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

Alan Roberts, January 2013

SUPPLEMENT 008 : Assessment of a JVC GY-HM650 camera

Initial tests were made on a production model of the JVC HM650 HDTV camcorder (serial number 177M0158).

The camera is very similar to the HM600 and shares many features with it. It could well be identical apart from the extra features of the 650.

It has an integral lens (Fuji, F/1.6, 23:1 4.1~94.3mm) and records onto two solid-state storage SDHC or SDXC 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 and in MXF and web formats. 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. In-camera editing can be done by WiFi control or network connection

The camera is quite light (about 2.5kg 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 13 watts at nominal 12 volts. The battery lasts about 110 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 8.5 to 9.5-stop dynamic range. The recommended settings allow about 1 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, resolution 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. 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. Note that the camera under test had slightly different menu contents from that listed in the printed manual, the listings below refer to the actual camera.

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	
Up/Down/Left/Right	Left	Push	Navigation When in shooting mode: Centre=shutter on/off Up/Down=shutter speed 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, 6, 3, 0, -3, -6dB	Defaults to L=0, M=6, H=12	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		
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,: Focus assist, OIS, Lolux, AE Lock, Zebra, Marker, C.Review	

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	

[1] Flash band correction works well, and should be used for journalism shooting. Doesn't work with shutter on, or in some operating modes, see the manual.

[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.

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		{f} Cinema {v} Standard
Level	-5 ~ 0 ~ +5	+ = black stretch/white crush - = 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 -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 -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 …	
Top	Over, 100% ~ 80 ~ 5%	Max level	
Bottom	100% ~ 70 ~ 0	Min level	
Marker Settings …			
Marker …	On, Off		

[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.

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	

SYSTEM menu

Item	range	comments	Pref
Record Set …			
Record Format ….			

System	HD, SD, HD+SD, HD+Web		
A Format	QuickTime(MPEG2), MP4(MPEG2), MFX (MPEG2), AVCHD, QuickTime(H.264)	Only AVC in SD	
A Resolution	1920x1080, 1440x1080, 1280x720	Changes to '720x576 or 720x480' in SD	
A Frame & Bit Rate	60i(HQ), 30p(HQ), 50i(HQ), 25p(HQ), 24p(HQ)	Changes according to HD/SD and Resolution setting	
B Format	QuickTime(MPEG2), MP4(MPEG2), MFX (MPEG2), AVCHD, QuickTime(H.264)	Only AVC in SD	
B Resolution	1920x1080, 1440x1080, 1280x720	Changes to '720x576 or 720x480' in SD	
B 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)	
Media …			
Format Media		Format either card	
Reset Media		Rescue operation when needed	
Setup File …			
Load File …		Camera settings	
Picture File			
Scene File			
Store File ….			
Picture File			
Scene File			
Delete File …			
Picture File			
Scene File			
Auto Power Off	On, Off	Power-down after 5 minutes inactivity	
Tally Lamp	On, Off		
GPS	On, Off		
Network …	On(SDI Off), On(HDMI Off), Off		
Import Metadata			
Settings ….		All sorts of stuff to do with networks	
Reset All		Factory reset	
Date/Time		Enter settings	
Time Zone	UTC+14:00 ~ UTC ~ UTC-12:00		
System Information …			
Version	V0101		
Fan Hour	000007H		
Open Source License			

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 was done on a 24" LCD monitor supplied by JVC and on a 42" consumer grade plasma Panasonic display with 'studio' settings. 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.

