1/2in IMAGE FORMAT REDUX

BY LARRY THORPE AND GORDON TUBBS

The 1/2in camera-imager format has returned, but this time around it's a *high-definition* 1/2in camera-imager format.

A year ago, two of the major camera manufacturers shut down production of all SDTV camcorders conforming to the 1/2in image format. Born in the 1980s, this image format was destined to propel thousands of cost-effective SDTV cameras and camcorders into a broad variety of sectors of lower-budget production, corporate production and smaller market television stations. The format reached a zenith in the late 1990s and then entered a slow decline, displaced by increasingly lower-cost 2/3in image format products and higher-end 1/3in image format cameras. Now, however, a contemporary HDTV camcorder squarely centered on a 16:9 1/2in image format has entered the market.

The 1/2in format holds the promise of the same advantages for HD that successfully thrust it into the lower-budget SD world 20 years ago. Namely, the 1/2in format facilitates the production of a more compact camcorder at a lower cost.

A survey of contemporary 2/3in image format SDTV newsgathering camcorders offered by all of the major manufacturers shows these products broadly range from $20,000 to $30,000 in cost. Lenses for these camcorders (from all of the manufacturers) span roughly the same pricing range. Broadcasters have made little secret of the fact that they believe that HDTV newsgathering can only be successfully implemented if the HD camcorders and lenses entail a modest cost premium over SDTV ENG camcorders.

The challenge to produce HDTV camcorders and lenses that meet this criterion has sparked an extraordinary diversity of innovative design strategies. The use of the smaller 1/2in image format is only one of these design exigencies. Indeed, no less than three HD image formats have emerged—the traditional 2/3in, the 1/2in and the even smaller 1/3in.

Some of the optical manufacturers have

New tapeless HD systems are emerging in three image-format sizes (2/3in, 1/2in, and 1/3in). Sony's HD XDCAM uses the 1/2in image format. Photo by Jim Huibregtse.

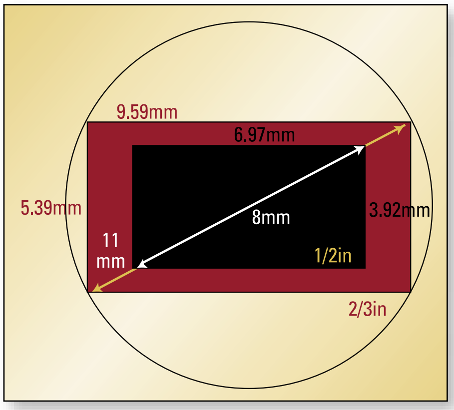

Figure 1. A scaled comparison between the sizes of the standard 2/3in image format and the 1/2in image format

already planned to develop more cost-effective HDTV lenses for both the 2/3in and the 1/2in image formats on the assumption that these two image formats will coexist in the larger HD marketplace. In the case of the separate tape-based HDV format, interchangeable HD lenses for the popular 1/3in image format play a role. This article will, however, focus on the 2/3in and 1/2in formats.

The possible lens options for the 1/2in format

It is useful to open the discussion with a reminder of the difference in image size for the 2/3in and 1/2in image formats. (See Figure 1.)

The dilemma for many end users contemplating the new 1/2in HD systems, however, is that they are entering a marketplace awash in 2/3in camcorders and lenses — both HDTV and high-end SDTV. Accordingly, many are naturally asking:

- Will the same family of 1/2in HD lenses emerge that are operationally compatible with established 2/3in optics (in terms of popular angles of view and ranges of focal length)?
- Can a 2/3in HDTV lens work with these 1/2in HD cameras?
- Can legacy 2/3in SDTV lenses be considered for the new 1/2in HDTV cameras?
- Would a new 2/3in HD lens purchase be a better investment if a downstream transition to a higher-level 2/3in HDTV camera were, for some end users, a possibility?

