Colorimetric and Resolution requirements of cameras

Alan Roberts

ADDENDUM 31 : Assessment of, and settings for, Panasonic HPX171

Data for this section is taken from the user manual and a short examination of a production model of the Panasonic HPX171 camcorder (serial number J8TCA0195). This is a HDTV camcorder, physically very similar to the standard-definition DVX100 and HVX200 with 3 ⅓" ccds, the manual gives no clue as to the sensor resolutions. The model under test ran at both 60 and 30Hz video rates (actually 59.94 and 29.97), 24Hz (actually 23.98), and 50 and 25Hz. It records HDTV using the DVCProHD algorithm (1080i, 1080psf, 720p), SDTV using any of the DVCPro50 or DVCPro or DV algorithms (480i, 480psf, 480psfa or 576i, 576psf, 576psfa), all onto P2 flash cards. There is no tape mechanism.

The camera is relatively light (1.9kg) and has an integral lens and viewfinder, with side lcd panel, and seems aimed at the high-end consumer/professional market rather than full broadcast, which would normally demand interchangeable lenses.

It has the usual internal menus for setting the performance, not as complex as in broadcast cameras, but enough to control most of the important features. It is not suited to multi-camera operation because it cannot be genlocked or remotely controlled. It has analogue video outputs (components at both HD and SD via a multi-pin connector) and digits via IEEE1394 Firewire and USB, and perhaps crucially, HDSDI. The HDSDI facility raises the expectations of the camera a little, but its performance is somewhat mixed. There is a section on measurements at the end of this document.

The same assessment procedure was used as for other HD cameras, partly attempting to get a good "film-look", and the settings reflect that. It is useful to think of the camera, when used in this way, to be mimicking a film camera and telecine, with "best light" transfer to tape, with about 10.5 stops, maybe 11, 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. The recommended settings allow about 1.3 stops of over-exposure and one of under-exposure relative to normal operation. This is not as good as can be achieved in most 2"/3 cameras.

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The assessment of this camcorder was aimed mostly at discovering what it could do, rather than deriving a preferred setting, results are given in Section 2. The controls are not as flexible as for full "broadcast" cameras, so it may or may not be possible to derive a specific "film-look" for it. However, there is sufficient flexibility to achieve much of what is desirable in "film-look" settings. Photographic "speed" was not specifically measured, but is assumed to be similar that that of the HVX200, about 640ASA, since the camera is strikingly similar to the HVX200 in very many ways.

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, e.g. -99~99, the values indicate the range, and zero means no alteration to factory setting, not zero effect, and no scales are given. For each item, the factory setting is given if it is known, and the range offered by the camera under test. "BBC" settings are in the last column, where appropriate. The following table shows the menu settings when the camera is in "Camera" mode, these affect picture performance; other menus are included for completeness. Values that are underlined are the factory default settings. The menus are very similar to those of the HVX200 and share some features with the Varicam, in that Scene Files store a great deal of information, permitting widely different settings to be stored. When shooting in 720p mode, the camera can shoot at a variety of frame rates between 12 and 50 or 60, depending on the system speed.

BBC-preferred values are given for SD operation, for 1080 interlaced and psf, and for 720 film and sport (where sport covers all uses that are not intended to look like film). Items that have an important affect on picture appearance are highlighted. It is unfortunate that the colour bars that the camera generates are only 100/0/75/0 (i.e. EBU) rather than the much more useful SMPTE or ARIB bars that are ubiquitous in HDTV. Factory default values, where known, are underlined.

This is not intended as a replacement for reading the manual.

1 Menus and Settings

CAMERA MENU	
SCENE FILE	Camera operational controls, needs lab work to get the best from these
CAMERA SETUP	Basic camera setup controls
SW MODE	Configuration of switches
AUTO SW	Control of camera automatic features
RECORDING SETUP	Tape and P2 card controls
AV IN/OUT SETUP	Configure audio/video connections
DISPLAY SETUP	Viewfinder and LCD panel settings
CARD FUNCTIONS	P2 flash card controls
OTHER FUNCTIONS	Sundries that don't fit anywhere else
OPTION MENU	Control of IEEE1394 (Firewire) connection