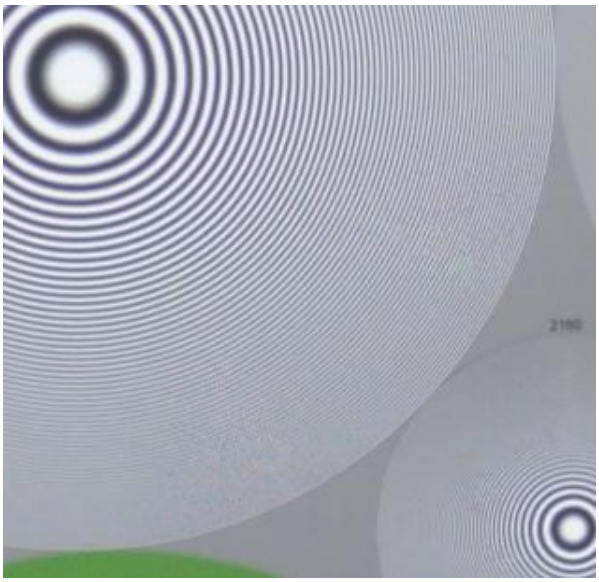

Figure 1 Resolution 1080p, detail off

2.2.1 1920x1080p

Figure 1 shows the luma resolution when the camera detail enhancement was switched off, the native performance of the camera in 1080 progressive scanning. The lens aperture was about F/2.5, in the centre of the expected best-performance aperture range of the lens. 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 so clean.

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

2.2.2 1080p 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

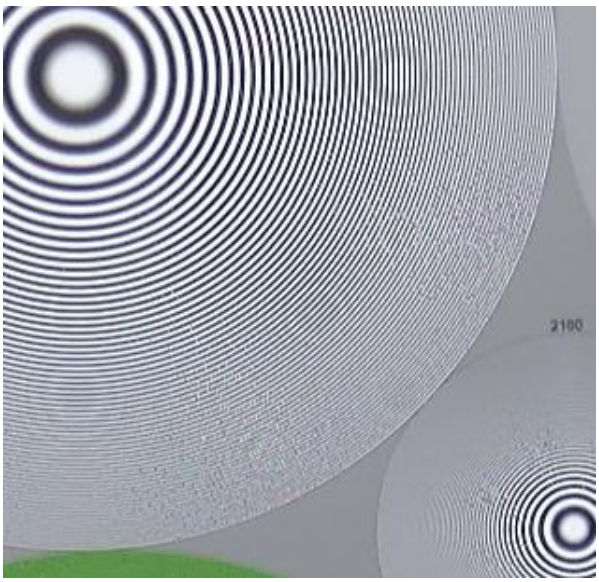

Figure 2 Resolution 1080p, detail +10

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).

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.