The new 1/2in HDTV lenses

New lenses specifically designed for the new 1/2in HDTV cameras are the optimum choice for that format. Their optical performance effectively matches the performance of 1/2in imagers that typically employ a subsampling lattice for the 1080-line production format. So far, only 1080-line cameras have been unveiled. The same lenses will match well with the full 1280 x 720 sampling lattice of the alternate 720-line system when that inevitably emerges.

Strenuous design efforts have targeted the production of lenses close in price range to the established 2/3in SDTV lenses. That is a crucial consideration for broadcast HD ENG.

Direct coupling of these 1/2in lenses with 1/2in imager-equipped cameras makes full use of the entire operational capabilities of these acquisition systems in terms of angles of view, range of focal lengths and system sensitivity. In that sense, these new lenses closely match the operational capabilities of the traditional 2/3in lenses presently popular in SDTV and HDTV broadcast newsgathering.

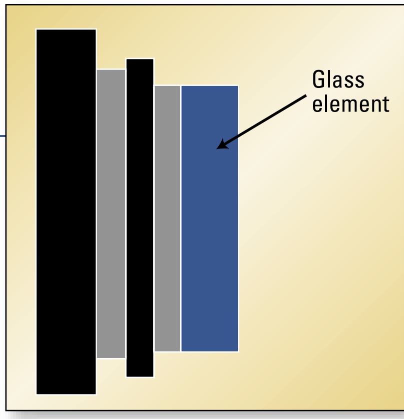

Figure 2. The LO-32MBT adapter supports the mounting of a 2/3in lens on a 1/2in camera

A 2/3in HDTV lens with adapter

For rental houses already well-stocked with 2/3in HD lenses, it is natural to question whether these lenses can be made functional with the new 1/2in cameras.

The answer is that yes, it is technically possible to couple a 2/3in lens to these new 1/2in cameras. However, there are important operational considerations that must weigh on any decision here.

The mating of the 2/3in HD lens with the standardized B4 mount to the 1/2in camera is accomplished by using a relatively simple and inexpensive adapter. (See Figure 2.) The task of the adapter is threefold:

- provide the appropriate mechanical

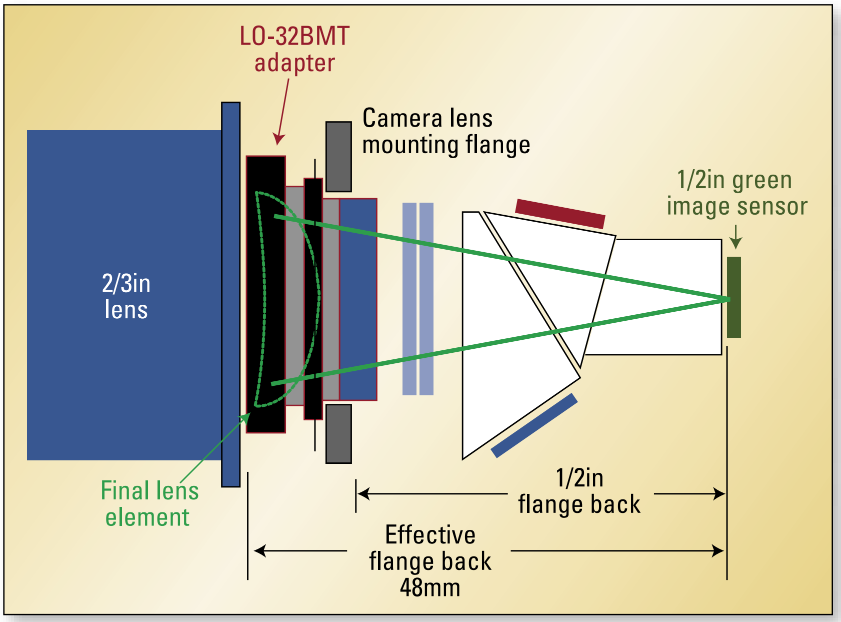

Figure 3. A simplistic illustration of the coupling of a 2/3in HD lens to the 1/2in HD camera

coupling between the larger format lens and the smaller image format camera

- restore the correct flange back distance of 48mm required by the 2/3in lens (the smaller 1/2in camera optics have a shorter distance) to ensure that its back focus control operates in accordance with its original design
- restore the effective optical path length for which the 2/3in lens was designed, in terms of the optical interface with the camera's beam-splitting block.

