



Lens selection is crucial because lenses are the most important element of the lens-camera imaging system in terms of final HD picture performance.

SPECIAL REPORT:

Testing HDTV Lenses

BY LARRY THORPE AND GORDON TUBBS

Conventional testing of competing high-definition lens-camera systems generally favors the camera, with lens testing often being cursory at best. Lenses are often misperceived as a necessary appendage to the chosen camera or to be pretty much equal in performance regardless of the model or brand.

In reality, the opposite is true. Lenses are not equal in performance. They are much more than an appendage to the camera. They are arguably the most important element of the lens-camera imaging system in terms of final HD picture performance.

Given that there are five major camera manufacturers and at least three major lens suppliers, it must be acknowledged that choosing the optimum HD lens-camera system from

the many possible combinations for a specific production application poses a significant logistical challenge. Some simplification to the overall approach is warranted. It is suggested to give the first priority to choosing the camera. If the assumption is made that all high-end HD lenses are good, then an arbitrary initial choice of one lens (that meets the operational requirements) to support the camera selection makes sense. Using this one lens on all competing cameras will help expose the overall performance differences between the contending cameras (assuming, of course, that some appropriate technical measurements are made).

Having finally chosen the camera that best meets performance and operational needs, the end user can now turn attention to the competing

lenses and assess their differences using that single camera of choice. The test procedures to be described will be based on the quest for the lens exhibiting the best overall performance optimization.

While the professional lens system has many important imaging parameters, there are five key attributes for any HD lens the end user should carefully evaluate. All five will invariably differ to some degree between lenses from the world's major manufacturers. They are:

- sensitivity
- contrast
- resolution
- color reproduction
- geometrical distortion.

Lens sensitivity

The spectral transmittance of

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similar lens types made by different manufacturers will not be the same. Therefore, any two contending lenses having the same f -number *are likely to have different optical speeds* (f -number by definition assumes 100 percent transmittance efficiency [1]). This needs to be carefully accounted for in any side-by-side test between different lenses. The precision of a given lens calibration can be established using known optical techniques (involving light meters, etc.).

However, the simplest test of the transmittance efficiency of a given lens is to fully open the iris and record the video level (at 0dB master gain setting) of a gray scale test chart under a given scene lighting level. If two competitive lenses are sequentially mounted on a single HD camera and this simple measurement made on each (with fixed lighting level and fixed camera gain), this will quickly reveal the maximum relative aperture performance for each.

Lens contrast

The contrast performance of an HD lens bears significantly on the overall subjective picture quality. At one extreme is the optical noise floor of the lens, determined by the manufacturer's control of flare and veiling glare.

With today's 2/3in HD camera signal-to-noise ratios in the vicinity of 54dB (which translates to a contrast ratio capability of 500:1), it is imperative that the associated HD lens have a contrast ratio performance for nominal exposure that exceeds this. There are new gray scale test charts that facilitate accurate exploration of the contrast ratio performance of a lens-camera system. (See Figure 1.)

This examination does entail meticulous adjustment to the overall transfer characteristic of the camera to ensure optimum reproduction of the lowest black steps of the chart. This must, of course, be done with one chosen lens imaging the chart. Swapping to the other contending lenses — without any readjustment of the camera settings — should expose pertinent differences between the lenses in terms

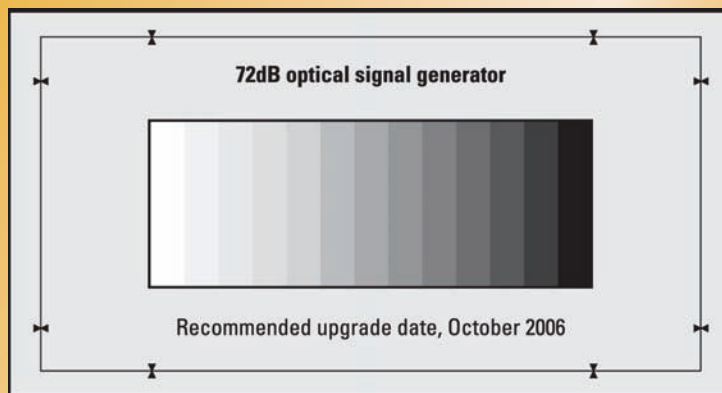


Figure 1. A wide dynamic range gray scale chart specially designed to explore lens-camera contrast ratio capabilities

of any optical limitations at the lowest extremes of illumination.

