Calibrating LED fixtures and Video Walls to the camera's chroma signal

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This presentation is directed to productions using LED Lighting including productions using LED fixtures who want to calibrate their lights to the needs of the camera. Gaffers, Lighting Directors, LED fixture manufactures, virtual productions, video engineers and technical directors.

Viewers will take away the following

- **Differences between LED lighting and other light sources**
- **Deficiencies in the current lighting metrics used to measure light as they are inadequate to show on camera results of a LED light source**
- **How the use of the cameras chroma signal as a guideline to calibrate LEDs lighting camera to improve the on-camera colour reproduction and create harmony between led sources colour reproduction on camera.**

The presentation deals with Novel Technological Approaches and Case Studies for industry proposal changes

I am retired from the Canadian Broadcasting Corporation/ Société Radio Canada, having worked at CBC /SRC for 37 years as a Senior Lighting Director. I have lit for both film and video cameras using a variety of light sources. While at CBC I created the worlds first all LED lit News Studio along with an all-LED lit Studio for the Beijing Olympics. I initiated the conversion of many CBC/SRC studios across Canada to LED lighting in the early 2000. CBC/SRC was an incubator for LED manufactures as we worked with them in their product development stages.

History of lighting for the camera.

For many decades lighting for the camera was based on natural light sources be it actual daylight or artificial sources such as those created by heat like tungsten lighting. Arc sources were introduced based on ionization of gases to create a daylight equivalent on camera. One common element between these sources is that they provided a light output that contained the full wavelengths of the visible spectrum. The relative energy of wavelengths varied between these sources and could be displayed in the form of a Spectral Power Distribution graph. While the SPD (Spectral Power Distribution) reading showed output of a light source it didn't show a correlation between a light source's spectral output and its influence on the cameras ability to accurately reproduce colours.

While light sources such as tungsten, daylight arc sources varied in their relative energy levels along the visible wavelengths, approximately 400nm to 700nm, they had a full spectral output. Manipulation was possible using gels to filter out specific portions of the spectrum emitted. With the dominance of tungsten lighting being the light source of choice for in studio productions, obtaining consistency between light fixtures on camera was possible albeit with alteration with gels if needed. Tungsten with its ability to provide a spectral output that included all wavelength of the visible spectrum it provided the necessary wavelength to render skin tones accurately on camera

Measuring Light

Since tungsten lights dominated the in-studio lighting, measurement of lighting for the camera with regards to colour output of a source, was based on lighting metrics established by industries other than the broadcast and cinema production industry. Kelvin temperature, Colour Rendering Index, Spectral Power Distribution. TM 30 and other measurements were not specific to reflect the needs of the camera. While TLCI (Television Lighting Colour Index) was intended to provide a reference that was better than the IES (Illumination Engineering Society) Colour Rendering Index, it was build upon the response of the 3-chip prism camera. TLCI provides averaging using a virtual 3 Chip camera and is not based on the variety of Bayer Filter cameras used for many productions. TLCI gave a score based on the amount of correction that was estimated to be required for optimum performance on a 3 Chip camera would be needed. Correlated Colour Temperature, CCT, is assigned to light sources output based on their relationship to the black body curve but a light source above or below the black body curve can be assigned the same CCT value. Too often I have seen a CCT value of 3200 CCT be synonymous with a tungsten's source that emits 3200 Kelvin. However, the two light source's spectral output can match only in assigned values such as 3200 it does not reveal their impact on camera due to their spectral differences.

Unfortunately, many of these legacy lighting measurement terms were applied to a wide array of light sources that created light in ways very different from traditional tungsten source or carbon arc sources. However, some new light sources such as florescent and mercury-based arc sources gave a spectral output that was used on camera. But the deficiency of these lighting metrics to accurately describe and differentiate light sources spectral output on camera was not referenced in lighting specifications. While a 3200 CCT with a TLCI of 90 and a CRI of 90 may look good as a lights specification it doesn't guarantee a good look on camera.

With the introduction of LED light sources on camera their narrow spectral output showed the issues of the standard lighting metrics as mixing of Red Green Blue LED sources did not equate to a similar full spectral output of previous light sources.

LED sources changed the Lighting metrics needed.

