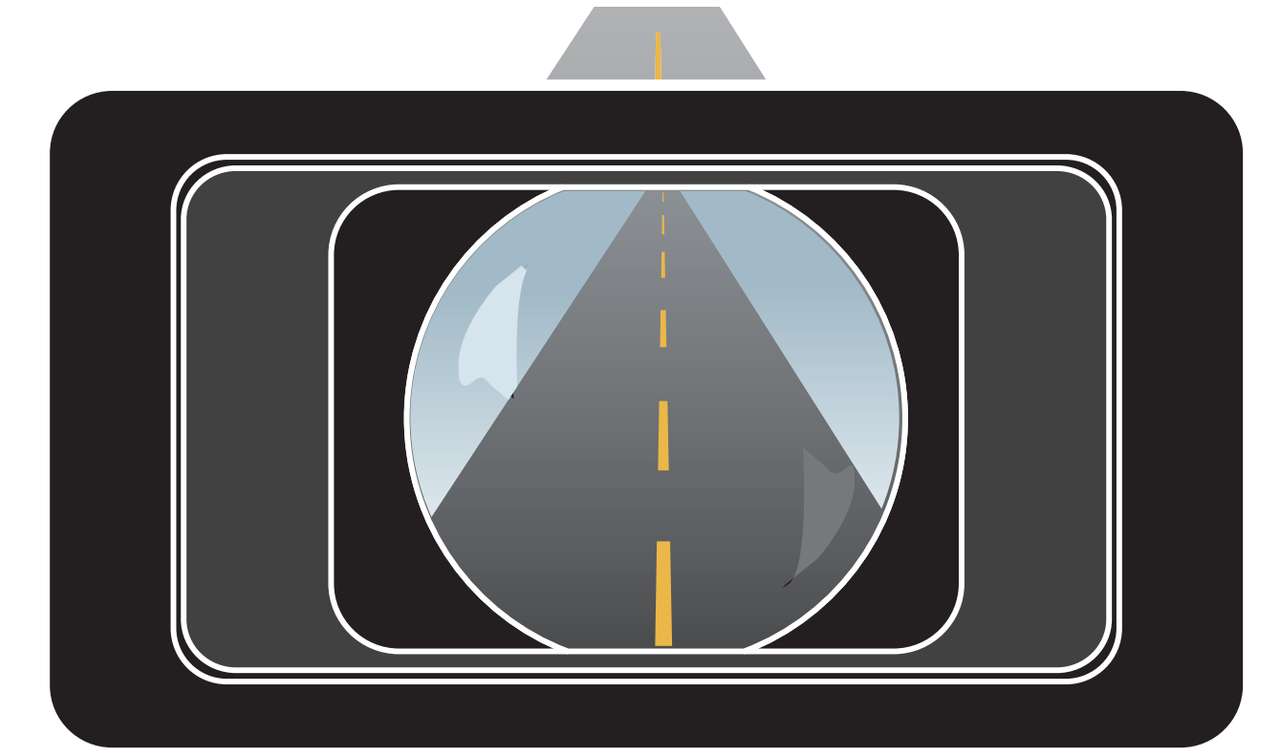

HDTV optics

and the many roads to HD newsgathering

BY LARRY THORPE AND GORDON TUBBS

Across the country, broadcasters are examining possibilities in migrating to HDTV newsgathering as part of the larger DTV transition. At this juncture, broadcasters appear separated into two broad philosophical camps:

- a near-term total transition to HD, entailing conversion of the news studio and allied infrastructure to full HDTV production and outfitting all in-field news crews with HDTV equipment. In many cases, this simultaneously encompasses a switch to a tapeless nonlinear IT-based system.
- a more paced transition, involving conversion of the news studio to full HDTV production, but with in-field news crews shooting widescreen digital component SDTV that will be subsequently upconverted to the chosen HDTV format. A second downstream transition to HD news acquisition is generally anticipated.

