Panasonic proposed Studio system SDR/HDR Hybrid Operation

Ver. 1.3b

May, 2019

Overview

Improvement in image quality is always pursued by video creators and video equipment makers, we have taken various approaches such as improvement of resolution and development of compression technology so far.
In recent years, with the development of image display technology, it has become possible to express images exceeding the base of television image signals so far, such as expansion of expressible dynamic range and expansion of color gamut.

Changing the standard of terrestrial broadcasting as a social infrastructure is not easy, but in a new video distribution method such as Internet video delivery, it is based on the UHD/HDR/BT.2020 standard aimed at expanding the resolution, dynamic range, color gamut Video delivery is planned.
Meanwhile, it is desirable to be able to simultaneously produce images at new standards (UHD, HDR, BT.2020 color gamut) at the time of making normal HDTV signal for the current terrestrial broadcasting without great cost increase.
In this paper, we explain technological development to image production equipment as Panasonic toward this realization.

Live broadcast on HDR

When creating HDR video, the process with post-production which there are time lag from shooting to broadcasting (screening) by a several-day level, and cases where live broadcasting (screening) with a delay of several frames or several seconds, are quite different in the operation.

In the first case, post production HDR image production (grading), already various tools are used, and elaborate the image on the monitor over time and show the results to the viewer so there are few chance of failures.
In the case of the live broadcast, basically the video quality is determined with the camera, and the directing effect is added by the switcher. Since the video quality is confirmed almost in real time and it is shown to the viewer as it is, the camera is required to have the function of immediately deciding the video quality to avoid to fail (to show unexpected quality video).
As described in the overview in live broadcasting, we will simultaneously produce new standards (UHD, HDR, BT 2020 color gamut) images for new video distribution systems and existing video (HD, SDR, BT.709 color gamut). The camera system is required to have the function of creating images of both standards without difficulty.

> Note)
> In this paper we will describe UHD, HDR, BT.2020 color gamut as a package as a new standard image, but we can handle resolution, dynamic range, color gamut separately. In other words, it seems that the HDR image at HD resolution, BT.709 color gamut is also used in the actual case

HDR in live broadcast BT. 2084 or HLG?

HDR has BT.2084 (PQ) standard based on the display system and HLG (Hybrid Log Gamma) in consideration of use in video shooting system. In the case of BT.2084 specifies the brightness on the screen of the display by the absolute value. It is an easy-to-understand

system to show packaged media such as movies as intended by the producer, and it is an appropriate standard when creating images with grading of post-production.

In a UHD Blu-ray Disc considered as a package medium for HDR distribution of movies, HDR10 is basically standardized with the same gamma characteristic as a subset from this PQ curve.
On the other hand, in the case of live broadcasting, considering simultaneous output with the current television system (HD resolution, SDR, BT.709 color gamut), even TVs with various luminance performances make use of their maximum dynamic range Relative HLG which is a luminance expression is used.

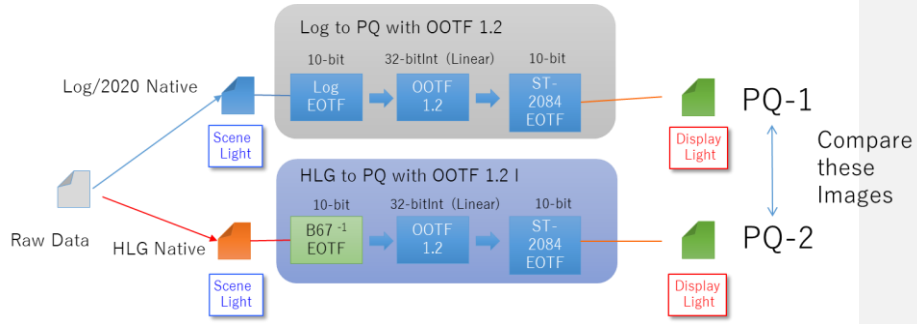
> Note)
> In the current HD SDR television signal, it is a relative system that expresses from black to peak luminance within 100% of the signal.

In addition, the compatibility of the HLG with the current SD SDR signal is also considered in some level in that standard.
In this way, the live UHD HDR signal to be broadcasted (distributed) is based on HLG characteristics. This signal standard is specified together with PQ as ITU-R BT.2100.