LED lighting changed lighting for the camera in many ways especially with regards to power consumption and heat generated. They became a preferred light source primarily due to economic reasons. But once on camera it was clear that LED lighting was not like any other traditionally used lighting source as previously seen on cameras It was evident that accurate colour reproduction, including pleasing skin tones on camera, could be an issue with LED lighting. The mixing of narrow bands of spectral output from RGB (Red Green Blue) RGBA (Red Green Blue Amber) RGBW (Red Green Blue White) LED sources required varying intensities between these LED combinations. Manufactures of LED fixtures often set preset values of mixed intensities in their fixtures to attain a desired spectral output. They utilized lighting measurements that were not designed exclusively for an LEDs performance on camera. Obtaining a preset of overlapping separate LEDs spectral outputs may achieve a desired traditional lighting measurement on a meter but not the cameras image sensor.

Even during the creation of an LED obtaining a close matching of spectral output is not a matter of creating a batch of LEDs that meet those targets. During the creation process a number of LEDs created will fall short of meeting their targeted desired spectral output. The then requires LEDs to go through the binning process. A factor of sorting of LED into which bin is called Standard Deviation Colour Matching also known as McAdam Ellipse. Thus, we get a one step value which indicates the eye cannot detect colour differences therefore LEDs in this bin would have no noticeable variations. Two steps mean colour differences are detectable to most people. Three Steps means colour differences become progressively noticeable. This means two separate LED fixatures could have a mixture of LEDs from different bins yet still be classified as an LED source.   Does a Red LED from manufacturer "A" match to a Red LED from manufacturer "B"? Given that both fixtures are using the same LED source acronyms of RGB RGBA RGBW etc. how do we know they both adhered to a high binning standard n their selection of LEDs?

As I noted previously The Television Light Colour Index (TLCI) was developed based on an averaging of 3 prism cameras performance. There was also Spectral Similarity Index (SSI) introduced to show how closely a light sources SPD match a traditional light source. While they both gave additional information, my preference was to obtain a mapping of a spectral output that would provide colour accuracy on camera.

Measurement based on the camera.

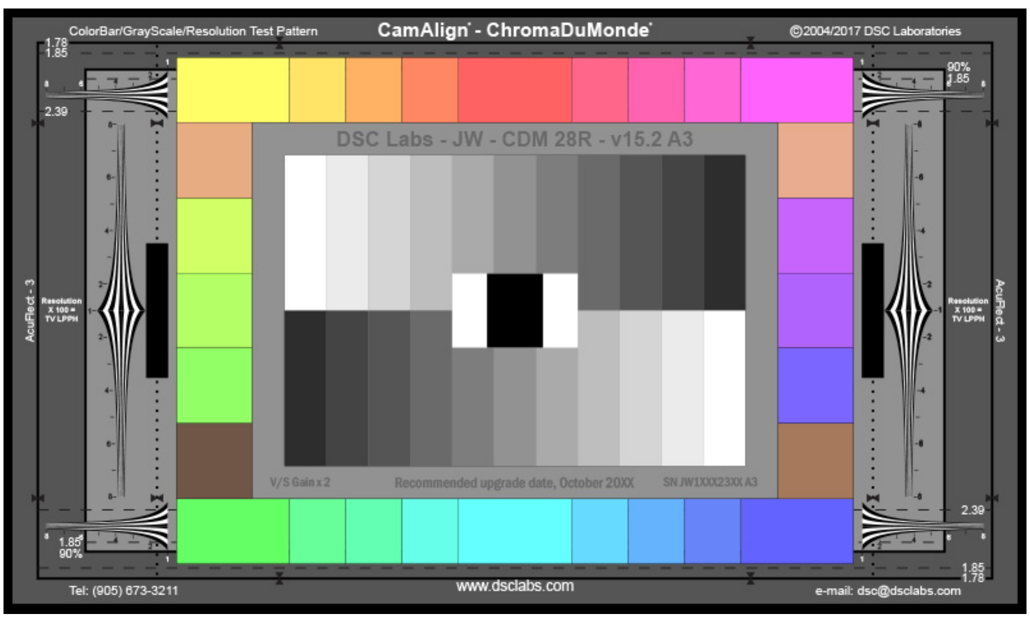
Since light hitting an electronic image sensor is converted into an electronic signal of chroma I used it to measure how well the light source is able to reproduce colours accurately. The impact of a light sources intensity on the Luminance signal can be measured externally with a light meter. The light meter can be calibrated to represent the response of the camera such as ISO setting f stop etc. However, a colour meter displays the electronic response of the light meters sensor and does not indicate the various cameras sensors response to a light source. Since LEDs as RGB (Red Green Blue) RGBA (Red Green Blue Amber) RGBWLA (Red Green Blue White Lime Amber) RGBACL (Red Green Blur Amber Cyan Lime) mix spikes of spectral output in the visible spectrum. Getting the right combination is important to attain accurate colours on camera. However, can a generic blending of intensities from a mixture LEDs equate to optimum colour accuracy for every camera considering that all camera manufactures have their own method of reacting to light falling on the image sensor? Don’t we need to blend the values of the various spikey LEDs output for individual camera image sensors as they all do not respond identical? Unfortunately attaining a value setting based on a conventional colour meter reading will show a discrepancy on various cameras and a possible mismatch between fixtures.