At the other illumination extremity, the behavior of a given lens when stimulated by strong light sources (studio lights, the sun, etc.) should also be carefully explored. This can be done in a studio by observing all optical phenomena that manifest themselves

Lens resolution

As discussed in January [2], the modulation transfer function (MTF) performance of the lens-camera system is an assessment of how that imaging system's contrast behaves with increasing spatial detail. Contrast performance is inextricably intertwined with the visual sharpness capability of

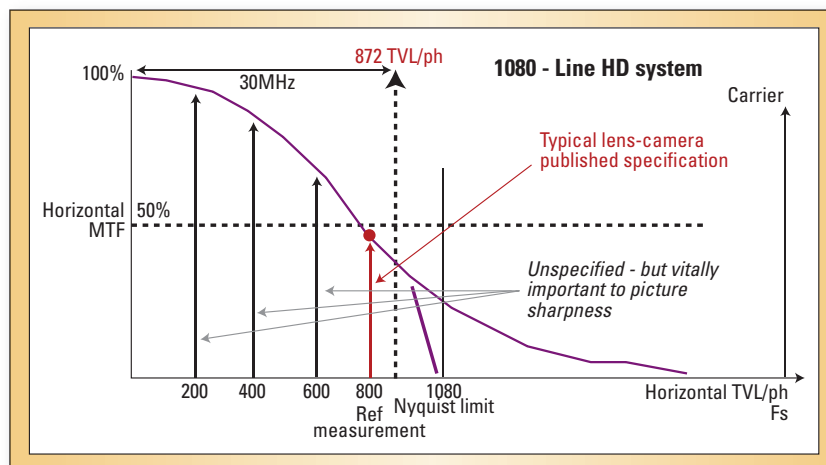


Figure 2. Measurement of the lens-camera system's depth of modulation at picture center should be carefully recorded for the four spatial frequencies shown.

when high-intensity light sources are directly imaged by the lens-camera.

Equally important is the behavior of the lens when these light sources are placed off-axis just outside the image area and the camera is subsequently panned vertically and horizontally. This exercises the design strategies that manage off-axis bright light rays. The observations will differ between lenses, and the end user must decide which behavior is more acceptable.

the HD imaging system. The *shape* of the system MTF curve is of great importance here. Thus, the test should seek establishment of the MTF profile, with four measurements as indicated in Figure 2.

It is essential that this measurement be made on an HD waveform monitor (connected to the HD SDI output of the camera system). An HD studio monitor should *never* be used to evaluate MTF; the best contemporary

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HD monitors typically have a limiting resolution of only 1000 television lines per picture height (TVL/ph) and, as such, their own MTF profile exhibits a substantial roll-off across the important HD passband.

There are a variety of commercially available 16:9 image format test charts that can support such an MTF measurement. (See Figure 3.)

Carefully used in conjunction with a waveform monitor, this will allow an MTF profile to be recorded and later plotted. (Special attention must be paid to flat lighting and to physically aligning the test chart for absolute horizontal and vertical alignment with respect to the camera.)

The first comparative assessment of an HD lens MTF should be made on the luminance (Y) video signal at picture center where MTF is at its highest. All camera nonlinear processing (gamma, knee, etc.) should be removed. The test starts with a gain adjustment of the waveform monitor so that the 50 TVL/ph horizontal burst precisely fills the 100 IRE scale, which becomes the 100 percent spatial contrast reference.

This is followed by slight panning of the camera to sequentially position each of the four spatial frequency bursts at the center of the image plane and carefully record the amplitude of each (relative to that of the 50 TVL/ph burst). This pre-calibration and measurement is then repeated for each of the contending lenses.

An MTF profile can then be plotted from these four measurements. The lens-camera MTF profile with the highest belly across the 200 TVL/ph to 800 TVL/ph band to the plotted curve will produce the higher picture sharpness.

