Are your lenses good enough for that 4k high definition camera?

By Guy Genin

Lens resolution versus video camera resolution:

Motion picture lenses in good working order produced in the last 30 years can still easily resolve 100 line pairs with excellent contrast in white light at the center and 50 line pairs at the picture width. (That is at the edge of the frame on the right side or the left side). Most of those lenses have better than double that resolution but at a somewhat lower contrast mostly at the edges. There have been a lot of improvements during the last 3 decades that have allowed the creation of faster lenses with better contrast and a tighter control of the aberrations. But the main difference has been in the frame size covered. 30 years ago the sound was recorded on the film beside the image so the maximum frame size used was the Academy format (22mm h x 16mm v or a diagonal of 27.2mm). For cost reason most of the lenses of that era were limited to that coverage. When the sound could be recorded separately, thanks to the progress made with the electronic synchronization of the equipment, the image could again occupy the full size of the negative between the perforations. All modern motion picture lenses are now designed to cover 24mm h. x 18mm v. or a diagonal of 30mm, they routinely resolve more than 200 line pairs per millimeter in most of the image field. Any video camera with an active sensor area bigger than 27mm diagonal will have to use the more modern lenses for full coverage.

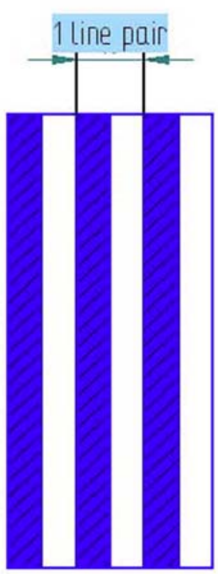
One example of a high resolution video camera has 4k delivery at 4096 h. x 2304 v. pixels in a 16:9 aspect ratio. The sensor is said to be 24.4mm h. x 13.7mm v. and has 4520 h x 2540 v photo-sites. The diagonal is 27.98mm.

How many photo-sites are needed to properly resolve a line pair?

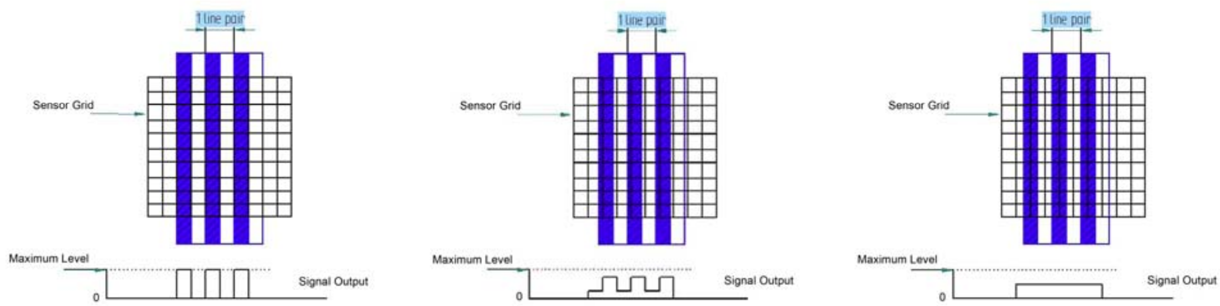
Let's ignore the fact that in front the sensor there are several filters for the color rendition and to control some artifacts due to the stationary nature of the sensor grid as those can only reduce the maximum possible resolution.

So for this discussion, let's assume each photo-site participates equally and receives the same amount of light when fully illuminated.

The blue lines represent illuminated segments.

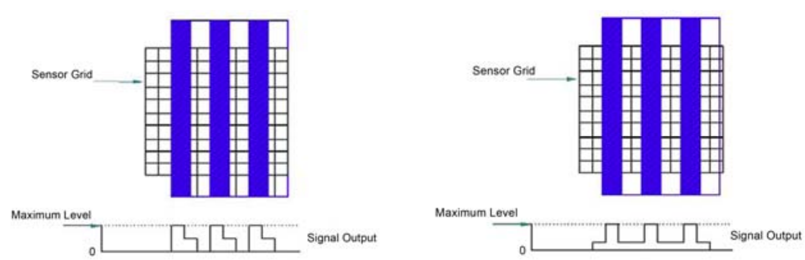


If the subject was aligned with the grid pattern of the sensor one photo-site per line would be enough.



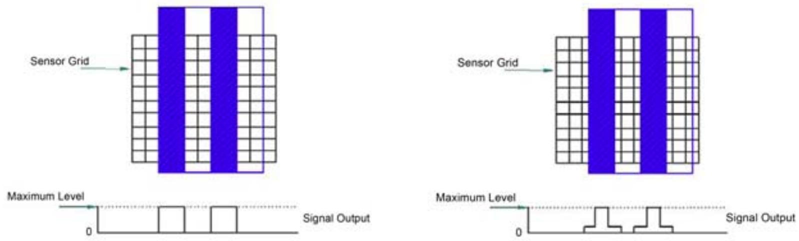
But as it gradually shifts from alignment, the signal deteriorates to the point of not showing any detail. This is an illustration of the Nyquist theorem that in essence states that at a given frequency a signal (in this case a repeating pattern of line pairs) needs more than two samples per cycle to be properly represented.

Increasing the number of samples improves the image representation. But even with 3 photo-sites for each line pair, the signal is still distorted or the amplitude is reduced.



The distorted signal results in jagged edges very noticeable when the lines are at a slight angle with the sensor grid (effect that is called aliasing) and the reduced amplitude is a reduction in contrast that negatively affects the resolution perception.

Only with 4 photo sites for each line pair can we see the full amplitude regardless of the relative position of the sensor grid.



The signal can still have a significant amount of distortion (aliasing) but the white is at full level and the black reaches the 0 level.

The allocation of 4 photo-sites per line pair results in a maximum of 1130 line pairs across the 24.4mm of the sensor, or 46 line pairs per millimeter. Let’s not forget we are talking about an ideal situation where each photo site participates equally to the encoding of the image (as it would be in a monochrome camera) and the image has an unobstructed path to the sensor. This resolution is already below what is achieved by even an older lens in good working order.

Now so far we have ignored the fact that in an attempt at limiting the aliasing artifacts of the stationary grid pattern of the sensor the image is intentionally blurred inside the camera by the presence of a filter placed in front of the sensor. Further more for color rendition, the Bayer pattern can reduce the resolution by a factor of 20 to 50% depending on the processing.

Taking a conservative resolution reduction of 24% for all the filtration, the best a 4k high resolution camera would be capable of seeing are nearly 35 line pairs per millimeters before electronic processing. This limit is determined solely by the video camera at the sensor level as it generates a RAW signal. As stated above, motion picture lenses easily exceed theses values by a good margin and modern lenses have the capacity to resolve more than 5 times this requirement.

If you think your 4k video images do not look as good as they should, by all means have your lens checked but realize the camera is still by far the primary limitation for maximum resolution.

ZGC tech desk
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