	BT.709	BT.2020	BT.2100
Resolution	HD	4K, 8K	HD, 4K, 8K
Frame Frequency	24/1.001, 24, 25, 30/1.001, 30 50, 60/1.001, 60	24/1.001, 24, 25, 30/1.001, 30 50, 60/1.001, 60 120/1.001, 120	24/1.001, 24, 25, 30/1.001, 30 50, 60/1.001, 60 120/1.001, 120
Display Method	Interlace Progressive	Progressive	Progressive
Dynamic Range	SDR	SDR	HDR PQ (BT.2084) HLG
Color Space	BT.709	BT.2020	BT.2020
Bit Depth	8, 10 bit	10, 12 bit	10, 12 bit

Live camera output: HLG? or Log?

Even if HDR broadcasts are delivered under the HLG standard, there are many cases where the same content will be distributed later as a Blu-ray package media. The signal for Blu-ray HDR will be encoded with PQ-based standard HDR 10. For this reason, although there is a view that it is more advantageous to output the camera output in Log, it seems to be advantageous for subsequent HDR grading, but practically it was graded from HLG output to ST.2084 and Log captured data was graded ST.2084.
We verified how much significant difference there is.
As a result, if the content is limited to 1,000cd/m² or less, there was no difference between the grading from HLG and the ST.2084 content completed by grading from Log.



As a possibility that there is a difference in this creation method, two points are conceivable.

(1) In the case where the image contains a high-brightness portion which greatly exceeds 1,000cd/m², the difficult to express in HLG

(2) The gradation resolution of Log is lost by passing 10 bits of HLG

Currently, the luminance of the latest consumer TV set is set to 1,000cd/m² as a certain upper limit, ITU etc. assumes that the brightness of the TV set is assumed to be 1,000cd/m² as assumption at the time of conversion of PQ and HLG, it is said that high brightness is too dazzling to both the film producer and the viewer and the eyes get tired, we think that (1) is virtually no problem.
Also in (2), it is considered that there is no problem because actual signal exchange and distribution are performed on the basis of 4:2:2 10bit, there is a limit on the gradation expression power of the monitor.

Furthermore, when the switcher system is configured on a Log basis, it is necessary to convert the HLG signal sent from other station as the feed, to Log, and convert it again to HLG, so the necessity of equipment and conversion error problem etc. may come.

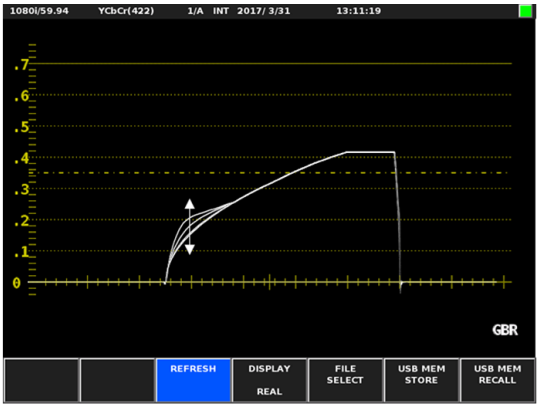
Although it does not completely deny outputting by Log due to future technological progress, there is the following merit by putting HLG as it is from the camera, and it is considered that it is beneficial to take advantage of this merit at the present condition.

(1) Camera output can be used for delivery as it is.
There is no need for conversion equipment from Log to HLG. It is also possible to record as it is and use the playback signal for distribution.
(2) Camera output can be sent directly to the HLG compatible monitor, making it easy to confirm the video at the time of shooting
(3) Commercially available TV which does not have gamma conversion function can be used for video confirmation.
(4) In the Log monitor, the information displayed differs depending on the difference in the maximum brightness of the display, but the display of the entire signal is guaranteed by the HLG monitor
(5) By unifying the system to HLG, it becomes unnecessary to consider necessity of conversion equipment, problem of conversion error, etc.

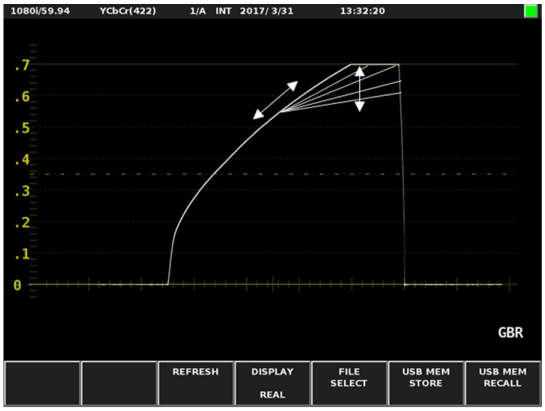
Live Output HLG signal Adjustment

To enhance expressiveness in SDR shooting so far, the studio camera is equipped with various image creation functions such as black gamma, knee adjustment, color matrix adjustment, and so on.
Even in HDR shooting, the same image creation function is expected depending on the scene.
Our HDR compatible studio camera has black gamma and knee adjustment, color matrix and similar image quality adjustment function like SDR, and it has a structure that can create appropriate picture according to the scene and the sensibility of the maker. For confirmation of this picture, we think that it is appropriate to output

HDR output from the studio camera with HLG which can be monitored as it is.