MCR MENU	
RECORDING SETUP	Timecode, IEEE1394, User bits audio, etc
PLAYBACK FUNCTIONS	Audio matters
AV IN/OUT SETUP	Analogue connection and IEEE1394 settings
DISPLAY SETUP	Viewfinder and LCD panel settings
OTHER FUNCTIONS	Sundries that don't fit anywhere else
OPTION MENU	Control of IEEE1394 (Firewire) connection

CAMERA MENU

SCENE FILE (1-6)	mode	range	comments	BBC
Load/Save/Init	Camera	Load, Save, Init	Load, Save or initialise a scene file	
Operation type	Camera	Video/Film	Set shutter and fps values, also sets SynchroScan indicator to time or angle	
Frame rate	Camera	59.94: 12, 15, 18, 21, 20, 22, 24, 25, 26, 27, 28, 30, 32, 34, 36, 40, 44, 48, 54, 60 50: 12, 15, 18, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30, 32, 34, 37, 42, 48, 50	Shooting speeds for 720p only	
Synchro scan	Camera	1/n~1/249.8	n=frame rate, or degrees for FILMCAM, will not set longer than 1/field or frame	
Detail level	Camera	-7~0~+7	Horizontal and vertical edge detail[1]	0 (1080i) -2 (1080p) +2 (720sport) -4 (720film) 0 (SD)
V Detail level	Camera	-7~0~+7	Vertical edge detail	-2 (1080i) -4 (1080p) +3 (720sport) 0 (720film) -2 (SD)
Detail coring	Camera	-7~0~+7	Noise limiting for detail	+2[2]
Chroma level	Camera	-7~0~+7	Saturation	0
Chroma phase	Camera	-7~0~+7	Hue	0
Color temp Ach	Camera	-7~0~+7	Fine white balance offset, affects A preset	
Color temp Bch	Camera	-7~0~+7	Fine white balance offset, affects B preset	
Master Ped	Camera	-100~0~+100	Master black lift	
A. Iris level	Camera	-10~0~+10	Auto iris gain	
DRS	Camera	Off, 1, 2, 3	Dynamic Range Stretch	
Gamma	Camera	HDnorm, Low, SDnorm, High, B.press, Cine-likeD, Cine-lineV	HDnorm= ITU709, Low=high contrast (skin press), SDnorm=DVX100, High=black stretch, B.press crushes, CineV=more contrast than CineD	HDnorm (HD), High (SD)
Knee	Camera	Auto, Low, Mid, High	Reaches ~ 250%, knee at 80%,90%, 100%	90%[3]
Matrix	Camera	Norm1, Norm2, Fluo, Cine-like	Not tested in depth	Norm1/ Norm2[4]
Skin tone detail	Camera	On, Off	Reduces skin detail	Off
V Detail freq	Camera	Thin, Mid, Thck	Thin and Mid may cause twitter	Thin
Name edit	Camera		Names the selected scene file	

CAMERA SETUP	mode	range	comments	BBC
Aspect conv	Camera	Side crop, Letter box, Squeeze	Recording format for SD	
Setup	Camera	59.94 | 0%, 7.5%	Composite black level for NTSC output	
Mid gain	Camera	0, 3, 6, 9, 12dB	12dB gain is fairly noisy but probably acceptable	3dB
High gain	Camera	0, 3, 6, 9, 12dB		9dB
ATW	Camera	Ach, Bch, Prst, Off	Assign AutoTrackWhite to gain switch	
Handle zoom	Camera	L/Off/H, L/M/H, L/OFF/M	Set zoom speed switch settings	
Iris dial	Camera	Down open, Up open	Reverses iris control (when Manual)	

[1] These values for detail enhancement are taken from the settings document for the HVX200, since this camera is almost identical to it. One set of values was checked, and found to produce the expected results.
[2] Noise levels are lower than in the equivalent camera, the HVX200, so coring level can be set lower, resulting in slightly sharper pictures.
[3] The knee function cannot be switched off. Although this makes some measurements difficult to make, at least it ensures that overloading will not necessarily cause clipping.
[4] Norm1 appears to be normal, Norm2 produces higher saturation, the other matrices produce special effects.

