, the user can set thresholds for specific gamut alarm indications. As the operator chooses upper and lower voltage limits from the configuration menu as shown in Figure 15, the large dashed graticule line on the display graphically shows the selected gamut limits. These limits are also used with the error logging function, and for the status indicators at the bottom of the waveform monitor's display. Three settings are used to configure gamut limit. The High and Low thresholds determine the acceptable range of gamut violations. The selected values of 721 mV and –21 mV represent ±3% from the valid signal range. The Area parameter defines the percentage of total pixels in the image that may be out of gamut without reporting that the signal has a gamut error.

The EBU R103 standard provides the recommended tolerance for illegal colors in television. Tektronix waveform monitors have configurable gamut limits, including a preset for R103 values. For RGB, these are 5% to 105% (–35 mV to 735 mV) and for the luma signal the limits are –1% to 103%.

Figure 16. P'b timing error shown on Diamond display.

Timing Errors

Component video systems cannot provide the crisp, clear picture expected of them if inter-channel timing errors are present. Using the Diamond display, timing errors appear as bowed transients (Figure 16). Even relatively small timing errors, such as a 20 ns delay, become obvious due to sensitivity of the Diamond display. A small amount of bowing is present at the transition between each color, shown here in Figure 16, due to the timing shift of one of the channels. The upper diamond has a significant bowing across the horizontal transition, whereas the lower diamond does not have this error. Therefore we can conclude that the timing error is present within the blue channel. The direction and magnitude of the bowing does not provide quantitative information. Similarly, an error in the red channel would affect the lower half of the display.

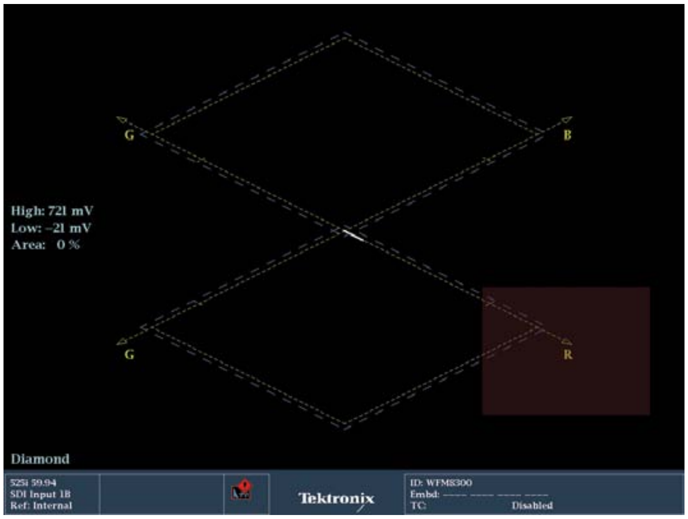

Figure 17. Red balance error on Diamond display.

Figure 18. Live signal with red balance error.

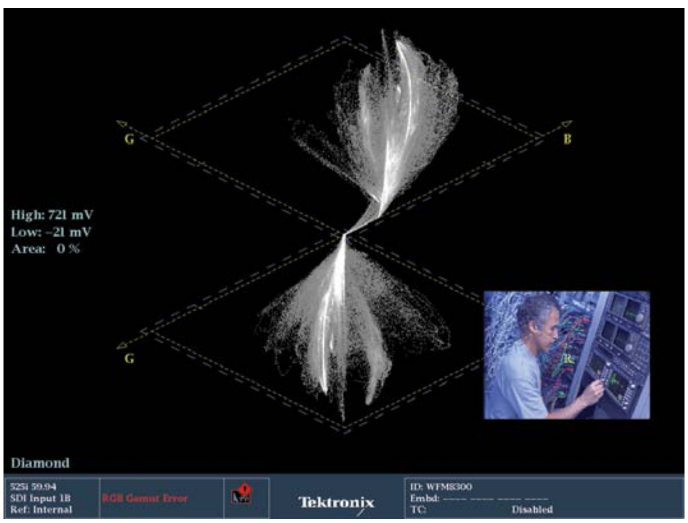

Figure 19. Live signal with blue balance error.

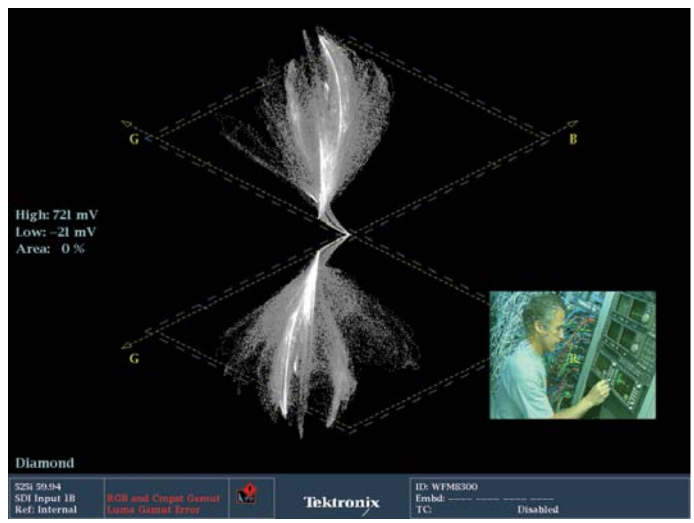

Figure 20. Live signal with green balance error.

Black Balance

Like inter-channel timing errors, black balance problems are easy to detect with the Diamond display. Any signal containing truly black areas produces a dot at the exact connecting point of the upper and lower diamonds. If the black balance is off, the center dot will be stretched in the direction of the signal component that is too strong. Figure 17 shows the effect of too much red during a standard, lens-capped black balance adjustment. The Diamond display not only reveals black balance problems with test signals or a capped lens, but it also exposes errors occurring in live video as well (Figures 18, 19 & 20).

