EBU - Tech 3335 : Methods of measuring the imaging performance of television cameras for the purposes of characterisation and setting

Alan Roberts, January 2015

SUPPLEMENT 16: Assessment of resolution and noise in a RED Epic Dragon camera

Tests have been conducted in line with EBU R.118. This document is a report of the results of the tests defined in Tech3335 and is not an endorsement of the product.

This is a report on tests carried out on a RED Epic Dragon camera. It is not a normal complete report because of the nature of the camera.

The sensor is a single large-format CMOS with the Bayer pattern of photo-sites (6144x3160, 30.7x15.8mm). It's size is between 35mm movie and 35mm stills format. However, not all of the sensor is used in most formats, only the central part is extracted. Thus lens choice can be confusing, since the magnification changes with format size.

The tested lens mount was PL for film-style shooting, a central part is used for each shooting format so that the effective magnification of the lens depends on the shooting format. This implies that the Bayer-pattern decoding is the same for each format and the same performance can be expected, scaled to the format size. Other lens types can be used via adaptors.

The specification claims dynamic range of at least 16 stops and noise levels at -80dB, but does not describe the conditions for noise measurement. The camera shoots at all the usual television frame rates, 23.976 to 59.94 in RAW format, and can run at maximum speeds of 100fps (6k mode) or 300fps (HD/2k). Using REDCINE-X Pro software, many other formats are possible. Monitoring is HDSDI, whatever the camera shooting mode, thus there is no direct way of viewing images without standards-conversion unless the camera is shooting in 1920x1080 HD. It can also shoot in compressed REDCODE.

It is quite small and light, only 5lbs, needs a separate viewfinder. The body has many mounting screw-holes for the fitting of extras. Control is via buttons on the viewfinder (there is a choice of several) with only On/Off, Record Start/Stop and two User Buttons on the camera body.

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Initial tests were made with a zoom lens, later with a 135mm prime lens.

Menu contents are not reported here, since most of the camera control is done in software after acquistion.

The aim of the tests was to establish which resolution setting, if any, is acceptable for nominal 4k shooting, to deliver pictures with pixel dimensions 3840x2160. To accomplish this, the camera was set to several shooting modes and a standard HDTV test card was framed to fit exactly half the horizontal and vertical image dimensions, thus simulating the condition in which camera footage is scaled to 3840x2160 after shooting.

Recordings were made onto CFast card in the camera, and then exported to 16-bit TIF files using REDCINE-X Pro software. Still frames were exported from this for analysis. The software automatically rescales the video footage to sRGB coding, either 12- or 16-bit, 16-bit was chosen in order to reduce the possible effects of the conversion and to preserve the maximum low-level detail in the pictures.

1. Resolution for 4K

Tests were made at about T4 using a short-range zoom lens.

Three resolutions were tested '4k', '5k' and '6k'. Two Bayer-pattern decoders were available in the camera, both were tested. In each case, only one quadrant of the luma test pattern is used, together with a quadrant of the smaller double-frequency pattern.

4k mode (Fig.1, 3840x2160)

There is little image-content resolution above about 2450x1380, with unacceptable coloured aliasing at higher frequencies. Aliasing is also present in the smaller double-frequency pattern, centred at 7680 (horizontal) and 4320 (vertical). This shows that the optical low-pass filter is not eliminating these unwanted higher frequencies. This performance is very like that from a single 1920x1080 sensor for conventional HD, for all the same reasons. The 'Dragon' decoding is slightly better in that it appears to deliver a little more resolution, but the level of aliasing is also higher, so there is no net gain. This mode is not acceptable for 4k shooting.

5K mode (Fig.2, 4800x2700)

This is a little better, but not much. The image-content resolution limits are about 2930x1650 with the same level of coloured aliases above those limits, but centred on higher frequencies. Again, the Dragon decoder delivers a little more resolution and aliasing.

6K mode (Fig.3, 5568x3132)

This is a little better still. The image-content resolution limits are now about 3400x1900. The level of aliasing appears to be lower, because the optical low-pass filter and lens are not passing so much of the unwanted frequencies to the sensor. This mode is acceptable for 4K shooting, in the same way that shooting on a 2880x1620 sensor is good enough for conventional HDTV. However, the zoom lens did not fully cover the sensor, resulting in significant vignetting at wide angles, clearly the sensor is rather larger than ideal for the design of the lenses.

Although not specifically tested, it is safe to say that the 6k mode is also the best way to get HD footage, since aliasing is at its lowest. Certainly, the 2k mode will not be good enough.