HS Scope a new measurement scope.

With the variables of binning, camera image sensors, traditional lighting metrics, colour meter, preset colour combinations of LEDs created by various LED fixture manufactures. I went back to the cameras chroma signal as my guide to evaluate and calibrate LEDs to meet the needs of the camera I was using for a production.

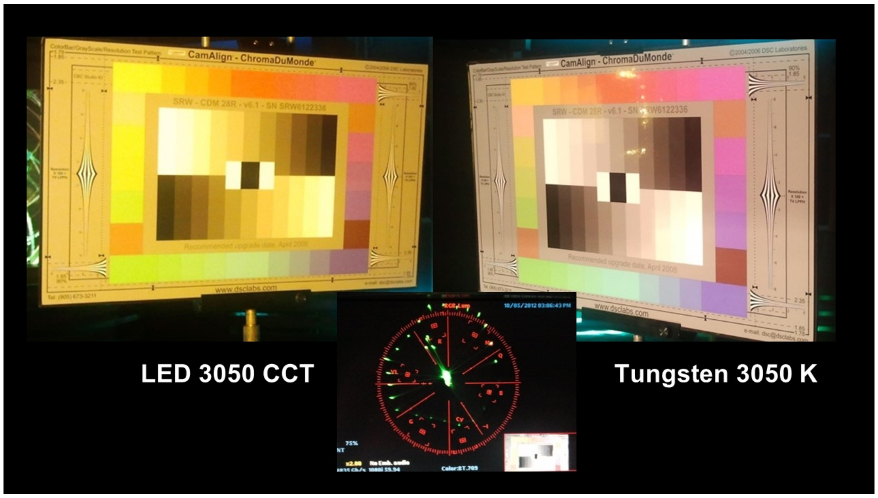
I had used the vectorscope as my guideline for decades when working with light sources on camera. If I had different light sources producing the exact same chroma response on camera when measured separately then I was confident I had attained harmony between these two sources as seen by the camera.

As my colour reference I use the DSC chart which includes multi hued chips that are calibrated to match the hue and saturation values of a vectorscope. The DSC chart also includes four chips for a reference to various skin tones. I have used the DSC charts for decades when calibrating a different light source to the camera, even prior to LED lighting. If the vectorscope chroma response was the same when looking at individual light sources lighting the DSC chart on camera then I had harmony between these sources.

