# HD RGB and 2K data

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***Thoughts on resolution, color space and bit depth.***

This paper draws together previous papers addressing HD RGB, HSDL 2K data transport streams and the use of aspect ratios in film and television production particularly in regard to High Definition production.
We have now had an extended period of using HD video and 2K data in both video and film production and so have the benefit of experience to apply to the discussion of how much is enough when discussing resolution for film capture, scanning and Digital Intermediate (DI) processes.

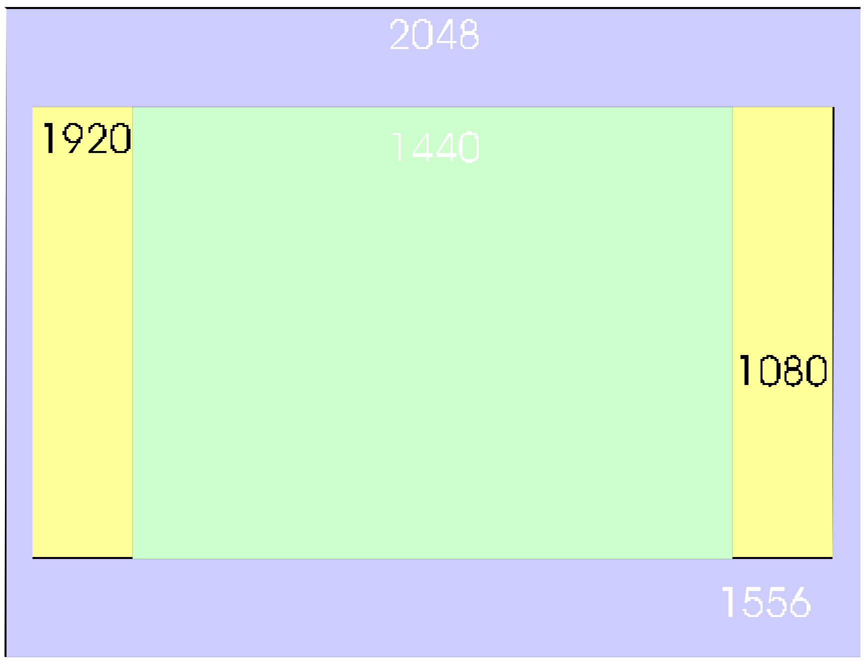
2K data has become the common format for the scanning and use of film images in digital intermediate post workflow. 2K data is commonly a scan of a super 35mm negative sprocket to sprocket, frame line to frame line, full width of the film retaining the 4 x 3 aspect ratio of the image which has been shot with spherical lenses (straight rather than anamorphic).

The scanned resolution is 2048 x 1556 at 10 bit RGB, usually into a dpx or cineon computer file. These scanned film images are then used for various intermediate functions such as visual effects, opticals and eventually conforming of the offline edit and then color timing prior to film out. It is generally accepted that 2K 10 bit RGB materials are good enough for the feature film process and many if not most features are being digitally conformed and color corrected instead of a physical negative cut and optical color timing.

HD common picture format at 1920 x 1080 has quickly become the standard for many television and lower budget film projects. However, HD RGB has also become acceptable for 2K for post production and DI. Many producers and directors have expressed the wish to be able to acquire images digitally and HD and HD RGB cameras have started to fulfill this function.

Resolution

The main justification given for 2K scans are resolution for the given aspect ratio. This is shown figure 1 where we can clearly see that 2K data has a resolution advantage of 50% in the vertical domain, 30 % in the horizontal when HD is used for a 4 x 3 aspect ratio but only a slight advantage when the full 1920 pixels are used ( representing less than a 5% advantage ). When film is scanned it is generally scanned edge to edge including frame lines and even sprocket holes for Super 35mm scans. Resolution is most key in the horizontal where most of our efforts technically has been focused over the years. Figure 1 shows the relative sizes of 2K scan against HD 16 x 9 and HD 4 x 3.




Relative resolution at native aspect ratio

Figure 1.

The aspect ratios that are in general use in film making today are either 1.85:1 or 2.37:1 (mean of 2.35 and 2.40). The main use of a 2K scan therefore is to allow film makers to perhaps be able to tilt inside the 4 x 3 aspect before making their choice of framing.

