

EBU

OPERATING EUROVISION AND EURORADIO

R 118

TIERING OF CAMERAS FOR USE IN TELEVISION PRODUCTION

VERSION 2

Geneva
April 2017



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.
OR indicate that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.
- '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") pre-sets that can, optionally, be overwritten by user action or supplemented with other options in advanced applications. Mandatory defaults shall 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.

Contents

Recommendation	7
1. Criteria for camera Tiering	9
1.1 Critical testing criteria	9
1.2 Recommended Tiers.....	9
1.3 Codec or recording format.....	9
1.3.1 Codec Categories	10
1.3.2 Codec for Tiers.....	10
2. Guidance on Camera Tiers	11
2.1 Camera Tier Overview	11
2.2 UHD2 Tier 1	11
2.2.1 Three Sensor.....	11
2.2.2 Single Sensor	12
2.3 UHD2 Tier 2.....	12
2.3.1 Three Sensor.....	12
2.3.2 Single Sensor	12
2.3.3 Four Sensor for Bayer pattern	13
2.4 UHD1 Tier 1	13
2.4.1 Three Sensor.....	13
2.4.2 Single Sensor	13
2.5 UHD1 Tier 2.....	13
2.5.1 Three Sensor.....	13
2.5.2 Single Sensor	14
2.6 Tier SP	14
2.7 HD Tier 1	14
2.7.1 Three Sensor.....	14
2.7.2 Single Sensor	15
2.8 HD Tier 2	15
2.8.1 HD Tier 2 criteria	15
2.9 HD Tier 3	15
2.10 HD Tier 4.....	16
3. Results Criteria	16
3.1 Assessment Guidance	16
3.1.1 Noise	16
3.1.2 Sensitivity (F Measurement)	17
3.1.3 Exposure Range	17
3.1.4 Spatial Resolution	18
3.1.5 Spatial Aliasing.....	18
3.1.6 UHD with cinematic sensor ratios (4k & 8k)	18

Tiering of HD & UHD Cameras for use in Television Production

<i>EBU Committee</i>	<i>First Issued</i>	<i>Revised</i>	<i>Re-issued</i>
BHD	2012	2013, 2015, 2017	

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

Recommendation

The EBU, considering that,

- UHD and HD TV shall have minimum quality standards in order to satisfy the audience, the international exchange of programmes and the archive,

and that,

- quality thresholds may be beyond the capability of some platforms and equipment,
- it is unreasonable to expect some programme production techniques to be able to meet the required quality standards under normal circumstances,

and in addition notes that,

- production companies are using a range of cameras where the photo site count does not always directly align to the pixel count (1920 x 1080, 3840 x 2160 or 7680 x 4320) of the finished programme.

Recommends that,

a practical approach be taken to the grading, or *Tiering* of cameras according to their technical specifications and their 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.

Notes: Many cameras can acquire a significant higher image dynamic range than conventional Standard Dynamic Range television however; these guidelines assume Standard Dynamic Range production. The broadcaster must be consulted if High Dynamic Range (as described in ITU-R BT.2100) images are required especially about the use of RAW codecs and about the use of High Dynamic Range gamma curves in camera.

Frame rates of 25 and 50 fps are explicitly mentioned in this document but this does not preclude the use of other frame rates specified in ITU-R BT.709 (HD) and ITU-R BT.2020 (UHD).

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.

- Codec (does not apply to system cameras unless on-board recording is used)
- Noise
- Sensitivity
- Exposure Range
- Spatial Resolution
- Spatial Alias artefacts

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

1.2 Recommended Tiers

The tiers can be summarised as:

UHD2 Tier 1:	Full Resolution Ultra High Definition Cameras capable of delivering the full UHD2 measured output resolution equivalent to 7680 x 4320.
UHD2 Tier 2:	Ultra High Definition Cameras with UHD2 outputs which deliver a measured output resolution equivalent to at least 5430 x 3054.
UHD1 Tier 1:	Full Resolution Ultra High Definition Cameras capable of delivering the full UHD1 measured output resolution equivalent to 3840 x 2160.
UHD1 Tier 2:	Ultra High Definition Cameras with UHD1 outputs which deliver a measured output resolution equivalent to at least 2715 x 1527.
Tier SP:	Specialist or special effects cameras (broadcaster approval required before use).
HD Tier 1:	Shoulder mounted or handheld single or 3 sensor professional cameras.
HD Tier 2L:	(Long-form) professional cameras.
HD Tier 2J:	(Journalism) professional cameras.
HD Tier 3:	Small, high quality semi-professional for production use.
HD Tier 4:	Small consumer HD cameras (broadcaster approval required before use).