The deployment of the adapter is depicted in Figure 3 on page 98. (This is illustrative only and not an accurate optical tracing.)

The adapter does not make any optical adjustment to image size. Accordingly, the 2/3in HD lens projects its normal size image into the camera optical port. Only that central rectangular portion of the image that lands on the 1/2in 16:9 imagers is relevant for sampling. The camera ignores all of the remaining peripheral circular imagery.

The optical element in this adapter is simple, and its optical transmission characteristics are high. Thus, it leaves no discernible optical footprint on an HDTV optical image in terms of modulation transfer function (MTF) loss, chromatic aberrations, colorimetric alteration or contrast ratio impairment.

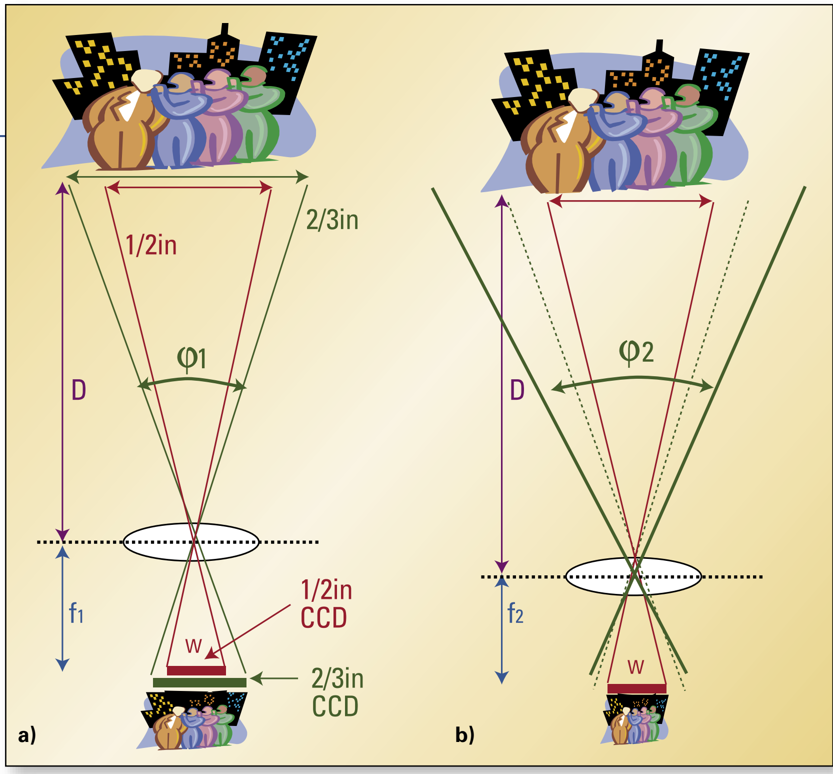

Figure 4. (a) The effective reduction in angle of view when the 2/3in lens is set for a specific image width on a 2/3in image sensor and that same image is projected on to the 1/2in CCD; (b) The lens focal length must be shortened to restructure the same size image onto the 1/2in image sensor.

Using a 2/3in HDTV lens on a 1/2in HDTV camera

While the technical optical performance can be protected, there are inevitable compromises in the operational aspects. Figure 4 simulates a 2/3in lens set to present a certain angle of view φ 1 to a 2/3in CCD. For that same lens focal length setting of f1, when that image is presented to the 1/2in CCD, it will intercept only a truncated inner section of the image. In order for the 1/2in sensor to see the same image being presented to the 2/3in CCD, the focal length of the lens must be readjusted to a shorter focal length that provides the same angle of view — namely, the new setting of φ 2. This effectively shrinks the horizontal width of the image to squarely fit the entire image content to the 1/2in imager size.