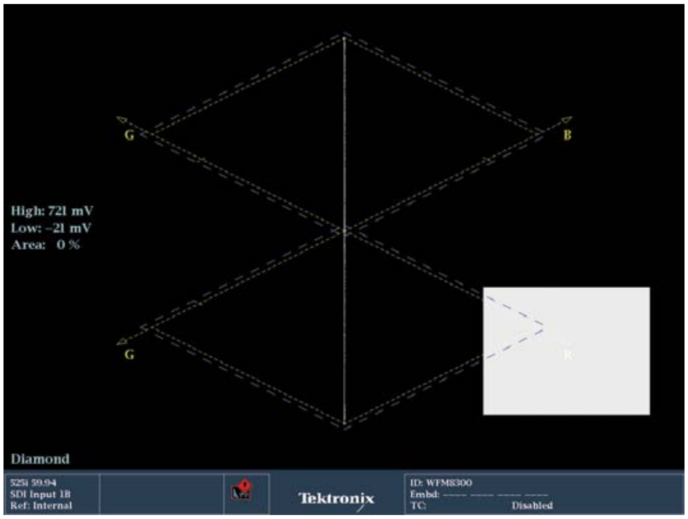

Figure 21. Correctly balanced white field shown on Diamond display.

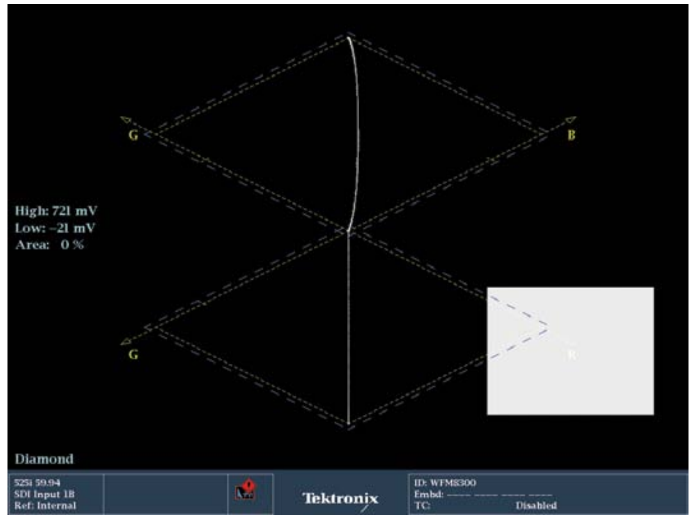

Figure 22. Blue gamma error on Diamond display.

Gamma Adjustments and Gray Scale Tracking

The Diamond display is a useful tool during gamma adjustments. It is, however, important to understand the limitations of the display in this application. The vertical or center axis of the Diamond display does not indicate true luma, but instead plots points of equal green and blue on the top and points of equal green and red on the bottom diamond area. Therefore, all monochrome signals (R'=B'=G') must fall on a centered, vertical line of both diamond areas, making the Diamond display very convenient for gray-scale tracking adjustments.

Recall that for a trace to extend straight upward from the diamond's center dot, blue must be exactly equal to green, and to extend straight downward from the center dot, red must be equal to green.

In R'G'B' systems this occurs only when R'=G'=B', and results in a white, or monochrome, signal as shown in Figure 21. Bearing this in mind, any inequality in channel gains would result in a trace skewed from the vertical axis. Figure 22 shows a Diamond display resulting from a camera pointed at a standard white field. The camera's blue channel has been set for a gamma that will brighten the darker areas of the scene.

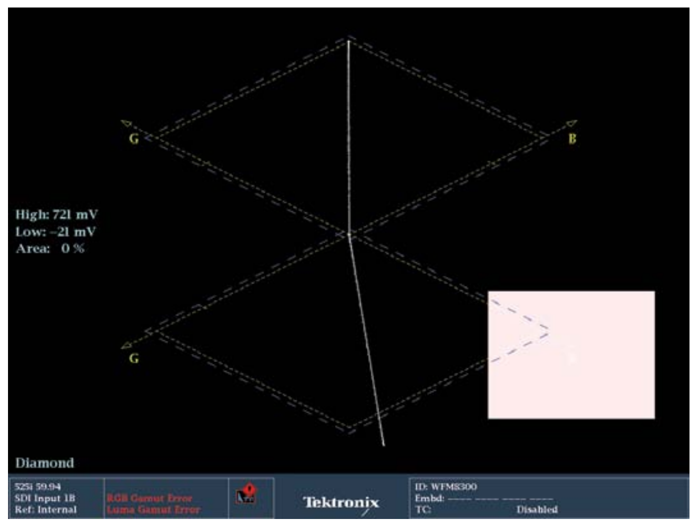

Figure 23. Red gain error on Diamond display.

In Figure 23, the red gain must be misadjusted because it affects only the lower diamond. Matching the three channels from black to white is a simple matter of adjusting the B' and R' channels to straighten the trace on the Diamond display. Note that the Diamond display makes no provision for calibrated gamma adjustments. Gamma must still be set using a waveform display, but matching the gamma of the blue and red channels to that of the green channel becomes easier than ever, particularly when adjusting gamma for a specific effect on a picture monitor.

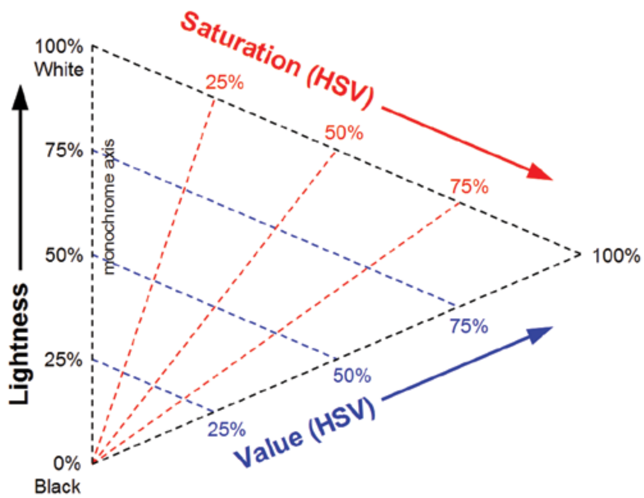

Figure 24. Spearhead display with graticule lines of constant saturation and value.