Adjustment of Master Black Gamma (HDR)



Adjustment of Knee Point and Slope (HDR)

Studio camera SDR / HDR Hybrid (simultaneous output) operation

In the case of broadcasting and distribution of live programs and events, terrestrial broadcasting is HD-SDR, but prime distribution is

assumed to be performed simultaneously in UHD-HDR (or HD-HDR). In SDR/HDR simultaneous broadcasting, it is unrealistic to install separate cameras of SDR and HDR and separate signal processing system, which is doubly costly, and SDR and HDR signals from one camera are desirably output at the same time.

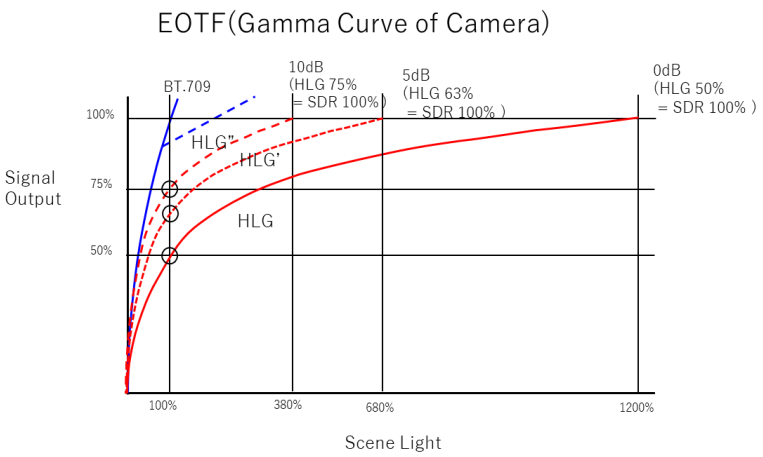
Although there is only one adjustment of the iris of the camera, the operator (cameraman, or VE: video engineer) adjusts the iris so that both the SDR and the HDR have the good image (utilizing the expressiveness of each).

Basically, the operator confirms the images of both HDR and SDR, confirming that the HDR characteristics are appearing in the region of 100% or more, while being able to express it as an image even if the SDR image is 100% or less. It is necessary to confirm.

As a camera capable of performing the SDR/HDR hybrid operation, it is necessary to provide the camera with a function capable of making the above iris adjustment without hesitation by the operator.

For this purpose, it is necessary to develop a function that firmly defines the relationship between the HDR signal and the SDR signal output from the camera. Since the gamma curves of SDR and HDR (HLG) are strictly prescribed, it is easy to think that it is only necessary to issue signals along this curve, but if you output as specified, shoot the same 100% video If you do, the HDR compatible monitor appears darker than the SDR compatible monitor. In addition, although the signal standard in SDR-TV assumes 100% maximum brightness 100cd/m², in reality it is brightened to the full brightness of TV, so SDR monitor will be brighter than HDR compatible monitor, such an Inversion phenomenon occurs

Hereinafter, it will be described in detail using a graph.



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The above figure shows the basic gamma curve characteristics of SDR (BT.709, blue) and HDR (HLG/STD-B67, red).
Although 100% in SDR is 50% in HDR, it is necessary to be aware that this graph is the camera side conversion curve (OETF).
The relationship between the scene light (the brightness of the subject to be shot) on the monitor and the brightness of the monitor display (OOTF) is shown in the graph below.