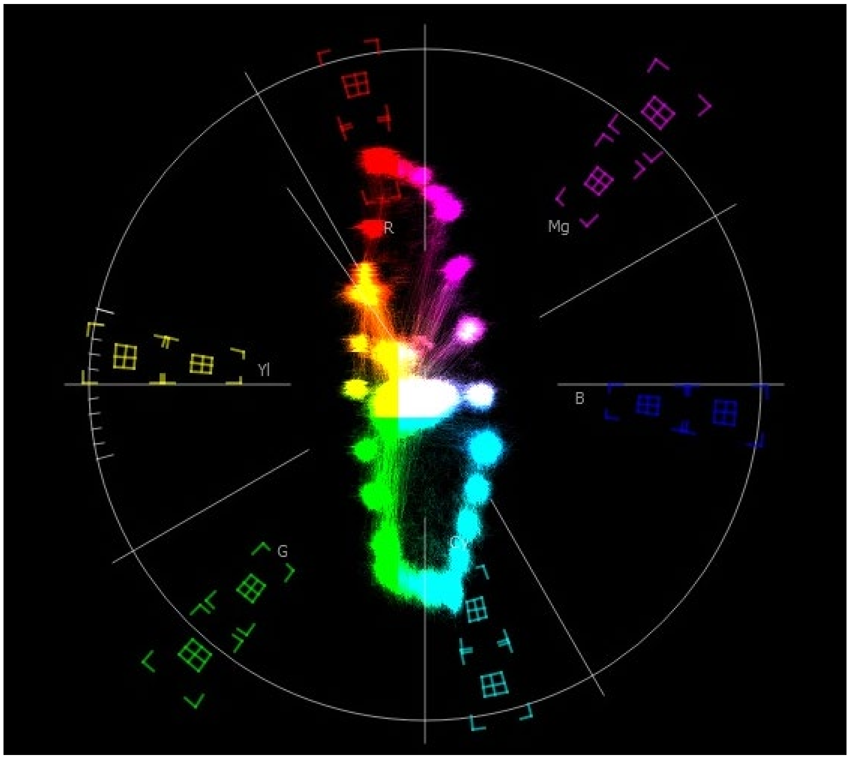


DSC Chroma DuMonde Chart 24+4R Chart

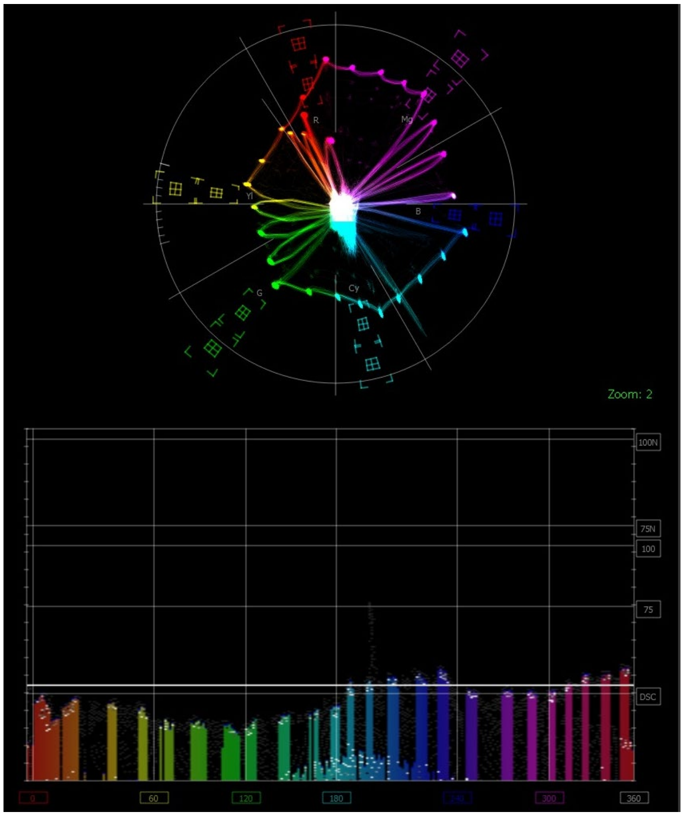
My initial work with LEDs involved evaluating and calibrating LED fixtures by lighting the DSC chart with a reference light source, such as a tungsten light, lighting the DSC chart on camera then looking at the vectorscope reading. This was done after the camera was adjusted to optimum performance for colour accuracy based on the tungsten reference light source. I then would turn off the tungsten source and look the output from an LED fixture often using the LED fixture manufacturers preset “tungsten” values. It was evident that the preset values established by the LED manufacturers could be wildly off as illustrated in this example.



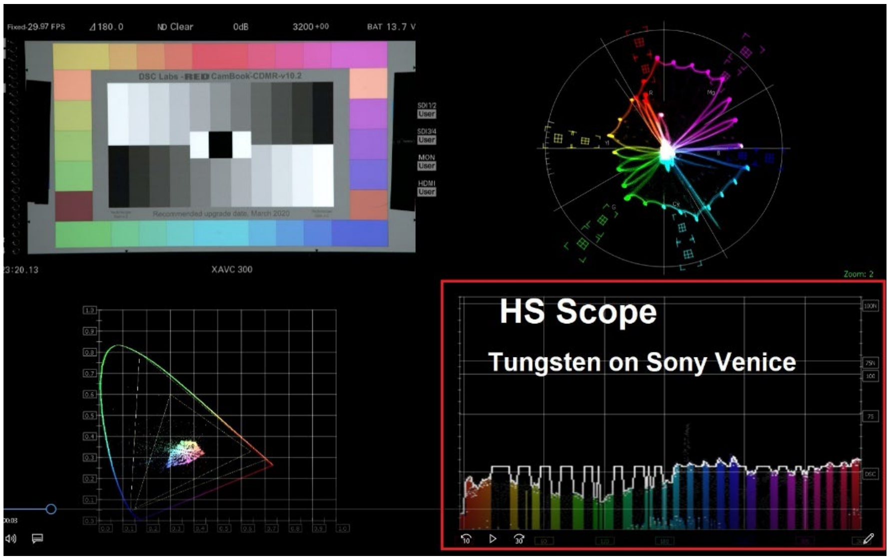
Looking at a preset RGB LED value set to a “tungsten setting” on a vectorscope ,we can see a white point has been attained but there is a deficiency in colour response in other parts of the signal.



