# EBU – Tech 3335 : **Methods of measuring the imaging performance of television cameras for the purposes of characterising and setting**

Alan Roberts, November 2012

## SUPPLEMENT 007 : Assessment of a JVC GY-HM600 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.**

Initial tests were made on a protoype model of the JVC HM600 HDTV camcorder (serial number 40006) and subsequently on another (beta version, serial number 147M008).

The camera has an integral lens (Fuji, F/1.6, 23:1 4.1~94.3mm) and records onto two solid-state storage SDHC cards. The lens has conventional 3-ring control, with manual or automatic operation, but the rings are all servo-driven and only the zoom ring has proper markings. It has a set of neutral density filters for exposure control. The sensors are 3 ⅓" CMOS of 1920x1080 photo-sites, but the specification makes no statement about pixel dimensions. Recording HDTV uses MPEG2 4:2:0 in Quick Time or MP4 format. HQ mode records at 35Mb/s VBR, 1920x1080, 1440x1080 and 1280x720 at all the usual frame rates from 23.98 to 59.94. SP mode records at 18.3M/s, 1440x1080 or 1268x720. It also records in AVCHD (H.264): HQ mode is 24Mb/s max at 1920x1080, SP mode is 17Mb/s at 1920x1080. Only the MPEG2 HQ mode was used for the tests. All recording is 8-bit.

It can also record in standard SDTV modes, Quick Time format, AVC (MPEG4) at 8Mb/s.

Recording can be set to change between cards when one is full, or to record two identical cards as a backup, or simultaneously at different resolutions.

The camera is quite light (about 2.4kg in including battery) which is typical for a camera of this type. It has an integral monocular viewfinder (852x480) and top-handle mounted screen (4⅓" LCD, 800x480), and seems aimed at the mid- to high-end professional markets. It has time-code input and output and a remote control socket, so may well be usable in multi-camera shoots. Power consumption is about 10 watts at nominal 12 volts. The battery lasts about 160 minutes continuous use and takes around 4 hours to charge, in the camera.

Variable speed recording is possible, from 2 frames/second up to the nominal frame rate setting (24/25/30 when recording 1080-line, 24/25/30/50/60 when recording 720-line).

There are internal menus for setting the performance, not as complex as in a full broadcast camera, but enough to control many of the important features. There are analogue-only video outputs (SD-composite via a multi-pin connector for monitoring) and digits via USB-2 for data file transfer, HDMI and HDSDI with 8-bit content. It has a built-in microphone and XLRs for external inputs.

The same assessment procedure was used as for other HD cameras, partly attempting to get a good "film-look", and the settings reflect that. In the search for a "film-look" setting it is normal to think of the camera to be mimicking a film camera and telecine, with "best light" transfer to tape, with about 11 stops of tonal range. Assuming that a grading operation will be used in post-production, the settings attempt to give the colourist the same range of options as with film, achieving about 8.6- to 8.9-stop dynamic range. The recommended settings allow about 0.7 stops of over-exposure relative to normal operation. This is not unusual for a small camera with ⅓" sensors, but the camera has the unusual feature of selectable sensitivity, which allows for a trade-off between sensitivity and noise levels.

The 720p mode is very clean, as is the SD mode, it is unusual to be able to say this of any camcorder.

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Many of the menu items have little or no effect on image quality. Those that have significant effect are highlighted. The full set of menu items is given for completeness. Bear in mind that these tests were on prototype cameras, and that the actual menu contents differed slightly between the cameras and from the manual, therefore the released cameras may have slightly different menus as well. In boxes with a range of numeric settings, the values indicate the range, and no scales are given. Default settings, where known, are underlined. My recommendations are in the last column, labelled "Pref", where appropriate. Settings are given for:

v Television production
f Film-look television

In the tables, items that have an important effect on picture appearance are highlighted with grey background. Rather than just making assertions about performance, I have included measurement results that illustrate the reasons for the recommended settings.

This is not intended as a replacement for reading the manual. Note that since the second camera tested had slightly different menu items, the tables below show the items in that camera rather than those in the manual.

### 1. Switches and Menu settings

**SWITCHES, SOCKETS and BUTTONS**

| name | place | feature | comment |
|---|---|---|---|
| Zoom speed | Handle | Switch | |
| Rec start/stop | Under lens front | Push | |
| Zoom servo/manual | Under lens front | Switch | |
| Headphones | Back right | 3.5mm socket | |
| Aux input | Back right | 3.5mm socket | |
| Rec start/stop | Back right | Push | |
| C.Review | Right grip | Push | User 7 |
| Zoom | Right grip | Lever | |
| TC I/O | Right grip front | Phono socket | |
| TC I/O | Right grip front | Switch | |
| Input 1/2 | Top front | XLR x 2 | |
| Rec/hold | Top front | Push/Switch | |
| Zoom | Top front | Lever | |
| Focus auto/manual | Left | Switch | |
| ND filter | Left | Lever | |
| Push auto (focus) | Left | Push | |
| Iris auto/manual | Left | Push | |
| Iris auto | Left | Push | |
| Gain | Left | Switch | |
| Wht bal auto/manual | Left | Push | |
| Shutter | Left | Push | |
| One Push auto white bal | Left | Push | |
| Full auto | Left | Switch | |
| AE lock | Left | Push | User 4 |
| Zebra | Left | Push | User 5 |
| Marker | Left | Push | User 6 |
| Mode | Left | Push | Camera/Playback |
| Power | Left | Switch | |