SW MODE	mode	range	comments	BBC
User 1,2,3	Camera	RecCheck, Spotlight, Backlight, Blackfade, Whitefade, ATW, ATWlock, Gain18dB, Dzoom, TextMemo, ShotMark, LvlMeter, LastClip, PreRec, F.Rate+, F.Rate-	Assign user switches. 18dB works only with 50/60i/p formats, and not with slow shutter. F.Rate works only in 720p. Default:1=Whitefade, 2=Backlight, 3=Index/Memo	
Focus assist	Camera	Expanded, Graph, Both	Assign Focus Assist button, Graph shows frequency graph	
MF assist	Camera	On, Off	Semi-auto focus, refer to manual	
WFM	Camera	Wave, Vector, Wave/Vect	Waveform or vectorscope	
LCD	Camera	LCD rev, Overscan, LCD bl	Assign LCD button. Bl is backlight	

AUTO SW	mode	range	comments	BBC
A.Iris	Camera	On, Off	Auto iris	
AGC	Camera	6dB, 12dB, Off	Set auto gain maximum	
ATW	Camera	On, Off	AutoTrackWhite	
AF	Camera	On, Off	AutoFocus, disables Focus/Push Auto	

RECORDING SETUP	mode	range		comments	BBC
Rec format	Camera	59.94	1080i/60i, 1080i/30p, 1080i/24p, 1080i/24pa[5], 720p/60, 720p/30, 720p/24, 720p/30pn[6], 720p/24pn, 480i/60i, 480i/30p, 480i/24p, 480i,24pa	Recording format, this terminology is non-standard, but the meaning is clear.	
		50	1080i/50i, 1080i/25p, 720p/50p, 720p/25pn, 576i/50i, 576i,25p		
MCR format	MCR	59,94	1080i/60i, 720p/60p. 720p/30pn, 720p/24pn, 480i/60i	Playback form at, or IEEE1394 input format	
		50	1080i/50i, 720p/50p, 720p,25pn, 576i/50i		
576i/408i rec mode	Camera	DVCPro50, DVCPro, DV		Set recording mode for SD	
576i/408i MCR mode	MCR	DVCPro50, DVCPro, DV		Set playback mode for SD or IEEE1394 input	
Rec function	Camera	Normal, Interval, One shot, Loop		Non-standard recording functions	
One-shot time	Camera	1F, 2F, 4F, 8F, 16F, 1s		Frames or time to record	
Interval time	Camera	2F,4F,8F,16F, 1s, 2s, 5s, 10s, 30s, 1m, 5m, 10m		Frames/seconds/minutes	
Prerec mode	Camera	On, Off		Memory cache for prerecording	
Mic alc	Camera	On, Off		Auto level control	
Mic gain 1	Camera	-50dB, -60dB		External mic level control	
Mic gain 2	Camera	-50dB, -60dB		External mic level control	
25M rec ch sel	Camera	2ch, 4ch		DV/DVCPro25 sound channels	
1394 TC regen	Mcr	On, Off		On=TC from 1394, Off=other controls	
TC mode	Cam/Mcr	59.94	DF, NDF	Only relevant in the 59.94Hz variant, 24p uses NDF	

[5] **psfa** is the slightly improved variant of the 2:3 pull-down process used to derived 60 fields from 24 frames. Conventionally, 2 fields are made from one frame, then 3 fields from the next; this results in video frames grouped in sequences of 5, only two of which contains only information from one source frame, the others contain information from 2 source frames. In this variant, the pull-down sequence is 2:3:3:2, such that only 1 video frame in a group of 5 contains information from 2 source frames. This solves many problems production and distribution, while somewhat attenuating the uneven progress of motion caused by the 2:3 process.

[6] **pn** mode records only new frames, for over/under-cranking, i.e. there is no frame repetition.

TCG	Cam/Mcr	Free run, Rec run	TC runs free or only when tape runs	
TC preset	Cam/Mcr		Set initial TC, when recording 24p, set frame to multiple of 5 for it to make sense	
1394 UB regen	Mcr	On, Off	Source of UserBits	
UB mode	Cam/Mcr	User, Time, Date, TCG, FrmRate	FrameRate uses a code, refer to manual	
UB preset	Cam/Mcr		Set info, select User in UB mode	
Time stamp	Camera	On, Off	Burns in time/date	

PLAYBACK FUNCTIONS	**mode**	**range**	**comments**	**BBC**
Audio out	Mcr	Ch1Ch2, Ch1, Ch2, Ch3Ch4, Ch3, Ch4	Channels 3 and 4 available only on P2 recording	