While a vectorscope can be used to evaluate different LED fixtures performance and their ability to accurately reproduce colours a new scope called the HS Scope (Hue /Saturation) presents the cameras electronic signal in a new format. Unlike a vectorscope display the HS Scope shows the hues and saturation values in a horizontal format with the vector points on a scale underneath. Hue and Saturation values are still based on the amplitude and phase of the signal.

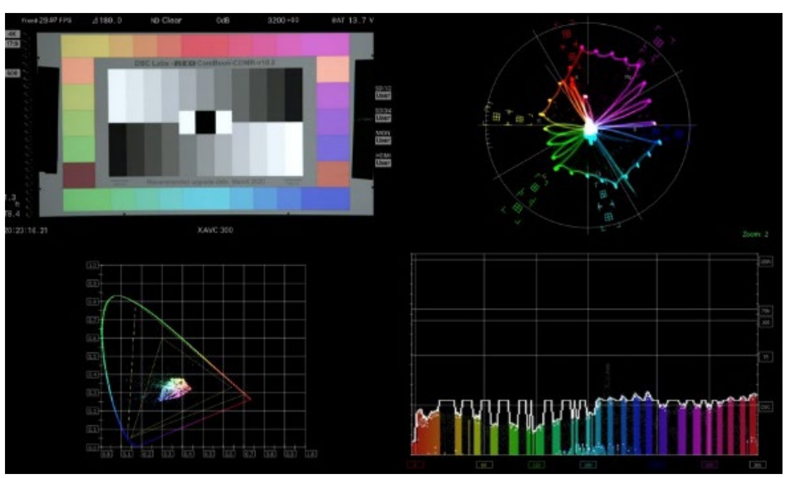


The HS Scope can store the “peaks and valleys” of the hue and saturation values from the camera, generated by a light source lighting the DSC chart, falling on the image sensor.

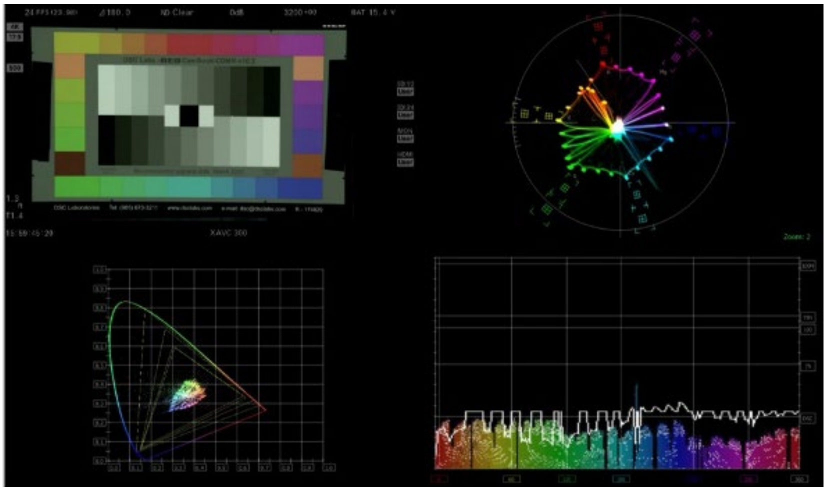


These white reference lines can be stored as a file in the HS Scope and then layered over another chroma response from a different light source to ensure a match on camera. For example, the DSC chart can be lit by a tungsten source on a Sony Venice camera then the HS Scope reads the Sony Venice chroma output. Those hue and saturation values created on the HS Scope, from the Sony Venice chroma signal by the tungsten source, is stored as a white reference line. We then light the chart with a LED source set to be what the LED manufacturers claims to be a “tungsten” setting. We can layer the previously stored refence line obtained from the tungsten source over the LED sources chroma response from the Sony Venice to compare how accurately they match. We can immediately see what spectral values differ and in what arears we need to adjust in the LED lights values to meet the same peaks and valleys created by the tungsten source by the Sony Venice.