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| | | | |
|---|---|---|---|
| Up/Down/Left/Right | Left | Push | Navigation<br>When in shooting mode:<br>Centre=shutter on/off<br>Up/Down=shutter speed<br>Left/Right=AE level |
| LoLux | Left | Push | User 3 |
| OIS | Left | Push | User 2 |
| Focus assist | Left | Push | User 1 |
| Menu/Thumb | Left | Push | |
| Cancel | Left | Push | |
| USB | Back right | Socket | |
| AV Out | Back right | 3.5mm Socket | |
| HDMI | Back right | Socket | |
| Remote | Back right | 2.5mm socket | |
| HDSDI/SDI | Back right | BNC | |
| DC input | Back right | Socket | |
| Menu/Thumb | LCD | Push | |
| L/R/U/D | LCD | Joystick/Push | |
| Cancel | LCD | Push | User |
| Ch12/Ch2 rec level | Under LCD | Knobs | |
| LCD Bright | Under LCD | Push | |
| Peaking | Under LCD | Push | |
| Display | Under LCD | Push | |
| Status | Under LCD | Push | |
| Monitor | Under LCD | Switch | |
| Input1/Input2 | Under LCD | Switch | |
| Ch1/Ch2 | Under LCD | Switch | |
| Ch1/Ch2 auto/manual | Under LCD | Switch | |

## CAMERA FUNCTION menu

**Basic camera settings**

| Item | range | comments | Pref |
|---|---|---|---|
| Bars | On, Off | SMPTE | |
| OIS … | On, Off | Optical Image Stabiliser | |
| Level | High, Normal | | |
| Flicker Correction | On, Off | E,g, fluorescent lighting | |
| Flash Band Correction | On, Off | Compensate for rolling shutter | On[1] |
| Shutter | Variable, Step | | |
| AE Level | -6 ~ 0 ~ +6 | | |
| AE Speed | Fast, Middle, Slow | | |
| ALC Limit | 24, 18, 12, 6dB | | 12[2] |
| Auto Iris Limit (Open) | F5.6. 4, 2.8, 2, 1.6 | | |
| Auto Iris Limit (Close) | F11, 8, 5.6 | | 5.6[3] |
| EEI Limit | 4Fstop, 3Fstop, 2Fstop | Auto shutter range | |
| Smooth Trans | Fast, Middle, Slow, Off | Response speed to auto changes | |
| Gain L/M/H | +24dB, 21, 18, 15, 12, 9, 5=6, 3,0, -3, -6dB | Defaults to L=0, M=9, H=18 | 0, 6, 12[4] |
| AE Level Sw | AE level/VRFR, AE level, Disable | What the L/R buttons on cam right do | |
| Handle Zoom Speed | 1 ~ 5 ~ 8 | | |
| AF Assist | On, Off | Focus assist | |
| User Switch Set | Preset Zoom 3, Preset Zoom 2, Preset Zoom 1, White Balance, Load Picture File, Clip Review, Backup Trig, Clip Cutter Trig, OK Mark, Face Detect, Spot Meter, AE Lock, LoLux, LCD Backlight, Flash Band, OIS, Focus Assist, Bars, Marker, Zebra, None | User buttons 1~7, L/R/U/D joystick pushed on the LCD, Lolux, Clip Review, Spot Meter, Face Detect, Face Detect Sensitivity, Face Detect Hysteresis, AE Lock, Preset Zoom Speed | |

[1] Flash band correction works well, and should be used for journalism shooting.
[2] Maximum gain the AGC will go to, setting depends on noise level, which also depends on sensitivity setting.
[3] Iris diffraction starts to be visible at F/5.6.
[4] Gives decent noise performance in Standard shooting mode. Extended shooting mode is more sensitive but noisier.