AV IN/OUT SETUP	**mode**	**range**	**comments**	**BBC**
Cmpnt/SDI sel	Cam/Mcr	Auto, 1080i, 576i/480i	Set output to component or SDI	
SDI out	Cam/Mcr	On, Off	Switch SDI socket on	
SDI metadata	Cam/Mcr	On, Off	Adds metadata to HDSDI	
SDI EDH	Cam/Mcr	On, Off	Adds EDH to SD SDI	
Downcon mode	Cam/Mcr	Side crop, Letter box, Squeeze	Usual stuff	
HP mode	Camera	Live, Recording	Headphone feed, use Live for off-speed	
Test tone	Camera	On, Off	Add 1kHz to bars, ch 1~4	
Int mic	Camera	On, Off	Enable on-board mic	

DISPLAY SETUP	**mode**	**range**	**comments**	**BBC**
Zebra detect 1	Camera	50%~105% by 5%	Default 80%, left-leaning zebra	
Zebra detect 2	Camera	50%~105% by 5%, Off	Default 100%, right-leaning zebra	
Marker	Camera	On, Off	Press Zebra button to display markers	
Safety zone	Camera	Off, 90%, 4:3, 13:9, 14:9		14:9
Focus bar	Camera	On, Off	Show Focus Assist bar graph	
Video out OSD	Camera	On, Off	Screen info to video output, beware, it goes to 1394 as well	
Date/Time	Cam/Mcr	Off, Time, Date, Time&Date	What to show on screen	
Level meter	Cam/Mcr	On, Off	Audio levels on screen	
Zoom, focus	Camera	Off, Number, mm/feet, mm/mm	Show real distances, maybe ☺	
Card/Batt	Cam/Mcr	On, Off	Remaining capacity	
P2card remain	Cam/Mcr	One card, Total	Remaining time on card/cards	
Other data	Mcr	Off, Partial, All	Level of screen displays	
Camera data	Mcr/Vcr	On, Off	Show camera settings on DV playback	
LCD backlight	Cam/Mcr	High, Normal, Low	Brightness	
LCD set	Cam/Mcr	LCD color level, LCD brightness, LCD contrast	Panel, set brightness, contrast, colour	
EVF set	Cam/Mcr	LCD color level, LCD brightness, LCD contrast	V/F, set brightness, contrast, colour	
Self shoot	Camera	Normal, Mirror	For when panel is forward-facing	
Display aspect	Cam/Mcr	Auto, 4:3	Widescreen always appears letterboxed	
EVF color	Cam/Mcr	On, Off	For black/white V/F	
Rec counter	Camera	Total, Clip	Record counter	

CARD FUNCTIONS	**mode**	**range**	**comments**	**BBC**
Scene file	Camera	File select, Read, Write, Title reload	Save up to 4 scene files to P2 card	
User file	Camera	File select, Read, Write, Title reload	Save up to 4 file settings (not Scene) to SD card	
SD card format	Camera		Wipes the lot	

OTHER FUNCTIONS	mode	range	comments	BBC
User file	Cam/Mcr	Load, Save, Initial	After Load, turn power off/on to take effect	
Remote	Cam/Mcr	Off, 1, 2	Remote control access	
1394 control	Camera	Off, Ext, Both Chain	Backup via 1394, Ext controls remote deck with Start/Stop, Chain uses remote deck as extra recorder	
1394 cmd sel	Camera	RecP, Stop	Set remote deck to stop or pause	
PC mode	Cam/Mcr	USB device, 1394 device, 1394 host	1394 host controls external deck for backup	
Access led	Cam/Mcr	On, Off	Card access indicator	
Rec lamp	Camera	Off, Front, Rear, Both	Tally lamp	
Beep sound	Camera	On, Off	Warns of card/tape full	
Clock set	Cam/Mcr		Set clock/calendar. Really, honest, that's what it does	
Time zone	Cam/Mcr	-12~0~3	Time zone offset from GMT, for foreigners	
Power Save	Camera	On, Off	Disables 5-minute inactivity shut-down	
System freq	Cam/Mcr	59.94, 50		50
Menu init	Cam/Mcr		Factory reset for all menu items	
Operation	Cam/Mcr		Shows power-on time (5 digits per hour)	

Press Disp/Mode Chk button and Menu to get this menu, then Menu to cancel

OPTION MENU	mode	range	comments	BBC
1394 status	Cam/Mcr	Format, Rate, 60/50, Ch, Speed, Status, Video, Audio	IEEE1394 status info display	
1394 config	Cam/Mcr	Dflt, 1~255	1394 extended menus	

2 Measurement results

The HPX171 has no built-in test signal generator. This alone sets it apart from most professional and broadcast cameras. Thus measurements of the gamma curve are difficult, using optical test cards and an awful lot of data processing.

