# HOW TO READ A WAVEFORM MONITOR AND VECTORSCOPE

When television began in the U.S. it was black and white only and a testing instrument was devised to measure the video signal so that adjustments and verifications could be performed. This instrument is called a waveform monitor. When color came along in the late 1950s another instrument had to be developed to adjust and verify the color portion of the video signal and that instrument is called a vectorscope. Together they comprise the only way we have to KNOW that things are right in the video.

There is a plethora of ways that these scopes can used with different testing signals and generally they are used to read color bars, either from a camera for system alignment or from video tape to adjust the deck's proc amp and verify that the video output is correct. However, these instruments are also very useful for evaluating video from a camera or switcher.   We will start with the waveform monitor.
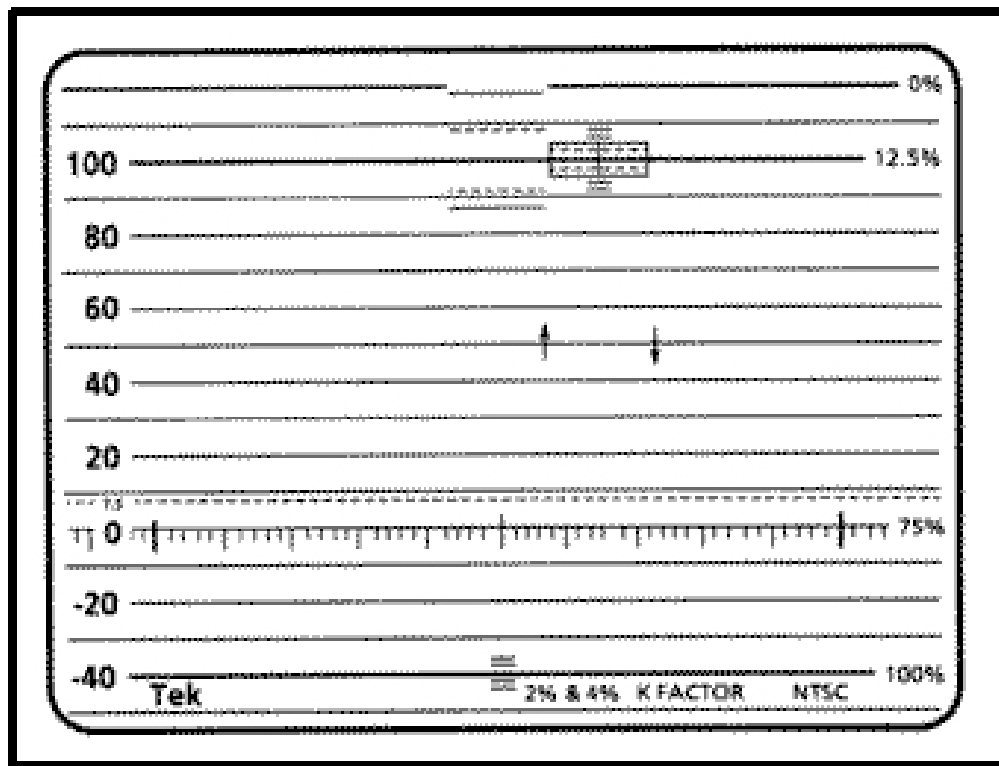

The illustration above is of a waveform monitor reticule. While it has several mysterious things included in the graphics, the most important are the horizontal lines that go from 100 at the top to -40 at the bottom with a heavy subdivided line about a third of the way up from the bottom at 0 on this scale. These are the primary measuring lines that we will be using. The units here are in IRE, and there are a total of 140 of them. (IRE stands for the Institute of Radio Engineers, the organization that created this standard and later became the IEEE, the Institute of Electrical and Electronics Engineers.) The video portion of the scale is from zero to one hundred, while the area below zero is for synchronizing signals.

Between the zero and the 10 IRE line is a dashed line at 7.5 IRE. This level is called setup, or pedestal. The original idea was that 0 IRE would be blackest black and 100 whitest white with all the other tones in-between. However, for technical reasons it just didn't work and the only fix they could come up with

was to raise the black level from 0 to 7.5. The area between 7.5 and 0 IRE is referred to as super black. While the technical issue that plagued early television sets has long ago been solved, this artificially high black level is the standard for NTSC video. Note that one of the wonderful things about HD is that it does NOT use setup and black levels do indeed go to 0 IRE as was originally intended.