Figure 1 4k mode (3840x2160) a) normal decoding b) Dragon decoding

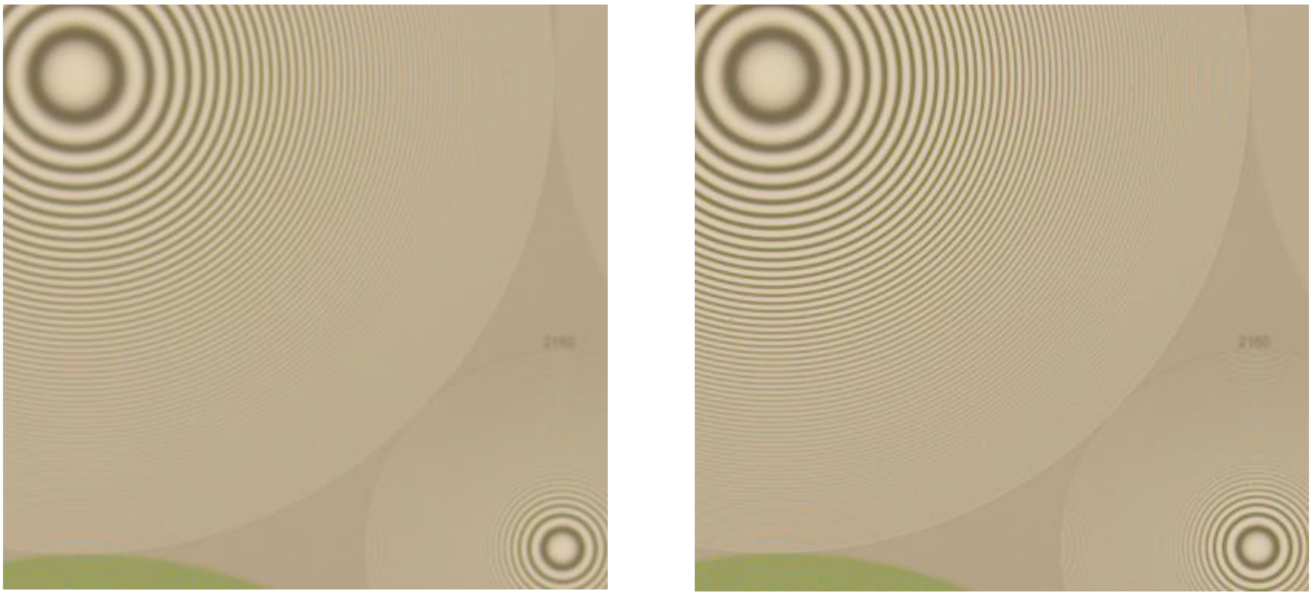

Figure 2 5k mode (4800x2700) a) normal decoding b) Dragon decoding

2. Dynamic range and noise

Dynamic range is defined by the extremes of the coding range. At high exposure, the highest signal level should be not quite going into clipping, while at low exposure the lowest signal should be just distinguishable from other parts of the picture, i.e. not crushing. Noise affects this range dramatically, since high noise at low signal levels can obliterate any detail in the picture at those levels.

When noise levels are high, measurement is easy, but at low levels it can be quite tricky since my normal process runs out of accuracy at about -62dB. Since this camera is claimed to have noise levels approaching -80dB, I expected problems. Nevertheless, I made exposures of test signals, and have found a way to proceed.

Recordings were made of a normal Colorchecker test card, using a prime lens (135mm). The zoom could not be used because of pronounced vignetting, resulting in a highly curved field (i.e. the centre of the picture is significantly brighter than the edges/corners).

The iris was used to control exposure, plus the shutter. Starting at T/2 360° and ending at T/22 1.4°, which represents a range of 15 stops. The grey-scale on the chart has a reflectance ratio of 90.01%:3.13% for the white and black patches, or 28.76:1 about 4.84 stops. Thus the total exposure range explored was 19.84 stops.