2.1 Transfer characteristic (gamma-correction)

By inspection, the available gamma curves seem to be identical to those of the HVX200, therefore, specific measurements were not made on this camera and the results for the HVX200 are quoted here, except for the overexposure range, which was confirmed as 250%.

The found equations for the *Hdnorm* curve are:

$$V = 4.5L \text{ for L<0.03, else } V = 1.05L\text{^}0.5 - 0.05$$

This is a reasonable match to ITU709, but is not perfect. The Knee causes the curve to break at signal levels of 80% (Low), 90% (Mid), 100% (High) and then extend to an exposure limit of 2.5 (250%) before clipping occurs at about 107%.

The ITU.709 curve, the nominal standard for all HDTV cameras is:

$$V = 4.5L \text{ for L<0.018, else } V = 1.0099L\text{^}0.45 - 0.099$$

The contrast range for the settings given in this document are derived from these equations. The maximum exposure the camera can handle is 250%, while the minimum exposure that is visible in the output can be defined as that which causes the signal voltage to be 2% of the coding range (the video level of the super-black bar in ARIB colour bars, used for setting display black level). Since the noise level is reasonably low, a lower point can be taken, 1% would be the normal minimum considered relevant here. For the *Hdnorm* curve, this defines the contrast capture range to be about 1100:1 (10.1 stops), quite good for a camera in this category. Measurements of the High (Black Stretched) gamma-correction curve produced a decent match to the BBC 0.4 law:

$$V = 5L \text{ for L<0.02262, else } V = \left(\left(L - 0.037703\right)/\left(1 - 0.037703\right)\right)\text{^}0.4$$

This gamma-correction curve generally produces more accurate colour rendering.

The user should generally choose one of these two curves for working in HDTV, *Hdnorm* produces more vivid colouring while *High* is more accurate. For normal use, *Knee* can be set to *Auto*, but when the production will be going to a colour grading operation, *Knee* should be set either to *Mid* or *Low*, depending on the type of programme (*Mid* for programmes where skin tone is prevalent, *Low* for natural-history).

The other variants of the gamma curve were not investigated; the descriptions given in the manual seem to be sufficiently accurate and explicit for the user to make an intelligent choice.

2.2 Resolution and Detail

The HPX171 is interesting in that the sensors do not appear to be native-resolution for HDTV. Although the specification does not say so, the 3 ccds are each 960 by 540 pixels spaced on a 5µm grid as in full-resolution 2"/3 1920x1080 sensors; it would be more usual to find sensors, in a 1080-line camera, having 1080 lines rather than only 540 but that would be at the expense of either sensitivity or video noise. Presumably, Panasonic chose to use these lower-resolution sensors in order to increase sensitivity (since the pixels are bigger, the same 5µm square dimension as is found in ⅔" format HDTV cameras). In most cameras with less-than-ideal numbers of pixels, the camera is made to deliver HDTV resolutions by physically offsetting the G sensor from R and B by a half-pixel both horizontally and vertically (It is normal to offset just horizontally, when the delivered horizontal resolution is apparently about 50% higher than would be dictated by the pixel count alone. This quincunx offset increases both horizontal and vertical resolution (just how well can only be judged by measurement) at the expense of introducing some coloured aliasing, similar to that from a Bayer-patterned single sensor. This is particularly relevant since the camera delivers signals at 1080, 720 and SDTV (both 576 and 480 lines in the two variants). Although this camera

