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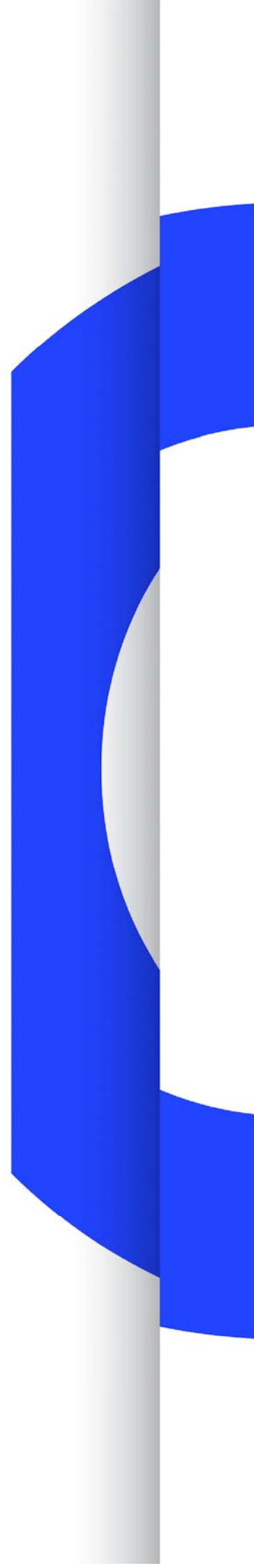
OPERATING EUROVISION AND EURORADIO

R 118

TIERING OF HIGH DEFINITION CAMERAS

VERSION 1.1

Geneva
August 2013



Conformance Notation

This document contains both normative text and informative text.

All text is normative except for that in the Introduction, any section explicitly labelled as 'Informative' or individual paragraphs which start with 'Note:'.

Normative text describes indispensable or mandatory elements. It contains the conformance keywords 'shall', 'should' or 'may', defined as follows:

- | | |
|----------------------------|---|
| 'Shall' and 'shall not': | Indicate requirements to be followed strictly and from which no deviation is permitted in order to conform to the document. |
| 'Should' and 'should not': | Indicate that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others.
OR indicate that a certain course of action is preferred but not necessarily required.
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| 'May' and 'need not': | Indicate a course of action permissible within the limits of the document. |

Default identifies mandatory (in phrases containing "shall") or recommended (in phrases containing "should") presets that can, optionally, be overwritten by user action or supplemented with other options in advanced applications. Mandatory defaults must be supported. The support of recommended defaults is preferred, but not necessarily required.

Informative text is potentially helpful to the user, but it is not indispensable and it does not affect the normative text. Informative text does not contain any conformance keywords.

A conformant implementation is one which includes all mandatory provisions ('shall') and, if implemented, all recommended provisions ('should') as described. A conformant implementation need not implement optional provisions ('may') and need not implement them as described.

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Tiering of High Definition Cameras

depending on their performance measured according to EBU Tech 3335

<i>EBU Committee</i>	<i>First Issued</i>	<i>Revised</i>	<i>Re-issued</i>
FT-V	2012	2013	

Keywords: UHD and HD Camera testing, Imaging performance, Tech 3335

Recommendation

The EBU, considering that,

- HDTV must have a minimum quality standard in order to satisfy the audience, the international exchange of programmes and the archive,

and that,

- currently the HD quality threshold may be beyond the capability of some platforms and equipment, and
- it is also unreasonable to expect some programme areas – primarily News – to be able to meet the HD standards under normal circumstances anywhere outside the News studio,

And in addition notes that,

- cameras with resolutions in excess of 1920 x 1080 are now widely used in the production of HD programmes.

Recommends that

a practical approach be taken to maximize the number of affordable HDTV programmes by acknowledging the current technology limitations and to grade, or *Tier* HD cameras according to their technical specifications and measured quality based on the results of tests that are specified in EBU Tech 3335.

Knowing which quality Tier a camera corresponds to will enable its targeting to programme genres and applications, a process that will help maintain the highest quality that is practical under a wide range of conditions and, in the case of News, to balance speed of delivery against quality.