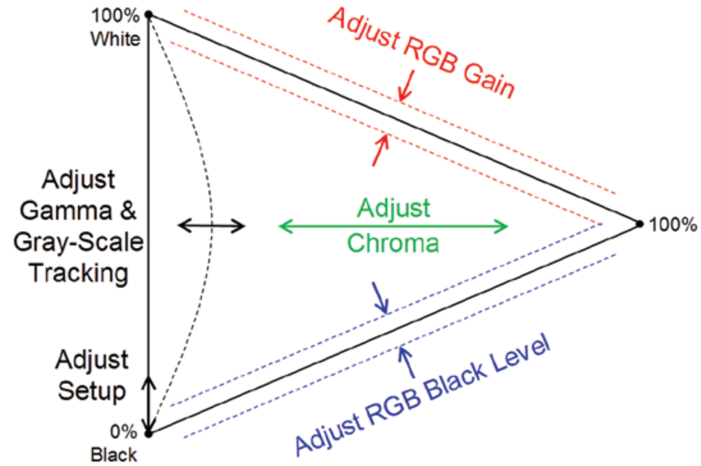

Figure 25. Using the Spearhead display for color correction.

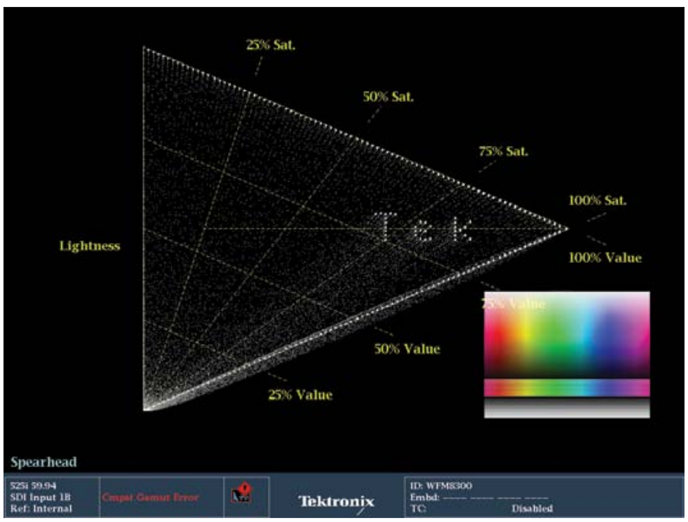

Figure 26. “Rainbow” test pattern on the Spearhead Display.

Color Correction with the Spearhead Display

The newest gamut display from Tektronix is the Spearhead display, which shows the artistic metrics of color saturation and color value or lightness combined with RGB gamut limits. This allows a colorist to adjust live video signals in the HSV (Hue, Saturation, Value) space within the valid signal gamut range. The Spearhead display is constructed by plotting the maximum of the R’, G’, and B’ color values for each sample versus the minimum of the three values. The resulting area, as shown in Figure 24, is a triangle that represents the full RGB color gamut. This triangle is rotated and scaled such that the vertical axis (max + min / 2) represents Lightness and the horizontal axis (max – min) represents non-normalized Saturation.

The Spearhead display can be used to quickly make color correction adjustments, as shown in Figure 25. The setup or black level is easily set by adjusting the image dot locations for alignment to the lower corner of the Spearhead triangle. The R’G’B’ White or Gain affects the image dot locations near the upper side of the triangle, increasing or decreasing the color Value or intensity. The R’G’B’ black-level controls affect the image dot locations near the lower side of the Spearhead triangle increasing or decreasing color Saturation. A chroma level change stretches or compresses the image dot locations along the horizontal axis, changing both Saturation and Value. Lastly, the gray-scale balance of the R’G’B’ gamma controls affects the alignment of the monochrome components of the image to the left side of the Spearhead.

Figure 26 shows a “rainbow” pattern generated on the TG700 test signal generator that contains a set of colors that completely fills the valid R’G’B’ gamut. Each line in the pattern spans the full range of color hues for a fixed Value and Saturation, with ramps from red to yellow to green to cyan to blue to magenta to red. The lines in the top portion of the pattern all have 100% Value, and range from 0% Saturation (white) to 100% Saturation (primary colors). The middle set of lines all have 100% Saturation, and range from 100% Value (primary colors) to 0% Value (black). The bottom portion of the image contains a text identification pattern and a monochrome step pattern.

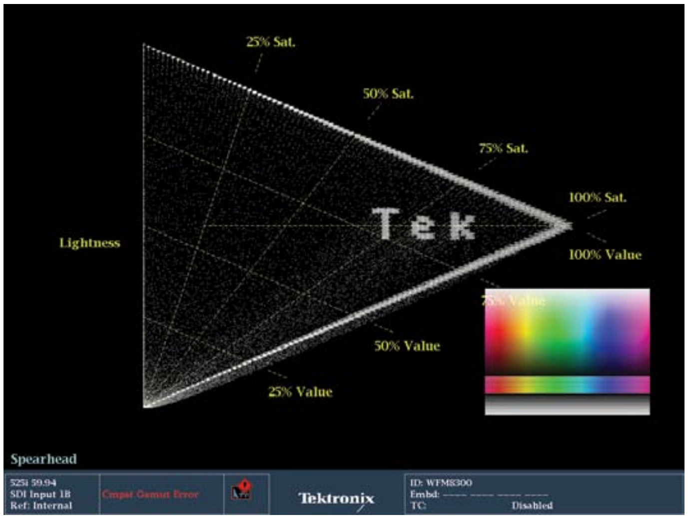

Figure 27. Hue error on the rainbow test pattern.