Assessing the MTF dynamics of an HD lens

As outlined in March's lens article [3], all lenses exhibit variations in MTF as their three operational controls (iris, zoom and focus) are exercised during a production. Accordingly, the testing of a lens should, to the degree possible, anticipate this

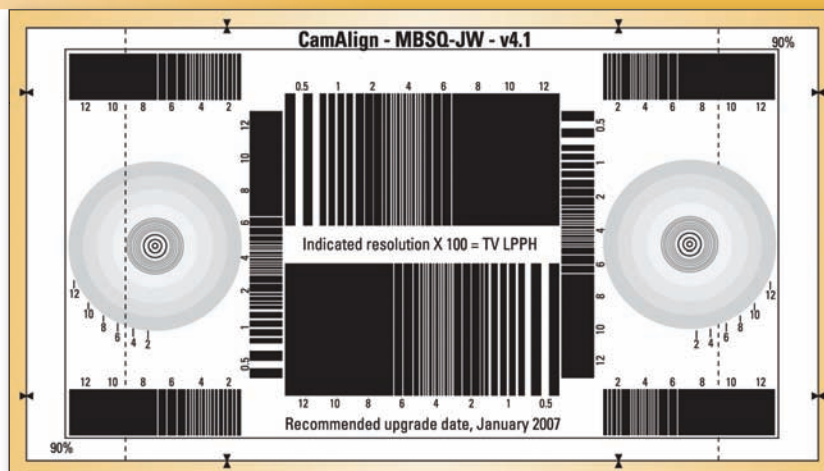


Figure 3. An example of a useful multiburst test chart to facilitate measurements of HD lens-camera MTF

and be reflective of the actual usage anticipated for the lens and camera.

At a minimum, tests on MTF at three focal lengths (spanning the typical focal range anticipated in the specific intended usage of the lens-camera system) should be made. These should include the expected regular close-ups, medium shots and wide-

ever, the measurement at the wide-angle setting requires a much larger chart that ensures its position does not intrude into the minimum object distance (MOD) of the lens. Fortunately, such charts are available.

These tests should be conducted at two lens iris settings: one at the iris setting that provides nominal

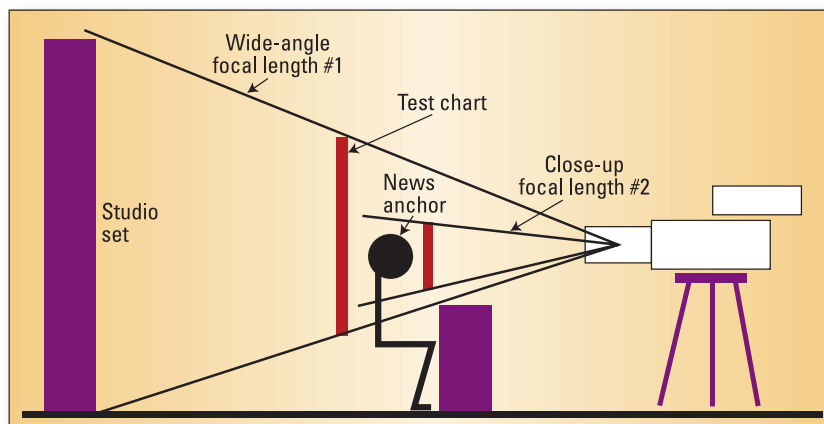


Figure 4. Suggestive of a news studio with two primary focal lengths and exposing the issue of test chart size

angle shots. These measurements will expose how a specific lens has been optimized for picture sharpness.

There are, however, some logistical issues relating to these tests. While the HDTV broadcast news set is perhaps a relatively simple set, it does serve as a useful and simple illustration of the issues. (See Figure 4.)

As can be deduced from Figure 4, the assessment of MTF at the focal length for the anchor close-up is relatively straightforward in that a normal-size test chart can be readily used. How-

ever, the measurement at the wide-angle setting requires a much larger chart that ensures its position does not intrude into the minimum object distance (MOD) of the lens. Fortunately, such charts are available.