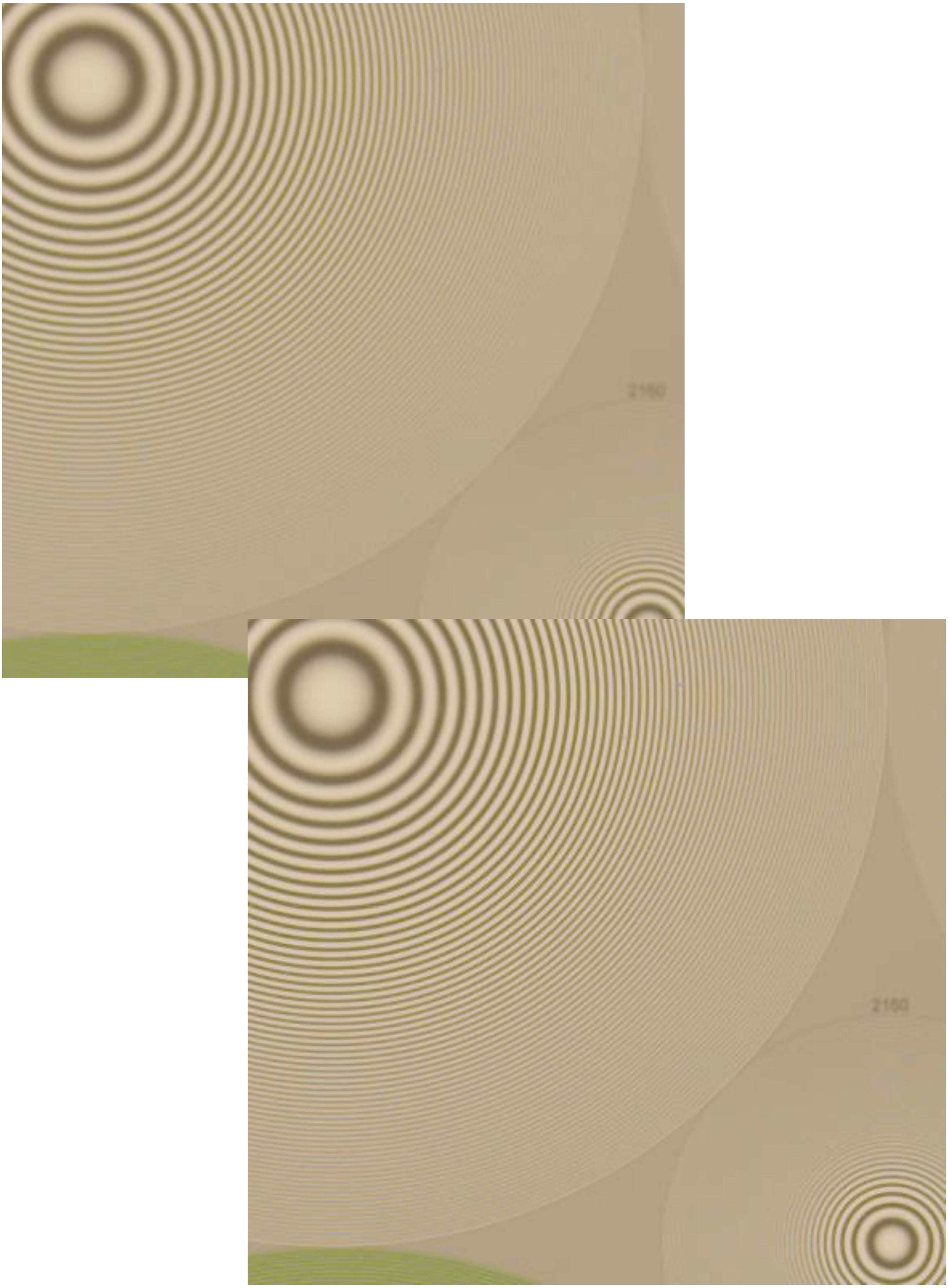

Figure 3 6k (5568x3132) a) normal decoding b) Dragon decoding

My normal noise analysis system is based on direct measurements on BMP files, using BBC BASIC for Windows, which can deal only with 8-bit files, and only up to 2048 pixels wide. However, the images exported from REDCINE-X Pro can be 16-bit TIF files at higher resolution. Therefore some pre-processing was necessary. For the higher exposures, 8-bit BMPs were generated then cropped to just four of the grey-scale patches. For the lower exposures, the contrast was increased by 2, 4 or 8 before cropping and saving.

Fig.4a is a log/log plot of the grey-scale exposures. The range over which there is significant slope appears to be at least 10,000:1 (around 13.5 stops), however, this plot conceals details near black and white. Fig. 4b is an expanded plot of data values near black, plotted linearly. Clearly the signal value is still changing below an exposure value of 0.001 (T/22 with 2.8° shutter). The exposure values are the reflectances of the grey-scale patches (percentage) muptiplied by a factor derived from the iris and shutter settings, they are not related directly to any standard illumination level.