Note also that there are two lines above 100 at 110 and 120 IRE. This is called the Superwhite area, where really strong light peaks (glints of the sun off shiny objects, for instance) may travel. What we perceive as white on a monitor is not 100 IRE but is actually around 75 to 85 IRE depending upon the visual content of the picture. So you should think of 100 IRE and above not as whites but as highlights that are a normal part of the picture. As an illustration, look at the waveform below:
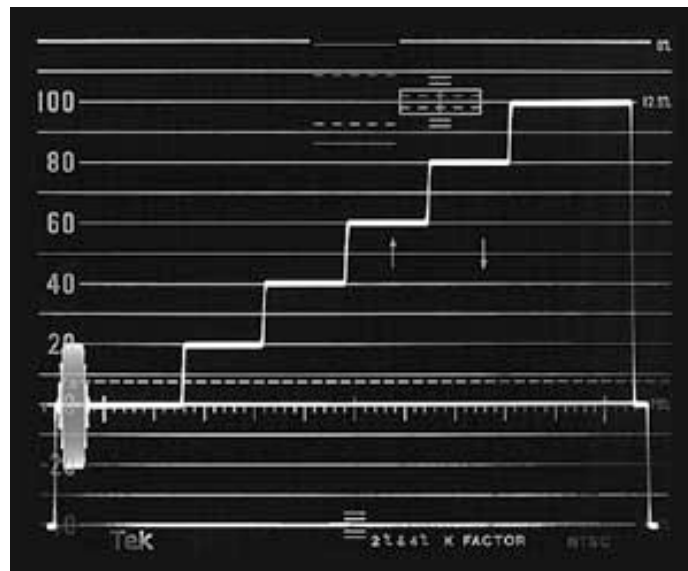
In this waveform we see a simple "staircase" test signal that has levels at 0, 20, 40, 60, 80, and 100 IRE from left to right. The step on the left would be below black, the next step a dark gray, the next step a bit lighter gray and so on up to the last step which would be bright white. It looks like this:
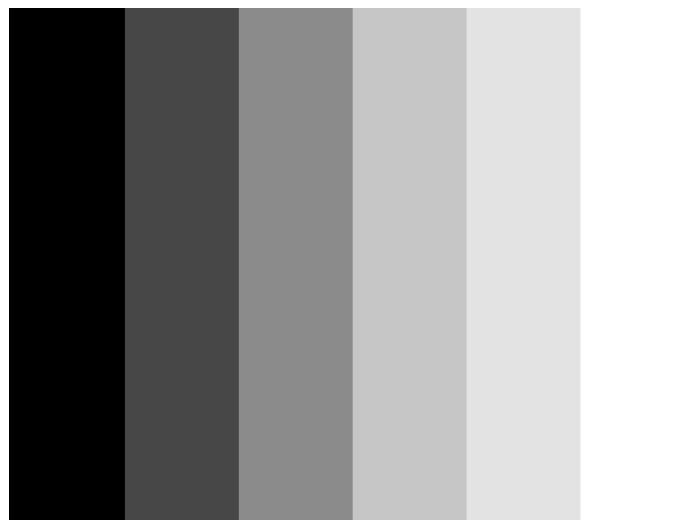
Now let's look at a more complex test signal, SMPTE color bars. This is the standard test signal used for calibrating tape decks and cameras. Please note that there are many different variations of color bars that have been used over the years, but the culmination of much research and practical experience has resulted in this format.

The color patches are arranged in three rows which I will describe here. The top row begins with a white strip followed by yellow, cyan, green, magenta, red and blue. These are the three primary colors (red, green and blue) and the three secondary colors (yellow, cyan and magenta), often referred to as the additive and subtractive colors.

The second row duplicates the top in reverse order but with only four of the patches (blue, magenta, cyan and white). This is used for calibrating monitors.