Evaluating corner-to-center sharpness

While the lens designers typically concern themselves with a multi-point optimization of MTF over the image plane [3], the end user really need

Suppliers of HDTV test charts

- DSC Laboratories (Canada), www.dsclabs.com
- ZGC (USA), www.zgc.com
- Dai Nippon Printing (DNP) (Japan), www.dnp.co.jp

only be concerned with two primary regions: the central region and the corner regions, as indicated in Figure 5. An assessment of the sharpness behavior in these two spatial regions will constitute an effective summary of the success of the lens manufacturer in implementing their respective MTF optimization strategies. This involves a separate check on corner focus relative to picture center and then corner MTF (when it is sharply focused).

Evaluating lens corner focus

This test is a scrutiny of the curvature of field aberration that is inherent to all lens systems. While this cannot be made zero, it can certainly be minimized in a good optical design. A test chart has been developed that has a large Siemens focusing chart in its center to facilitate a convenient lens back-focus adjustment followed by a precision lens-camera center image focus. (See Figure 6.)

The chart has, in addition, four radial multiburst charts in each corner, spanning the critical 200TVL/ph to 800 TVL/ph HD spatial frequency region. With picture center sharply focused, the four corners should be closely inspected to assess the degree of defocus relative to center. The chart easily reveals any differences between the corners, and these should be noted. This chart also serves to quickly reveal any chromatic aberrations [4] that might be present in the picture extremities.

Evaluating lens corner MTF

While this measurement is closely related to the preceding measurement on corner focus, there is a difference. Measuring corner MTF is a supporting examination of the lens-corner resolution performance. It constitutes

an examination of the MTF characteristic in each corner *when it is focused*. This tells how well the optical design has been able to optimize MTF across the image plane.

For this test, each corner should be carefully focused in turn using the multiburst test chart shown in Figure 3, which contains a multiburst in each corner. Each of these four multibursts is used to evaluate the MTF behavior within these corner regions over the 200 TVL/ph to 800 TVL/ph spatial frequency region. (See Figure 6.)

While it might be asked why this secondary test on corner MTF is useful, it should be borne in mind that racking focus can be a common creative action during production. It may well be that an initial focus might be on a person or scene object located in the picture center, but that shot could be followed by a focus pull to another person (or portion of the scene) located in one of the corner regions. It is important that that corner scene content appear with a sharpness close to that at the picture center.

Color reproduction

As discussed in May's lens article [1], the spectral response of the HD lens is one of four critical elements defining the final color reproduction characteristics of the HD lens-camera system. The other three elements are the beam-splitting optics of the camera, the spectral response of the camera imagers and the linear matrix designed by a given camera manufacturer.

While all of the lens-camera combinations should meet the prescribed SMPTE 274M/296M colorimetry standard (when the camera operational controls are set to their detent positions), there will still be subtle differences in terms of the color gamut

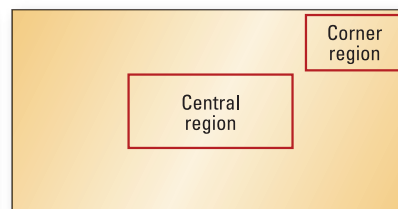


Figure 5. Corner focus should be checked when the picture center is in focus, and separately, each corner MTF should be recorded when the corners are refocused.

that each HD lens-camera system can reproduce. These are a consequence of the separate design preferences of both camera and optical manufacturers and inevitable tolerances in the spectral responses of lenses, prisms and image sensors [5]. Because color is a quite subjective topic (even though a rigorous color science does exist), the final conclusion usually reduces to the subjective preferences of the end user. For that reason, HD lens testing should always include a careful comparative evaluation of color reproduction characteristics.

The comparative HD lens test for color reproduction

Assuming that the end user has already made a prior choice of an HD camera, then three of the four variables that bear on color reproduction are now predetermined. Only the lens contribution remains to be evaluated. The lens testing should be done on an A/B basis — using the selected HD camera — by separately evaluating each lens on that single reference camera.