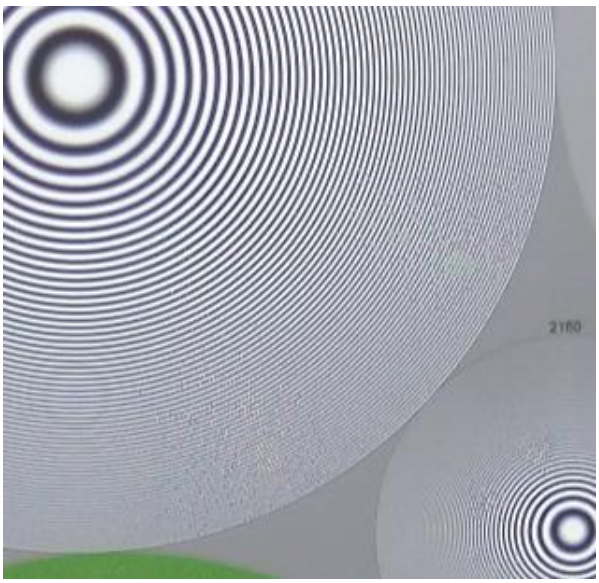

Figure 3 Resolution 1080p, detail 0

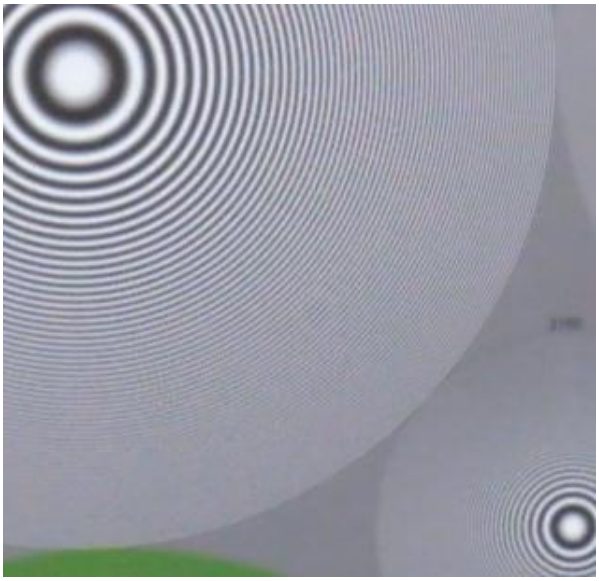

Figure 4 Resolution 1080p, +12dB F/5.6

Figure 4 shows the result at F/5.6 and +12dB gain with detail off. 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.

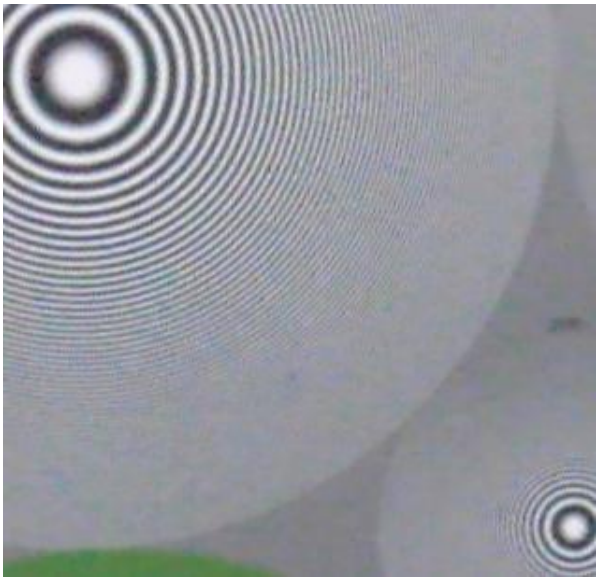

Figure 5 Resolution 1080p, +24dB F/5.6

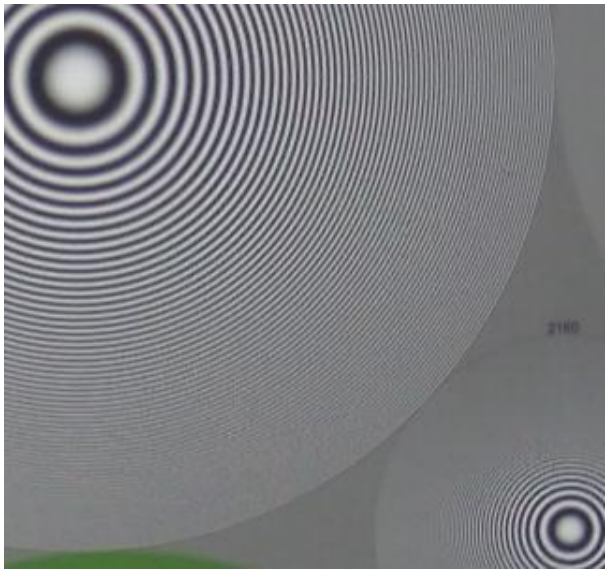

Figure 6 Resolution 1080i, detail -4

There is further resolution loss at +24dB gain (*Figure 5*), 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, together with to the effects of dynamic noise-reduction, and is quite normal in all cameras.

2.2.3 1920x1080i

Figure 6 shows the resolution at 1080 interlaced, with the detail settings given in the table. The loss of vertical resolution is due to the interlaced scanning process and is quite normal.

2.2.4 1280x720p

Figure 7 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 to use excessive detail enhancement.