The bottom row shows a dark blue patch called I, then 100 IRE super white, another dark purplish patch called Q, then black, then three small strips called a pluge, then another black patch. On a waveform monitor it looks like this:
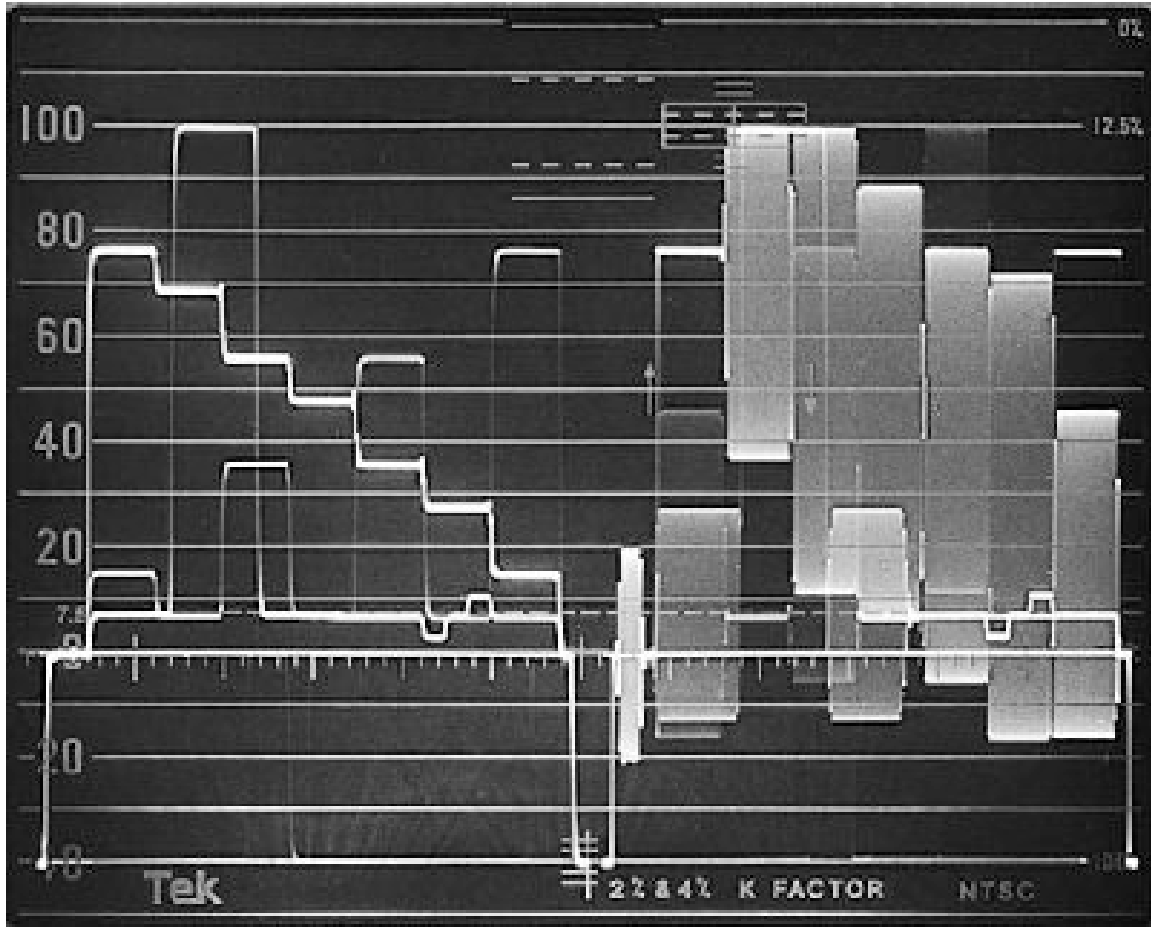
On the right is the waveform for SMPTE color bars with both the chrominance (color) and luminance (black and white) signals superimposed on top of one another. This is the FLAT setting on the waveform monitor. On the left is the same signal with the chroma signal striped out so that what is seen is only the luma. This is the IRE or Filter setting on the waveform monitor. This setting is preferred as it is much easier to see the full white and black levels, which are the critical parts that need to be set right. Notice that there is a descending stair step signal which is the top row of bars, and four "steps" that ascend from left to right which is the second row of bars.