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## CAMERA PROCESS menu

| Item | range | comments | Pref |
|---|---|---|---|
| Detail | -10 ~ 0 ~ +10 | | {f}-7, {v}-4, {SD}-4 |
| Adjust … | | | |
| V/H Balance | H+4, H+3, H+2, H+1, Normal, V+1, V+2, V+3, V+4 | | |
| H Frequency | High, Middle, Low | | {f} High {v} Middle |
| V Frequency | High, Middle, Low | [5] | {f} High {v} Middle |
| Skin Detail … | On, Off | | |
| Level | -1, -2, -3 | Skin softening | |
| Range | -5 ~ 0 ~ +5 | | |
| Master Black | -50 ~ 0 ~ +50 | | |
| Black Toe … | Stretch, Normal, Compress | | |
| Stretch Level | 1, 2, 3, 4, 5 | Stretch improves colour performance | |
| Compress Level | 1, 2, 3, 4, 5 | Compress improves noise performance | |
| Knee … | Manual, Auto | | Manual |
| Level | 100%, 95, 90, 85 | Manual | {f}85 {v}95 |
| Sensitivity | Fast, Middle, Slow | Auto | |
| White Clip | 108%, 100% | | 108%[6] |
| Gamma … | Cinema, Standard, Off | | {f} Cinema {v} Standard |
| Level | -5 ~ 0 ~ +5 | + = black stretch/white crush<br>- = black crush/white stretch | |
| WDR | Strong, Natural, Weak, Off | Wide Dynamic Range, another gamma | |
| White Balance … | | | |
| Preset Temp | 7500K, 6500, 5600, 4800, 4200, 23200, 3000, 2800K | CCT of Preset White Balance setting | |
| Alternative Temp | 7500K, 6500, 5600, 4800, 4200, 23200, 3000, 2800K | Different CCT for Preset, toggled with White Bal switch. Neat idea. | |
| AWB Paint | -32 ~ 0 ~ +32<br>-32 ~ 0 ~ +32 | Shift the balance (A or B) | |
| Clear Paint after AWB | On, Off | Resets Paint values on doing a White Balance | |
| FAW Paint | -32 ~ 0 ~ +32 | Swing R/B gains in Auto White Balance | |
| Color Matrix … | Cinema Subdued, Cinema Vivid, Standard, Off | Quite powerful, beware | {f} Cinema Subdued {v}Standard |
| Adjust | Red, Yellow, Green, Cyan, Blue, Magenta<br>-5 ~ 0 ~ +5 | RGB gains in hue sectors, very nice intuitive display | |
| Color Gain | Off, -50 ~ 0 ~ +15 | Saturation | |
| Reverse Picture | Off, Rotate | H and V reversal | |
| Shooting Mode | Standard, Extended | | Standard[7] |
| Reset Process | Revert to factory | | |

## TC/UB menu

| Item | range | comments | Pref |
|---|---|---|---|
| TC Generator | Free Run (Ext), Free Run, Rec Run, Regen | The usual | |
| TC Preset | 00:00:00:00 | Enter the time code | |
| UB Preset | ** ** ** ** | Hexadecimal entry, 0~9, A~F | |
| Drop Frame | Non Drop, Drop | Only in 60/30 fps. ND is fixed in 24p | |

## LCD/VF menu

| Item | range | comments | Pref |
|---|---|---|---|
| Shooting Assist … | | General help, all good stuff | |
| Focus Assist …. | On, Off | Sets VF to mono and adds colour edges | |
| Type | Accu Focus, Normal | Accu Focus opens the lens to help | |
| Color | Blue, Green, Red | | |
| Zebra … | On, Off | Bracketing levels … | |

[5] Only active in 1280x720, shame.
[6] Set to 100% if the footage is going to be used in analogue SD television. When using 108%, make sure that the client knows you've done so, to make sure he doesn't clip in post-production.
[7] Changes basic gain by 6dB.



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| | | | |
|---|---|---|---|
| Top | Over, 100% ~ 80 ~ 5% | Max level | |
| Bottom | 100% ~ 70 ~ 0 | Min level | |
| Marker Settings … | | | |
| Marker … | On, Off | | |
| Aspect Ratio | 16:9 + 4:3, 2.35:1 Top, 2.35:1 Centre, 1.85 Top, 1.85 Centre, 16:9, 1.75:1, 1.66:1, 14:9, 13:9, 4:3 | | |
| Aspect Marker | Line+Halftone, Halftone, Line, Off | For all but 16:9 | |
| Safety Zone | 95%, 93, 90, 88, 80, Off | | |
| Centre Mark | On, Off | Centre cross | |
| Display Settings … | | | |
| Zoom | Number, Bar, Off | | |
| Focus | Feet, Meter, Off | | |
| ND Filter | On, Off | | |
| Record Format | On, Off | | |
| Media Remain | On, Off | | |
| TC/UB | UB, TC, Off | | |
| Audio Meter | On, Off | | |
| Battery | Time, Capacity%, Voltage, Off | | |
| Date/Time | On, Off | | |
| Date Style | DMY2, DMY1, MDY2, MDY1, YMD | | |
| Time Style | 24 hour, 12 hour | | |
| Shutter | Deg, Sec | Nice to see this choice | |
| LCD+VF | On, Off | | |
| VF Color | On, Off | | |
| VF Bright | -10 ~ 0 ~ +10 | | |
| VF Contrast | -10 ~ 0 ~ +10 | | |
| LCD Contrast | -10 ~ 0 ~ +10 | | |
| LCD Backlight | Bright, Normal | | |
| LCD Mirror | Mirror, Normal | | |