This is not normally required however as the film aspect was framed in the camera which generally represents an extraction directly from the center. This is protected with markers in the film camera viewfinder along with the video assist monitors being set to the required size and the rest blanked off, and tilt is not often used against a center extraction.
So the resolution advantage of 2K data instead of being greater than 50 % at 4 x 3 becomes nearer 50 lines rather than 500. The native image format for HD is a 16 x 9 aspect which represents a 1.77:1 aspect (the same as 3 perf. 35mm and Super 16mm ).

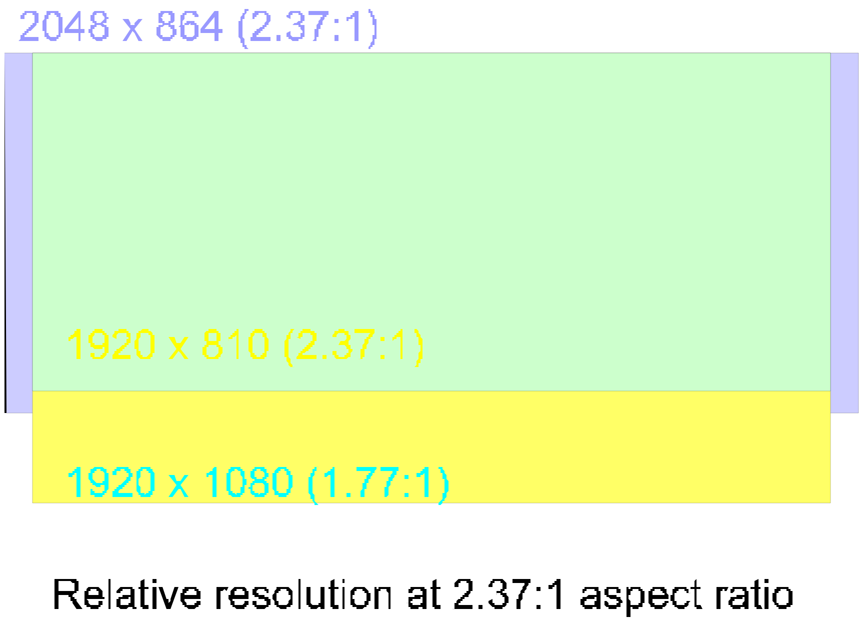



Figure 2.

Figure 2 shows a 2K data scan at 2.37:1 which has a base resolution of 2048 pixels x 864 lines. The HD frame at the same aspect ratio is 1920 x 810, this is a substantially smaller difference than that shown at 4 x 3 in both directions. The normal HD frame is 1920 x 1080 and therefore has greater resolution than the 2.35:1 frames.

The obvious thing to do is to fit the 2.37:1 aspect into the full frame HD format. This is easily achieved by using anamorphic techniques. In order to circumvent the identified issues that arise with optical methods we can do the anamorphic squeeze digitally by manipulation of the pixel shape. HD has square pixels. By stretching the pixels we are able to fit the 2.37 into HD common picture format giving us a slight squeeze but full 1080 resolution. Digital anamorphic uses spherical glass lenses so there are not the issues normally associated with shooting film with anamorphic lenses such as edge and corner distortion with cross field differential shading.

This technique has been adopted by Thomson Grass Valley for the Viper FilmStream camera with Dynamic Pixel Management (DPM) so that it has an inherent resolution advantage over normal HD video cameras of nearly 300 lines at 2.37:1. Effective resolution of 2k is 1848 x 1536 when frame bars and edges are taken into consideration. So a straight extraction of 2:37:1 aspect ratio gives a resolution of 1848 x 780. If we use the HD anamorphic provided with Viper DPM there is a resolution advantage over spherical 2K 2.35:1 extraction of 300 lines in the horizontal and nearly 80 pixels in the vertical.

Color space and bit depth

Color for film is essentially RGB in nature. Film has chemical layers for each primary color sensitive to red, green and blue. Computers are also natively full color bandwidth using red green and blue as are most monitoring systems. Television adopted a technique of sub sampling the color from RGB to an intermediate step on the way to encoding color into a composite signal required for transmission over the air. This technique is known as color difference and is derived from using the green channel to generate a luminance signal where color is then seen as a difference between the luminance and the red and blue signals. This is often referred to as YUV but there are many technical versions that can fall under this, YIQ (NTSC color component), Y, r-y, b-y (625 betacam), Y, pr, pb (HD analog component), Y, cr, cb (SD digital) and so on.