As you can see, the white patch in the bottom left of the SMPTE color bar signal is sitting right on the 100 IRE line and the five black patches are right on the 7.5 IRE dashed line. This represents a correctly adjusted video signal. When playing back color bars from a tape this is what you should make the bars look like by adjusting the two knobs on the deck that adjust the white level and the black level. The white level is adjusted with the knob labeled "Video" or "Video Level" and the black level is adjusted with the "Setup", "Black Level" or "Pedestal" knob. These two knobs are somewhat interactive so when you adjust one it may be necessary to readjust the other slightly to get both white and black on their respective lines.

Now let's look at a vectorscope reticule:
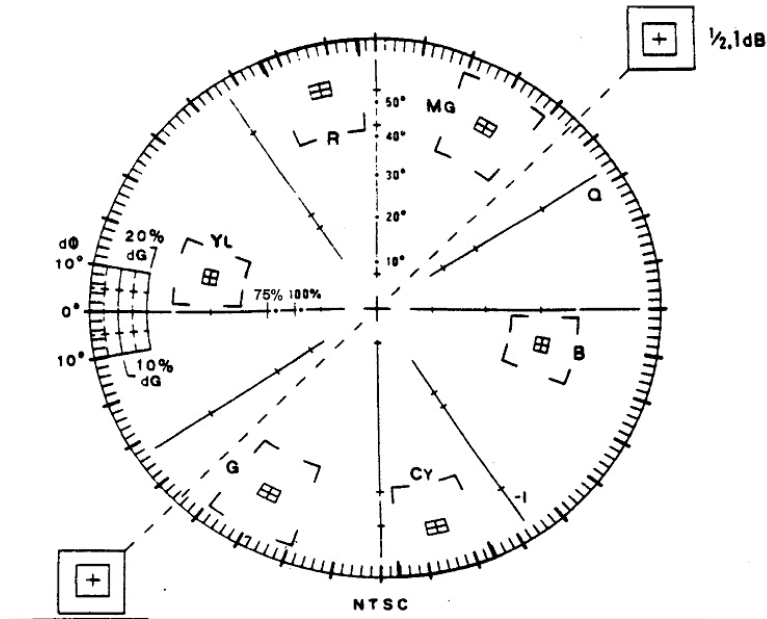
Here again there are a number of mysterious hieroglyphics but the one's we are most concerned about are the small crosshairs in the exact center, the 0 line to the left of the crosshairs and the six targets that are the aim points for the three primary and three secondary colors. The larger box surrounding the target represents the acceptable limit of error: if it's inside this box then it's legal. Below is a detail of one of the targets.
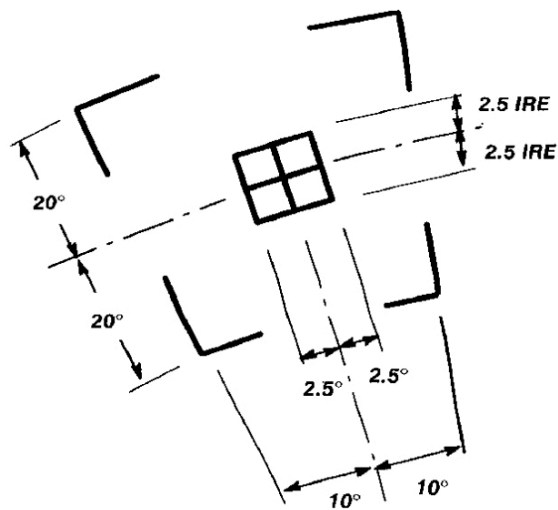

Before we can begin to make measurements with a vectorscope we first need to calibrate it to the incoming signal. This involves two steps, the first of which is placing the very center of the waveform exactly on the crosshairs in the center of the reticule. The procedure for doing this varies from scope to scope but there are usually knobs or small "tweaker" controls somewhere on the unit to accomplish this (some newer scopes do this automatically). The second step is to set the burst phase to 0.