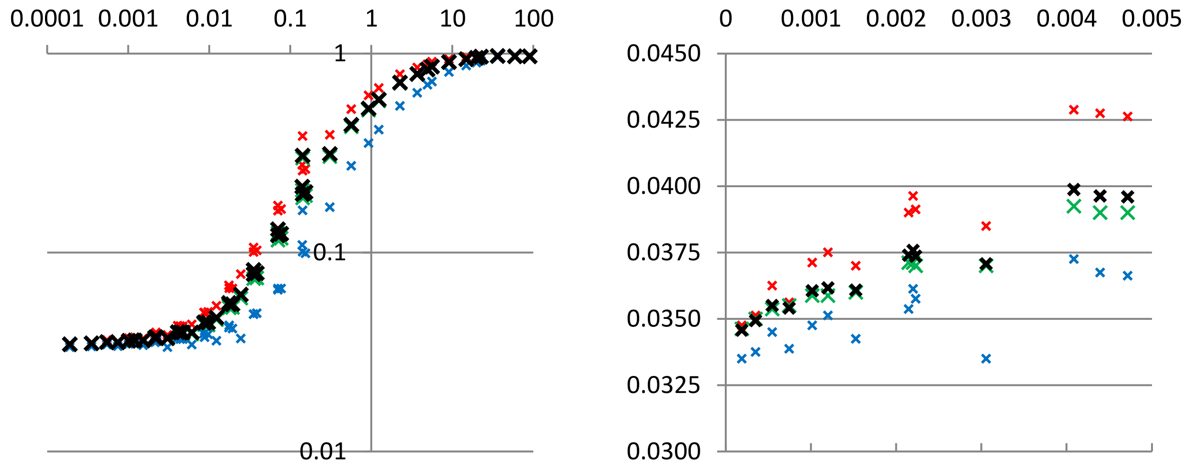

Figure 4 Grey scale exposure a) log/log **b) lin/lin near black**

Fig. 5 is an expanded plot near white, which shows that signal values do not change significantly above an exposure value of about 35. Thus the exposure range within which different exposure levels are separable is about 35,000:1, around 15.15 stops. Whether this rage is all useful depends on the noise levels.

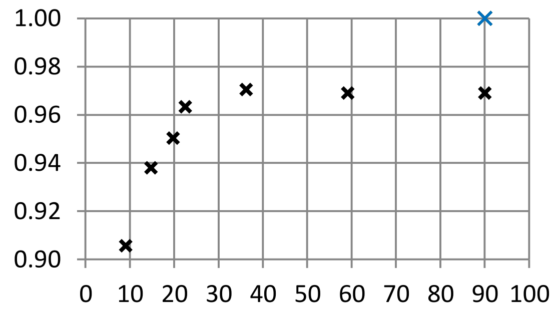

Figure 5 Grey scale exposure lin/lin at white

Fig. 6 shows the noise levels in the RGB channels, and the calculated noise in luma. In a conventional camera, the noise level would increase towards black, following the slope of the non-linear, gamma-correction curve. In this case, the droop near white is expected since the photo-sites are too big for photon noise ('shot noise') to dominate, but the fall near black is unusual, although not unexpected. This type of curve is increasingly found in large-format single-sensor cameras. Most of these appear to use either multiple-reading of the sensor or some other trick to increase the exposure range by reducing the noise near black. Also, electronic noise-reduction can produce similar effects in smaller cameras.

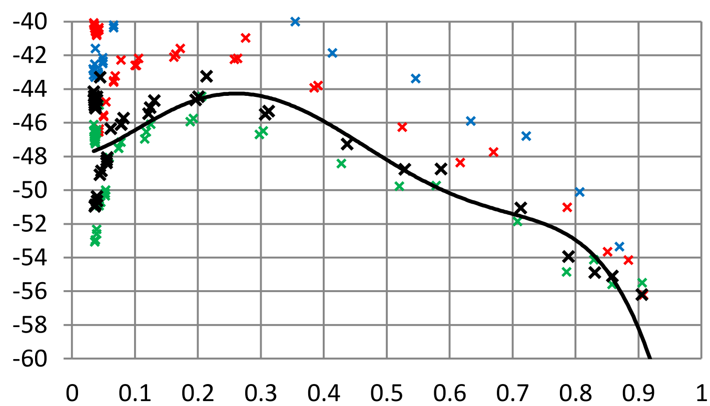

Figure 6 Noise distribution

The noise at mid-grey is normally expected to be representative of the noise level when the electro-optical transfer curve is switched off, but that cannot be true in this case since the noise profile does not follow the slope of the effective gamma-correction curve. However, the noise at 50% is -48dB, which qualifies the camera for high-end production according to the recommendations in EBU R.118.

Since the noise levels near black are considerably lower than at mid-grey (although much harder to measure accurately), it would appear that the full exposure range is useable. All the analysis uses exposures from T/2 360° to T/22 2.8°, a range of 14 stops.