No free lunch

The singular challenge to the second approach is integrating the upconverted widescreen SD material from the field with the pristine and sharp programming of the HDTV news studio. A first important premise is understanding that the upconversion process cannot add picture sharpness to an original SDTV image. The best that this process can do is to:

- eliminate the visibility of the line carrier structure of the SDTV signal, which does clean up the image, especially when viewed at close range
- reformat the 16:9 SDTV video signal to the 16:9 HDTV video signal so that the two can be seamlessly integrated within HD switchers, editing systems, etc.

With careful planning (and some operational training), the upconversion of 16:9 digital SDTV can be acceptably integrated into an overall HDTV news program.

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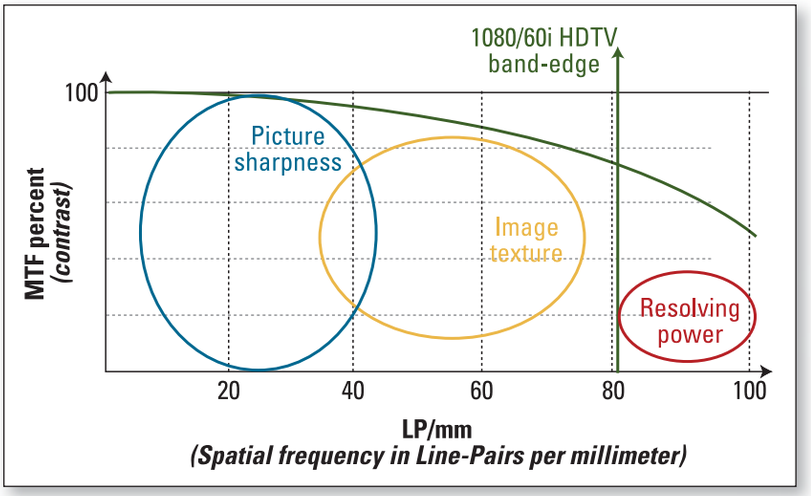

Figure 1. A typical MTF curve (measured at picture center) of a contemporary 2/3in HDTV lens and the approximate regions of spatial frequencies

Upconverting SDTV newsgathering material

What should be sought is the best visual fit between the upconverted SD imagery from the news crews and that originated in the studio by the HD cameras. That visual match encompasses all of the numerous dimensions of an image, including picture sharpness, contrast, tonal reproduction and color reproduction. With careful planning, the match can be quite excellent — except in the realm of picture sharpness.

The in-field SDTV video capture must be the best possible. There are a number of key things to consider:

- use the best lens — and it should be an HDTV lens
- use 4:2:2 digital SDTV recording in the field-acquisition system
- use the optimum camera setup that expedites quality upconversions (this especially bears on the setting of detail enhancement systems in the camera)
- learn the rules of image framing for acceptable upconversion
- use a high-quality upconversion system.

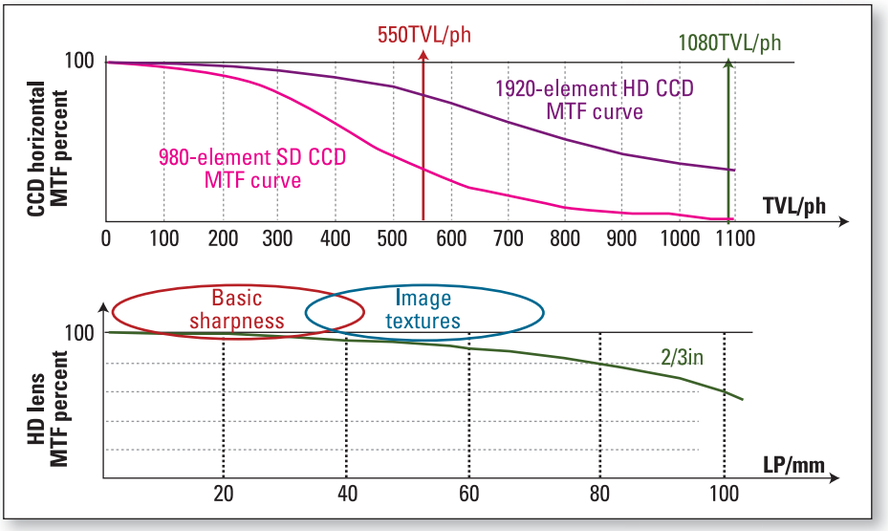

Figure 2. An HDTV lens that is projecting an image onto a 2/3in SDTV CCD (with a Nyquist frequency of 550TVL/ph) and onto a 2/3in HDTV CCD (with a Nyquist frequency of 1080TVL/ph)

Taking each of these in turn:

- *The lens.* Picture sharpness on large HDTV screens will be more readily evaluated in the picture extremities as well as picture center. It is important that the lens used on the SDTV camcorder have as even a modulation transfer function (MTF) distribution from picture center to corners as possible.