## A/V SET menu

| Item | range | comments | Pref |
|---|---|---|---|
| Video Set … | | | |
| Display on TV | On, Off | | |
| HDMI/SDI Out … | HDMI+SDI, SDFI, HDMI, Off | | |
| Resolution | 576i. 576p, 1080i | Options change with frame/resolution setting | |
| HDMI Color | RGB, Auto | | |
| HDMI Enhance | On, Off | | |
| SD Aspect | Side Cut, Letter, Squeeze | | |
| SD Set Up | 7.5%, 0 | Only for NTSC-related frame rates | |
| Audio Set … | | | |
| Input 1 Mic Ref | -62dB, -56, -50, -44, -38 | Relevant when Input is MIC or MIC+48V | |
| Input 2 Mic Ref | -62dB, -56, -50, -44, -38 | | |
| Int Mic Gain | +12dB, +6, 0 | | |
| Aux Gain | +12dB, +6, 0 | | |
| Ref Level | -12dB, -18, -20 | | |
| Limiter | Ref Level, -8dBFS, -5dBFS, Off | | |
| AGC Response … | | | |
| Attack Time | Fast, Middle, Slow | | |
| Decay Time | Fast, Middle, Slow | | |
| AGC Mode | Link, Separate | | |
| XLR Manual Level | Link, Separate | | |
| Int Mic Separation | 1, 2, 3, 4 | Stereo enhancement, Coo ☺ | |
| Test Tone | On, Off | 1kHz | |
| Input 1&2 Wind Cut | Both, Input 2, Input 1, Off | | |
| Int Mic Wind Cut | On, Off | | |
| Equalizer | +6dB ~ 0 ~ -6 | 5-band graphic equaliser | |
| Monitor | Mix, Stereo | Headphones feed | |
| Alarm Level | High, Middle, Low, Off | | |
| Audio On FULL AUTO | SW Set, Auto | Audio control when the camera is in Full Auto mode | |



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## SYSTEM menu

| Item | range | comments | Pref |
|---|---|---|---|
| Record Set … | | | |
| Record Format …. | | | |
| System | HD, SD | | |
| Format | QuickTime(MPEG2), MP4(MPEG2), AVCHD | Only AVC in SD | |
| Resolution | 1920x1080, 1440x1080, 1280x720 | Changes to '720x576 or 720x480' in SD | |
| Frame & Bit Rate | 60i(HQ), 30p(HQ), 50i(HQ), 25p(HQ), 24p(HQ) | Changes according to HD/SD and Resolution setting | |
| SD Aspect | 16:9, 4:3 | Fixed at 16:9 in SD mode | |
| Rec Mode … | Normal, Pre Rec, Clip Continuous, Frame Rec, Interval Rec, Variable Frame | Options change with frame/Bit rate | |
| Pre Rec Time | 5sec, 10, 15 | Cache length | |
| Rec Frames | 1, 3, 6 | | |
| Rec Interval | 1sec, 2, 5, 10, 30, 1min, 2, 5, 10, 30, 1hour | | |
| Variable Frame Rate | | Options depend on Frame/Bit rate setting | |
| Slot Mode … | Series, Dual, Backup | Allows different modes in the cards, nice | |
| Backup Rec | | Separate control of backup recording | |
| Time Stamp | On, Off | Burns in Date/Time | |
| Clip Set … | | | |
| Clip Name Prefix | | Set first 4 chars of clip name | |
| Reset Clip Num | | Resets to 0001 (0000 in AVCHD) | |

## 2. Measurements

All measurements were made on frames captured onto a SDHC card. In this section, I shall use the EBU system of designating scanning standards. Live viewing for the first tests (on S/N 40006) was done on a 24" LCD monitor supplied by JVC, the second camera was monitored on a 42" consumer grade plasma display with 'studio' settings. On both occasions, waveform monitoring was via a Black Magic Ultrascope waveform monitor using the HDSDI output.

### 2.1. Colour performance

Colour performance was assessed visually, using ColorChecker charts. The most accurate colour rendering was obtained using the Standard matrix, as expected. The reds and skin tones were a little bright and oversaturated, but not enough to cause problems. No individual colour was markedly wrong, the pictures looked nice overall. There was no response to near infra-red.

### 2.2 Resolution and aliasing

All resolution measurements were made with a circular zone plate test chart. This has 6 circular patterns, each exploring the frequency space of the 1920x1080 limits of HDTV. Each pattern has DC (low frequency) at the centre, and reaches 1920 lines/picture width (960 cycles) horizontally and 1080 lines/picture height (540 cycles) vertically. There is a separate pattern to explore each of R G and B, luma (Y'), $P_b$ and $P_r$. Generally, only one quadrant of each pattern is needed since it fully explores both horizontal and vertical frequency spaces.

#### 2.2.1 1920x1080

*Figure 1* shows the luma resolution when the camera detail enhancement was switched off, the native performance of the camera in 1080 progressive scanning. There is no in-band aliasing, and only very low-level aliasing centred on 1920 (horizontal) and 1080 (vertical) visible in the smaller double-frequency pattern. This indicates that the lens is delivering only low-level resolution to the camera at above the limits of HD, and that the optical low-pass filter is removing the residue. The performance is rather good because it is clean.