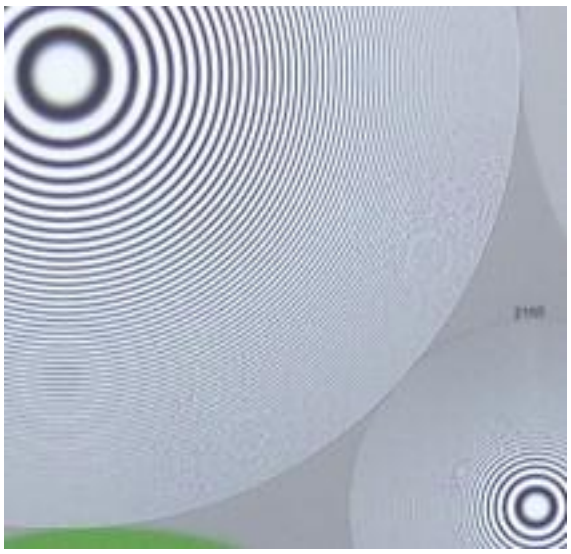

Figure 7 Resolution 720p, detail -4 F/2.5

2.2.5 720x576 SD

The same is true for SD resolution. *Figure 8* 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 any level higher than -4 increases the visibility of the aliases, without significantly increasing perceived sharpness.

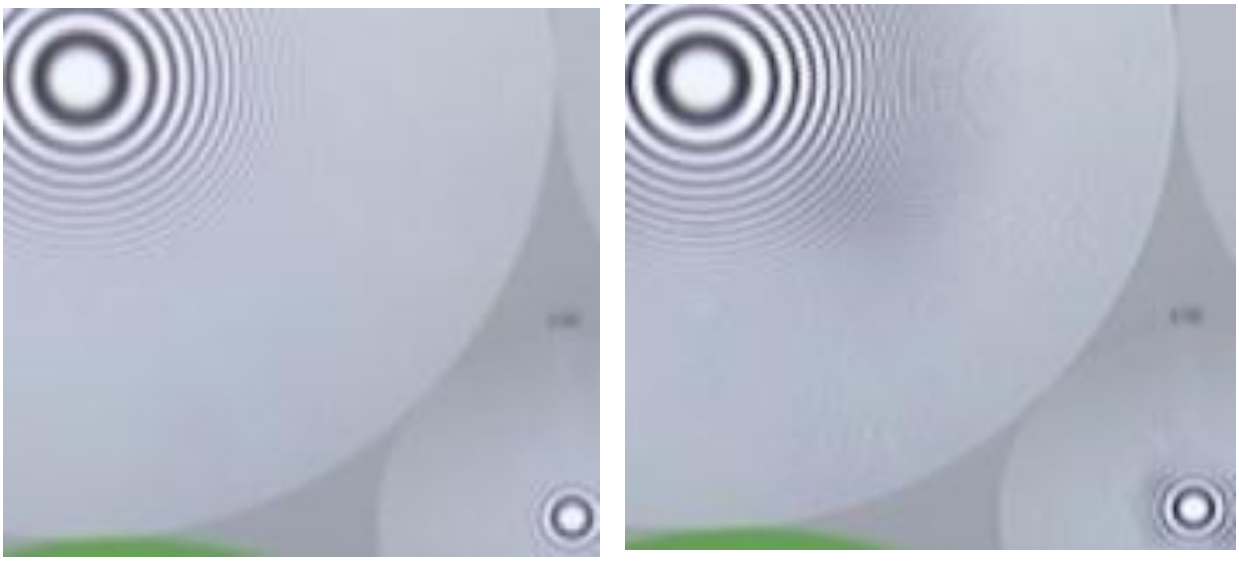

Figure 8 Resolution SD, (a) detail off (b) detail -4

2.3 Lens aberrations

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

Figure 9 shows the results from one corner of a grab at mid zoom and F/2.5, 1080p, with detail off. 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.

Figure 9 Lens aberration

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/7.5 for 2000 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/10.5. 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 are high sensitivity values for a camera with ⅓" sensors.