Generally together they are known as component video which is used in many recording techniques and is the basis of digital television. The digital expression is 4:2:2 where 4 is luminance, and the two '2' 's are the color difference. If we digitize equal color channels the expression is 4:4:4 where each '4' is a color, GBR. Having equal color allows us to move images around the computer applications and provides a path back to film. RGB is also necessary for many visual effects applications such as keying and matting. For digital cinematography RGB is a prime requirement.

Another overriding issue is bit depth. This translates into the number of steps we use when sampling the analog picture (all pictures are analog, all capture devices are also analog – digital systems digitize the outputs of the sensors as soon as possible, this is true of CCD, CMOS and PEC technologies), the more steps there are the better the fidelity of the digital picture.

Originally we used 8 bit sampling which gives us a range of 0 to 255, where 0 should be black and 255 is peak white. 10 bit sampling is 0 to 1023. 8 bit images were soon found to be very limited for effects use as there were not enough steps to define edges well. Edge definition is very important in a 2 dimensional media as it is the only thing that makes one object different from another. The more detail we use to describe the image, the easier it is to determine differences between one thing and another. Television cannot use the full range due to the nature of video technologies so a range is picked within these numbers reducing video sampling further. It could be said that the difference between video recorders and data capable recorders may be defined by their ability to record full range images.

Recording Formats – HD

If we compare recording techniques the resolution, color space and bit depth issues become very important. If we look at the most common HD recording format, HDCAM, which is the normal HD acquisition format, we find that it is heavily compressed. It actually records a bit rate of less than 140Mbits per second (the very same rate as Digital Betacam) from an original 1.485Gbits per second. In order to achieve this compression ratio, HDCAM uses some remarkable techniques, the first thing it does is to sub-sample the picture from 1920 pixels across to 1440 pixels, a one quarter reduction in resolution. It then sub-samples the color from a 4:2:2 YUV to a 3:1:1 color providing a one quarter resolution luminance signal and cutting color information by half. It then sub-samples the bit rate from full 10 bit to only 8 bits, this means that the 10 bit quantizing steps which are 0 – 1023 in range are reduced to 0 – 255 in range. This is a logarithmic bit rate reduction.

After this the result is compressed at roughly 7:1 using M-JPEG techniques which are not symmetrical and are lossy in themselves. The intra frame compression means that it not only does block to block compression within the field, it also compresses across fields. As it cannot record true progressive images the intra frame compression acts on what was left of edge and moving color information to soften it still further. What is remarkable is not what it does to the images but that there is anything left to work with at all.

One of the newest video format is the compressed HDCAM-SR. This is an advance on HDCAM as it has a much higher bit rate of 440Mbits. It can also record 4:4:4 color space and 10 bits. However, it is a video recorder and cannot record full range data so it affects the color when using full range image sensor devices. The portable unit can record double rate (by doubling the number of heads) to 880mbits but this is more for dual 4:2:2 recording and does not really help with 4:4:4.

Any video based system is raw recording in its own closed environment so requiring additional steps to process or ingest into a visual effects or editing image application.

When we make 2K images from a film via telecine or film scanners they are typically recorded as uncompressed DPX frames at 12 or 14 bits linear or 12 to 14 bit to 10 bit log files. These images are native computer files and can be used immediately by imaging applications. They have a problem being played back at full resolution in real time.

When we record from HD RGB cameras using S.two DFR D.MAG system Digital Film Magazines we are also recording uncompressed 10 bit log DPX frames making maximum use of HD, RGB and 2K images that can be used in any computer environment and application without further processing. These images are recorded as computer native image files that can be used by applications immediately and can be played in real time at full resolution or as video pictures anywhere.

Conclusions

Native HD RGB uncompressed recording at 1920 x 1080 using 10 bit log and digital anamorphic techniques provides as much and in many cases more resolution, more color and greater fidelity than film transfer to video and always more than any video tape system currently available.

Video centric television cameras and recorders designed primarily for broadcast and news applications are not suitable for digital cinematography production.
The uncompressed S.two DFR digital field recorder provides the technology that affordably brings native DPX file format recording techniques to location and studio digital capture with a variety of video and digital cinematography cameras.