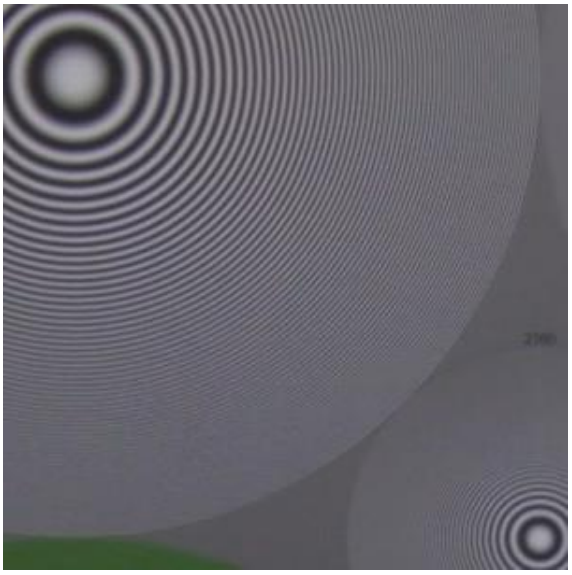

**Figure 1 Resolution 1080p det off**

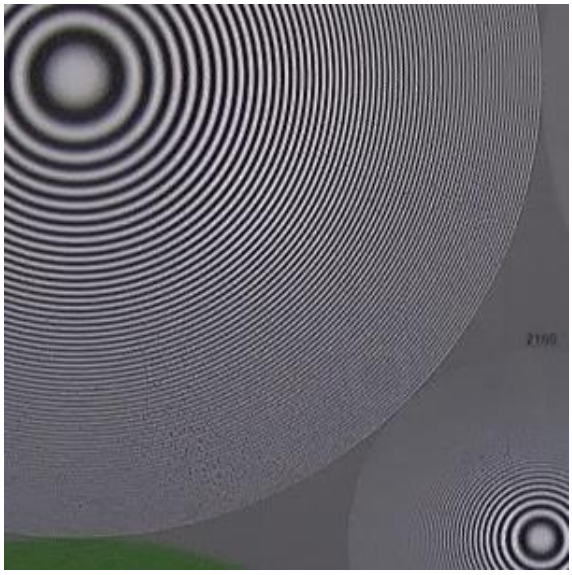

**Figure 2 Resolution 1080p det max**

Clearly the sensors are 1920x1080, and the optical low-pass filter is well-matched to this resolution with this lens.

### 2.2.2 Detail enhancement

The camera hardly needs any enhancement, but it has some controls for detail manipulation, so they were investigated.

The detail level control goes from -10 to +10, with factory default at 0, which does not imply zero effect. Even at -10, some detail enhancement happens. *Figure 2* shows the effect of maximum detail enhancement, which should be avoided at all costs since it over-brightness low frequencies and causes overshoots and ringing on high contrast edges. Setting the detail level control to between -4 and -7 produced much more pleasing pictures, suitable for video- and film-style shooting respectively.

*Figure 3* shows the zone plate at zero detail level setting, which shows rather too much brightening at lower frequencies (enhancement of this sort is a hallmark of SDTV and ought not to be necessary in HDTV).

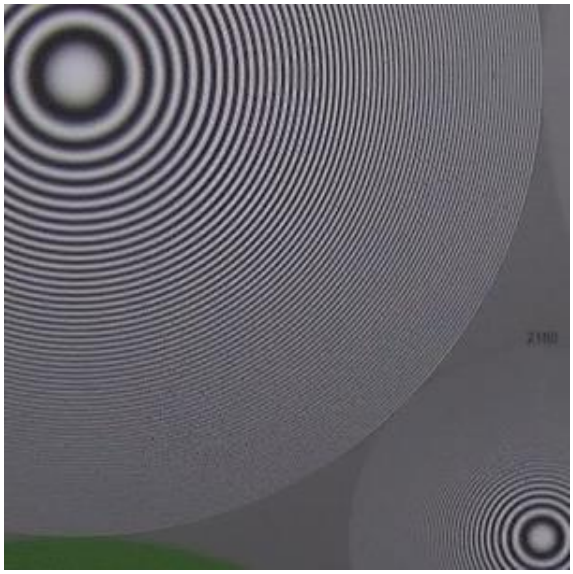

**Figure 3 Resolution 1080p det zero**

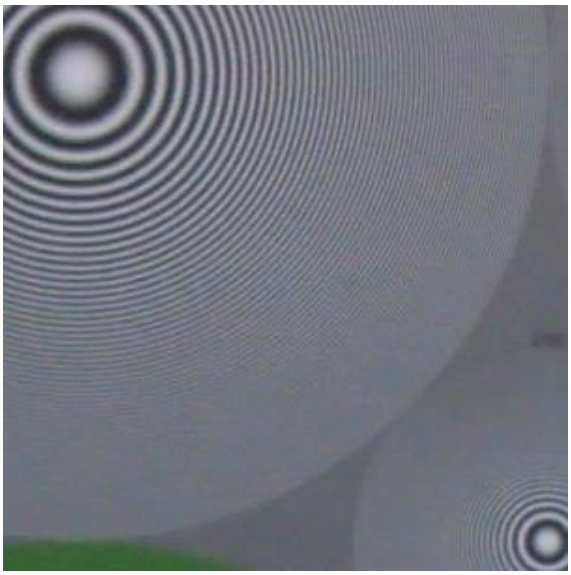

**Figure 4 Resolution 1080p +12dB det off**

Since the sensors are small, iris diffraction starts to be visible at between F/4 and F/5.6, so the lens should not be stopped down much beyond F/5.6 for the best effect. *Figure 4* shows the result at F/5.6 and +12dB gain. Clearly resolution is already being lost; F/5.6 should be regarded as the limit for good HDTV production. Fortunately, the camera has good neutral filters which should be used for exposure control, and has a viewfinder warning to use filters rather than aperture when resolution loss would become noticeable.