Tiering criteria

The critical measurements required for tiering can be summarised as:

- Resolution
- Sensitivity
- Noise
- Alias
- Exposure Range
- Codec or recording format in line with the relevant EBU recommendation (e.g. EBU R 132 for HDTV cameras with recorders)

Recommended Tiers

The tiers can be summarised as:

UHD1 Tier 1:	Full Resolution Ultra High Definition Cameras capable of delivering the full UHD1 resolution of 3840 x 2160 or greater
UHD1 Tier 2:	Ultra High Definition Cameras with UHD1 outputs but deliver a resolution between 1920 x 1080 and 3840 x 2160
HD Tier SP:	Specialist or special effects cameras
HD Tier 1:	Shoulder mounted professional single or 3 sensor camera
HD Tier 2L:	(Long-form) professional cameras with 50 Mbit/s minimum recording codec and full resolution sensor
HD Tier 2J:	(Journalism) professional with 35 Mbit/s minimum recording codec and full resolution sensors
HD Tier 3:	Small, high quality semi-professional for production use
HD Tier 4:	Approved small consumer HD cameras

1. Criteria for camera tiering

1.1 Critical testing criteria

Although camera testing is a combination of analytical and subjective assessment, especially when a specific camera look is being designed, it is possible to distil the results down to five areas that are specific to the actual camera and (where applicable) to the on-board codec.

- Noise
- Sensitivity
- Exposure range
- Resolution
- Alias artefacts

Apart from spatial aliasing, each factor can be measured using the procedures of EBU Tech 3335.

1.1.1 Resolution

The camera should achieve the full resolution of the recording/production system. This requires sensors in 3-sensor cameras to have pixel-dimensions which are not less than those of the transmission system, or for a single-sensor camera to have significantly more pixels in order to do a satisfactory decode of the colour-patch pattern.

1.1.2 Sensitivity

It is only a matter of custom or tradition that sensitivity is an issue. A move from film or SDTV to HDTV will inevitably result in a change of camera sensitivity, since the pixels of a HDTV camera are much smaller than those of a SDTV camera of the same sensor size. Nevertheless, sensitivity affects lighting levels, and so can be a major factor in camera choice

1.1.3 Noise

The video noise level (usually expressed as Peak-Signal-to-Noise-Ratio, PSNR) should be such that compression artefacts are not generated by the noise level. This can be compounded by spatial aliasing.

1.1.4 Spatial Aliasing

Ideally, no spatial-frequency content in the scene should cause aliasing in the camera. Aliasing causes motion-dependent video compression to fail in the extreme, since the aliased frequencies cancel motion detection. Aliasing is also highly distracting in a finished programme as it tends to move in the opposite direction to the movement of the camera, therefore drawing the viewers' attention to the effect.

1.1.5 Exposure Range

The greater the exposure range, the easier the camera is to use. It is limited at the low end by noise levels, and at the high end by the clipping level. The clipping level can often be manipulated in the camera to use any over-exposure range which the sensors may have (since it is unusual for the sensors themselves to clip at the conventional peak white signal level). However, this is only at the expense of using either a film-type optoelectronic transfer curve (gamma) or a conventional curve with an additional non-linearity. Either of these may be acceptable form some production genres, but neither may be suitable for others.

1.2 *Codec or recording format*

Although a camera can meet the requirements of a Tier (or standard) it may be let down (or even downgraded by an on-board codec. EBU R 132 recommends minimum acquisition codec.

- 50 Mbit/s 4:2:2 minimum for MPEG-2 based inter-frame codecs.
- 100 Mbit/s 4:2:2 minimum for intra-frame codecs.

Additionally, AVCHD above 35 Mbit/s 4:2:0 may be acceptable provided all post processing is carried out in the native camera codec.

For Journalism/News these standards can be relaxed to allow the use of.

- 35 Mbit/s MPEG-2 based inter-frame codecs at 4:2:0.
- 50 Mbit/s AVC intra-frame codecs at 4:2:0.

Additionally, AVCHD at a minimum of 24 Mbit/s 4:2:0 may be acceptable

Note: This does not apply to UHD1 Tiers 1 and 2. Guidance on UHD codecs is given in § 2.1 and § 2.2

2. Guidance on Camera Tiers

Based on the physical or operational parameters of a camera and the scoring of the key points in § 3.1, a camera can be placed in a tier.

As camera and codec technology develops there will inevitably be a quality overlap between cameras in adjacent tiers, however operational parameters will always be the primary factor in camera category selection.

It is possible for a camera to be in two adjacent tiers if external accessories can be used to change the score e.g. an external recorder that meets the requirements of § 1.2 where the internal does not.

2.1 UHD1 Tier 1

These cameras offer the full UHD1 3840 x 2160 resolution. They are usually single sensor cameras with an image size approximately the same as the 35 mm film image size. These cameras have a shallow depth of field and are primarily used for Fiction (Drama) productions.

- minimum sensor size 1",
- minimum sensor pixel count is a minimum of 3840 x 2160 in each of R & G & B,¹
- minimum 10-bit processing but 12 (or higher) preferred,
- 4:4:4 capable,
- interchangeable lenses with a quality commensurate with the cameras use,
- timecode gen-lock.