The 16:9 SDTV camera should use an HDTV lens. The HDTV lens will enhance the MTF of the SDTV video. The flatness of this MTF across the image plane will also be improved. It will optimize a number of additional picture parameters, including the optical contrast ratio. Picture sharpness and contrast are intimately related [1]. The HDTV lens will ensure that the SDTV camera is delivering all that it is capable of originating.

- *Digital 4:2:2 recording.* The SDTV camcorder should be full-bandwidth 4:2:2. Fortunately, there are a wide variety of such digital ENG camcorders to choose from, both tape-based and tapeless. All of that original color detail will be needed to ensure that upconverted video is as rich in detail as it possible.
- *Camera setup.* Use of minimum detail enhancement is important. The established instinct from the NTSC era is to use a significant amount of enhancement in order to overcome the resolution limitations of that analog system. However, SDTV is a component-based digital system and is inherently sharper. Upconversion processing works optimally when there are no overshoots on transitions and when aliasing (particularly vertical aliasing) is minimized.
- *Rules of image framing.* This is the most critical issue. The reproduction of image sharpness is highly dependent upon picture content, and the lens is the great dictator on this. There is no intuitive prediction of the optimization of upconversions. There are too many variables involved. Testing is the only way to develop a feel for the boundaries.
- *Upconversion system.* Over the past five years, a tremendous amount of

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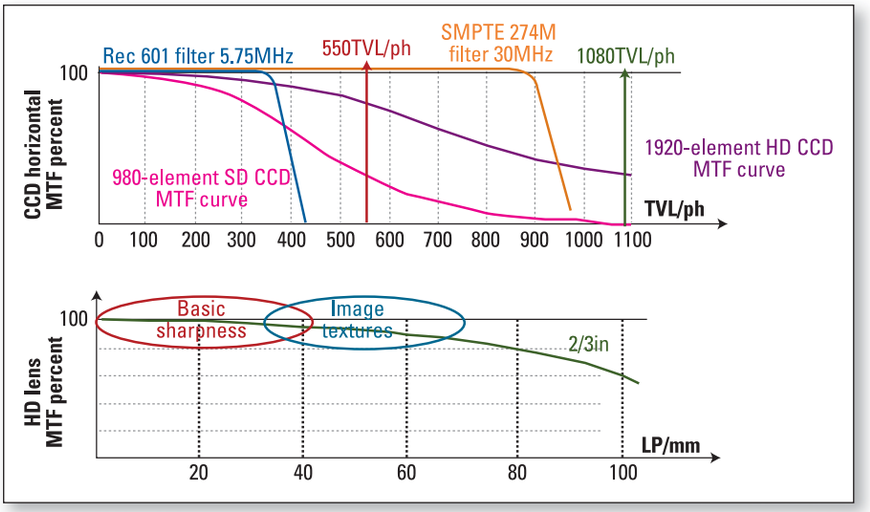

Figure 3. The effect of the SDTV 5.75MHz band-limiting filter in removing textural detail from the image

development has gone into digital upconversion processing, and sophisticated techniques have evolved. Testing is the best way to zero in on the system that works best for the type of imagery anticipated.

Now, let's look at the role optics plays.

Picture sharpness revisited

In the second article in this series [2], we looked at the topic of picture sharpness. It was explained that the visual perception of sharpness on a television screen viewed from a distance (six or seven times picture height being typical for SDTV) is proportional to the square of the area under the MTF curve [3]. This refers to the lens MTF multiplied by the camera MTF. What this translates to in real terms is that the lower spatial frequencies make the greatest contribution to the edge sharpness perceived by our eye-brain system. The higher spatial frequencies then augment this by contributing important textural information that adds to the reality of the portrayed image. Texture is generally low-amplitude, high-frequency detail relating to human facial portrayal (eyebrows, skin texture, etc.), clothing textures (wool, silk, etc.), nature (grass, leaves on trees, shrubs, etc.) and materials (wood, bricks, stucco, etc.).