1.3 Codec or recording format

Compression technology continuously develops and becomes more efficient with each new generation. Codecs also employ toolsets to improve efficiency, which means the “bit rate” alone for a given codec is no longer an adequate parameter for a quality assessment.

Some cameras offer the facility to add new codecs or upgrade existing installed codecs by means of software updates.

Note: Although a camera can meet the requirements of a Tier, it may be let down (or even be downgraded) by the on-board codec.

1.3.1 Codec Categories

To assist users, codecs have been divided into three categories,

1. **Raw Image Format (RAW).** These are usually vendor-proprietary formats that offer the sensor information with little or no processing. For the purposes of this document it will be assumed the RAW codec cannot change the Tier of a camera BUT as they are proprietary it is recommended that new or unknown versions are evaluated on a case-by-case basis.
2. **Intra Frame (I-Frame).** I-Frame codecs do not employ temporal compression, meaning each frame is processed alone. I-Frame codec implementation bit rates are generally much higher than the Long GoP equivalent. One advantage of I-Frame codecs is that they generally require less processing power in downstream operations than Long GoP codecs.
3. **Inter Frame (Long GoP).** Long GoP codecs offer most bit rate reduction for a given quality by looking and processing across multiple frames. To a point, the longer the “GoP” the more efficient the codec BUT the more processing power is required in downstream operations.

1.3.2 Codec for Tiers

Table 1: Codec parameters for Camera Tiers

Codec Type	Tier	GoP	Options (minimum)	Minimum Bit Rate (Mbit/s) ¹	
				25 fps	50 fps
RAW	All	N/A	Proprietary - User shall check	N/A	
Intra (ALL)	UHD2 1&2	N/A	4:2:0, 4:2:2 or 4:4:4 ¹	750	1500
	UHD1 1&2			250	500
	HD 2L & Above			100	200
	HD 2J and below			50	75
H.262 MPEG-2	UHD	N/A	Not to be used	N/A	
	HD 2L & above	0.5s	4:2:2 Interlace, 4:2:0 progressive	50	75
	HD 2J and below		4:2:0 (4:2:2 preferred)	35	50
H.264 AVC Main 10	UHD2 1&2	V ²	4:2:0, 4:2:2 or 4:4:4	400	600
	UHD1 1&2			150	250
	HD 2L & above	V	4:2:2 Interlace, 4:2:0 progressive	25	35
		0.5s		35	50
	HD 2J and below	V		15/12 ³	25
		0.5s		25	35
H.265 ⁴ HEVC Main 10	UHD2 1&2	V	4:2:0, 4:2:2 or 4:4:4	300	500
	UHD1 1&2			100	180
	HD 2L & above	V	4:2:2 Interlace, 4:2:0 progressive	20	35
		0.5s		25	30
	HD 2J and below	V		12	15
		0.5s		20	25

¹ The bit rates given are the MINIMUM for general-purpose 10-bit Standard Dynamic Range content. Post Production processing requirements, high value and Co-Produced programmes will often be required to use higher values as will the use of 4:4:4 codec options where available.

² V = Variable and not constrained to a maximum length.

³ It is recommended that the use of 12 Mbit/s be fully discussed with the broadcaster before use.

⁴ H.265 (HEVC) codec data rates are under review and will be revised as required. The Broadcaster **must** be consulted before using a H.265 camera codec.

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 recorder does not.

For resolution information about pixel count and output signal measurement requirements with section 3 “Spatial Resolution”.