There is further resolution loss at +24dB gain, to the extent that the pictures can no longer be described as HDTV. This is probably due to a limitation in the gain-bandwidth product of the analogue head amplifiers, and is quite normal in all cameras.

### 2.2.3 1280x720

*Figure 5* shows the result for 720p shooting, with the video-style detail settings. The down-conversion is quite well done; there is some inevitable aliasing centred on 1280 horizontally and 720 vertically, but the level is reasonably low, and the camera can be considered as suitable for 720p shooting providing care is taken not

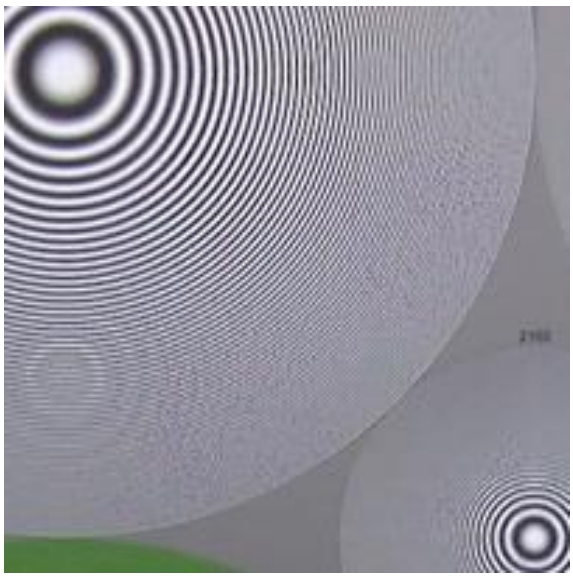

**Figure 5 Resolution 720p**

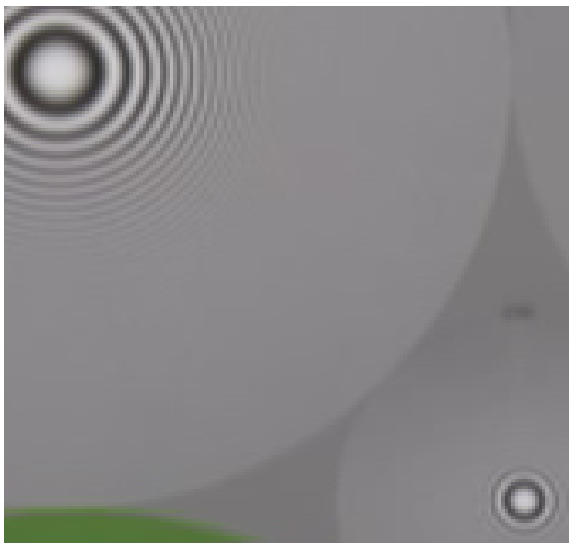

**Figure 6 Resolution SD 720x576**

use excessive detail enhancement.

#### 2.2.4 720x576 SD

The same is true for SD resolution. *Figure 6* shows this.

Frequency content beyond the limits of SDTV are well suppressed. While there are inevitable low-level aliases due to the down conversion process, they are well suppressed provided that the detail enhancement is kept at a low level. Setting the detail level to anything higher than -4 only increases the visibility of the aliases without significantly increasing perceived sharpness.

### 2.3 Lens aberrations

In small cameras with fixed lenses, it is common to find significant lens aberrations, particularly in the image corners.

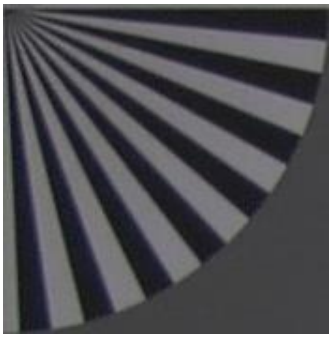

**Figure 7 Lens aberrations**

*Figure 7* shows the results from one corner of a grab at mid zoom and F/2, 1080p. There is hardly any displacement of the red/green/blue images, just a small horizontal blue/yellow shift which would be invisible on normal pictures. This is good performance for a small camera.

### 2.4 Video Sensitivity, Noise and Dynamic Range

This camera has an unusual menu item called 'Shooting Mode': it has two settings, Standard and Extended. The effect of this control is to change the camera basic sensitivity by 6dB which would normally affect noise performance by about 3dB. The gain setting range starts at -6dB in Extended mode, but at 0dB in Standard mode. This allows the user to make some trade-off between sensitivity and noise.

In the Shooting Mode 'Standard' setting, sensitivity at 0dB gain was measured as about F/5.0 for 1000 lux illumination of a 90% reflectance Kodak Gray card to produce 100% video level (with the knee set to 100% and clipping to 108%). In the 'Extended' setting the aperture was F/8.0. Note that both these aperture settings are only approximate since aperture reporting in the camera is only in steps of ¼ or ⅓ stop. These figures convert to about F/7.2 and F/11 for 2000 lux, both of which are high values for a camera with ⅓" sensors. Initial measurements of noise in the early model showed noise levels which were acceptable but not particularly good, this was effectively in the 'Extended' mode (since the earlier camera did not have these two modes).