Burst on a vectorscope is the line with a dot on the end that doesn't connect to any of the other signals on the display except the center point. On the vectorscope reticule, if you look carefully at the horizontal line to the left of the center crosshair you will see two dots with vertical lines, one labeled 75% and the other labeled 100%. Turn the phase knob until burst lines up with one of these two dots, or at least is on this line. SMPTE bars should line up directly with the 75% dot or very close to it. The illustration below shows SMPTE bars on a correctly calibrated vectorscope.
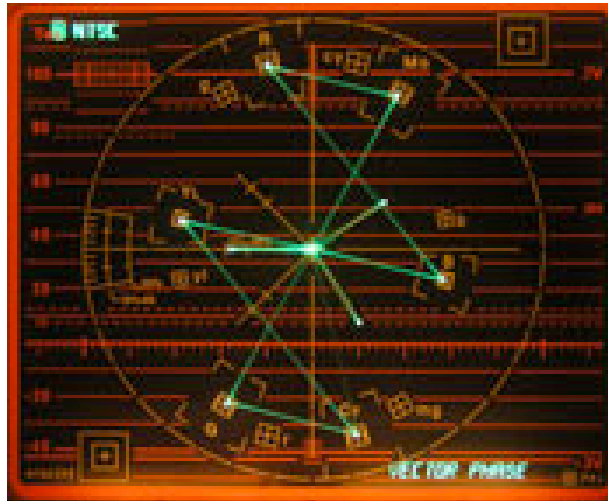
These images were made using a test signal generator. Let's see what a camera signal looks like:
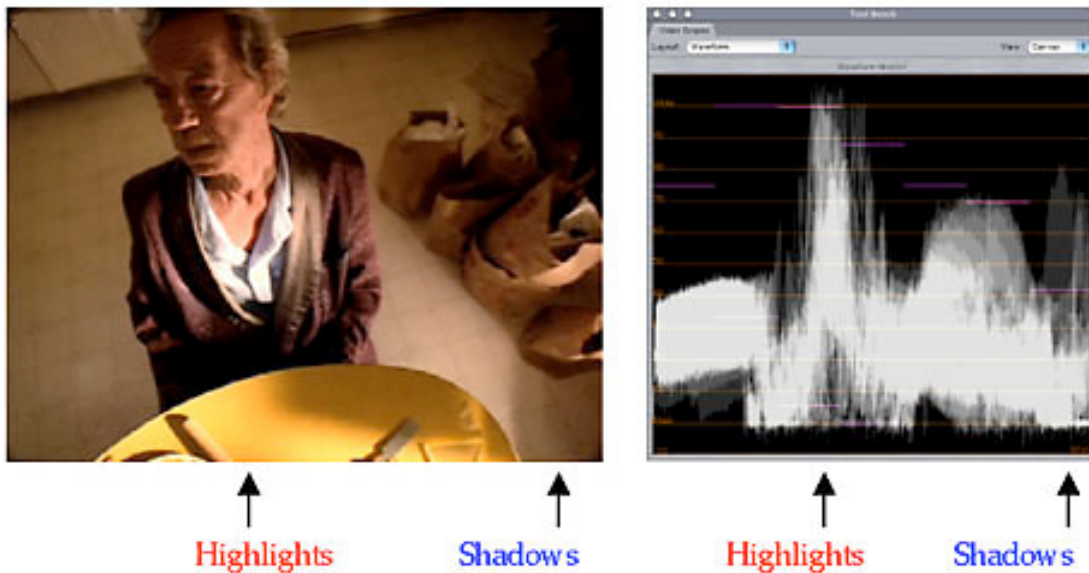
The image on the left is represented in the waveform monitor on the right. In order to understand it you must know a few things about waveform representations.

1. The waveform monitor shows the video level (essentially exposure) for every line in the image raster all at once. In other words, all the lines top to bottom are piled on top of one another to form the waveform image. As such the waveform image will correspond exactly to the picture from left to right, but not from top to bottom.

2. Waveform monitors can show both the black and white (luminance) portion of the signal AND the color (chrominance) portion superimposed on top of one another. Seeing both is often confusing and makes it hard to set correct exposure so it is usually better to set the scope to the "Filter" or "IRE" setting to see only the luminance.

3. Black is at the bottom, white is at the top, and in between are all the mid-tones. Remember, full black is 7.5 IRE for NTSC and 0 IRE for HD.

4. Caucasian skin tones will be at about 60 to 70 IRE on a correctly exposed camera. Black and Hispanic skin tones will be darker and vary greatly depending on the darkness of the subject's skin. I have seen very dark Nigerian people standing next to correctly exposed Caucasian people and their skin tone can be down around 45 IRE. And then there are the pail-skinned Irish girls who are correctly exposed at 75 or 76 IRE. So it varies, but 65 IRE is about average for Caucasian skin.