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 most cameras it is impossible to turn off gamma-correction, and so it can be difficult to get accurate measurements. This camera is no exception, 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, MXF format. *Figure 10* shows the results of using Standard and Extended Shooting Mode.

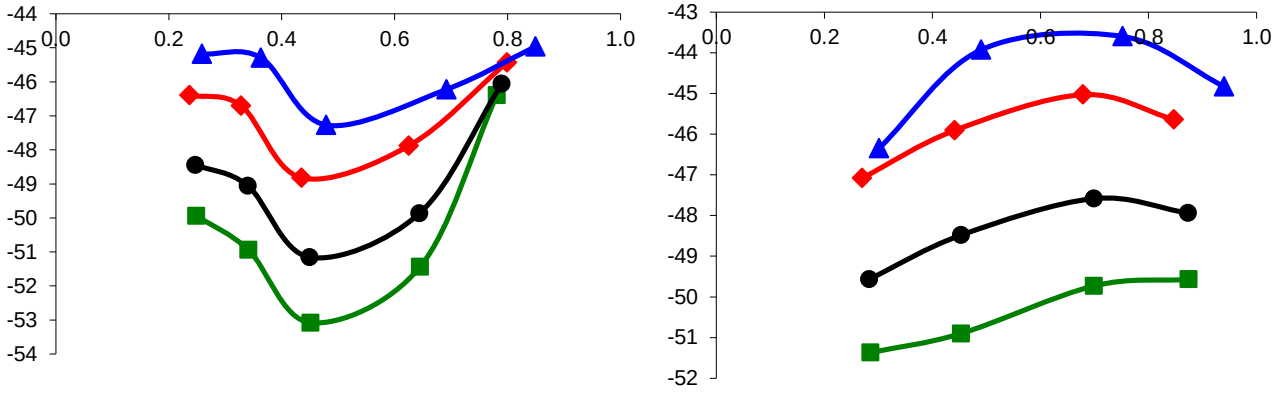

Figure 10 Noise distribution (a) Standard mode **(b) Extended mode**

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.

Taking the luma channel noise levels around mid-grey (50%), the values are about -50.5 and -48.5dB for the two modes, a difference of about 2dB although it is not consistent across the distributions. The distribution of noise does not follow the slope of the gamma-correction in either case, all of 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). The visual character does not entirely coincide with these measured results, because the noise near black (where it should be at highest level) is being most heavily reduced. This should have the effect of reducing the resolution or detail near black, which seems to be quite acceptable. The rise in noise near white makes the pictures look rather film-like, irrespective of the gamma–correction curve.

However, noise levels should change with gain level, by 3dB per 6dB of gain. *Figure 11* shows how the noise levels change with gain. The signal level was about 50% for each measurement point.

There is such a relationship in the Extended Mode, but only when the gain exceeds +12dB. Below that gain, the effects of noise reduction are interfering with the normally expected results, providing a noise floor. In Standard Mode, the relationship is almost completely lost. This implies that noise reduction is fairly powerful, which is borne out by the resolution loss shown in *Figure 3*.

Nevertheless, the mid-grey (30~60% video level) noise level at 0dB gain is about -50dB in Standard Mode, about -48.5dB in Extended Mode. These are highly creditable figures for a camera in this category.

Lowering the camera gain setting to -6dB does not produce a major change in noise levels, but is worth doing because the pictures appear to be subjectively 'cleaner' since the noise reduction does less harm to thr resolution..