On-board codec can either be a full resolution RAW format or a UHD H264 based codec of 200 Mbit/s or better.

2.2 UHD1 Tier 2

These cameras have a UHD output but a sensor that does not offer the full UHD 3840 x 2160 resolution. They are usually single sensor cameras with an image size approximately the same as the 35 mm film image size. These cameras have a shallow depth of field and are primarily used for Fiction (Drama) productions.

- minimum sensor size 1",
- sensor pixel count must be greater than 2880 x 1620
- 10-bit processing but higher preferred,
- 4:2:2 but 4:4:4 preferred,
- interchangeable lenses with a quality commensurate with the cameras use,
- timecode gen-lock.

¹ The actual resolution of a UHD1 Tier 1 camera may have be confirmed by measurement as described in EBU Tech 3335

On-board codec can either be a full resolution RAW format or a UHD H264 based codec of 200 Mbit/s or better.

2.3 HD Tier SP

Specialist or special effects cameras including very high frame rate camera, minicams, macro cameras etc.

- minimum active sensor size at least 1280 x 720 three sensor or 1920 x 1080 single sensor,
- minimum 1280 x 720 output resolution,
- 35 Mbit/s AVCHD is acceptable but a minimum 50 Mbit/s MPEG-2 based inter-frame or 100 Mbit/s intra-frame 4:2:2 is preferred for cameras with internal recording,
- minimum 3x 1/4" sensor size (1/3" preferred).

Cameras that do not meet some of the minimum HD requirements can be included in the SP Tier if they offer a unique facility as they may represent the best that can be done with current technology.

This does mean however that a camera can be removed from the Tier if another matching the operational specifications of the current version meets the requirements of HD Tier 1 or HD Tier 2L.

2.4 HD Tier 1

Tier 1 cameras can be used without restriction on any high definition programme. They are usually shoulder mounted or system (studio) cameras with interchangeable lens mounts.

On-board codec scores could exclude a camera from the Tier but if the camera quality is high enough an external recorder is permitted.

Cameras will meet the Tier 1 criteria laid out in § 3.

2.4.1 Three Sensor

- minimum 50 Mbit/s inter-frame or 100 Mbit/s intra-frame (if applicable),
- 4:2:2 (or 4:4:4) 10-bit recording (if applicable),
- minimum 3x 1/2" 1920 x 1080 sensors size but 2/3" preferred,
- capable of shoulder mount,
- interchangeable lens,
- timecode gen-lock.

2.4.2 Single Sensor

These cameras will meet all the criteria expected of three sensor HD Tier 1 cameras but are differentiated by the sensor size and type. They have a single sensor cameras with an image size approximately the same as the 35 mm film image size. These cameras have a shallow depth of field and are primarily used for Fiction (Drama) productions.

- minimum sensor size 1",
- minimum sensor pixel count is 2880 x 1620 (Bayer pattern),

- minimum on-board recording format is 100 Mbit/s inter-frame,
- 4:2:2 or 4:4:4,
- interchangeable lenses with a quality commensurate with the cameras use,
- timecode gen-lock.

2.5 HD Tier 2L

Tier 2 Long-form programmes are defined as any programmes that are not news (or journalism)! Tier 2L cameras may have certain restrictions for unlimited high definition use by some broadcasters. They are “professional” handheld or shoulder-mounted cameras,

- minimum 50 Mbit/s inter-frame or 100 Mbit/s intra-frame,
- 4:2:2 at 8-bit or 10-bit recording (10-bit preferred),
- minimum 3x 1/2" 1920 x 1080 sensor size¹, OR a single 2/3" 2880 x 1620 (Bayer pattern),
- 2x external balanced line/mic audio inputs.

Cameras will meet the Tier 2L criteria laid out in § 3.

2.6 HD Tier 2J

Tier 2 Journalism cameras are fundamentally the same as Tier 2L however there is a relaxation of some of the criteria to take account of the balance between speed to air and quality that News programmes may have to make.

- 35 Mbit/s (minimum) AVCHD is acceptable but a minimum 35 Mbit/s MPEG-2 based inter-frame or 50 Mbit/s AVC intra-frame recording is preferred,
- 4:2:2 or 4:2:0 can be 8 or 10-bit but 10-bit is preferred,
- minimum 3x 1/3" 1440 x 1080 sensor size 1920 x 1080 preferred,
- 2x external balanced line/mic audio inputs.