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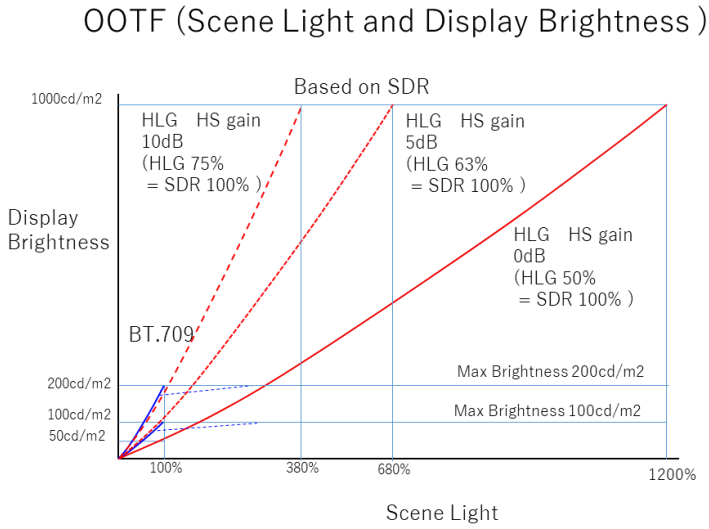


When a white object with a level of 100% of the scene light is shot, SDR-TV follows the standard when displayed as 100cd/m², and HDR-

TV shows 1200% as 1,000cd/m².

Level of white object SDR-TV	100cd/m² on screen
Level of white object HDR-TV	50cd/m² on screen
.	(half brightness of SDR-TV)

At the normal brightness level, the SDR-TV will be brighter (blue line).

Furthermore, in the current consumer SDR-TV, since the highest brightness of the screen is over 100cd/m², the SDR-TV looks brighter, which means that HDR likeliness cannot be expressed.
In order to avoid this, it is assumed that a certain gain difference is previously set between the HLG image and the SDR image and image adjustment is performed based on the SDR image.
By doing this, it is possible to obtain the same image as the conventional SDR image while using the high dynamic range of HDR effectively in the HLG image.

Although it is necessary to set the optimum value for the gain difference between the HDR video and the SDR video by operation, it is assumed that it will ultimately become a fixed value in consideration of program exchange and the like.

The mapping method of SDR signal to HDR signal in SDR / HDR simultaneous output operation has been studied, and it is proposed to correspond 100% SDR signal to 75% HLG signal (equivalent to 200cd/m² at peak 1,000cd/m²: pink line) and a proposal (green line) corresponding to a 100% SDR signal corresponding to a 63% HLG signal (corresponding to 100cd/m² at a peak of 1,000cd/m²) are specifically studied.

Difference between OOTF in HLG and OOTF in SDR

In the video system, a real scene (linear signal) is temporarily converted into an electric signal by a camera, and the electric signal is converted into light (linear signal) of a display by a monitor. The conversion on the camera side is called OETF (Opto-Electronic Transfer Function), and the conversion on the monitor side is called EOTF (Electro-Optical Transfer Function). Normally, the characteristic

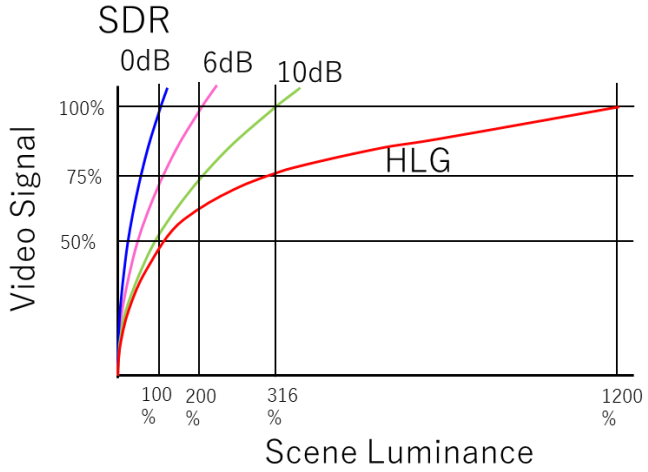
that the dark part is lifted on the camera side, the reverse characteristic that the highlight is lifted on the monitor side is applied.

In the conventional SDR system (BT.709), the OETF on the camera side is about 0.45 (1/2.2), the EOTF on the monitor side is 2.4 from the characteristic of the CRT, and it is not completely reverse characteristics, and 1.2 Gamma remains, but this is called OOTF (Opto-Optical Transfer Function) as the characteristic of the whole system. Thus, OOTF is a conversion function between real scene and display light, and is not necessarily a linear relationship. The OOTF represents end to end image conversion between a real scene and a monitor display, and includes an adjustment concerning intention and expression.