2.1 Camera Tier Overview

Table 2: Camera Tiers Overview

Camera Tier	Sensor	Recommended sensor size	Measured output equivalent to:	Minimum Signal Processing	Preferred options
UHD2 Tier 1	Single	1 x 1”	7680 x 4320	10-bit (12-bit preferred) 4:4:4 or 4:2:2 or 4:2:0	Capable of shoulder mount Interchangeable lens External timecode input Interchangeable or fixed lens External timecode input preferred 2 x external mic/line inputs
	Three	3 x 1”			
UHD2 Tier 2	Single	1 x 1”	5430 x 3054	10-bit (12-bit preferred) 4:2:0	
	Three	3 x 1”			
	Four	4 x 1”			
UHD1 Tier 1	Single	1 x 1”	3840 x 2160	10-bit (12-bit preferred) 4:4:4 or 4:2:2 or 4:2:0	
	Three	3 x 2/3”			
UHD1 Tier 2	Single	1 x 2/3”	2715 x 1527	10-bit (12-bit preferred) 4:2:0	
	Three	3 x 1/2”			
HD Tier 1	Single	1 x 2/3”	1920 x 1080	10-bit 4:2:2	
	Three	3 x 1/2”			
HD Tier 2L	Single	1 x 1/2”	1920 x 1080	8-bit (10-bit preferred) 4:2:2	
	Three	3 x 1/3”			
HD Tier 2J	Single	1 x 1/3”	1280 x 720	8-bit (10-bit preferred) 4:2:0 (4:2:2 preferred)	
	Three	3 x 1/4”			
HD Tier 3	Single	1 x 1/3”	1280 x 720	8-bit (10-bit preferred) 4:2:0 (4:2:2 preferred)	
	Three	3 x 1/4”			
HD Tier 4	Broadcaster to advise (see § 2.10)				
Tier SP	Broadcaster to advise (see § 2.6)				

2.2 UHD2 Tier 1

UHD2 Tier 1 cameras can be used without restriction on any programme.

All cameras shall offer the full UHD2 7680 x 4320 resolution. They can be either single or three sensor.

2.2.1 Three Sensor

- minimum 3 x 1" sensors but smaller sensors may be acceptable subject to testing,
- output signal measurement is equivalent to 7680 x 4320,
- see Table 1 for codec requirements,
- capable of shoulder mount,
- interchangeable lens preferred but fixed lens may be acceptable subject to testing,
- minimum 10-bit processing but 12-bit preferred,
- 4:4:4 processing capable,
- external timecode input optional but preferred.

2.2.2 Single Sensor

- minimum sensor size 1" but smaller sensors may be acceptable subject to testing,
- output signal measurement is equivalent to 7680 x 4320,
- see Table 1 for codec requirements,
- capable of shoulder mount,
- interchangeable lens preferred but fixed lens may be acceptable subject to testing,
- minimum 10-bit processing but 12-bit preferred,
- 4:4:4 processing capable,
- external timecode input optional but preferred.

2.3 UHD2 Tier 2

These cameras have a UHD2 output but have a sensor or processing that does not offer the full UHD2 7680 x 4320 resolution. There may be restriction placed on the use of UHD2 Tier 2 by some broadcasters. UHD2 Tier 2 cameras can be used without restriction for UHD1 and HD programmes.

2.3.1 Three Sensor

- minimum 3 x 1" sensors but smaller sensors may be acceptable subject to testing,
- output signal measurement is greater than 5430 x 3054,
- see Table 1 for codec requirements,
- capable of shoulder mount,
- interchangeable lens preferred but fixed lens may be acceptable subject to testing,
- minimum 10-bit processing but 12-bit preferred,
- 4:2:0 processing or better,
- external timecode input optional but preferred.

2.3.2 Single Sensor

- minimum sensor size 1" but smaller sensors may be acceptable subject to testing,
- output signal measurement is greater than 5430 x 3054,
- capable of shoulder mount,
- see Table 1 for codec requirements,
- interchangeable lens preferred but fixed lens may be acceptable subject to testing,
- minimum 10-bit processing but 12-bit preferred,
- 4:2:0 processing or better,
- external timecode input optional but preferred.

2.3.3 Four Sensor for Bayer pattern

- minimum 4 x 1" but smaller sensors may be acceptable subject to testing,
- output signal measurement is greater than 5430 x 3054,
- capable of shoulder mount,
- see Table 1 for codec requirements,
- interchangeable lens preferred but fixed lens may be acceptable subject to testing,
- minimum 10-bit processing but 12-bit preferred,
- 4:2:0 processing or better,
- external timecode input optional but preferred.

2.4 UHD1 Tier 1

UHD1 Tier 1 cameras can be used without restriction on any but UHD2 programmes.

UHD1 Tier 1 cameras shall offer the full 3840 x 2160 resolution. They can be either single or three sensor.