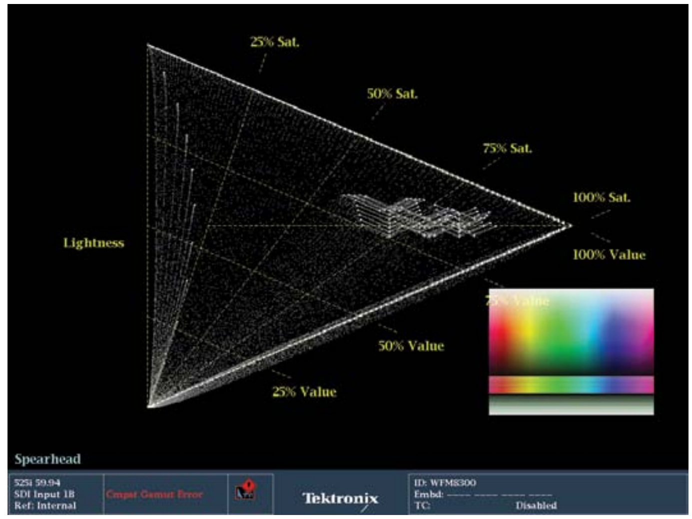

Figure 28. Green gamma error on the rainbow test pattern.

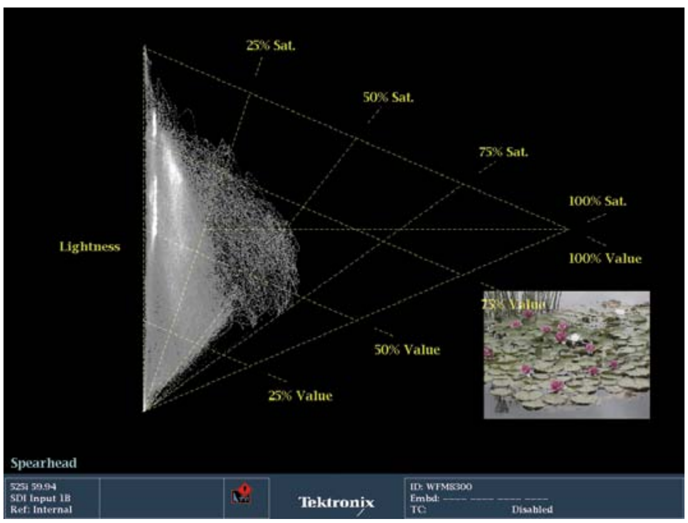

Figure 29. Image before color correction.

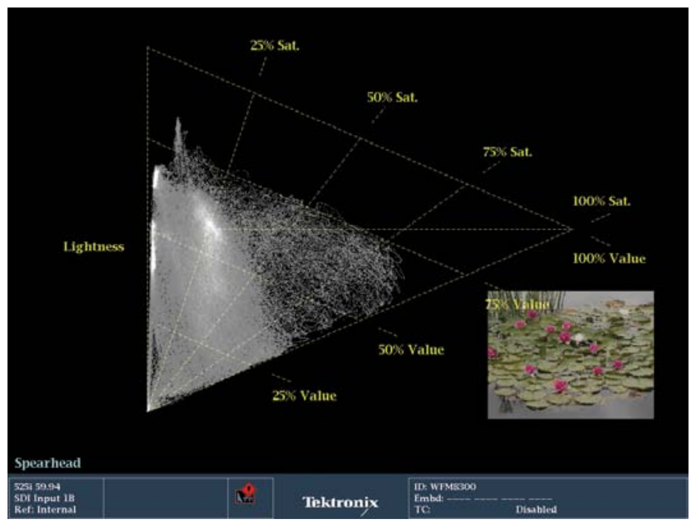

Figure 30. Image after color correction.

A Hue error added to the rainbow pattern will cause the text marker to blur, as seen in Figure 27. This type of color correction adjustment will also show as a rotation on the vector display. In Figure 28, a green gamma error has been added to the test pattern, resulting in distortions in the text identifier. Additionally, the points on the Lightness axis (from the monochrome step-scale portion of the test pattern) are bowed inwards, since these points now have some color. Proper gamma adjustment will remove the tint from monochrome parts of the image.

The image in Figure 29 shows how the Spearhead display can be used effectively by a colorist. Before correction, this image has too much near-white brightness and relatively unsaturated colors. The thumbnail display of the picture shows that the flowers and lily pads appear “washed out”. After correction, the colors appear vibrant but not excessively bright. The trace in the Spearhead display as seen in Figure 30 shows a wider range of color saturation, with lightness and color values kept within the 75% targets desired by the colorist.

Pushing the trace toward the left side will remove color components and make the RGB signal monochrome. This type of correction can be used to remove color components for the luma parts of the image, and help in the adjustment of greyscale tracking.

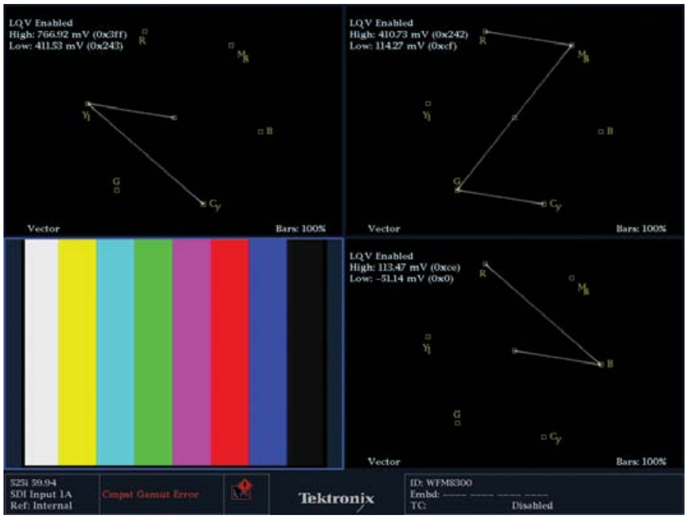

Figure 31. Luminance Qualified Vector display.