Here, in the conventional SDR regulation, OOTF is a form in which gamma is applied to each of the R, G, B signals, but in the HLG regulation in BT.2020, a form in which gamma is applied only to luminance. This is to avoid color distortion when applying a gamma curve individually to each component. Also, the gamma value of the OOTF is changed according to the peak luminance of the display. This is to reproduce the same appearance perceptually regardless of the peak luminance of the display when displaying the video signal.
The difference in appearance due to the difference between OOTF of HLG and SDR, specifically, HLG appears to be thinner in color, etc. However, as described above, by the intentional mechanism for operating a new method considering that the design and image creation of the consumer TV set is done based on that signal, we think that it is preferable to operate the regulations in compliance with the regulations on the sending side, without making corrections.

Control of gain and Knee to establish SDR video with HDR image adjustment

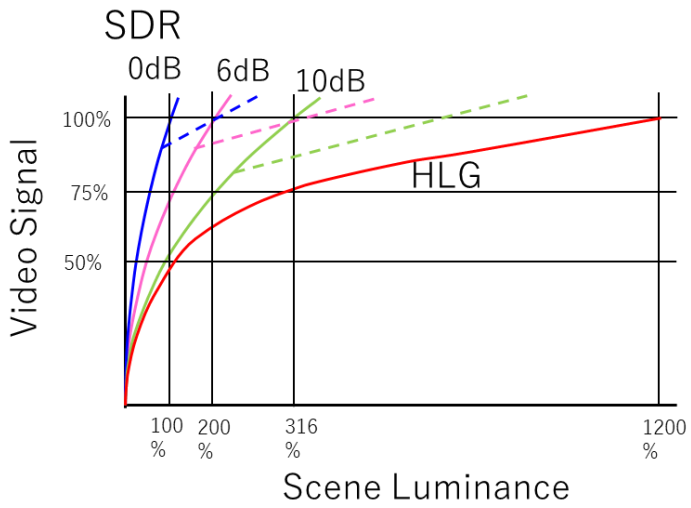
In the previous chapter, it explained that it is necessary to provide a gain difference according to the scene in the SDR and HDR signals at the simulcast of SDR and HDR.
For a case where the screen is bright and there are many high luminance objects (objects with a wide dynamic range), when setting a gain difference of about -10dB in SDR and HDR and setting the 75% point of HDR to the 100% level in SDR , both SDR and HDR images are easily established.
Also, with a slightly narrow dynamic range image, setting with reduced gain difference becomes appropriate.
Thus setting the proper gain difference for the conversion of SDR and HDR according to the scene brings out both characteristics and becomes a practical solution to make HDR video according to it by checking SDR video.
However, it is not recommended to dynamically change this gain during shooting. It seems to be appropriate to follow the degree of changing the gain difference only when the shooting is performed with the fixed gain difference as much as possible and the shooting environment is changed greatly (outdoor shooting changed from fine weather to cloudy, etc.).
This area seems to accumulate know-how by accumulating experience of simultaneous shooting of SDR and HDR.



Knee control

In addition to the gain difference control, SDR gamma setting, by adjusting the Knee point, it is possible to expand the expression range of dynamic range in SDR video.

By incorporating Knee adjustment at the time of conversion established as a method to expand the dynamic range within the signal standard in the original SDR shooting and display, it becomes possible to convert SDR video with expressive power from HDR video.



Color gamut conversion BT.2020 and BT.709 color gamut

The UHD (3,840 x 2,160) signal standardized by BT.2020 has a dynamic range of HDR and also has a color gamut (also called BT.2020 color gamut) wider than the conventional BT.709 standard in the color gamut It is recommended.

In recent years, the expansion of the color gamut in display devices such as TV set is proceeding, and it seems that the future BT.2020 color gamut will be used in a wider range. Even in the studio system, with the performance of the camera output and vision mixer such as and the switcher, it is required to cover the BT.2020 color gamut, and it is necessary to be able to select the color gamut of BT.709 or

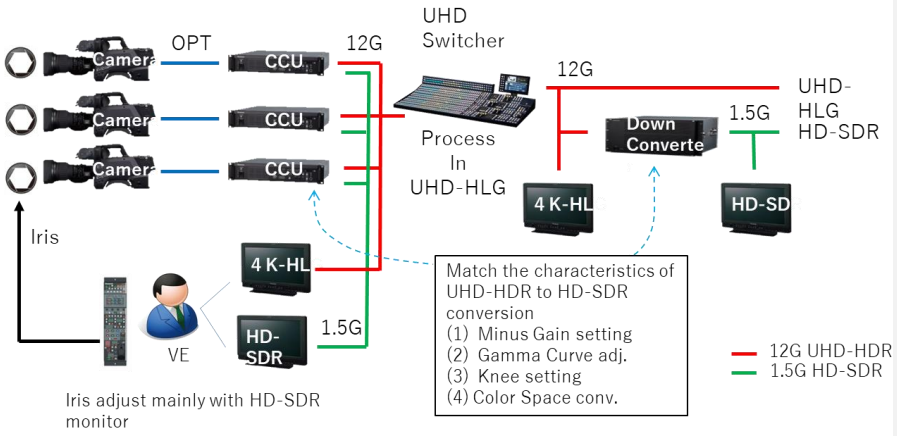
BT.2020.