Normally, the main source of video noise in a camera is the analogue circuitry of the camera's front end and the sensors themselves. In many cameras it is impossible to turn off gamma-correction, and so it can be difficult to get accurate measurements. Although, unusually, gamma-correction can be turned off in this camera, it will never be used in this mode so measurements were made using Standard gamma.

Video noise levels were measured by capturing defocused exposures of a white card at four video signal levels, with the camera set to Standard gamma curve and 0dB gain. 1080P HQ mode was used. *Figure 8* shows the results of using Standard and Extended Shooting Mode. Normally, the noise level should follow the slope of the camera gamma curve, with at least 10dB difference between the level near white where the gamma slope is about ⅓ and near black where the slope is 4.5, an extreme range of about 22dB. Also, there should be a general difference of about 3dB between these two sets of curves, due to the gain difference.

Obviously, that is not happening here. There are two reasons:

- The rise in noise level near white is due to shot noise, a fundamental electronic effect often seen in cameras with small sensors.

- The camera has electronic noise reduction permanently in place, which is distorting the noise profile.

There is little practical difference in the noise levels between the two modes, although the visual character of the noise differs in that in Standard mode it appears to be significantly 'quieter'. The distribution of noise does not follow the slope of the gamma-correction in either case, and the noise levels are very similar, all of

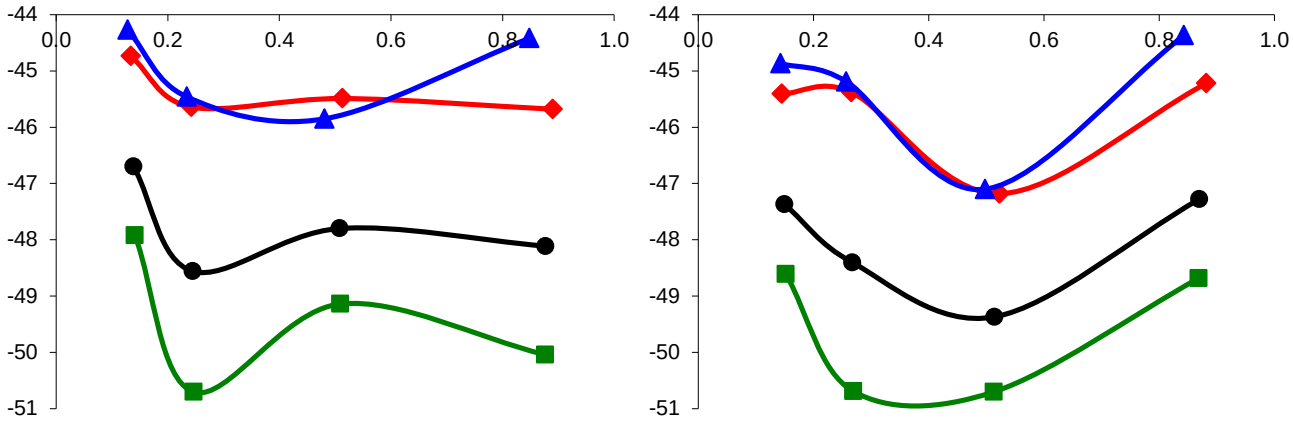


**Figure 8 Noise levels (a) Extended** **(b) Normal**

which is fairly firm evidence for the presence of significant noise reduction in the camera (which has the effect of setting the noise level independent of gain).

However, noise levels change with gain level in the expected way. *Figure 9* shows how the noise levels change with gain, measured in the early prototype camera (which corresponds to the Extended mode in the later camera). The signal level was about 50% for each measurement point. There is a clear lowering of noise level, at 3dB per stop or 6dB of gain, as expected.

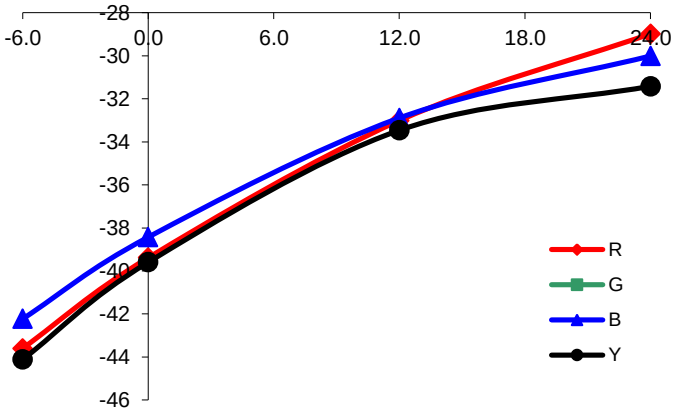


**Figure 9 Noise 1080p**

It seems possible that the ADCs are non-linear or that there is some form of pre-gamma before the ADCs, in order to reduce the bit-depth of the processing. This could account for some of the non-rising noise level near black since the fixed gain-bandwidth product of the analogue amplifiers would reduce the high-frequency content as the gain increases, thereby limiting the noise. There is evidence that this is so in the softening of images at high gain (see *Figure 3* and comments in section 2.2.3).