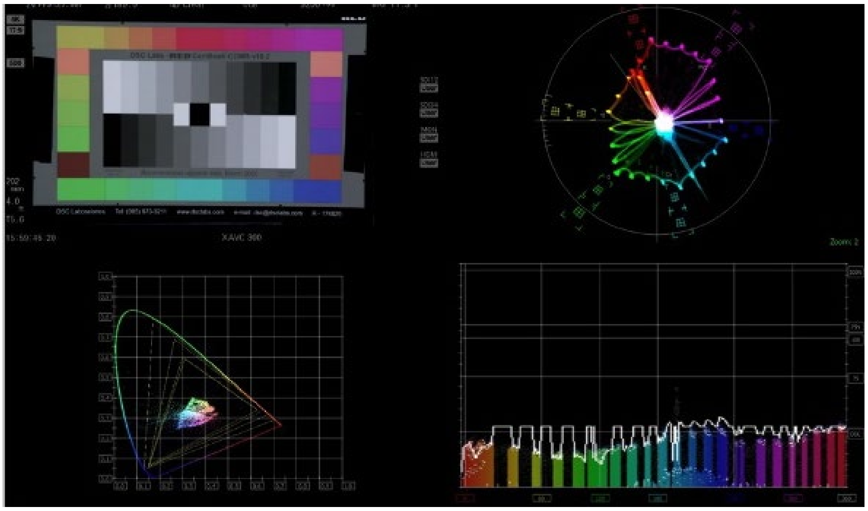
In the first graphic the HS Scope displays reference line of the Hue and Saturation values from a Sony Venice Camera shooting a DSC chart lit by a tungsten 3200K light source.



We Layer the tungsten reference line stored in the HS Scope of the tungsten source over the Sony Venice chroma response to an LED fixture lighting the DSC chart preset to the LED fixtures preset “tungsten” setting. We can see immediate the inaccuracy between the two as the Sony Venice does not produce a match on the HS Scope.



By adjusting the separate LED intensities, in this case an RGBA fixture, we can achieve overlaps of the spectral output that are harmonious with the original signal obtained on the HS Scope from the Sony Venice when shooting the DSC chart lit by a actual tungsten light source.

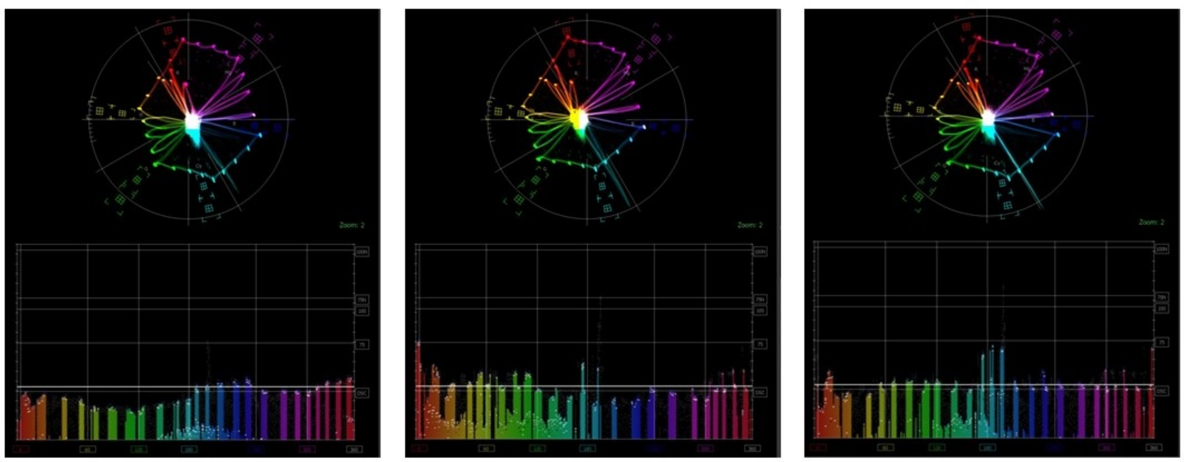


HS Scope Vs Colour Metering.

Unlike a colour meter reading the HS Scope readings are based on the cameras actual chroma signal response to a light source. Therefore, it answers some questions as to how will this light look on camera? Will this light match my other lights? What do I need to adjust in this light to get it to look like the other fixtures on camera?

In the following graphic we can see the HS Scope reading from a Sony Venice shooting a DSC chart lit by an actual tungsten source. Rather than using the HS Scope to store the tungsten reading in the HS Scope as a reference line and layer it over the LED fixtures response to get a match, we only used a colour meter as our guide.