Because this is an important operational limitation that must be catered to, it is helpful to illustrate the issue with some simulated imagery. In Figure 5, that simulated imagery clearly shows that there is a quite discernible difference in the angle of view seen by the 1/2in camera sensors compared with that seen by a 2/3in camera. If the 2/3in lens is not at the end of its focal range, then a simple adjustment of the zoom control can restore the original wide angle of view to fit to the camera image sensors. (See Figure 6.) If the lens is operating close to its widest angle, then that readjustment to parity with the 2/3in angle of view will not be possible — it does not have the requisite focal range.

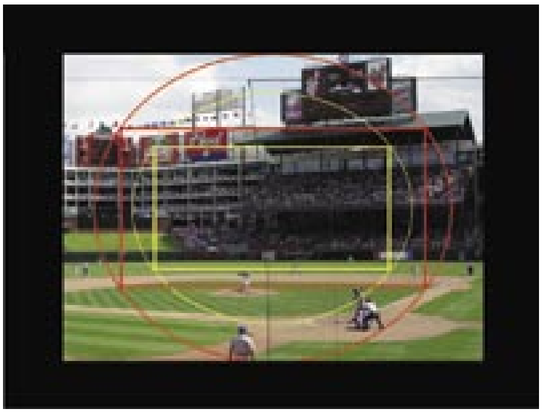

Figure 5. The red circle shows the object image from the 2/3in lens as it is projected into the camera. The portion of that larger image inside the yellow rectangle is all that is seen by the three 1/2in CCD sensors — the associated shortfall in effective angle of view is evident.

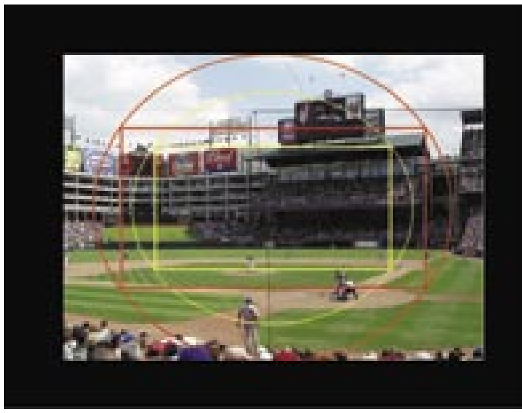

Figure 6. Recovery of the original angle of view created in the 2/3in image format by adjusting the lens zoom control to reduce the focal length.

In practice, what is the magnitude of this shortfall in angle of view? A simple calculation can quantitatively produce that answer. If the width of the image sensor (w in mm) and the focal length f (also in mm) are known, the angle of view can be readily calculated from the well-known formula:

$$\varphi = 2\ \mathrm{Tan}^{-1}\ w/2f$$

As was shown in Figure 1, the width of the 2/3in sensor is 9.59mm and that of the 1/2in sensor is 6.67mm. Using this information and considering two portable 2/3in HD lenses (a wide angle 4.7mm lens and a telephoto to 158mm lens), it is simple to calculate the percentage change in angle of view from the 2/3in lens image to that applied to the 1/2in sensor — at both extremities of the focal range of each lens. (See Table 1.) The effect is not linear over the focal range of the lenses.