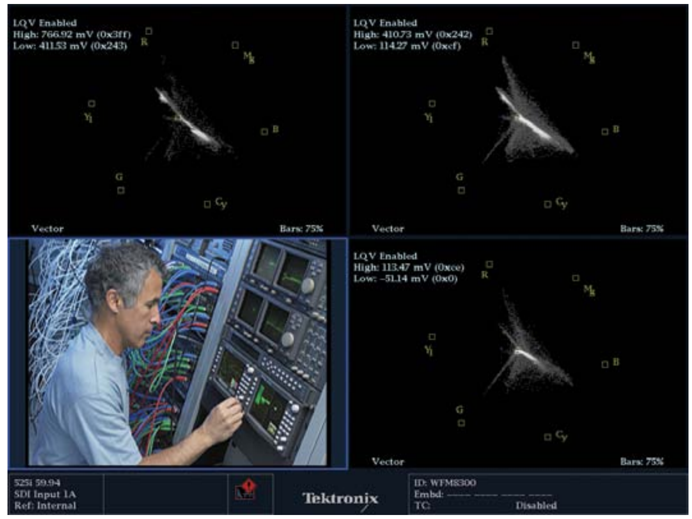

Figure 32. Four-tile display of the WFM 8300 showing multiple vectorscope displays, with independent LQV thresholds.

Luma Qualified Color Correction

The Vector display can be used when making hue adjustments as part of the color correction process, but it has sometimes been difficult to focus in detail on areas of interest. A colorist may wish to isolate specific regions of luma, such as highlights, mid-tones and shadows. Tektronix developed the Luma Qualified Vector (LQV) display to assist this type of work. For example, the user may set LQV limits near 0 mV to remove color offset in the black region. Using LQV limits at the high end of the valid range, the editor or colorist can remove an undesired color cast from bright lights in the scene.

Figure 31 shows how the LQV display can be configured, using 100% color bars to demonstrate luma limits. The upper left display is set to isolate colors above 411 mV in luma, which corresponds to the white, yellow, and cyan bars. The upper right display is set with luma limits in the mid-range, between 114 and 411 mV in luma, which includes cyan, green, magenta and red bars. Finally, the lower right display shows the red, blue and black bars, corresponding to luma limits below 114 mV.

These same limits are used for the image shown in Figure 32. A colorist may decide to adjust the color hues observed in each of these luma ranges, using the LQV display to more easily view those hues.

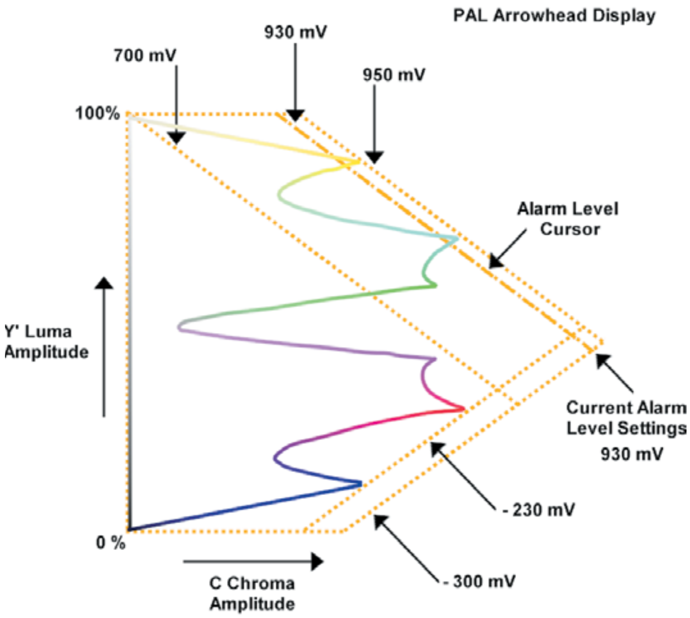

Figure 33. PAL Arrowhead construction.

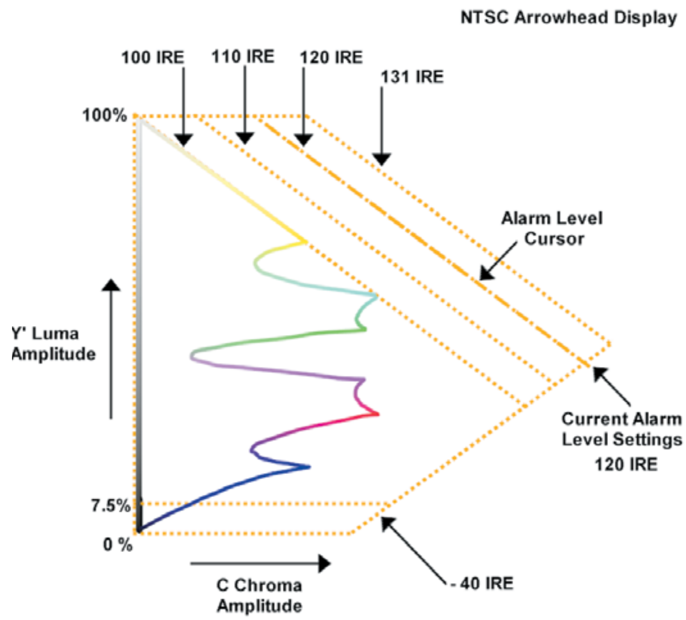

Figure 34. NTSC Arrowhead construction.

Gamut/Amplitude Monitoring

In creative and operational environments where monitoring R'G'B' gamut limits is critical, the Diamond display is unsurpassed. Conventional waveform monitor display modes, such as parade and overlay, are great for measuring signal levels, but gamut limit violations don't stand out like they do on Diamond. The Diamond display allows gamut limit monitoring with any signal. Using stable test signals, small timing errors are indicated on the two component displays. The specific component causing the error can be determined with the Diamond display.

Signal monitoring in the R'G'B' color space does have several very important applications. Even though signal transmission in R'G'B' is rare, many creative and operational controls continue to bear the labels R', G' and B'. Computer graphics workstations and paint systems operate in R'G'B' color space and are among the most frequent sources of illegal video. Camera control units (CCUs), telecine, color correctors and gamma correctors also employ R'G'B' color space controls. Monitoring these types of systems is an obvious application for the Diamond display.

Diamond excels in several areas for R'G'B' gamut, however it is not the answer to every measurement question. Other color spaces, such as composite, require different displays and measurement techniques.