Fig.7 show the full Colorchecker chart exposed at T/22 and 1.4° shutter, and then lifted by 3 stops. The noise levels are therefore 18.09dB higher than reported in Fig.6, i.e. about -32dB near black. Also, it is very difficult to discriminate the adjacent patches of the grey scale, implying that this level of exposure is beyond the useful range. Therefore 15 stops should be regarded as the extreme limit, 14 stops or less delivering useful pictures.

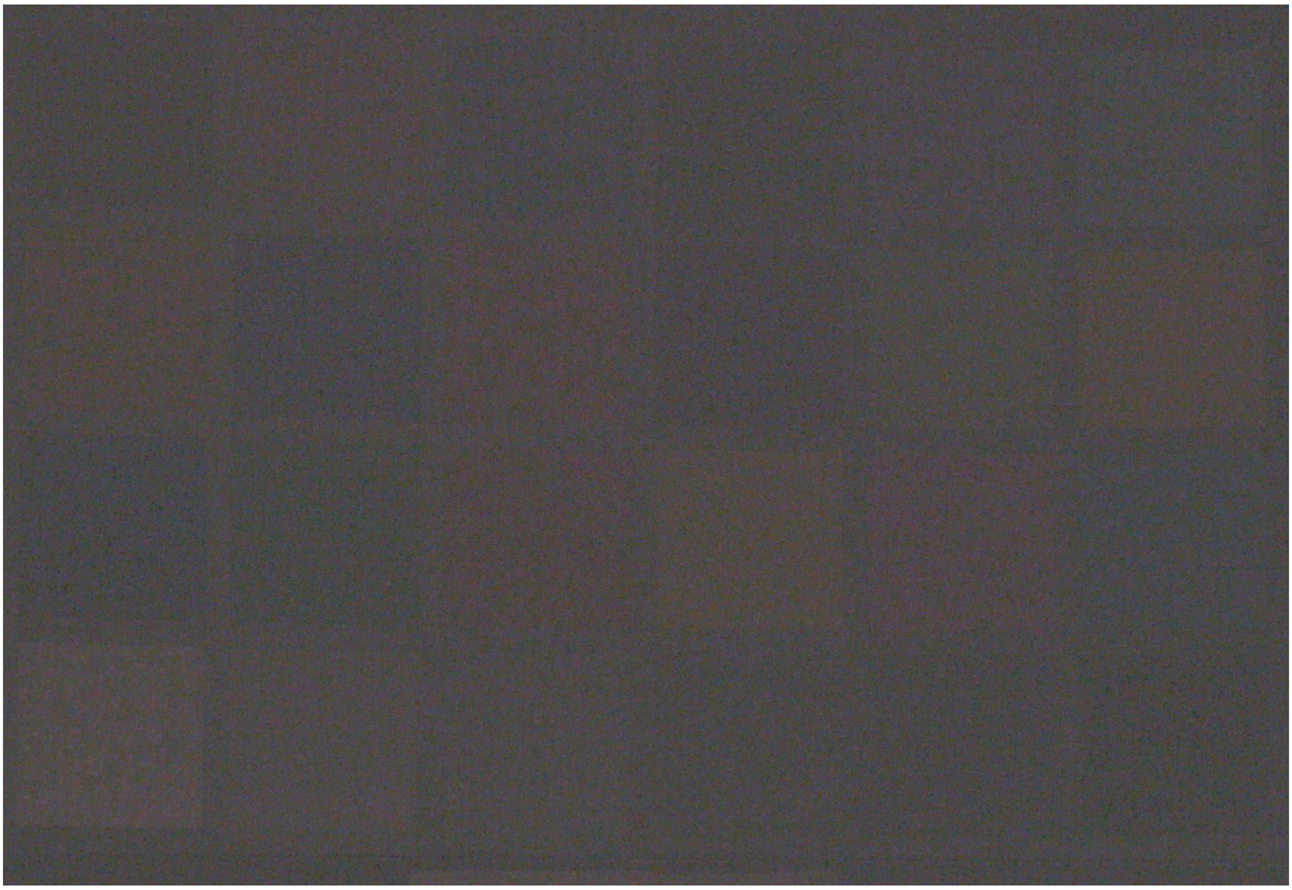

Figure 1 Colorchecker exposed at T/22, 1.4°

Also, the picture is much softer than at high exposure levels.

3. Conclusion

The RED Epic Dragon camera is well suited for programme-acquisition for EBU R.118 Tier 2 UHD provided the 6k shooting mode is used. 5k mode is probably also acceptable for Tier 2. The image-content resolution at 6k is almost good enough for Tier 1, but cannot fully achieve that status with this sensor.

The dynamic range is about 15 stops, although the lowest part of the range is only marginally useful.