SONY VENICE / Metered CCT Kelvin VS HS Scope

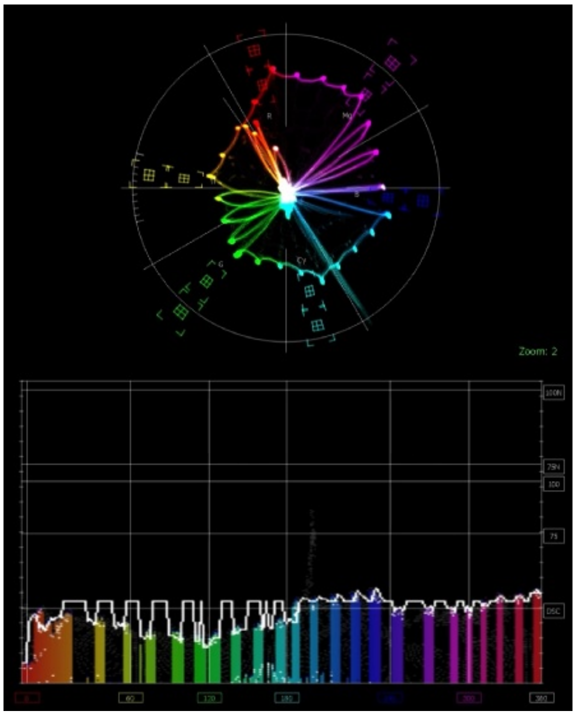


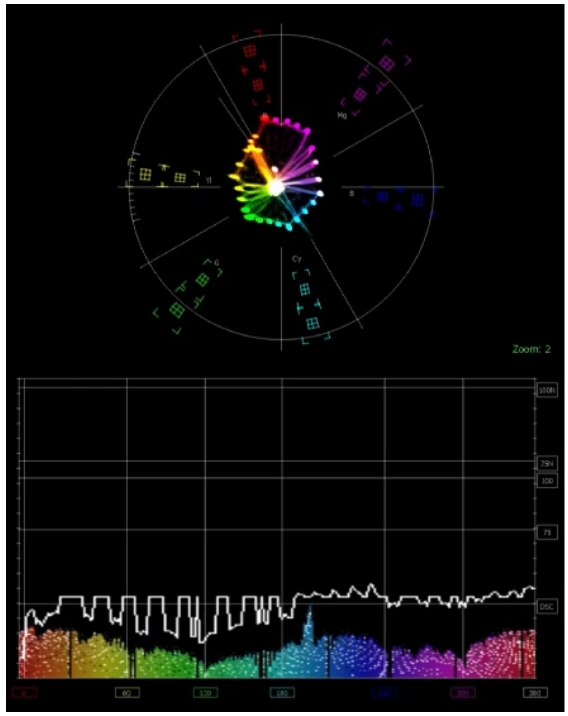
3200K Tungsten | 2970 CCT LED Metered | 3196 CCT LED Metered

While we were able to attain favorable values on the colour meter as we came close to a 3200 CCT reading, we see in the HS Scope, that the Hue and Saturation phase and amplitudes don’t match the initial tungsten reading in the HS Scope, from the Sony Venice.

Claims vs Reality.

Led manufacturers have put a value on traditional light measurements that I feel favours their fixtures rather than their on-camera performance. Some LED fixture manufacturers claim their fixtures do not shift colour when dimmed. However, I always ask have they tested that claim on camera. In our tests we used an RGBA fixture set to the manufactures preset value lighting a DSC Chart. We shot the chart with the Sony Venice and then dimmed the fixture. As shown in this graphic we see a LED fixture at full intensity we then dim the LED and we see a shift in colour on the HS Scope and Vectorscope.





Video walls and led lights for the camera.

With the expansion of virtual productions, using video walls as the background and as a light source to light on camera talent, the same issues arise as seen with RGB LED fixtures. Video walls create spikes of RGB values and the overlapping of these values is important to be adjusted correctly to obtain accurate colour reproduction for the specific camera you are using. Once again, I feel, the chroma signal should be the guide to attain calibration that meets the needs of the camera.

While LED manufactures have addressed some of the initial spectral shortfalls of RGB LED fixtures by extending the LED used such as the addition of Amber, Warm White, Cool White, Lime, Cyan and others, LED walls remain RGB LED.

Using the LED video wall as your light source means you are using a light source that may not give you the best colour rendering on camera especially with skin tones. As shown in a previous graphic an RGB LED may get a white point accurate on camera but still be deficient in its ability to provide the spectral output the camera needs to accurately display other colours on camera.