Composite Color Space

Program material may still be transmitted as a composite signal in a hybrid plant or for distribution in local markets. The requirements are different for keeping this signal legal. Normally, the component signal is applied to a composite encoder. The composite signal is then measured and monitored using a familiar analog waveform monitor and vectorscope. Tektronix developed the Arrowhead display to allow engineers and operators to easily see out-of-gamut conditions in composite color space without requiring a composite encoder. Figures 33 and 34 show how the Arrowhead display is constructed for PAL and NTSC color space.

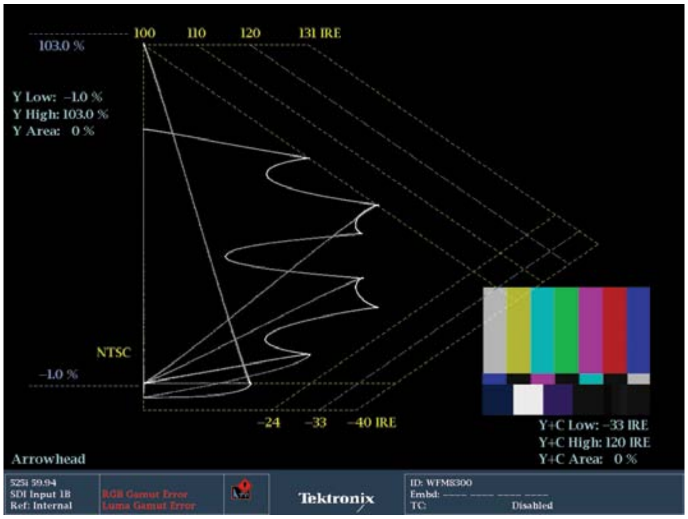

Figure 35. Arrowhead display showing SMPTE Color Bars.

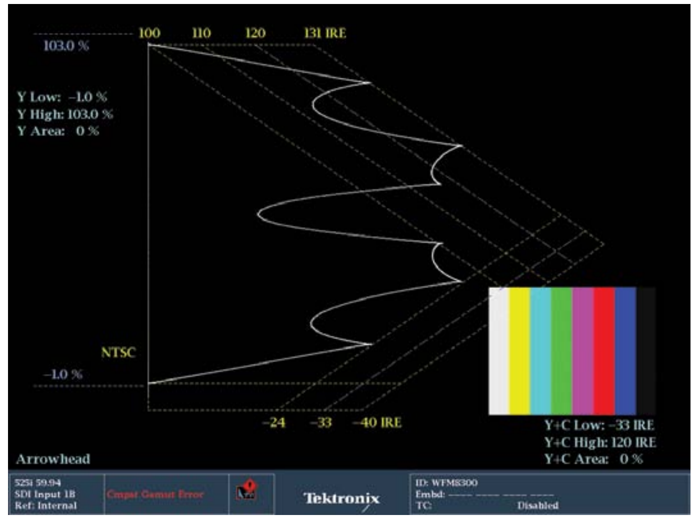

Figure 36. Arrowhead display with 100% Color Bars Signal.

The Arrowhead display plots luma on the vertical axis, with blanking at the lower left corner of the arrow. The magnitude of the chroma subcarrier at each luma level is plotted on the horizontal axis, with zero subcarrier at the left edge of the arrow. The upper sloping line forms a graticule indicating 100% color bars total luma + subcarrier amplitudes. The lower sloping graticule indicates a luma + subcarrier extending toward sync tip (maximum transmitter power). The electronic graticule provides a reliable reference to measure what the luminance plus color subcarrier will be when the signal is later encoded into NTSC or PAL. An adjustable modulation depth alarm capability is offered to warn the operator that the composite signal may be approaching a limit. The video operator can now see how the component signal will be handled in a composite transmission system and make any needed corrections in production.

Normally for NTSC transmission the threshold is set at 110 IRE because values over this limit can cause problems at the transmitter. Figure 35 shows an NTSC SMPTE Color Bars signal that falls within the limits of the Arrowhead display. However applying a 100% color bars signal, as shown in Figure 36, which is legal and valid in R'G'B' space, causes the limits to be exceeded in composite NTSC space. A range of thresholds can be set for NTSC between 100 IRE and 131 IRE. Similar threshold levels can be set for PAL signals of 700 mV to 950 mV.

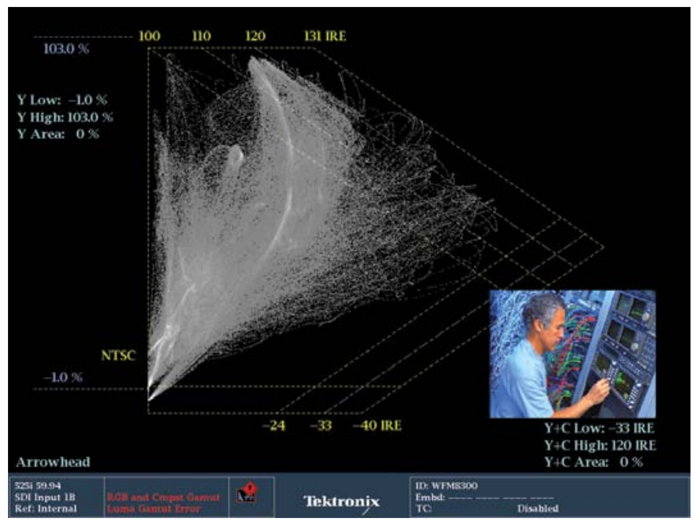

Figure 37. Live video signal monitored with the Arrowhead display showing clear indication of a composite gamut error.

Additionally, the setup level can be adjusted between 0% and 7.5% to suit the appropriate broadcast format. The multi-format nature of Tektronix waveform monitors permits the Arrowhead display to be used not only for standard definition, but also for high definition video signals which maybe downconverted to standard definition for broadcast or distribution.

The Arrowhead display works not only for test signals, but also on live signals, as shown in Figure 37. In this case, the limits were set to 120 IRE for the signal and a composite gamut error is indicated on the display.