Essential picture sharpness and the associated image texture can be mapped onto the HDTV lens MTF characteristic. (See Figure 1 on page XX.)

A good SDTV camera and 4:2:2 digital recorder can create a high-quality image at normal viewing conditions (six or seven picture heights from the SDTV display). Contemporary SDTV 2/3in CCD imagers that are super-sampled horizontally (in the vicinity of 1000-elements), in combination with a high-performing lens and 4:2:2 10-bit digital recorders, will do justice to edge sharpness. But, the reproduced picture will still lack fine textural detail. Texture plays an important role in contributing to the perception of sharpness. The detail in hair is an obvious one. The fine detail in facial skin is a more subtle manifestation — discernible in an HD image but much less so (or not at all) in an SDTV image. The textures in clothing are superbly reproduced in an HD image, but are usually significantly attenuated or may be eliminated entirely in an SD image.

If a scene is imaged by a lens, then the essential edge sharpness will be optically resolved over the spatial frequency range of 0LP/mm to approximately 40LP/mm. The textural detail in the face and the clothing, however, will be primarily resolved over the spatial frequency range of 35LP/mm to 75LP/mm [4]. Let us put a technical perspective on this.

Figure 2 on page XX shows an HD lens MTF (at picture center) whose optical response (in LP/mm) has been scaled to coincide with the spatial resolution of an SDTV CCD imager and an HDTV CCD imager (1920 horizontal samples) that are shown in TVL/ph. The MTF curves shown are typical of the two different 2/3in imagers. If the spectral energy from that scene were mapped onto the HDTV lens, then it would, in turn, project this onto an HDTV imager (assuming a 1920-element CCD) and onto a high-performance SDTV imager (assuming a 980-element CCD).

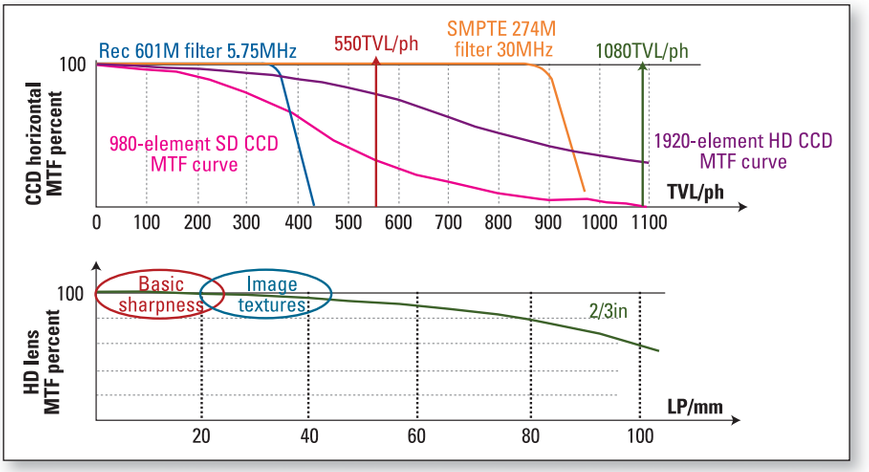

Figure 4. Comparing this with Figure 3 illustrates the lowering of the spatial frequency content of a given scene by adjusting the lens for a tighter shot

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It can be readily noted from Figure 2 that both imagers will do justice to the essential scene-edge sharpness. Both will resolve the higher textural information (and, if the SDTV camera employs spatial offset, it can do quite well here), even though the MTF curve of the SDTV camera is considerably lower over that region. The HDTV image will, therefore, be perceptually sharper.

The real problem, however, lies in the digital filters that define the separate SDTV production standard and HDTV production standard. Figure 3 on page XX shows the Rec 601 digital filter of 5.75MHz for the SDTV acquisition system and the SMPTE 274M digital filter of 30MHz for the HDTV acquisition system superimposed upon the respective imager MTF curves. Now the comparative image capture capability of the two video systems becomes starkly apparent.