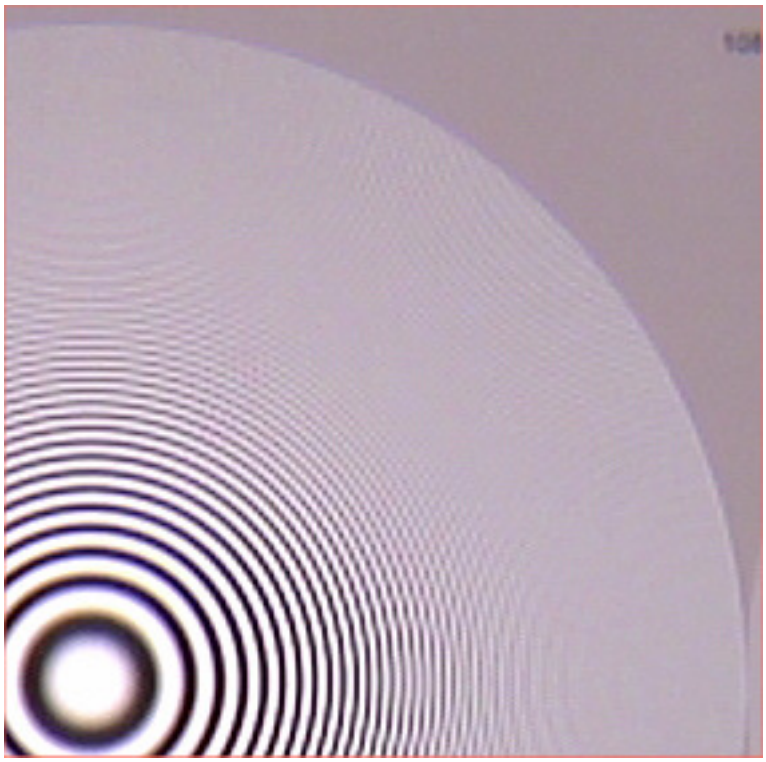
does have quincunx precision offset, there is only faint evidence of the diagonal aliases it inevitably produces, either the lens is a little soft, or the camera has good bi-refirngent optical filtering, or both.

A zone plate test chart was used, calibrated for 1920x1080 HDTV. It contains 6 circular patterns, each being a phase space of the spatial-frequencies (i.e. all possible frequencies in all possible directions) which such a camera should resolve. Analysis was made of one zone (in luma, or grey scale) to investigate the frequency responses and the presence of aliases.

2.2.1 Detail enhancement

The settings for the HVX200 were used here, since there seemed to be no good reason for changing them. Although this setting produces a little overshooting on edges (there was no setting in the HVX200 at which the overshoots were absent), *Detail level* settings of *0* and *-2* (horizontal and vertical) are still recommended, but the coring level can be lowered since the noise performance is rather good (see section 2.3, below).

2.2.2 Resolution (1080-line)



This is a quarter of one circular zone plate from the test chart, with zero-frequency at bottom left. The right-hand extreme is 1920 lines/picture width, the top extreme is 1080 lines/picture height. The alias patterns are clear (where the concentric circles are reversed, taking centres outside the pattern), and indicate that the camera does not deliver full resolution at 1080, either horizontally or vertically. However, it is reasonably well behaved, in that there do not appear to be significant aliases centred on other frequencies, as would be expected if the interpolation process from the 960x540 of the ccds were compromised in any way. The absence of coloured aliasing is evidence to support the supposition that nthere is no precision-offset of the sensors, and why there is no extension of the frequency response beyond 960x540.

The aliasing is not particularly strong, indicating that either there is probably good optical low-pass filtering (bi-refringent). The diagonal aliasing from the quincunx precision offset is well suppressed

The settings given in Section 1 are not ideal; they are a reasonable compromise, but overall performance of the camera is not a good match to other HDTV cameras in this respect, it is subjectively rather soft.

2.2.3 Resolution (576-line)

The down-converted zone plate pattern (to 576i) shows that the vertical filtering is better than the horizontal, since some new horizontal aliasing is clearly visible. Almost certainly, this is because the SD output is interlaced, and

the down-conversion is correctly limiting the vertical to that admissible in an interlaced signal. However, since the HDTV image is not particularly sharp anyway and relatively free from aliasing, the down-conversion is actually rather good.