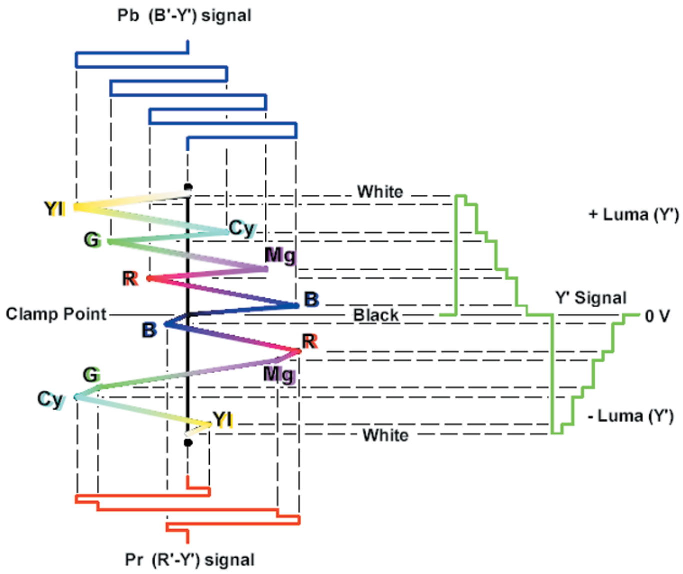

Figure 38. Construction of Lightning display.

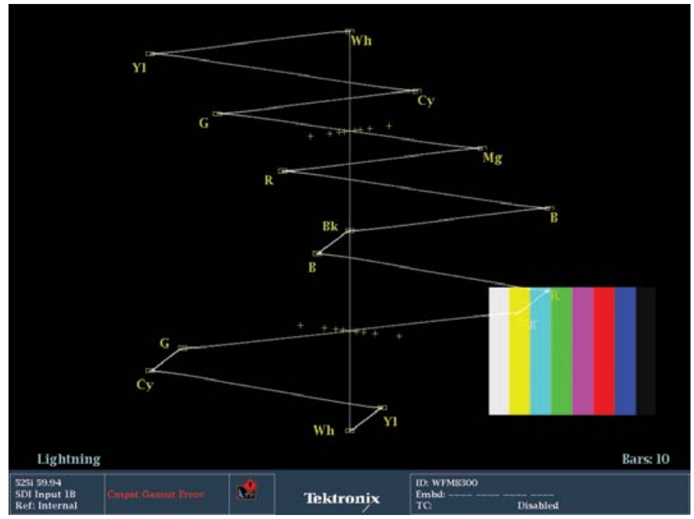

Figure 39. Lightning display with Color Bars signal.

Setup and Tape Alignment with Lightning Display

Often, operators and engineers want to monitor and adjust levels on the component signal. Many users are familiar with making these adjustments with a composite signal using a waveform monitor and vectorscope. Tektronix developed the Lightning display to simplify the task of making these adjustments within the component domain, using just one display. The display is constructed as shown in Figure 38. In contrast, a component vector display shows only the color difference signals P'b, and P'r and shows no information about the luma signal.

The Lightning display also offers inter-channel timing information by looking at the green/magenta transitions. When the green and magenta vector dots are in their boxes, the transition should intercept the center crosshair in the line of nine timing marks (Figure 39).

Therefore the Lightning display offers a simple means for checking luma and color difference signal amplitudes and inter-channel timing — all in one display using a standard color bars test signal.

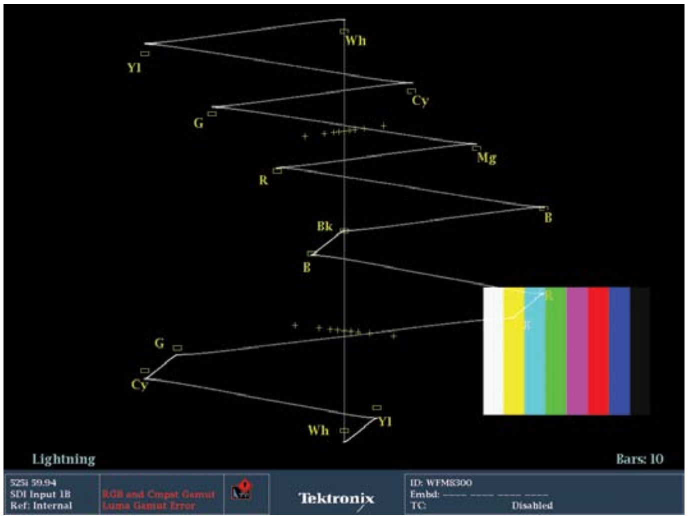

Figure 40. Luma gain error on Lightning display.

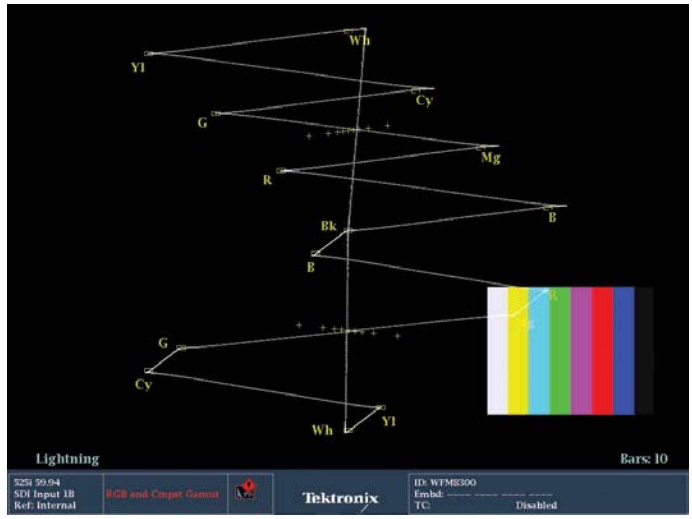

Figure 41. P'b gain error on Lightning display.