2.4.1 Three Sensor

- minimum 3 x 2/3" sensors but smaller sensors may be acceptable subject to testing,
- output signal measurement is equivalent to 3840 x 2160,
- see Table 1 for codec requirements,
- capable of shoulder mount,
- interchangeable lens preferred but fixed lens may be acceptable subject to testing,
- minimum 10-bit processing but 12-bit preferred,
- 4:4:4 processing capable,
- external timecode input optional but preferred.

2.4.2 Single Sensor

- minimum sensor size 1" but smaller sensors may be acceptable subject to testing,
- output signal measurement is equivalent to 3840 x 2160,
- see Table 1 for codec requirements,
- interchangeable lens preferred but fixed lens may be acceptable subject to testing,
- minimum 10-bit processing but 12-bit preferred,
- 4:4:4 processing capable,
- external timecode input optional but preferred.

2.5 UHD1 Tier 2

These cameras have a UHD1 output but have a sensor or processing that does not offer the full UHD1 3840 x 2160 resolution. There may be restriction placed on the use if UHD1 Tier 2 by some broadcasters. UHD1 Tier cameras can be used without restriction for HD programmes.

They are usually single sensor but three sensor cameras where the sensor size is 1/2" or less fall in this Tier.

2.5.1 Three Sensor

- minimum 1/2" sensors but smaller sensors may be acceptable subject to testing,
- output signal measurement is greater than 2715 x 1527,
- see Table 1 for codec requirements,
- capable of shoulder mount,
- interchangeable or fixed lens,

- minimum 10-bit processing but 12-bit preferred,
- 4:2:0 processing or better,
- external timecode input optional but preferred.

2.5.2 Single Sensor

- minimum sensor size 2/3" but smaller sensors may be acceptable subject to testing,
- output signal measurement is greater than 2715 x 1527,
- see Table 1 for codec requirements,
- interchangeable lens preferred but fixed lens may be acceptable subject to testing,
- minimum 10-bit processing but 12-bit preferred,
- 4:2:0 processing or better,
- external timecode input optional but preferred.

2.6 Tier SP

Tier SP cameras are specialist or special effects cameras including very high frame rate camera, minicams, macro cameras etc. that do not meet some of the minimum requirements for a given Tier.

Tier SP cameras will have restrictions on the amount used in a programmes but this content does not usually count against any percentage of lower resolution material in the programme.

A camera can be included in the SP Tier if it offers a unique facility that represent the best that can be achieved with current technology. This does mean however that a camera can be removed from the Tier should another that matches or exceeds the minimum operational specifications of the target Tier, become available.

- Cameras can be single or three sensor.
- The sensor(s) pixel count should preferably be in a 16:9 or "4k" ratio, but other aspects ratios can be used.
- Where possible, data rates for recording or any radio links should match the requirements for the target Tier in Table 1

Table 3: Tier SP minimum requirements

	HD	UHD1	UHD2
Measured minimum resolution	1280 x 720	1920 x 1080	3840 x 2160
Processing minimum	8-bit	10-bit	10-bit

2.7 HD Tier 1

Tier 1 cameras can be used without restriction on any high definition programme.

- HD Tier 1 cameras shall offer the full 1920 x 1080 resolution. They can be either single or three sensor.

2.7.1 Three Sensor

- minimum 3 x 1/2" sensors but smaller sensors may be acceptable subject to testing,
- output signal measurement is equivalent to 1920 x 1080,
- see Table 1 for codec requirements,
- capable of shoulder mount,
- interchangeable or fixed lens,
- 10-bit processing preferred,

- 4:2:2 processing,
- external timecode input optional but preferred.

2.7.2 Single Sensor

- minimum sensor size 2/3" but smaller sensors may be acceptable subject to testing,
- output signal measurement is equivalent to 1920 x 1080,
- see Table 1 for codec requirements,
- interchangeable or fixed lens,
- 10-bit processing preferred,
- 4:2:2 processing,
- external timecode input optional but preferred.

2.8 HD Tier 2

HD Tier 2 has been split into two options based on the type of programme material they are being used to capture.

HD Tier 2L (Long-form) is aimed at general HD productions where there is no co-production, sales requirements or where extensive colour or image size processing will not be carried out during post production (e.g. chroma-key, CG, resizing etc.). HD Tier 2L cameras may have certain restrictions for unlimited high definition use by some broadcasters. They are “professional” handheld or shoulder-mounted cameras.

HD Tier 2J (Journalism) cameras are fundamentally the same as HD 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.

Both Tier 2 options can either be single or three sensor, cameras can have interchangeable or fixed lenses and an external timecode input is preferred.