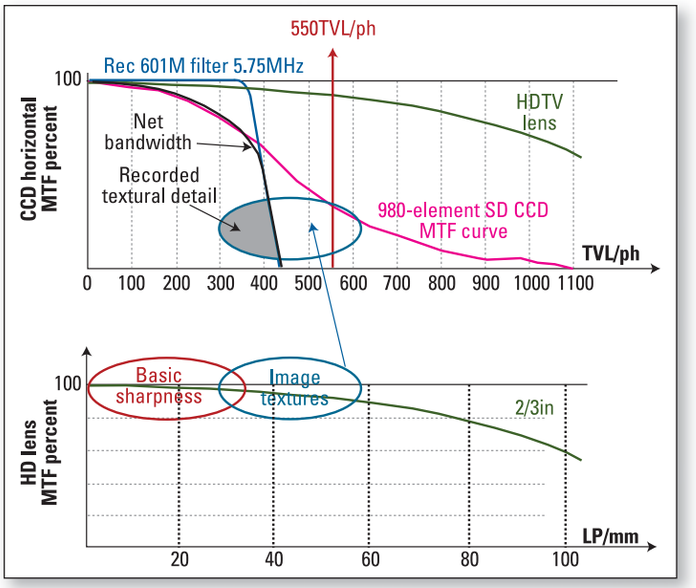

Figure 5. Depicts a lens setting that allows some of the high-frequency textural detail (shown shaded) to be captured by the SDTV camcorder, in which case the critical role of the higher MTF of the HD lens is apparent

The region containing the fine detail texture information that was captured by the CCD is completely eliminated in the recorded SDTV video (conforming to the 601 standard). Thus, from a viewpoint of reproducing a truly sharp image, there is an inherent failure in the SDTV system.

Long ago, the zoom lens was developed to become the supreme arbiter in forming imagery that could meet the quite limited spatial resolution capabilities of the approximately 4MHz analog NTSC system. Figure 4 on page XX illustrates the lowering of the scene spatial frequency by increasing the focal length of the lens until the band of spatial frequencies corresponding to low-level textural content is moved within the 5.75MHz passband of the SDTV acquisition system.

In the real world, the dictates of framing a scene may not allow the luxury of considerations of image detail. While it is important that the camera operator become sensitive to framing for optimized upconversion, there will still be many instances where compromise is necessary (dictates of required picture content). In Figure 5, a situation is postulated where the imperatives of picture framing only allow a portion of the textural spatial frequencies to fall within the system's electronic passband. But even that curtailed information is important, and the use of an HDTV lens will aid considerably in ensuring the highest level of that detail being applied to the CCD imagers and the in-camera or external video recording system.

Summary

Widescreen SDTV field acquisition that is upconverted and incorporated into an HDTV news broadcast system is an important migration track from the existing analog NTSC world to the all-DTV future. It recognizes significant realities that confront many broadcasters. Reconciliation of the two levels of imagery — that from the news crews and that originated in the studios — can never be complete, but it can, with proper attention, be made acceptable. The degree of acceptability achieved will call for iterative experimentation on the part of the news photographers and close collaboration with the technical and production staff at the station. There is no substitute for this testing in identifying the image-framing guidelines that work best for a given choice of SD camcorder, HD format, upconverter and news editing/post-production system. The use of an HDTV lens and minimum digital image enhancement in the camera is strongly recommended to ensure the best possible image sharpness in anticipation of the critical upconversion process. BE

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

References

[1] Larry Thorpe and Gordon Tubbs, "Management of MTF," *Broadcast Engineering*, March 2005.

[2] Larry Thorpe and Gordon Tubbs, "HDTV lenses, MTF and picture sharpness," *Broadcast Engineering*, January 2005.

[3] Otto H. Schade, Sr., "Image quality: A comparison of photographic and television systems," reproduced in the *SMPTE Journal*, June 1987, p567-595.

[4] Larry Thorpe, J. Hosoya. K. Ito, "A new HD cine zoom lens for digital motion pictures,"*SMPTE Journal*, October/November 2005.

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