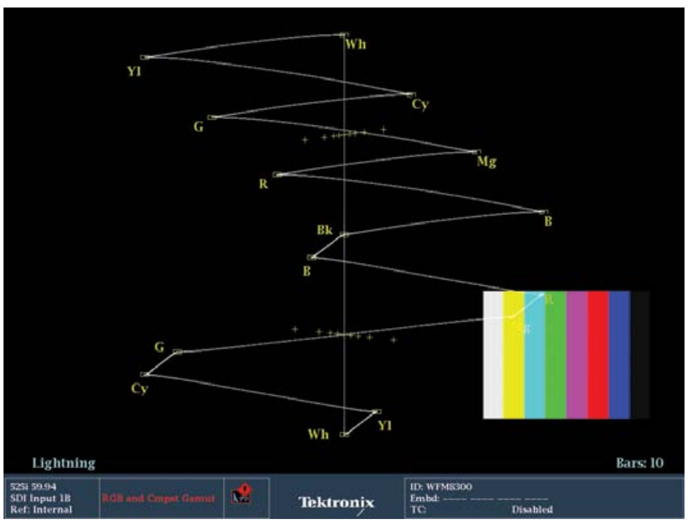

Figure 42. P'b advanced timing error on Lightning display.

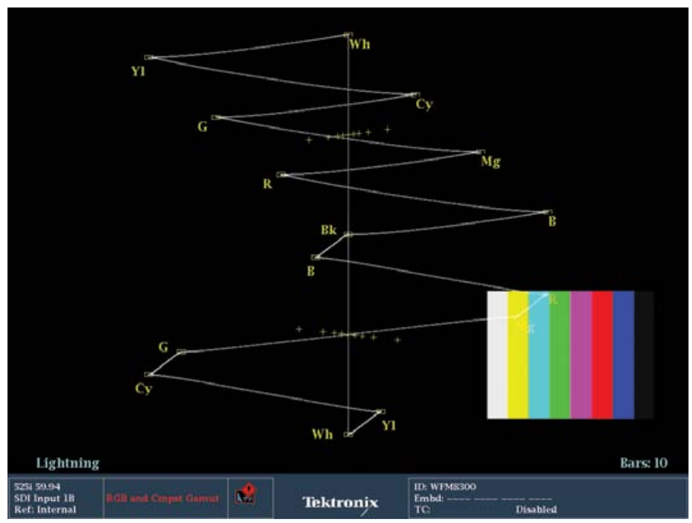

Figure 43. P'b delayed timing error on Lightning display.

The Lightning display is generated by plotting luma versus P'b in the upper half of the screen, and inverted luma versus P'r in the lower half — like two vector displays sharing the same screen. The bright dot at the center of the screen is blanking level (signal zero). Increasing luma is plotted upward in the upper half of the screen and downward in the lower half of the display. If luma gain is too high, the plot will be stretched vertically as shown in Figure 40. If P'r gain is too high, the bottom half of the plot will be stretched horizontally. If P'b gain is too high, like Figure 41, the top half of the display will be stretched horizontally.

If the color-difference signal is not coincident with luma, the transitions between color dots will bend. The amount of bending represents the relative signal delay between the luma and color-difference signals. The upper half of the display measures the P'b to Y' timing, while the bottom half measures the P'r to Y' timing. If the transition bends outward toward white, the color difference signal is leading the luma signal (Figure 42). If the transition bends inward toward the vertical center of the black region, the color-difference signal is delayed with respect to luma (Figure 43).

Conclusion

While virtually all component video transmission occurs in one of the standard color difference formats today, viewing those signals in the R'G'B' color space remains a necessity. As computers become more widely used in video applications, the possibility of creating illegal video signals increases — and the Tektronix-exclusive Diamond display is the best tool for keeping track of gamut violations. Performing color correction adjustments, gray scale tracking adjustments, or black balance adjustments on a CCU are additional tasks that are simplified by the Diamond display, Spearhead display, and Luminance Qualified Vector display. The Arrowhead display offers a means for the digital hybrid facility to ensure that the R'G'B' signal is valid for transmission in a PAL or NTSC environment, and it keeps the operator's task within the digital domain. For tape alignment, the Lightning display ensures correct amplitude and inter-channel timing of the signal using the familiar color bars test signal. This lets operators make quick and easy adjustments, if necessary, to the video signal before recording. These exclusive Tektronix displays help simplify the tasks that video professionals face in an ever increasing complex environment.

The Diamond, Split Diamond, Arrowhead, and Lightning displays are available in Tektronix WFM 4000, 5000, 6x20, 7x20, and 8x00 Series Waveform Monitors and Rasterizers for both HD and SD signals. The Spearhead display and Luminance Qualified Vector display are available in Textronix WFM/WVR 8200 and 8300 Series Waveform Monitors and Rasterizers.

Contact Tektronix:

ASEAN / Australasia (65) 6356 3900
Austria* 00800 2255 4835
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium* 00800 2255 4835
Brazil +55 (11) 3759 7600
Canada 1 (800) 833-9200
Central East Europe, Ukraine and the Baltics +41 52 675 3777
Central Europe & Greece +41 52 675 3777
Denmark +45 80 88 1401
Finland +41 52 675 3777
France* 00800 2255 4835
Germany* 00800 2255 4835
Hong Kong 400-820-5835
India 000-800-650-1835
Italy* 00800 2255 4835
Japan 81 (3) 6714-3010
Luxembourg +41 52 675 3777
Mexico, Central/South America & Caribbean 52 (55) 56 04 50 90
Middle East, Asia and North Africa +41 52 675 3777
The Netherlands* 00800 2255 4835
Norway 800 16098
People's Republic of China 400-820-5835
Poland +41 52 675 3777
Portugal 80 08 12370
Republic of Korea 001-800-8255-2835
Russia & CIS +7 (495) 7484900
South Africa +27 11 206 8360
Spain* 00800 2255 4835
Sweden* 00800 2255 4835
Switzerland* 00800 2255 4835
Taiwan 886 (2) 2722-9622
United Kingdom & Ireland* 00800 2255 4835
USA 1 (800) 833-9200

*** If the European phone number above is not accessible, please call +41 52 675 3777**

Contact List Updated 25 May 2010

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Tektronix maintains a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology. Please visit **www.tektronix.com**

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