When the color gamut on the monitor side is BT.2020, vivid colors exceeding the conventional BT.709 color gamut can also be correctly transmitted and displayed by setting the color gamut on the camera side to BT.2020. Care must be taken as accurate color reproduction cannot be obtained unless the color gamut of the camera and the color gamut of the monitor matches.

VE operation during SDR / HDR simultaneous broadcasting

The concrete operation when implementing simultaneous broadcasting of UHD-HDR/BT.2020 and HD-SDR/BT.709 will be described below.

1) When assuming simultaneous operation of UHD-HDR and HD-SDR, it is necessary to consider image output level suitable for each format.
2) For this reason, as described above, a predetermined gain difference is previously set between the UHD-HDR video and the HD-SDR video, and the video engineer adjusts the video based on the HD-SDR video. By doing this, it is possible to create images that effectively utilize the high dynamic range of HDR in UHD-HDR video while obtaining HD-SDR video as before.
3) The gain difference between the UHD-HDR video and the HD-SDR video is realized in the downconverter section of the CCU in the studio camera. In addition, conversion of gamma curve, color gamut conversion and Knee processing are also performed here.
4) The same value is set for the newly developed downconverter installed in the latter stage of the switcher as the processing setting value in the downconverter part of the CCU. This makes it possible to treat the HD output from the camera equally to the main line HD output from the final down converter.



Switcher in SDR / HDR Hybrid operation

In the description so far, we have described SDR and HDR signals from studio cameras, and the functions that the camera system should equip to have sufficient expressiveness as images.
In this case, although it is established as each SDR and HDR signal, when considering simultaneous broadcasting, there is a switcher which switches a plurality of video signals after the camera and performs video effect and graphics insertion with the switcher, the following discussion will be made on how to perform the hybrid operation of SDR/HDR. There are several possible system configurations at that time.

Parallel operation of UHD-HDR and HD-SDR

Switchers that process signals of HD-SDR and UHD-HDR are moving in parallel, and it is conceivable to have optimal signal processing, respectively. Although this configuration has advantages such as a sense of stability by an independent system and the ability to construct a system with the shortest delay, there are disadvantages in terms of cost, such as having to have two systems of systems.

Operation mainly for UHD-HDR

In this method, all processing is performed on the basis of UHD-HDR, and finally, conversion to HD-SDR is performed. In this case, only one signal processing engine of the switcher is sufficient, but the parameter at the time of SDR conversion is one, and it becomes difficult to change the gain of the camera side or Knee depending on the shooting scenes described above. However, from the viewpoint of image creation, it is sufficient to think that basic gain difference and Knee setting are one in the system, and they are individually changed from the viewpoint of offset as necessary.

How to proceed depends on the balance between the allowable cost and the expected image quality, and it will be decided through experience in the future.

In both methods, it is difficult to prepare all the input images in HDR with regard to UHD-HDR processing, and reuse of past contents and images from the other source are often provided by SDR in many cases. For this reason, as the internal processing of the switcher, after converting all the signals of the input system to the HDR characteristics, perform special effect processing, then output as the HDR main line signal, and apply SDR broadcasting gamma as simulation Output. Since it is necessary to convert gamma and color gamut before and after the switcher, we plan to provide a rack mount type signal conversion device that provides various conversion functions as a board additional type as a peripheral device of the switcher.

Conclusion

In this paper, we have discussed problems and solutions at the time of Spring 2017 to enable simultaneous distribution of SDR and HDR. This simultaneous distribution is a concern of broadcasting stations aiming for advanced operation, and various research and discussions are proceeding. In order to realize a system that achieves both an ideal solution and practical operation, consideration will be made in the future and in some cases a different approach from this paper may be realized.

As Panasonic, we would like to respond flexibly to building better

systems by repeated discussions with the users of broadcasting stations and video providers.