	Max wide angle	Max telephoto
HJ11ex4.7	4.7mm	52mm
2/3in camera	91.14°	10.54°
1/2in camera	73.14°	7.66°
Percent change	*19.7%*	*27.3%*
HJ22ex7.6	7.6mm	168mm
2/3in camera	64.5°	3.28°
1/2in camera	49.26°	2.38°
Percent change	*23.6%*	*27.4%*

Table 1. The percentage change in angle of view from the 2/3in lens image to the 1/2in lens image

Employment of a 2/3in SDTV lens with adapter

It is perfectly understandable that end users already in possession of a quantity of SD 2/3in lenses from the earlier SDTV ENG era — users who may now be contemplating a transition to HDTV ENG based on a 1/2in camcorder — might seek to ameliorate their capital investment by using those older SDTV lenses (via the same adapter described earlier). The argument is sometimes presented that a high-quality SDTV lens coupled to an HDTV camera — one that sports a subsampled HD imager — should actually manifest a reasonable technical imaging compatibility. Regrettably, this is not the case.

The optical bandwidth required for 1080-line HDTV is substantially greater than that for SDTV. It is 2.7 times that for SDTV (82 line-pairs per millimeter versus 31 line-pairs per millimeter). The very essence of what constitutes high definition lies in the additional spatial information contained within that frequency region beyond the 31Lp/mm boundary of the SDTV system. And, this is where the problems lie.

In an earlier article in this series on HDTV lens design, "Management of MTF" in March 2005, it was shown that the behavior of the MTF of an SDTV lens over those spatial frequencies beyond the SDTV passband are much less well controlled than in an HDTV lens. The behavior of the MTF of a typical SDTV lens (measured at a spot spatial frequency of 56Lp/mm, which lies halfway between the 31Lp/mm boundary of the SDTV system and the 82Lp/mm boundary of the HDTV system) is unruly. (See Figure 7.)

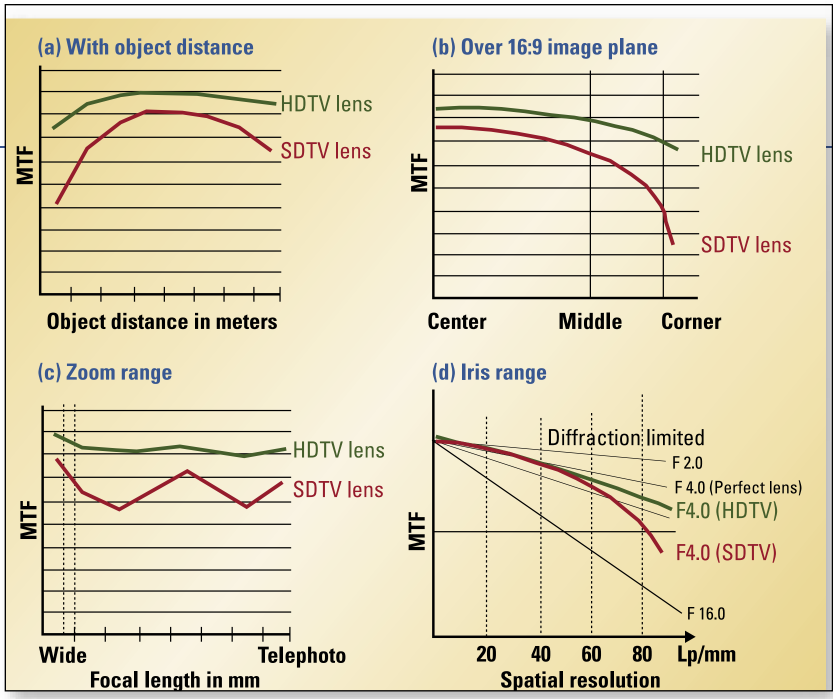

Figure 7. The variations in MTF of generic HDTV and SDTV lenses — measured at a spot spatial frequency of 56Lp/mm — across the image plane (b) and when the operational controls of focus (a) and zoom (c) are manipulated. The relative behavior of MTF with iris setting is indicated by (d).

These vagaries in optical MTF behavior apply to both the horizontal and the vertical domains. The consequences will be highly dependent upon scene content and are difficult to predict. But, they will mar the image sharpness of the acquisition system. For the record, an even worse technical choice would be deployment of older pro-video 1/2in SDTV lenses on these new camcorders.

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