Prior to these evaluations, each lens-camera combination should be carefully white-balanced. This is an *essential* step because competitive lenses will have different RGB transmittance characteristics that *must* be normalized by restoring the reference white that establishes the proper color-taking behavior of each lens-camera combination. Then, and only then, will the subsequent evaluation of a wide range of colors be valid. The comparative evaluation of lens contribution to color reproduction should

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be done with camera color correction zeroed out and with the camera linear matrix switched in.

The camera should be set up in a properly lit studio and a careful overall balance made on a gray scale chart. A variety of color test charts are available that support formal comparisons on vectorscopes.

From a production viewpoint, it is important to also explore a wider range of real-world colors on a carefully calibrated monitor. It is essential that this be the HD monitor planned for use in the production control room during normal program origination.

The test colors should include objects that are highly saturated, medium saturated and pastels, as well as materials that might be germane to a specific production (different ethnic skin tones, special colored clothing, particular set materials, etc.).

As this exercise becomes much a subjective evaluation, the production team should be active participants. Discussions will inevitably ensue on the perceived reproduction of certain colors. It will probably require a degree of consensus, as it is rare for two people to fully agree on color reproduction. It regularly becomes a discussion of the degree of accuracy of reproduction of certain colors versus the perceived pleasing nature of such color reproduction.

Clearly, the HD camera can allow additional color adjustments to enhance the color reproduction to the taste of the production team. However, as the

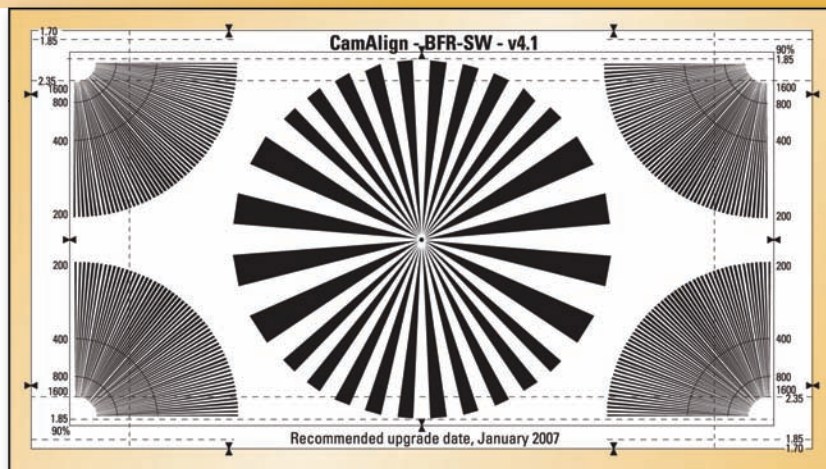


Figure 6. Test chart to facilitate examination of corner focus and corner MTF assessment

intent of this test is to search for *differences* in the competing lens contribution to color reproduction, it is important that the HD camera system remains in its “technical norm” detent mode.

Geometrical distortion

Geometrical distortion exists to some degree in all lenses. Terms such as *pincushion* and *barrel* describe the general shape of the common geometrical distortions. High-performance lenses have made significant strides in minimizing such aberrations.

The wider the angle of the lens, the more challenging the task of reducing such distortion. A quick evaluation of a lens can be as simple as zooming to the widest angle of the lens while imaging a studio set containing scene content that is orthogonal in nature, such as doors, windows, desks, pictures or any special feature (having straight

horizontal and vertical edges) of the studio set that is regularly visible during normal production. Any two lenses can be readily compared on this basis. A 1 percent difference in geometric distortion can readily be noted under such subjective test conditions. Test charts exist that facilitate objective measurements of geometric distortion.

Larry Thorpe is the national marketing executive and Gordon Tubbs is the assistant director of the Canon Broadcast and Communications Division.

References

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- [2] Larry Thorpe and Gordon Tubbs, “HDTV studio lens design,” *Broadcast Engineering*, January 2005.
- [3] Larry Thorpe and Gordon Tubbs, “Management of MTF,” *Broadcast Engineering*, March 2005.
- [4] Larry Thorpe and Gordon Tubbs, “Chromatic aberrations,” *Broadcast Engineering*, July 2005.
- [5] David Corley and Shirley Li, “Controlling image quality in a digital world,” *SMPTE Journal*, 9/04, Vol. 113, No. 9, pages 293-306.