Cameras will meet the Tier 2J criteria laid out in § 3

2.7 HD Tier 3

Small, high quality semi-professional or similar with broadcast audio capability. Broadcasters will usually limit the amount of Tier 3 material allowed in an HD programme to around 33% and may restrict the type of scene the cameras are used to acquire.

- minimum 24 Mbit/s AVC-HD codec,
- 4:2:0,
- minimum 3x 1/4" 1280 x 720 sensors (1/3" preferred) or 1/2" single sensor 1920 x 1080,
- 2x external mic/line audio inputs.

Cameras will meet the Tier 3 criteria laid out in the § 3.

Broadcasters may restrict the amount of Tier 3 camera material used in a programme and can

¹ Cameras with 3x 1/3" sensors that meet the testing requirement of EBU Tech 3335 can be classified at Tier 2L.

specify how and when these cameras are used.

2.8 HD Tier 4

Cameras in Tier 4 need not necessarily meet specific technical standards. They are more likely to integrate into the contribution and post production system easily and without intervention or transcoding. Tier 4 cameras should however have a native 16:9 sensor, removable or easily downloaded media and use a non-proprietary codec.

Outside these criteria, Tier 4 cameras are selected by the broadcaster to meet operational requirements

There are no specific technical specifications for Tier 4 cameras and broadcasters *will* restrict the amount and type of material a programme can use.

3. Results Criteria

There is no absolute scoring mechanism that can be used to calculate a camera's Tier position however there is an expectation that a camera's overall performance meets the requirements of the relevant Tier.

Each of the five camera criteria shall be measured in line with the relevant section of Tech 3335.

Noise	Tech 3335 § 2.2
Sensitivity	Tech 3335 § 2.3
Exposure range	Tech 3335 § 2.4
Resolution	Tech 3335 § 2.7
Alias artefacts	Tech 3335 § 2.7
Onboard codec	As defined in this document

It should be noted that a camera's resolution and the internal codec (if applicable) can be used as an absolute guide to the appropriate Tier.

3.1 Assessment Guidance

3.1.1 Noise

Noise should be rated by its impact and visibility as well as by measurement. The distribution and type of noise can mean a poor S/N measurement has less impact on the actual image quality than a camera with a better S/N measurement but where the noise distribution may be more disturbing.

Cameras in UHD1 Tier 1 & 2 and HD Tier 1 should have a better signal to noise ratio than cameras in other tiers. Both UHD1 Tiers should measure better than 50dB and HD Tier 1 better than 48dB but measurements must be assessed along side visual inspection.

Tier	Appropriate S/N	Notes
UHD1 Tier 1	Better than -50dB @ 0dB gain	Should be considered a minimum if the output is aimed at cinema release as well as television broadcast
UHD1 Tier 2	Better than -50dB @ 0dB gain	For guidance however a good S/N ratio is a requirement
HD Tier SP	Better than -42dB @ 0db gain	S/N may be worse for some specialist cameras
HD Tier 1	Better than -48dB @ 0db gain	For guidance however a good S/N ratio is a requirement (Note)
HD Tier 2L	Better than -44dB @ 0db gain	Guidance only
HD Tier 2J	Better than -44dB @ 0db gain	Guidance only
HD Tier 3	Better than -40dB @ 0db gain	For guidance - S/N may vary with broadcaster requirement
HD Tier 4	N/A	Not a requirement for Tier 4 cameras

Note: Some camera menus allow negative gain settings (with respect to the published 0dB). It is therefore possible to improve the S/N ratio using a negative (lower) gain setting.

3.1.2 Sensitivity (F Measurement)

Measure the exposure lens aperture, at 2000 lux illumination level and 0dB gain (or the recommended nominal gain setting), at which the white side of a Kodak Gray card produces peak white signal level (100%). This must be done either with all gamma-correction switched off, or with a standard gamma-correction curve having no knee compression.

Since the reflectance of Kodak Gray white is approximately 90%, the exposure figure should match the manufacturer's specification (normally taken for a white card with 89.9% reflectance).

3.1.3 Exposure Range

This may be more important for cameras used by less experienced operators than cameras used by Directors of Photography with far greater experience of exposure and lighting. A Director of Photography however, will be able to exploit the wider exposure range for artistic effect.

In general, the greater the exposure range, the better the camera.