5. White is NOT 100 IRE. White is actually about 80 IRE or so and is more defined as the absence of color on the vector scope than it is level on the waveform monitor. White is also perceived relative to the rest of the picture. So a white tablecloth in a very dark restaurant might be only 70 IRE or less whereas in a brightly lit restaurant it might be 85 to 90 IRE.

6. As you approach 0 and 100 IRE detail diminishes. Full black and full white portions of the picture have no detail information at all, so there is nothing that can be "brought out" in post. You can raise the blacks or lower the whites all you want, but there still won't be any details there. So if you want all the beautiful beadwork and lace in that gorgeous wedding gown to be seen you'd better not let it get very far above about 80 IRE.

7. Peak whites, like sunlight off a chrome bumper, are actually details themselves if they are small enough. Don't freak out if they go up to or even over 100 IRE. Exposure is set by the overall brightness of the scene or by human skin if that is available, especially the face. So if you have tiny pieces of peak white remember, those are just details and aren't there to set your exposure by.

8. Lastly, remember that the waveform monitor is only one of two tools that you should use to adjust exposure. The other is your eye viewing a correctly calibrated REAL video monitor, NOT a computer monitor. There are great differences between them and you should only trust a true NTSC or HD video monitor to evaluate the image results.

Now as to a Vectorscope, during shooting it isn't near as much help as a Waveform Monitor except for achieving a precise color or color match. For instance, look at the images below:

The flower has a particular shade of orange that can be clearly seen on the Vectorscope. If you needed to match that color to, say, some graphic then you could compare its Vectorscope reading and see the what the differences are. The other thing a Vectorscope is good for is confirming white balance. If you fill the frame with a white object then it should look something like this:
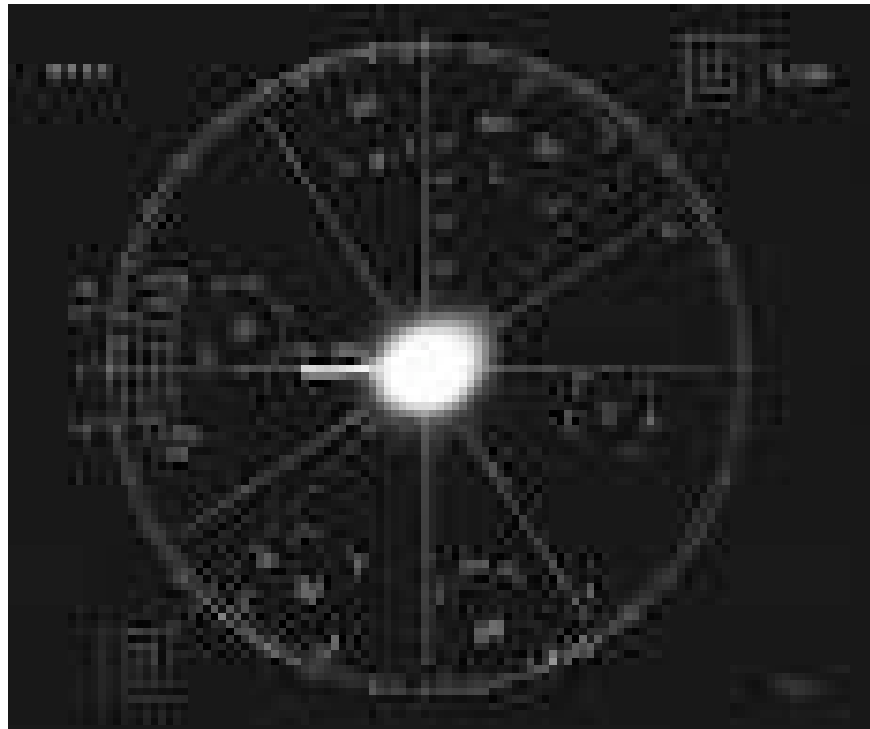
When everything is clustered in the exact center of the reticule, you are properly white balanced. If it is off center then you need to re-white balance. But remember; use the other scope to set exposure!

Jim Caldwell, Audio & Video Engineer, Three Eleven Associates
3437 Mapledale Circle, Farmer's Branch TX 75234
V: 972-484-0132, C: 214-783-9218, E: 311associates@tx.rr.com