LED video walls use thousands of RGB LEDs and expecting them all to be identically created is unreasonable. Variables of colour voltage and brightness in LEDs are an issue for LED fixtures so those same issues exist with LED video walls. The other consideration is the adjustment controls of the panels and their impact on camera. At what point do we correct the video walls? Is it at the panel or do we adjust the input feeds? Each LED color has its own non-linear response with brightness so this may cause colour casts in dark areas of the image at different brightness levels which may be more dominate when the panels are run at low levels. Of course, LED thermal sensitivity can cause artifacts such as cyan patterning. Red LEDs are often more sensitive to this which means a white image could shift bluer over the operational running time of the panel.

Eliminate the silo effect of measurement by using the cameras chroma response as the definitive guideline.

I feel LED fixture manufactures, video wall manufactures and software processing manufacture's work in silos as they want to meet their own standards. For example, they may all claim to meet a CIE XY value yet they omit the cameras actual CIE response. It might look good on a colour meter or within the software readings but the camera shows differing results and a possible mismatch.

In my tests I have seen the on-camera results of this "working in silos" creates. I have seen manufacture's generic tungsten settings not match others nor do they match the actual performance of a real tungsten source even though their specifications and in lab testing shows they obtained good scores on colour meter readings. I have also seen chroma shifts on camera as we dim LEDs.

The challenge of lighting for a virtual set with a video wall is what light source do we use to light the talent? While the initial response may be to use the video wall as the source since it is the environment seen on camera and as such would replicate the lighting of the real scene. The downfall with this is you are still using a limited RGB LED fixture in an attempt to attain a full spectral output light source to obtain optimum on camera colour reproduction. Just like in an RGB light fixture if there are portions of the spectral output that are limited that equate to poor reproduction on camera of some colours. Skin tones often suffer when being lit only by a video wall on camera. If you add in supplemental LED fixture the question is ,do we use its full spectrum or do we try to limit it to match the main source which may be the limited spectral output video wall?

My thoughts are mixed on this as I can see the benefit of matching the video wall spectral output, as seen by the camera, with an LED source thus limiting its spectral output to create harmony between the fixture and video wall. This means all sources match and although some colours will render poorly on camera, all deficiencies should be equal on camera. This means in post colour correction you shouldn't have a colour looking accurate from one light source yet be inaccurate from another as both will not be optimum but balanced in their spectral output. Ideally this should mean adjustments can be made globally in post colour correction.

However, if you overpower the LED video wall with a full spectral output light source, calibrated to the cameras chroma signal and use negative bounce by blacking out the screen not seen on camera to eliminate it being a potential off camera light source, then you can get accurate colours on your virtual set initially. While the idea to use a video wall as a light source for on camera talent sounds appealing, I prefer calibrating my lights to the needs of the camera with the HS Scope and use the video wall just as the background images.

I have seen virtual productions who have incorporated my methodology in their workflow and have improved on camera matching of light sources with their video walls resulting in better on camera skin tones and harmony in colour reproduction. They evaluate LED lighting fixtures with the HS Scope using a reference light source and then compare these stored results in the HS Scope to the HS Scope reading of the LED fixture they are evaluating on camera.

Establish standards specific for the needs of the variety of camera.

The cameras chroma signal is an equalizer in that it shows the exact response of a camera sensors to a light source. As we can store the Chroma signal created on the HS scope it means we can have a lighting measurement metric specific to the needs of camera. We are not limited to lighting measurements that are designed for other industries nor are we guessing about a fixture on camera performance. We create a reference to calibrate LED fixtures by adjusting the intensity of the separate LEDs spectral output for optimum overlap of their induvial narrow spectrum output. This means LED fixture manufactures need to meet camera chroma guidelines instead of other lighting metrics that do not reflect on camera performance. It offers LED manufacture's the ability to create custom settings specific to different camera sensors. Claims by manufactures can be verified as we can see if they hold true on camera by reading the Chroma signal. The HS Scope benefits in both the evaluation and calibration of LED fixtures for on camera use. It shows if a light source can attain the level of colour accuracy require for a production. You no longer rely on LED manufacturers setting as you can modify them as per your cameras needs by altering the intensities of the LEDs on the fixture. The HS Scope read out graphic display can be used by LED fixture manufacturers to assure their fixture's accurate performance on camera.

As the following graphic shows, we see the HS scope readings from a tungsten source lighting a DSC chart on the left image compared to the HS Scope reading from an LED fixture lighting a DSC chart on the right. In both readings an Arri Mini LF camera was the input source for the HS Scope. We see on the HS Scope both the tungsten reading and the LED fixture readings are extremely close to being identical in their ability to reproduce colours accurately on the Alexa Mini LF preset to 3200K. The HS Scope gives a visual confirmation of on camera performance.