See Table 1 for details of codec bit rates.

2.8.1 HD Tier 2 criteria

The minimum criteria for HD Tier 2 are detailed in Table 4.

Table 4: HD Tier 2 criteria

	HD Tier 2L		HD Tier 2J	
	Three Sensor	Single Sensor	Three Sensor	Single Sensor
Minimum sensor size	1/3"	1/2"	1/4"	1/3"
Minimum pixel count	1920 x 1080	2880 x 1620	1280 x 720	1920 x 1080
Minimum bit depth processing	8-bit	8-bit	8-bit	8-bit
Colour sub sampling	4:2:2	4:2:2	4:2:0	4:2:0

2.9 HD Tier 3

HD Tier 3 are small, high quality semi-professional or similar cameras 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 3 x 1/4" 1280 x 720 sensors or 1/3" single sensor 1920 x 1080,
- see Table 1 for codec requirements,

- 2x external mic/line audio inputs.

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

2.10 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 preferably 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.

Table 5: Tech 3335 References

Criteria	Section
Noise	Tech 3335 § 2.2
Sensitivity	Tech 3335 § 2.3
Exposure range	Tech 3335 § 2.4
Spatial Resolution	Tech 3335 § 2.7
Alias artefacts	Tech 3335 § 2.7
On-board 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 the key guide to the appropriate Tier.

3.1 Assessment Guidance

3.1.1 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. Noise levels are based on the performance of 'traditional' cameras using standard gamma-correction curves, where noise level increases towards black. Increasingly, new cameras do not exhibit this noise profile and so the calculations may not best reflect the camera performance.

A further revision of this document will be needed when current research into this effect is completed.

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 48 dB but better than 50 dB is preferable.

HD Tier 1 should be 48 dB or better but measurements shall be assessed alongside visual inspection.

Table 6: Signal to Noise

Tier	Appropriate S/N	Notes
UHD2 Tier 1	Better than -48 dB @ 0 dB gain	Should be considered a minimum if the output is aimed at cinema release as well as television broadcast
UHD2 Tier 2	Better than -44 dB @ 0 dB gain	
UHD1 Tier 1	Better than -48 dB @ 0 dB gain	
UHD1 Tier 2	Better than -44 dB @ 0 dB gain	For guidance however a good S/N ratio is a requirement
Tier SP	Better than -40 dB @ 0db gain	S/N may be worse for some specialist cameras
HD Tier 1	Better than -48 dB @ 0db gain	For guidance however a good S/N ratio is a requirement
HD Tier 2L	Better than -44 dB @ 0db gain	Guidance only
HD Tier 2J	Better than -40 dB @ 0db gain	Guidance only
HD Tier 3	Better than -40 dB @ 0db gain	For guidance - S/N may vary with broadcaster requirement
HD Tier 4	N/A	Not a requirement for Tier 4 cameras

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

Although it is expected that higher Tier cameras will have better S/N ratio than lower Tier cameras this is not always the case. The Broadcaster will give advice if necessary.

3.1.2 Sensitivity (F Measurement)

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

Measure the exposure lens aperture, at 2000-lux illumination level and 0 dB gain (or the recommended nominal gain setting), at which the white side of a Kodak Gray card produces peak white signal level (100%). This shall 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

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.

Exposure Range 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 Spatial Resolution

Camera resolution determines a camera's Tier position (see section 2). The sensor pixel count is not an acceptable measure of a camera's actual resolution.

The measured output signal of a Tier 1 camera should achieve the full resolution of the recording/production system its output is intended for.

UHD2 and UHD1 Tier 2 camera should achieve a measured output signal that is at least (and preferably exceeds) 50% of the full resolution of the intended output. For example, for UHD1 Tier 2, this is equivalent to $(3840/1.4143...) \times (2160/1.4143...)$ i.e. 2715 x 1527.

3.1.5 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.

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 UHD1 & 2 Tier 1 & 2, HD Tier 1 and HD Tier 2L cameras, although some may be permissible in Tiers SP, Tier 2J and Tier 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 UHD with cinematic sensor ratios (4k & 8k)

Where a camera produces an image that is actually 8192 x 4320 (8k) or 4096 x 2160 (4k) or 2048 x 1080 (2k) it should be assumed that 16:9 images should be extracted by cropping the image, not by scaling for testing purposes.

Cropping shall always occur before down-scaling if higher resolution cameras or post is used.