Nevetherless, the noise level at 0dB gain is about -48dB, which highly creditable for a camera in this category. Lowering the camera gain setting to -6dB does not produce any major change in noise levels, but is worth doing because the pictures appear to be subjectively 'cleaner'.

In Standard Shooting Mode and with Standard gamma, the camera has about 0.7 stops of headroom for overexposure, by using the knee. In Extended mode, it can cope with a little under half a stop. Using the Cinema gamma curve prohibits the use of the knee, but allows for a little under half a stop of overexposure anyway. Thus, since the headroom is between 0.4 and 0.7 stops (equivalent to about 2.5 and 4.5dB), and the noise floor is at about -49dB, the total dynamic range is between 51.5 and 53.5dB, which is about 8.6 to 8.9 stops, hardly adequate for a good film look, but quite acceptable for such a small camera.

## 2.5 Rolling Shutter effects

The camera has CMOS sensors and can therefore be expected to show geometrical distortion on moving objects, the 'rolling shutter effect'. Also, flash photography can cause banding if the flash exposure does not synchronise with the field/frame scanning process.

The camera was exposed to a small electric fan, speed-adjusted to strobe with the television scanning rate. *Figure 10* shows part of one frame, with the shutter set to 1/250 second. The blade on the left (going up) is shrunk in width by about 50% while that on the right (going down) is at least doubled in width. This indicates that there are no processing tricks in the camera to ameliorate the effect. So 'flash-banding' ought to be a problem, where stills-camera flashes will illuminate only a part of the field or frame, and intra-frame motion may be disturbing.

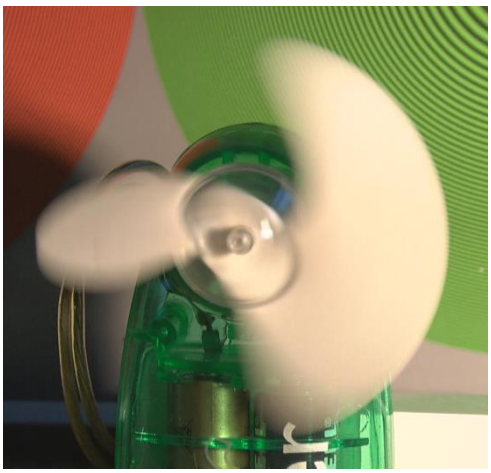

**Figure 10 Fan**

However, a new feature has been added in the second tested camera - 'Flash Band Correction'. *Figure 11* shows electronic flash from a small stills camera, without and with correction. On the left, the flash has gone off part way down the picture and highly overexposed the video camera, but on the right, the correction has detected that this has happened and greatly increased the gain in the upper, normally exposed, part of the video frame to match the lower, overexposed, part. This works very well, and the sharp line marking the join between the flash exposure and the artificially gain-increased part is not visible in practice since it exists on only one frame.

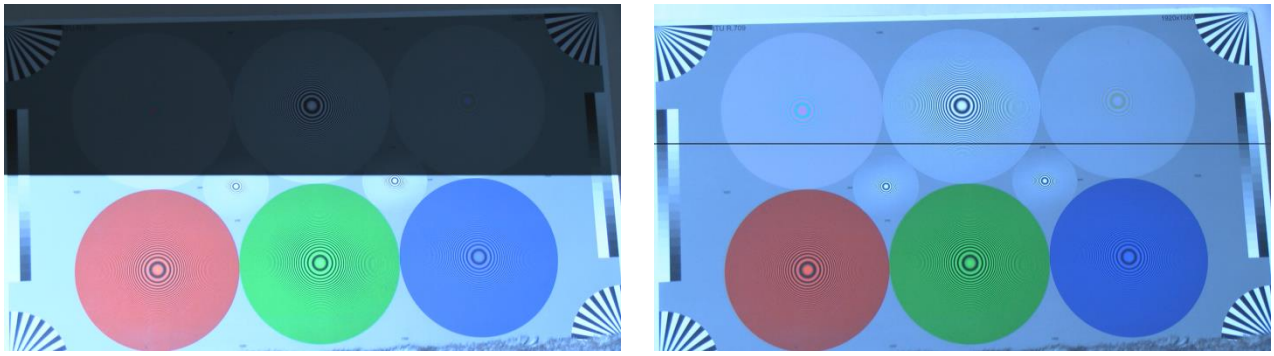

**Figure 11 Flash Band Correction**

## 2.6 Conclusion

The camera appears to qualify easily for EBU R.118 Tier 2J (Journalism). The noise level is fairly high but is comfortably inside the target level of -44dB. If it is recorded onto an external recorder with 50Mb/s MPEG2 or better, then it could qualify for Tier 2L as well, even though the recordings will inevitably be to 8-bit 4:2:2 rather than 10-bit 4:2:2 precision.

Resolution is good, alias levels are very low, and both 720P and SD performance is acceptable.

The total dynamic range of about 8.6 to 8.9 stops is quite low, but normal and acceptable for a camera of this size.

Motion artefacts from the 'rolling shutter' are as expected for a CMOS camera, but the Flash Band Correction can eliminate problems from electronic flash photography.