3.1.4 Resolution

Camera resolution determines a camera's Tier position. The measured video output resolutions of the various Tiers are as follows:

- UHD1 Tier 1 sensor resolution must be 3840 x 2160 in each of R & G & B. Where other sensor matrix technologies are employed, the actual resolution may have to be confirmed by measurement (EBU Tech 3335). As guide, a Bayer pattern sensor would need to be at least 5760 x 3240 to achieve full UHD1 resolution.
- UHD1 Tier 2 sensor resolution must be greater than 2880 x 1620 in each of R & G & B.
- HD Tier SP camera must be a minimum of 1280 x 720 native resolution
- HD Tier 1 (three sensor) must be 1920 x 1080 native resolution
- HD Tier 1 (single sensor) at least 2880 x 1620 (Bayer pattern) or 1920 x 1080 after processing
- HD Tier 2L (three sensor) must be 1920 x 1080 or a single sensor of at least 2880 x 1620
- HD Tier 2J should be 1920 x 1080 however a minimum of 1280 x 720 is acceptable. Techniques to increase the perceived resolution, such as pixel offset, are acceptable.
- HD Tier 3 camera should be at least 1280 x 720
- HD Tier 4 camera is decided by the broadcaster, based on how consumer devices are used in

the organisation concerned.

3.1.5 Aliasing

Cameras should not exhibit high levels of aliasing, at any spatial frequency. Spatial aliasing is evidence that the lens is passing spatial frequencies to the sensor, at frequencies beyond the limits of the camera. This will normally not be acceptable for cameras in UHD1 Tier 1 & 2, HD Tier 1 and 2L, although some may be permissible in HD Tiers SP and 3.

HD Tier 4 cameras may be selected for “other” reasons but it is recommended alias artefacts are checked and the response is part of the selection procedure for cameras in this tier.

3.1.6 Codecs

Camera codecs are an absolute measure of a camera/recorder combination. It does not matter in which Tier tests place a camera, the combination will sit in the codec's Tier (that is unless the tests indicate a camera should be in a lower Tier than the codec!).

Codec	EBU R (xxx) ¹	200 Mbit/s H.264 or full resolution RAW	UHD 1 & 2	4:4:4 10-bit preferred
	EBU R 132	100 Mbit/s AVCi or higher	HD 1 & 2L	4:2:2 8-bit acceptable but 10-bit preferred
		50 Mbit/s MPEG-2 (inter) or higher		
		35 Mbit/s MPEG-2 (inter) or higher	HD 2J	4:2:0 8-bit minimum
	'Pro-sumer'	35 Mbit/s AVC-HD or higher	HD 3	4:2:0 8-bit minimum
		H.264 based codec	HD 4	-

3.1.7 UHD cameras with 4k sensors

Where a camera produces an image that is actually 4096 x 2160 (4k), UHD programmes should be extracted by cropping the image to 3840 x 2160 and not by scaling. HD programmes should be produced by cropping before the image is down conversion to 1920 x 1080 (or 1280 x 720).

¹ At time of publishing, R (xxx) is being drafted. When this document becomes available, its correct number will be entered in the table and this note will be removed.

Annex 1: Example of Tiering Table

Tier	Camera	Details	Comments (examples)	Type
UHD1	Camera 1	1 x 1" or larger	Large sensor for Fiction and Documentary 2/3" sensor for Sport etc.	Camcorder System
	Camera 2	3 x 2/3" sensor		
UHD2	Camera 3	1 x 1" or larger	Large sensor for Fiction and Documentary 2/3" sensor for Sport etc.	Camcorder System
	Camera 4	3 x 2/3" sensor		
HD SP	Camera 5	Sensor size & type	Limitations or restrictions	POV/Helmet/ Covert etc.
HD 1	Camera 6	System 3 x 2/3"	Triax or Fibre, Viewfinder etc. Lens adapter Connection details	System
	Camera 7	Shoulder 2 x 2/3"		Camcorder
	Camera 8	Box 3x 1/2"		Box
	Camera 9	1 x 1"		TBA
HD 2L	Camera 10	3x 1/2"	MPEG-2 10-bit 4:2:2 AVCi 100 Mbit/s MPEG-2/AVCi	Camcorder
	Camera 11	3x 1/3" CMOS		Camcorder
	Camera 12	3x 2/3"		Camcorder
	Camera 13	1 x 2/3"		TBA
HD 2J	Camera 14	3x 1/2" 35 Mbit/s	2L with an external recorder	Camcorder
	Camera 15	3x 1/3" AVCi 50 Mbit/s		Camcorder
	Camera 16	3x 1/3" 35 Mbit/s	Limited lens types available	Camcorder
HD 3	Camera 17	3x 1/4"	AVC HD 24 Mbit/s, IR capable, Use restrictions	POV/Helmet/ Covert etc.
HD 4	Camera 18	1x 1/8"	H.264 (variant details), Use restrictions	Phone