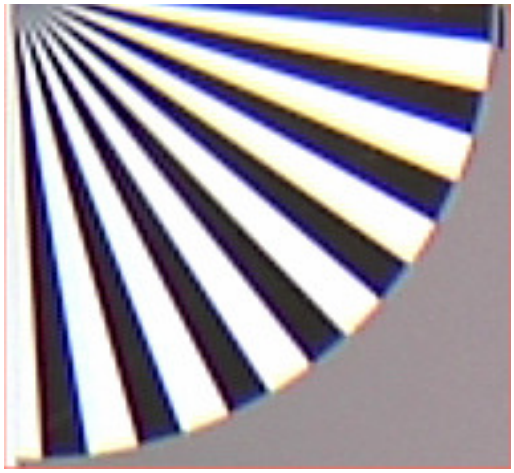
This is one of a very few HDTV cameras that makes a good SD picture.

2.2.4 Resolution (720-line)

Resolution at 720-line was not specifically tested since the BBC has little interest in 720p operation. However, since the 1080-line image is fairly soft, down-conversion to 720p should not introduce any new problems, a welcome change.

2.2.5 Lens aberrations

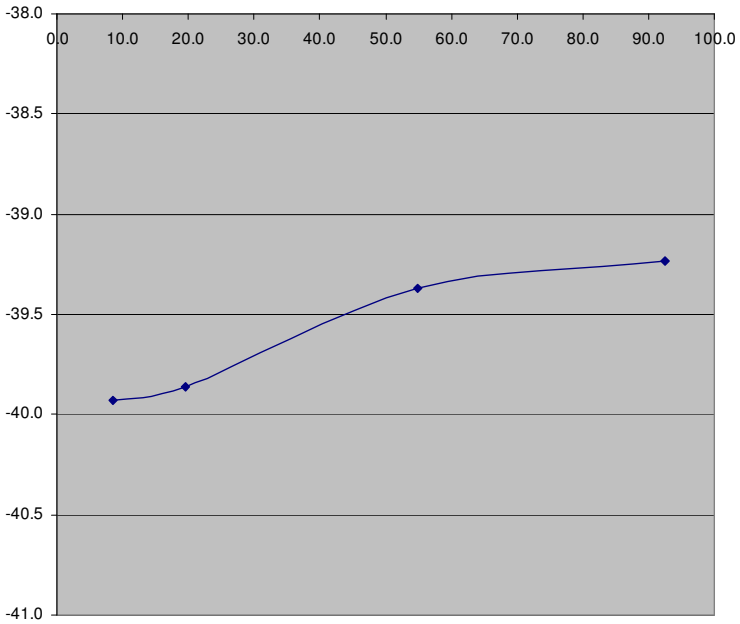
The lens showed some chromatic aberration in the corners. In this example, there a displacement of between 4 and 5 pixels. Thus is rather poor performance for an HD camera.



2.3 Noise

No calibrated noise meter was available during the measurement procedure, and the camera specification does not mention noise. Software analysis of captured frames gave some indication of performance. Measuring the signal-to-noise ratio at several signal levels, all at +12dB gain, produced noise levels from -39.2 to -40dB. Allowing for the 12dB gain in the camera, this means that the camera noise at 0dB gain must be about -52dB, quite good in any HDTV camera. This was confirmed by direct observation on the crt display and waveform monitor.

However, the noise level is normally expected to change with signal level, since it is primarily caused by the sensors and head amplifiers (before gamma correction) and thus should correlate with the slope of the gamma curve, typically by 10dB or more (noisier near black). There was no evidence of such a noise distribution.



One possible cause could be the use of head amplifiers with a limited gain-bandwidth product, this would produce softer pictures at low signal levels, and reduce the noise near black. It is very difficult to measure resolution at low signal levels, so it is almost impossible to establish whether this trick has been played. If it has, it has worked.

Another possible cause could be that the primary source of noise in this camera is the digital coding system rather than the sensors and heads amplifiers themselves. The performance measured is typical of 10-bit data in the linear signals, or 8-bits after gamma correction. DVCPROHD is an 8-bit recording system, so has a noise floor of about -54dB, but all measurements were made directly from the HDSDI output which would normally be expected to be 10-bit and to have a noise floor of around -70dB. However, on closer inspection, the data content of the HDSDI

feed was confirmed to be only 8-bit, even though 10 bits were output (i.e. the lowest 2 bits were permanently set to zero) and so a noise floor of about -54dB is appropriate.

Clearly, the camera noise performance is being limited by the nature of the digital processing. Nevertheless, it performs well in its class.