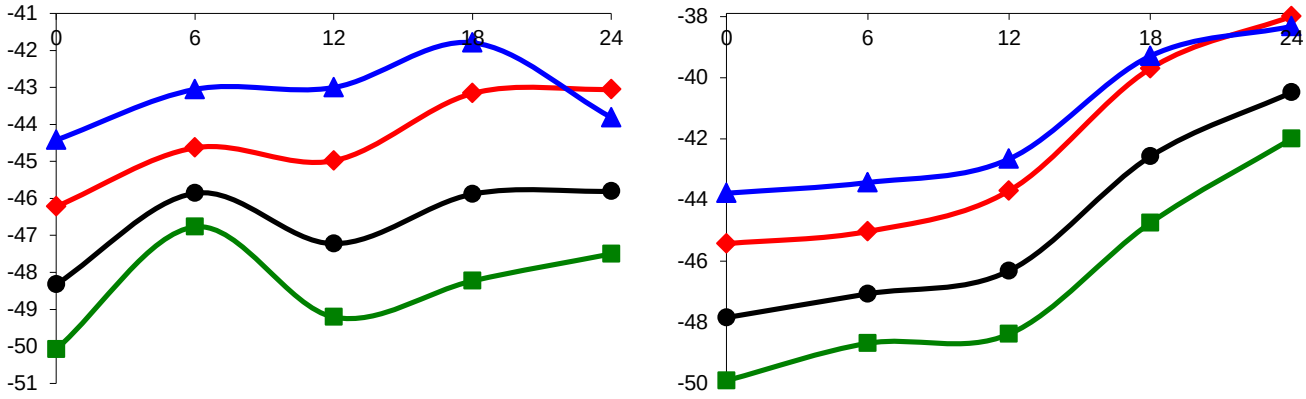

Figure 11 Noise distribution (a) Standard Mode **(b) Extended Mode**

In Standard Shooting Mode and with Standard gamma, the camera has about 1.0 stop of headroom for overexposure, by using the knee set to Manual and 85% Level. In Extended mode, it can cope with a little under 1.5 stops. Using the Cinema gamma curve allows for a little under a stop of overexposure. Thus, since the headroom is between 1.0 and 1.5 stops (equivalent to about 6 and 9dB), and the noise floor is at about -50dB, the total dynamic range is between 55 and 58dB in the two modes, which is about 8.5 to 9.5 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 12* shows part of one frame, with the shutter set to 1/1000 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. The effect is the same for both progressive and interlaced scanning.

Figure 12 Rolling shutter, fan

However, there is a new feature in this camera - 'Flash Band Correction'. *Figure 13* 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.

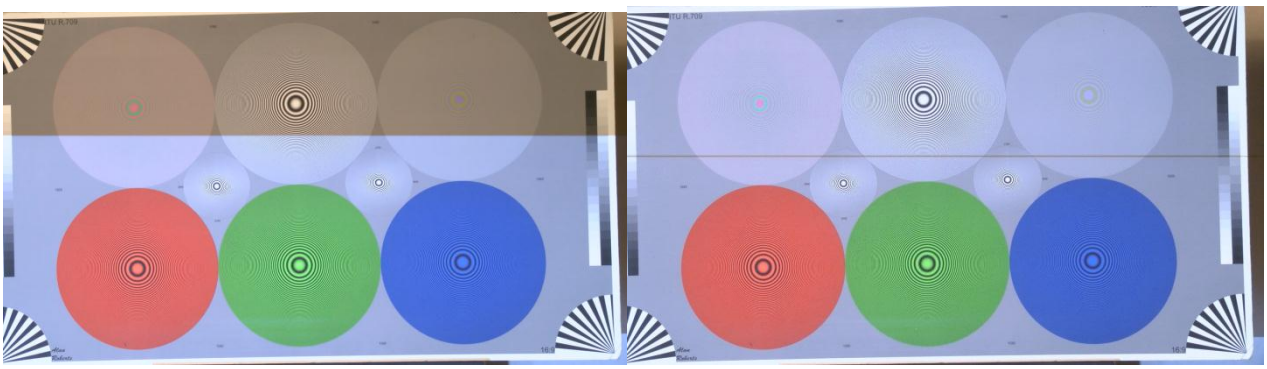

Figure 13 Flashbanding (a) original (b) corrected

3 Conclusion

The camera appears to qualify easily for EBU R.118 Tier 2J (Journalism). The noise level is not particularly high because of noise reduction, 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 8.7 to 9 stops is quite low, but is 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.